



# Disassembly and Assembly

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## **C15 and C18 Engines for Caterpillar Built Machines**

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L4X1-Up (Engine)

## Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

**Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.**

**Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.**

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the "Safety Alert Symbol" and followed by a "Signal Word" such as "DANGER", "WARNING" or "CAUTION". The Safety Alert "WARNING" label is shown below.



The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

A non-exhaustive list of operations that may cause product damage are identified by "NOTICE" labels on the product and in this publication.

**Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. You must not use this product in any manner different from that considered by this manual without first satisfying yourself that you have considered all safety rules and precautions applicable to the operation of the product in the location of use, including site-specific rules and precautions applicable to the worksite. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or become unsafe by the operation, lubrication, maintenance or repair procedures that you intend to use.**

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Cat dealers have the most current information available.



**When replacement parts are required for this product Caterpillar recommends using Cat replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.**

**Failure to heed this warning can lead to premature failures, product damage, personal injury or death.**

**In the United States, the maintenance, replacement, or repair of the emission control devices and systems may be performed by any repair establishment or individual of the owner's choosing.**

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 **WARNING**

**Accidental machine starting can cause injury or death to personnel working on the machine.**

**To avoid accidental machine starting, turn the battery disconnect switch to the OFF position and remove the key. If the machine is not equipped with a battery disconnect switch, disconnect the battery cables from the battery and tape the battery clamps.**

**Place a do not operate tag at the battery disconnect switch location to inform personnel that the machine is being worked on.**

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## Disassembly and Assembly Section

i03555845

### Muffler - Remove and Install (Clean Emissions Module)

SMCS Code: 1061-010; 1062-010

#### Removal Procedure

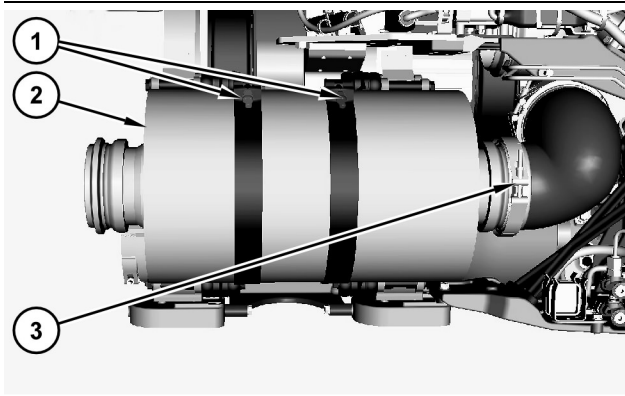


Illustration 1

g01880638

1. Loosen clamp assembly (3).
2. Disconnect clamp assemblies (1).
3. Use two people in order to remove muffler (2). The weight of muffler (2) is approximately 18 kg (40 lb).

#### Installation Procedure

1. Install muffler (3) in the reverse order.
  - a. Tighten clamp assembly (3) to a torque of 12 N·m (106 lb in).

i04060431

### Fuel Priming Pump - Remove and Install

SMCS Code: 1258-010

#### Removal Procedure

1. Turn the fuel supply to the OFF position and turn the power disconnect switch to the OFF.

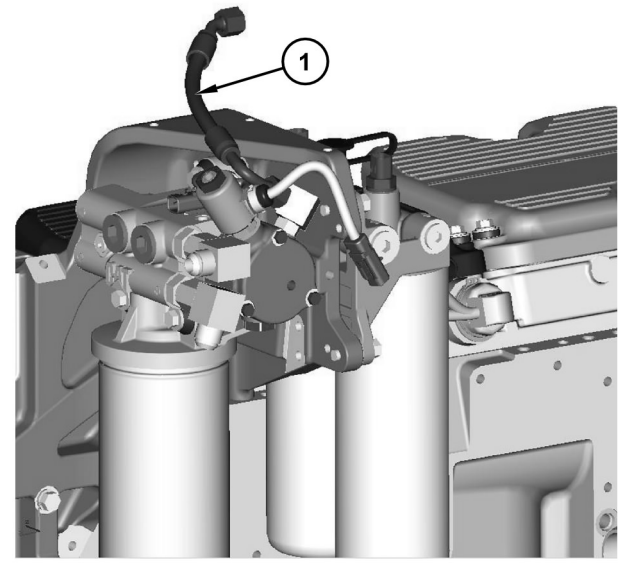


Illustration 2

g02138690

Typical Example

2. Disconnect the fuel line (1) to the ARD manifold from both ends.

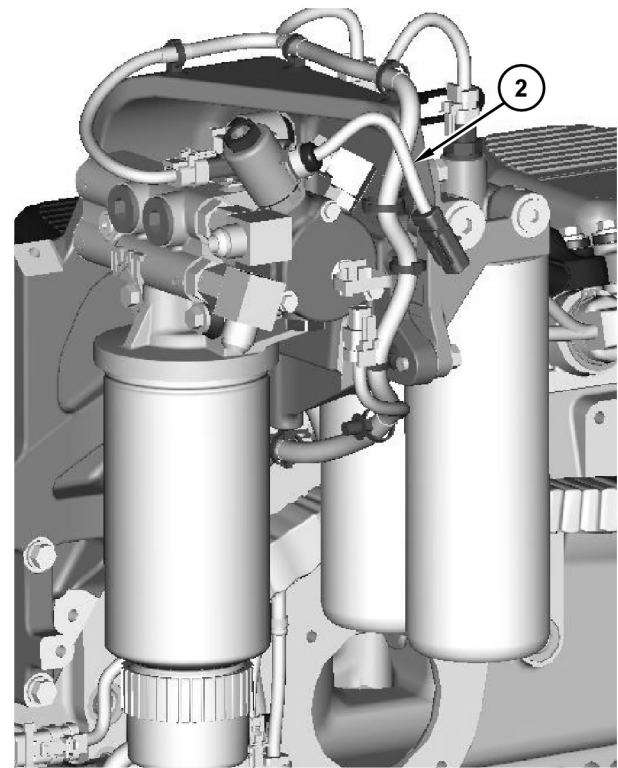


Illustration 3

g02140391

Typical Example

3. Disconnect the solenoid harness (2).

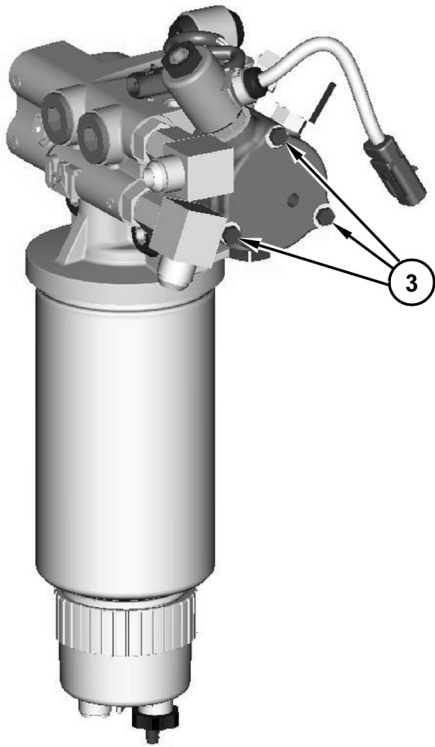


Illustration 4 g02139134

4. Remove the bolts (3) from the manifold.

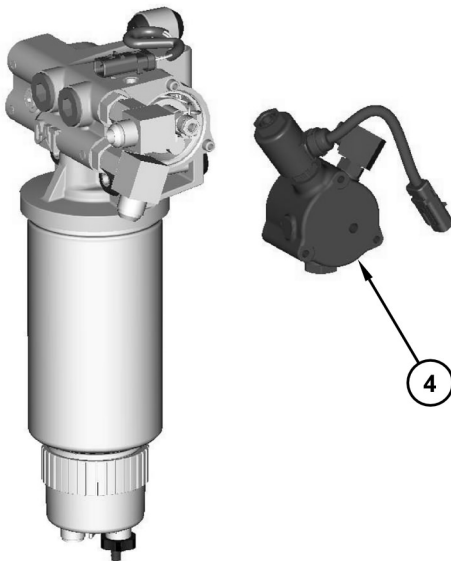


Illustration 5 g02139144

5. Remove the manifold (4).

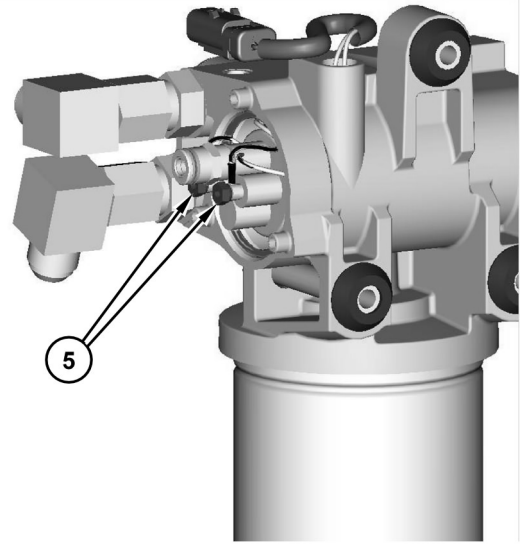


Illustration 6 g02138698

6. Remove the two locknuts (5).

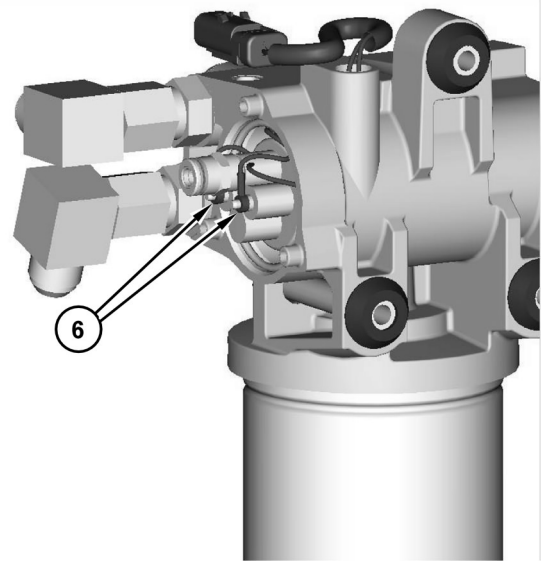


Illustration 7 g02139150

7. Write down the polarity and remove the wires (6) from the terminal studs. The polarity is designated by "+" and "-" signs around the terminal studs.

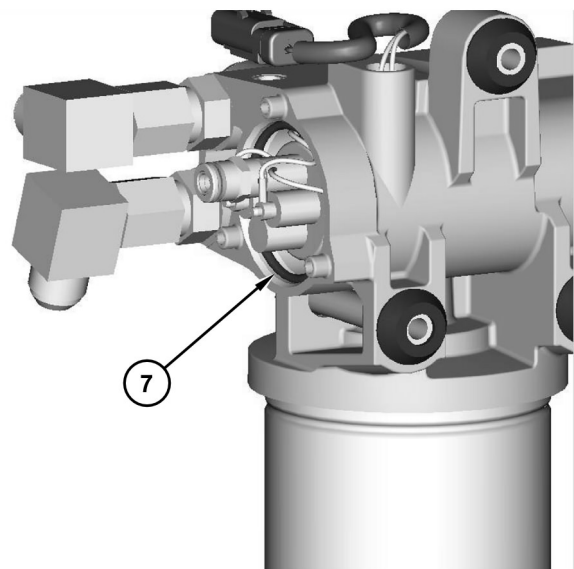


Illustration 8 g02139164

8. Remove the seal (7).

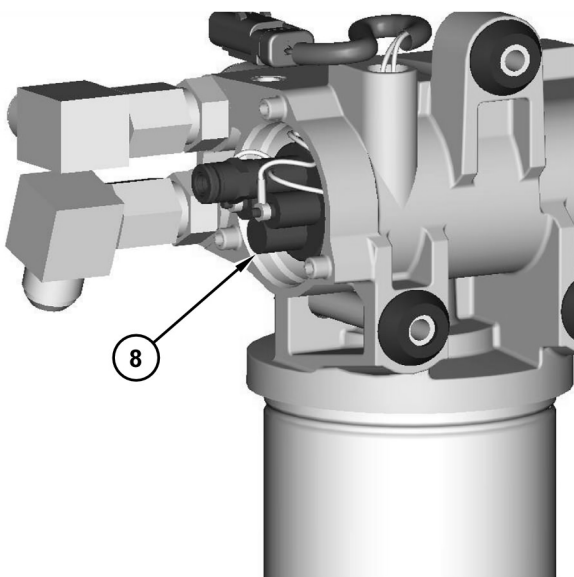


Illustration 9 g02139169

9. Remove the pump assembly (8).

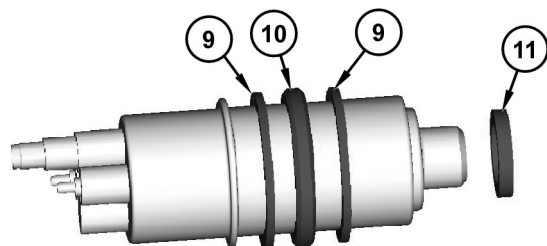


Illustration 10 g02167735

10. Remove the two backup rings (9), seal (10), and seal (11) from the pump assembly.

### Installation Procedure

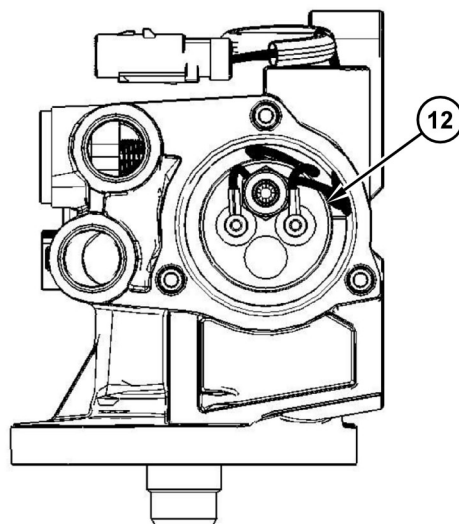


Illustration 11 g02139275

Proper orientation of the new fuel priming pump.

1. Use the pump seal installer that is provided in the pump kit to press in the new pump (12) and seals.

**Note:** The outlet of the pump should be at the top center position.

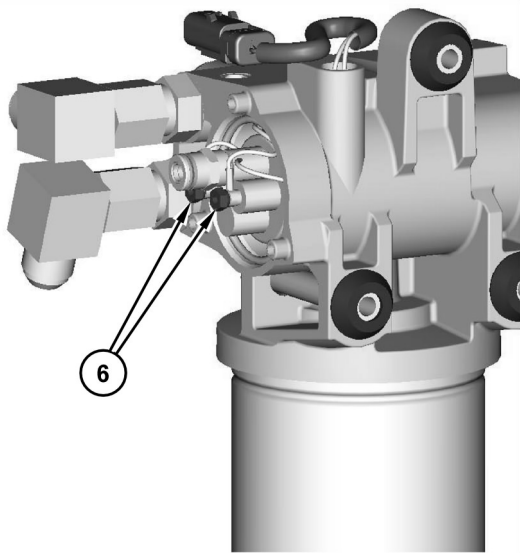


Illustration 12

g02139286

2. Reinstall the wires on the terminal studs. Install new locknuts (6). Torque locknuts to 1.3 N·m (1 lb ft).

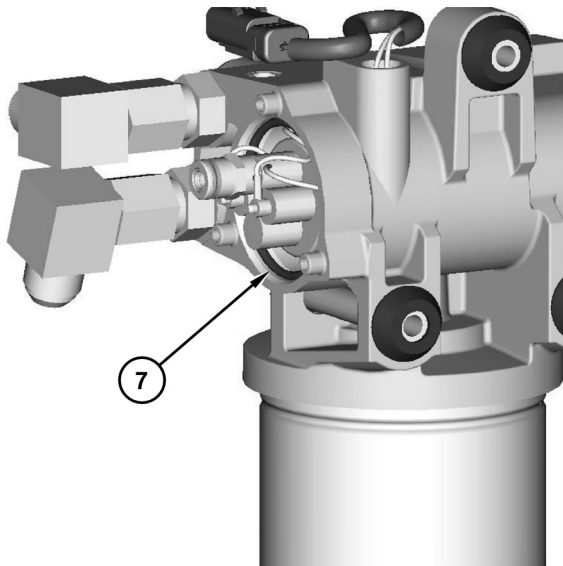


Illustration 13

g02139307

3. Install new seal (7).

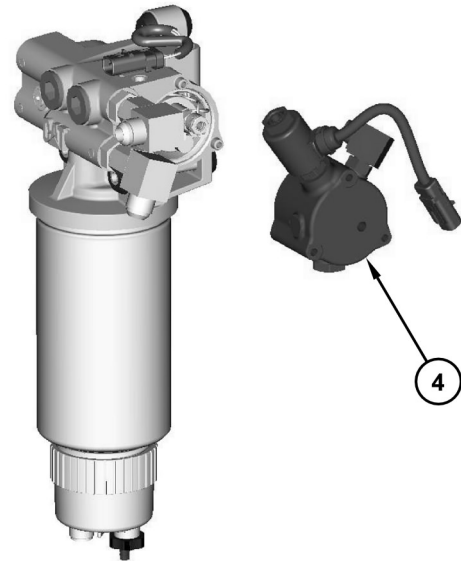


Illustration 14

g02139309

4. Reinstall the manifold (4).

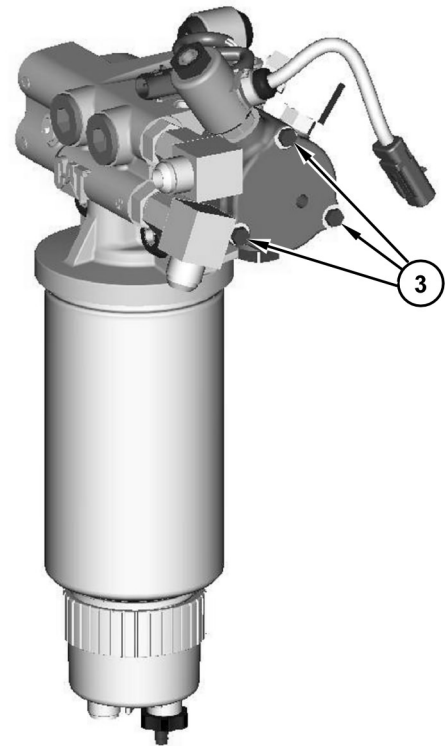


Illustration 15

g02139311

5. Reinstall bolts (3). Torque the bolts to  $12 \pm 3$  N·m ( $9 \pm 2$  lb ft).

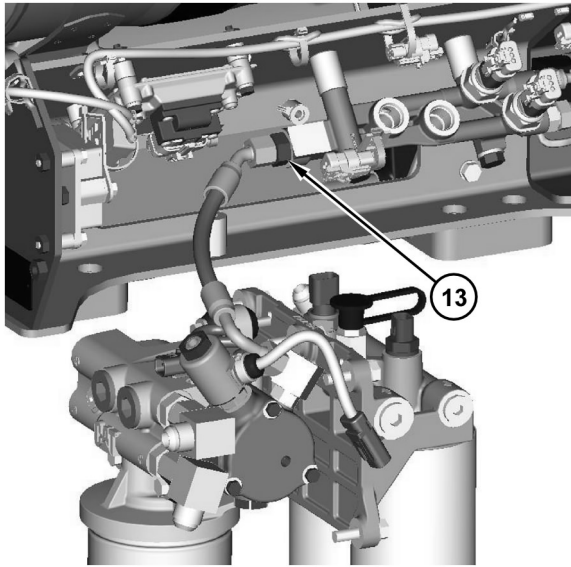


Illustration 16 g02138801

6. Replace the filter connector fitting (13).

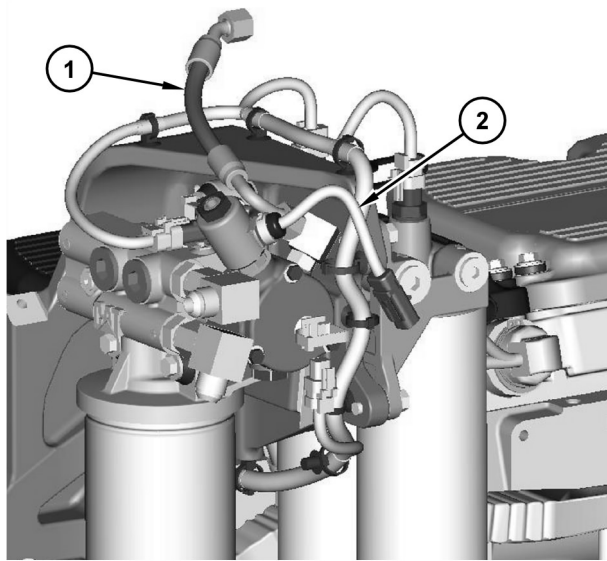


Illustration 17 g02139316

7. Reconnect the solenoid harness (2).
8. Turn the fuel supply to the ON position and turn the power disconnect switch to the ON.
9. Use two people in order to flush the fuel pump and fuel line (1) into a suitable container for disposal. The fuel pump can be activated by turning on the key or pressing the manual switch. The manual switch, if available, is located on the primary fuel filter base.
10. Connect fuel line (1) to the ARD manifold.

11. After reassembly, prime the engine by turning on the key or pressing the manual switch. The manual switch, if available, is located on the primary fuel filter base. Visually check for leaks around the pump and around the connections on the ARD manifold. If leaks are observed, resolve the leak issue before proceeding further.

i03929592

## Fuel Filter Base - Remove and Install

SMCS Code: 1262-010

### Removal Procedure

Table 1

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 185 - 3630  | Strap Wrench As  | 1   |

1. Turn the fuel supply to the OFF position and turn the power disconnect switch to the OFF.

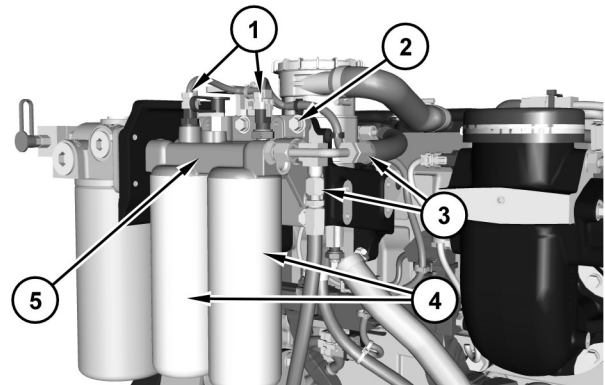


Illustration 18 g02153819

2. Disconnect harness assemblies (1).
3. Disconnect hose assemblies (3).
4. Use Tooling (A) and remove fuel filters (4) from fuel filter base (5).
5. Remove bolts (2) and remove fuel filter base (5).

### Installation Procedure

#### NOTICE

Check the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

1. Install fuel filter base (5) in the reverse order.

- a. Use Tooling (A) and tighten fuel filters (4) to a torque of  $35 \pm 3$  N·m ( $25 \pm 2$  lb ft).

i03934529

## Fuel Transfer Pump - Remove and Install

SMCS Code: 1256-010

### Removal Procedure

Table 2

| Required Tools |             |                       |     |
|----------------|-------------|-----------------------|-----|
| Tool           | Part Number | Part Description      | Qty |
| A              | 2P-8312     | Retaining Ring Pliers | 1   |
| B              | 8H-0663     | Bearing Puller Gp     | 1   |
| C              | 1P-0510     | Driver Gp             | 1   |

1. Turn the fuel supply to the "OFF" position and turn the power disconnect switch to the OFF position.

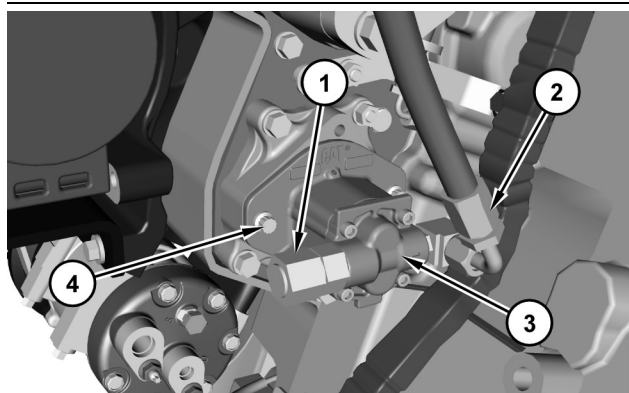


Illustration 19

g02155173

2. Disconnect tube assemblies (1) and (2).
3. Remove bolts (4).
4. Remove fuel transfer pump (3) and remove the O-ring seal (not shown).

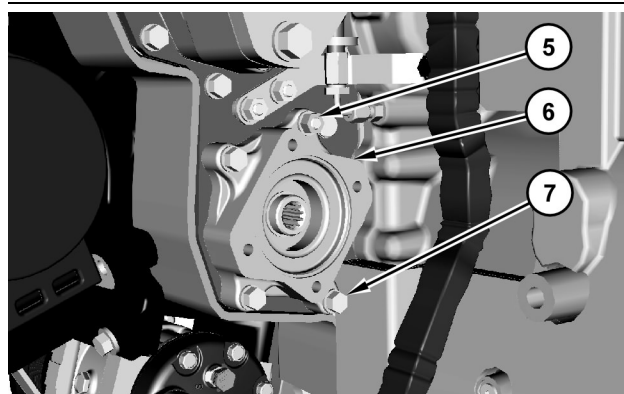


Illustration 20

g02155430

5. Remove nut (5). Remove bolts (7) and remove pump drive (6).

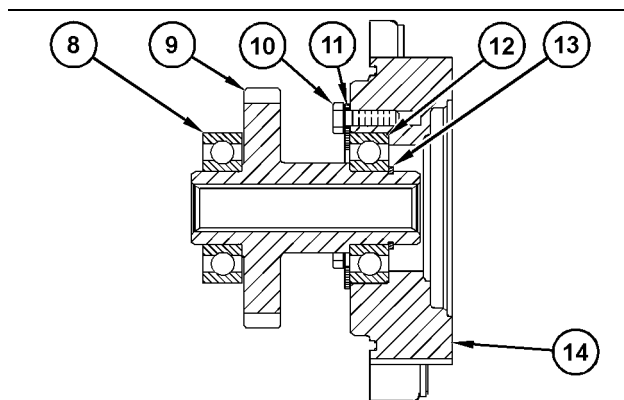


Illustration 21

g02155446

6. Remove bolts (10) and retainers (11) that secure adapter (14) to bearing (12).
7. Use Tooling (A) in order to remove retaining ring (13).
8. Use Tooling (C) and a suitable press to remove assembled bearing (12) and gear (9) from adapter (14).
9. Use Tooling (B) and a suitable press in order to remove bearing (8) from gear (9).
10. Use Tooling (B) and a suitable press in order to remove bearing (12) from gear (9).

### Installation Procedure

1. Install the fuel transfer pump in reverse order.

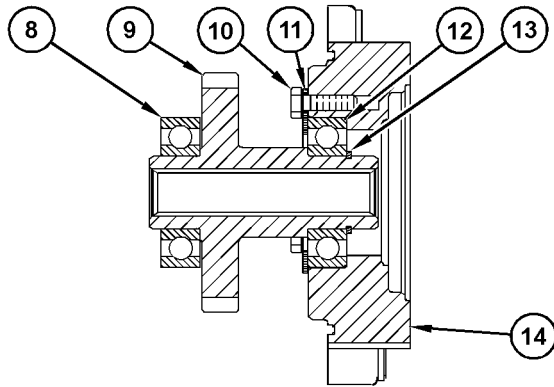


Illustration 22

g02155446

2. Raise the temperature of bearing (8) and install the bearing onto gear (9).
3. Raise the temperature of bearing (12) and install the bearing onto gear (9).
4. Use Tooling (C) and a suitable press in order to install assembled bearing (8), bearing (12), and gear (9) into adapter (14).
5. Turn the fuel supply to the "ON" position and turn the power disconnect switch to the ON position.
6. Remove the air from the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".

i03545969

## Fuel Pressure Regulator - Remove and Install

SMCS Code: 1715-010

### Removal Procedure

1. Turn the fuel supply to the "OFF" position.

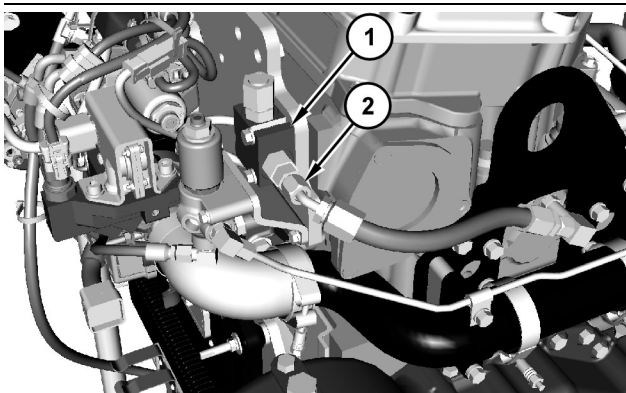


Illustration 23

g01873414

2. Disconnect hose assembly (2). Remove fuel pressure regulator (1).

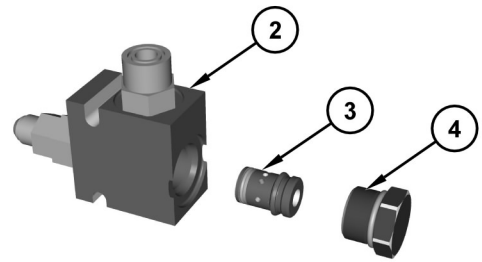


Illustration 24

g01873410

Typical Example

3. Remove plug (4) and check valve (3) from fuel pressure regulator (1).

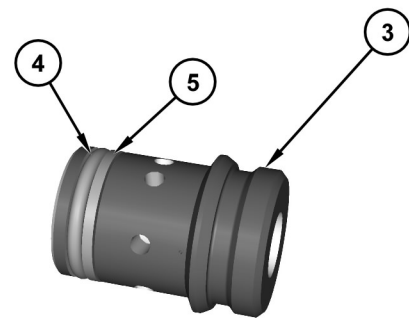


Illustration 25

g01873411

4. Remove O-ring seal (4) and backup ring (5) from check valve (3).

### Installation Procedure

1. Install fuel pressure regulator (2) in reverse order of removal.
  - a. Tighten plug (4) to a torque of  $35 \pm 2$  N·m ( $26 \pm 1$  lb ft).

i04329680

## Exhaust Cooler (NRS) - Remove and Install

SMCS Code: 1087; 108C-010

### Removal Procedure

Table 3

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 5P-3931     | Anti-Seize Compound | -   |

1. Drain the coolant from the cooling system into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change".

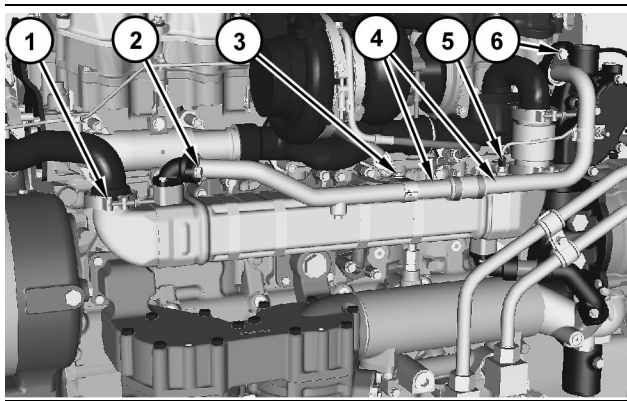


Illustration 26

g01842813

2. Remove clamp assembly (3).
3. Remove bolts (2) and (6). Remove tube assemblies (4).
4. If equipped, remove tube assembly (5).
5. Remove clamp assemblies (1) from both sides of the exhaust cooler.

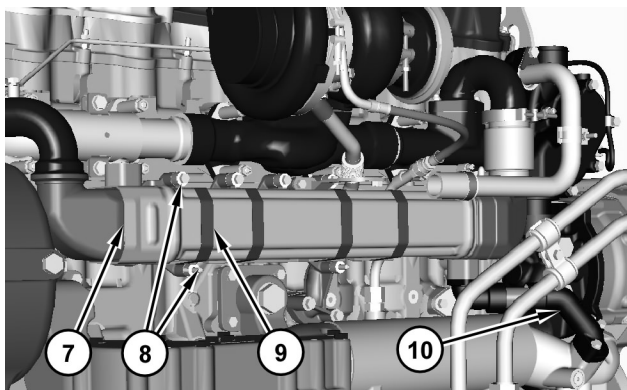


Illustration 27

g02485398

6. Remove elbow (10).
7. Remove bolts (8) and remove clamp assemblies (9). Use two people in order to remove exhaust cooler (7). The weight of exhaust cooler (7) is approximately 18 kg (40 lb).

### Installation Procedure

**Note:** Check the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

1. Install the exhaust cooler (7) in the reverse order.

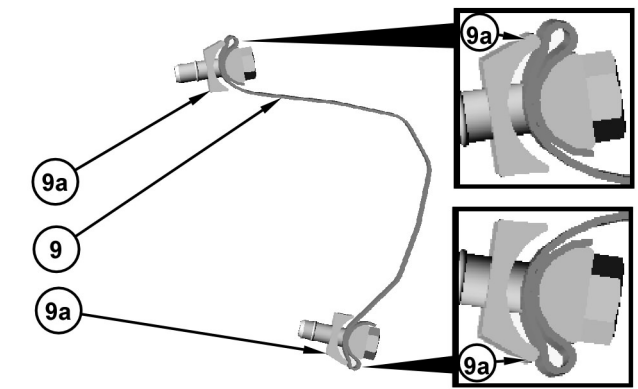


Illustration 28

g02485236

- a. When installing clamp assemblies (9), ensure the rounded edge of clamp spacers (9a) are oriented as shown.
- b. Tighten bolts (8) to a torque of  $40 \pm 5$  N·m ( $30 \pm 4$  lb ft).
- c. Apply Tooling (A) to the threads of clamp assemblies (1) and (5). Tighten clamp assemblies (1) and (5) to a torque of  $7.5 \pm 1$  N·m ( $66 \pm 9$  lb in).
- d. Lubricate the O-ring seals that are found on tube assembly (4) with the lubricant that is being sealed.

i03258415

# Electronic Unit Injector - Remove

SMCS Code: 1290-011

## Removal Procedure

Table 4

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 5F-4764     | Pry Bar          | 1   |

### Start By:

- a. Remove the rocker arms and the rocker arm shaft. Refer to Disassembly and Assembly, "Rocker Arm and Shaft - Remove".

#### NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

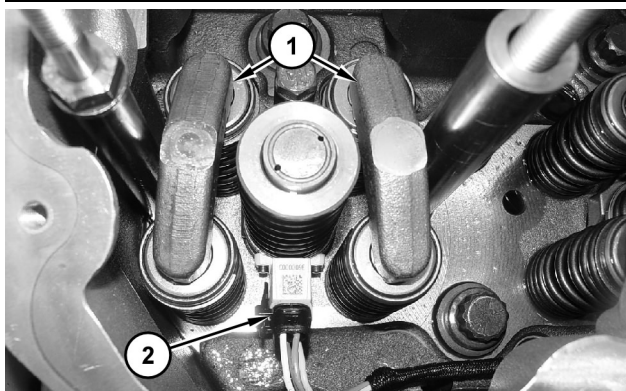


Illustration 29

g01259747

1. Remove valve bridges (1). Note the location and orientation of the valve bridges for installation purposes.
2. Disconnect harness assembly (2).

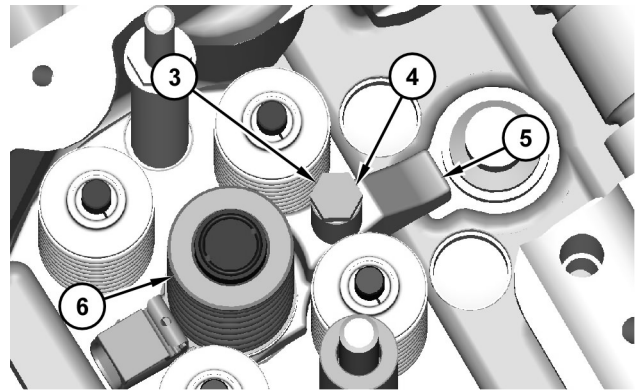


Illustration 30

g01259759

#### NOTICE

If the injector hold down bolt is loose during the removal procedure, inspect the injector bore for wear and debris. Replace the clamp and spacer.

3. Remove bolt (3) and spacer (4) from clamp (5).
4. Place an identification mark on electronic unit injector (6) for installation purposes. Each electronic unit injector must be reinstalled in the original location in the cylinder head.

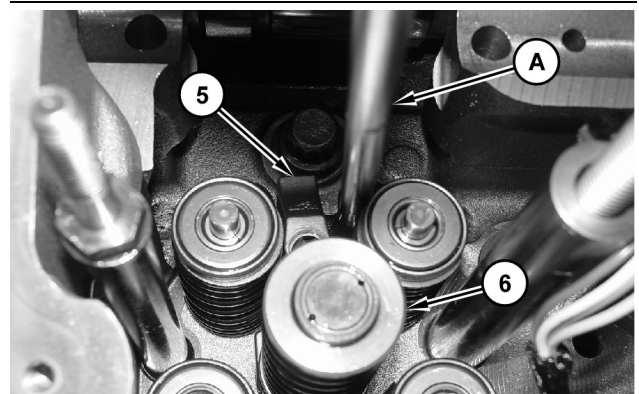


Illustration 31

g01259777

5. Use Tooling (A) in bolt hole in order to pry clamp (5) and electronic unit injector (6) free from the cylinder head.

**Note:** Improper use of Tooling (A) can cause damage to the spring or the unit injector.

6. Remove electronic unit injector (6) from the cylinder head.

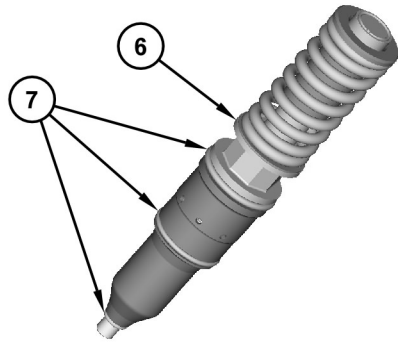


Illustration 32

g01259809

7. Remove O-ring seals (7) from electronic unit injector (6).

i02517803

## Electronic Unit Injector - Install

SMCS Code: 1290-012

### Installation Procedure

Table 5

| Required Tools |             |                               |     |
|----------------|-------------|-------------------------------|-----|
| Tool           | Part Number | Part Description              | Qty |
| B              | 8T - 2998   | Lubricant                     | -   |
| C              | 1U - 5718   | Vacuum Pump                   | 1   |
|                | 169 - 7372  | Fluid Sampling Bottle         | -   |
|                | 4C - 4057   | Tube<br>7.9 mm (0.31 inch) OD | -   |
| D              | 4C - 5552   | Large Bore Brush              | 1   |
| E              | 8T - 7765   | Surface Reconditioning Pad    | -   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Use Tooling (C) in order to remove the fuel and oil from the cylinder. Evacuate as much fuel and oil as possible from the cylinder before installing the electronic unit injector. Several evacuations may be necessary.
2. Use Tooling (D) in order to clean the carbon deposit from the inside of the electronic unit injector sleeve.

3. Use Tooling (E) in order to clean the carbon from the seat area that is inside of the electronic unit injector sleeve.

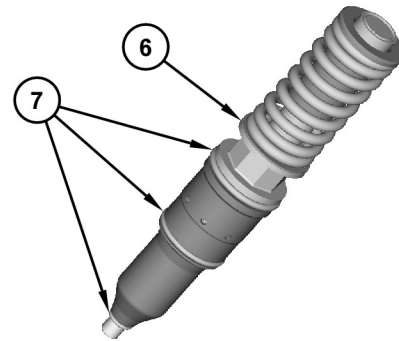


Illustration 33

g01259809

4. Install O-ring seals (7) on electronic unit injector (6). Lubricate the top two O-ring seals with a 50/50 mixture of clean engine oil and Tooling (B).

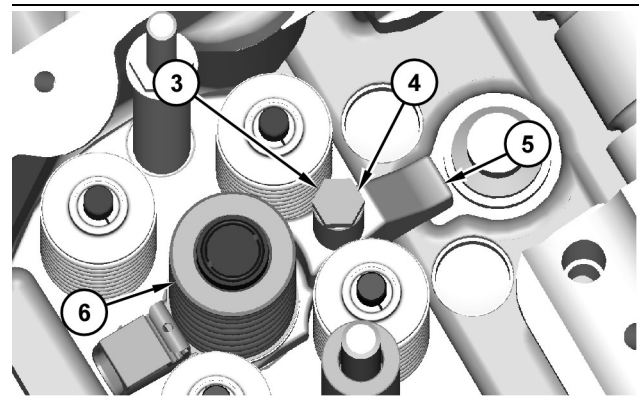


Illustration 34

g01259759

#### NOTICE

When an electronic unit injector is replaced, the new electronic injector code must be programmed into the engine's personality module software by using the calibration menu on the Electronic Service Tool. If the new electronic injector code is not entered, the characteristics of the previous electronic unit injector is assumed.

If it is not possible to immediately reprogram the electronic injector code into the personality module software, the engine will not be severely harmed. The new electronic injector code should be reprogrammed as quickly as possible in order to optimize engine performance.

5. Install electronic unit injector (6) and clamp (5) into the original location in the cylinder head.
6. Install spacer (4) and bolt (3). Tighten bolt (3) to a torque of  $55 \pm 10$  N·m ( $41 \pm 7$  lb ft).

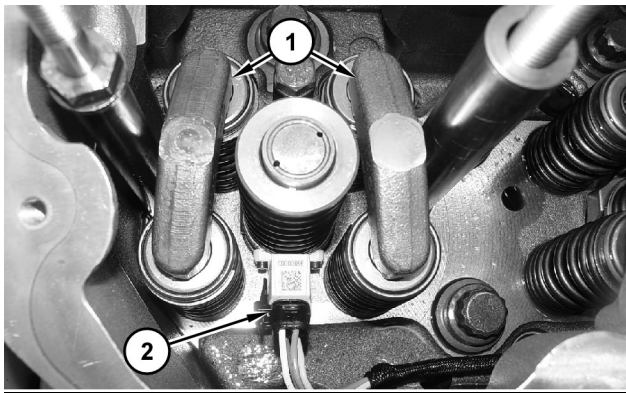


Illustration 35

g01259747

7. Connect harness assembly (2).
8. Install valve bridges (1).

**Note:** Make sure that the slotted end of the valve bridges are positioned toward the rocker arm shaft.

9. Remove the air from the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".

**End By:**

- a. Install the rocker arms and the rocker arm shaft. Refer to Disassembly and Assembly, "Rocker Arm and Shaft - Install".

i02518657

## Electronic Unit Injector Sleeve - Remove

SMCS Code: 1713-011

### Removal Procedure

Table 6

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 9U-6891     | Injector Tool Group | 1   |

**Start By:**

- a. Remove the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Drain the coolant from the cooling system into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change".

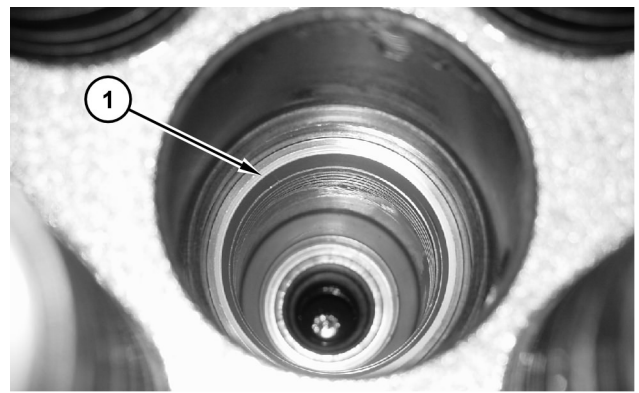


Illustration 36

g01260353

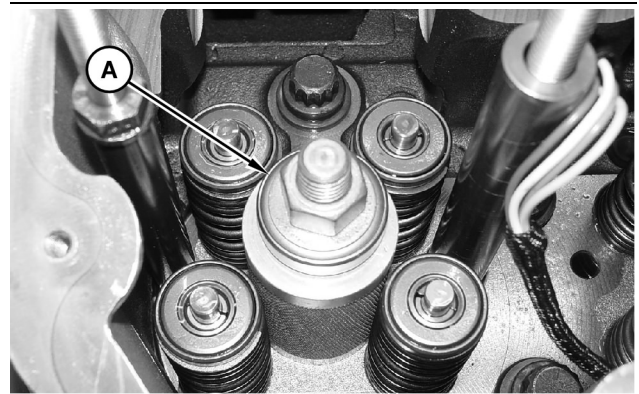


Illustration 37

g01260345

2. Install Tooling (A) in electronic unit injector sleeve (1).
3. Tighten the nut on Tooling (A) until the electronic unit injector sleeve is pulled free of the cylinder head.

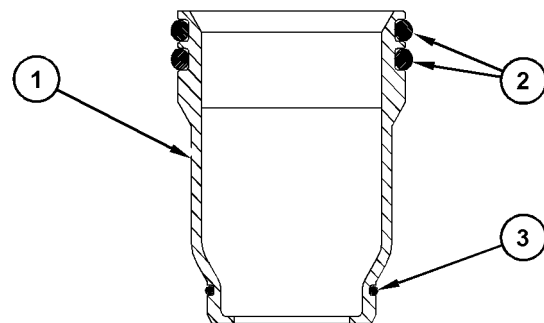


Illustration 38

g01260357

4. Remove O-ring seals (2) and O-ring seal (3) from electronic unit injector sleeve (1).

i02518658

## Electronic Unit Injector Sleeve - Install

SMCS Code: 1713-012

### Installation Procedure

Table 7

| Required Tools   |             |                    |     |
|------------------|-------------|--------------------|-----|
| Tool             | Part Number | Part Description   | Qty |
| B                | 9U-6862     | Tapered Brush      | 1   |
|                  | 9U-6863     | Small Bore Brush   | 1   |
|                  | 9U-7244     | End Brush          | 1   |
|                  | 9U-7237     | Brush Extension    | 1   |
|                  | 4C-5552     | Large Bore Brush   | 1   |
| C <sup>(1)</sup> | 221-9778    | Puller Stud        | 1   |
| D <sup>(1)</sup> | 9U-7258     | Driver Cap         | 1   |
| E                | 4C-9507     | Retaining Compound | -   |

<sup>(1)</sup> Part of the 9U-6891 Injector Tool Group

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Use Tooling (B) to clean the bore in the cylinder head for the electronic unit injector sleeve.

#### NOTICE

Ensure that the electronic unit injector sleeve and the cylinder head bore are completely free of oil, dirt, and sealant debris.

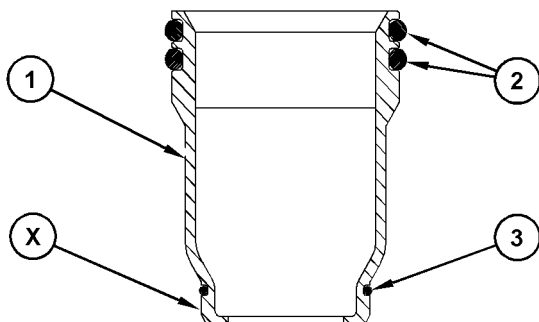


Illustration 39

g01260364

2. Install new O-ring seals (2) and O-ring seal (3) on electronic unit injector sleeve (1).

**Note:** Do not apply Tooling (E) to the cylinder head surfaces. Apply Tooling (E) on the electronic unit injector sleeve only.

3. Apply Tooling (E) to the contact surface of electronic unit injector sleeve (1) on the surface that is Marked "X".
4. Lubricate O-ring seals (2) with clean engine oil.

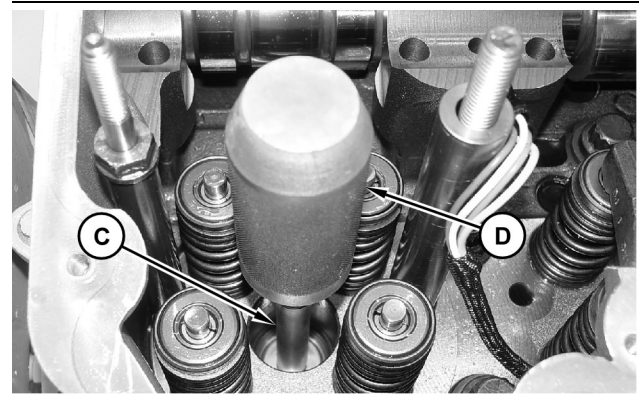


Illustration 40

g01260372

5. Install Tooling (C) into the threads of electronic unit injector sleeve (1).
6. Position Tooling (C) and the electronic unit injector sleeve in the cylinder head. Use care not to damage the O-ring seals on the electronic unit injector sleeve.
7. Use Tooling (D) and a hammer to install electronic unit injector sleeve (1) in the cylinder head.

#### NOTICE

Ensure that the electronic unit injector sleeve is properly seated in the cylinder head. The Tooling will "RING" when the electronic unit injector sleeve is fully seated in the bore of the cylinder head.

8. Remove Tooling (D) and Tooling (C). Use a clean towel and remove excess Tooling (E).
9. Fill the cooling system with coolant. Refer to Operation and Maintenance, "Refill Capacities" for the cooling system capacity.

#### End By:

- a. Install the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

i04446554

# Turbocharger - Remove and Install

SMCS Code: 1052-010

## Removal Procedure

Table 8

| Required Tools |             |   |     |
|----------------|-------------|---|-----|
| Tool           | Part Number | Part Description                              | Qty |
| A              | -           | Henkel Corporation Anti-Seize Compound (C5-A) | -   |

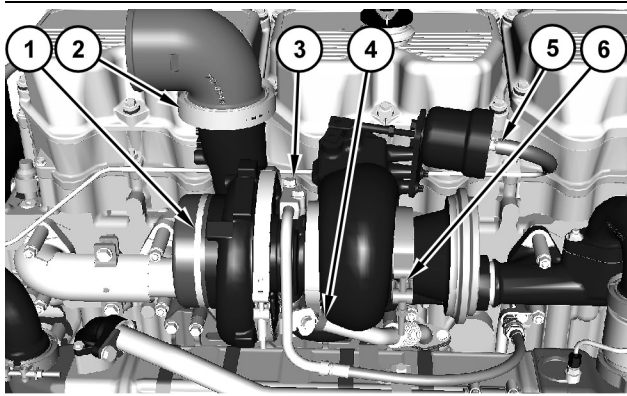


Illustration 41

g01841534

### NOTICE

Failure to follow established procedures can lead to damage of the parts.

To avoid damage to the parts, always identify and mark the parts so that the parts can be installed in the same location.



**The ends of the bellows are very sharp. Injury could occur if the bellows are not handled properly. Handle the bellows by the convolutions.**

**Note:** Refer to Special Instruction, REHS1728, "Application Guideline for the Bellows" for additional information on handling the bellows if the machine is equipped.

**Note:** Ensure that all main surfaces are clean and free of debris.

1. Loosen clamp assembly (1) and disconnect the hose that attaches to the intake side of the turbocharger (not shown).

2. Remove clamp assemblies (2), (5), and (6).
3. Disconnect both tube assemblies (3) and (4).

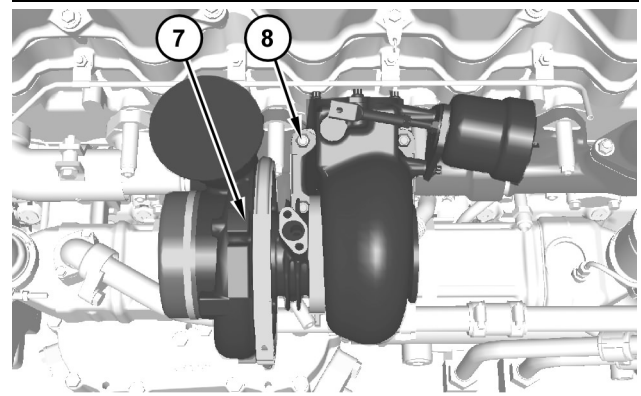


Illustration 42

g01841575

4. Remove nuts (8) and discard the nuts. Use two people in order to remove turbocharger (7). The weight of turbocharger (7) is approximately 31 kg (70 lb).
5. Remove the gasket from the exhaust manifold.

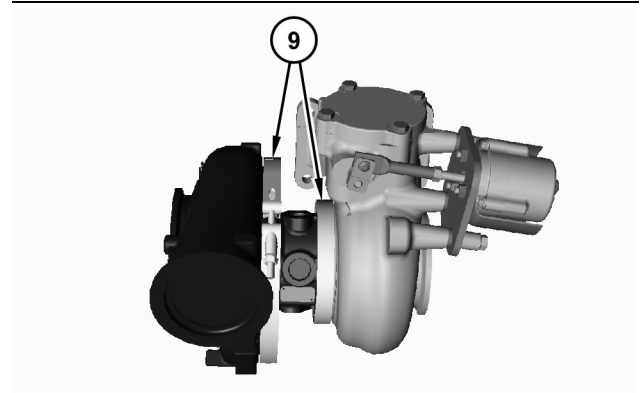


Illustration 43

g02216274

**Note:** Clamp assemblies (9) are one time use parts. Discard the clamp assemblies whenever they are loosened.

6. Loosen clamp assemblies (9) in order to separate the housings from the cartridge assembly. Discard clamp assemblies (9).

## Installation Procedure

**Note:** Check all of the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

**NOTICE**

The alignment of the bellows is important. Improper alignment may lead to premature failure of the bellows. Misalignment can be identified by visually inspecting the convolutions for uniformity of compression.

Inspect the bellows for damage prior to installation. If there is any damage to the convolutions, discard the bellows. Minor damage to the ends of the bellows may be repaired. However, if there is any difficulty in installation after the repair, discard the bellows.

1. Install turbocharger (7) in the reverse order.
  - a. Tighten new clamp assemblies (9) to a torque of  $13.6 \pm 1.2$  N·m ( $120 \pm 11$  lb in).
  - b. Apply Tooling (A) to the threads of the studs and to the threads of nuts (8). Tighten nuts (8) to a torque of  $70 \pm 5$  N·m ( $52 \pm 4$  lb ft).
  - c. Tighten clamp assemblies (2) to a torque of  $8.5 \pm 2$  N·m ( $75 \pm 17$  lb in).
  - d. Tighten clamp assembly (6) to a torque of  $12 \pm 4$  N·m ( $106 \pm 35$  lb in).
  - e. Tighten clamp assembly (1) to a torque of  $13.5 \pm 1$  N·m ( $119 \pm 9$  lb in).

i03939694

## Solenoid Valve (Exhaust Balance) - Remove and Install

SMCS Code: 1052-010-VL

### Removal Procedure

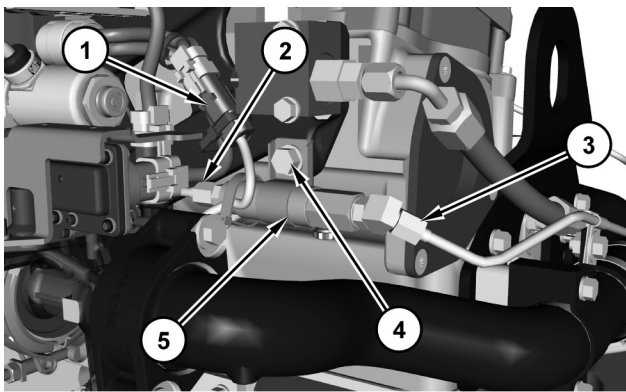


Illustration 44

g02155955

1. Disconnect harness assembly (1).
2. Disconnect tube assembly (2).

3. Disconnect tube assembly (3).
4. Remove bolt (4) and remove balance valve (5).

### Installation Procedure

1. Install the balance valve (5) in the reverse order.

i04024634

## Exhaust Sensor Lines - Remove and Install

SMCS Code: 1923-IL

### Removal Procedure

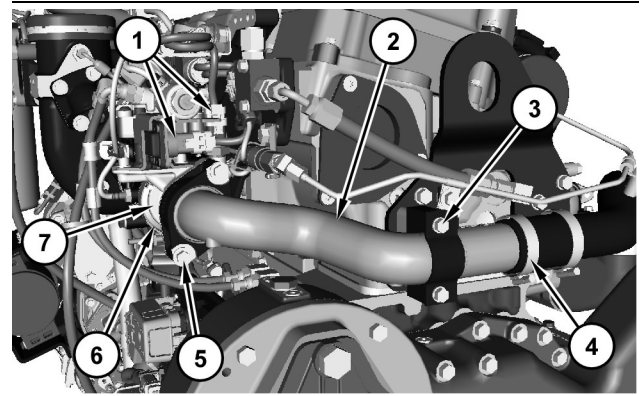


Illustration 45

g02156225

View from the rear of the engine

1. Disconnect harness assemblies (1).
2. Remove bolts (3).
3. Remove clamp (4)
4. Remove bolts (5) and remove tube assembly (2).
5. Loosen clamp assembly (6) and remove exhaust gas venturi (7).

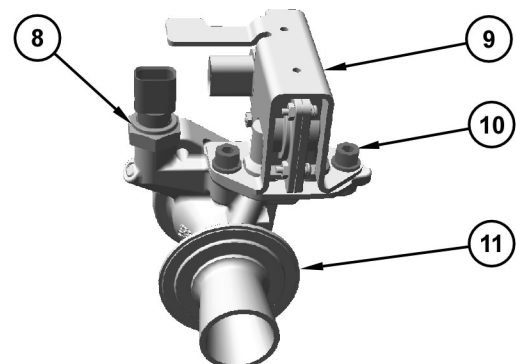


Illustration 46

g02156370

6. Remove pressure sensor (8).
7. Remove bolts (10). Remove differential pressure sensor (9) from venturi (11).

## Installation Procedure

1. Install the exhaust sensor lines group in the reverse order.

**Note:** Check the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

- a. Tighten pressure sensor (8) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).
- b. Tighten clamp assembly (6) to a torque of  $8.5 \pm 2$  N·m ( $75 \pm 18$  lb in).

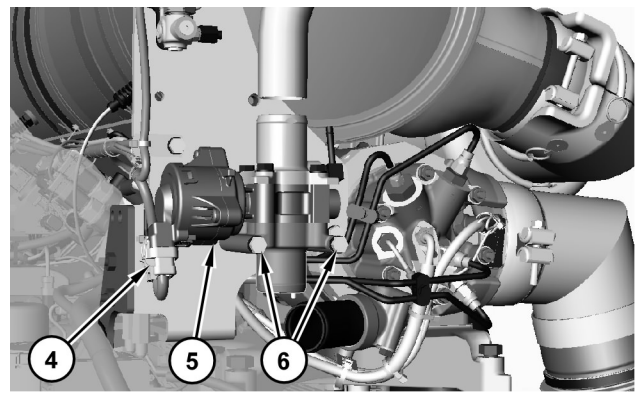


Illustration 48

g02204097

4. Disconnect harness assembly (4).
5. Remove bolts (6) and remove air control valve (5).

## Air Control Valve - Remove and Install (ARD Combustion, Clean Emissions Module)

SMCS Code: 108A-010

## Removal Procedure

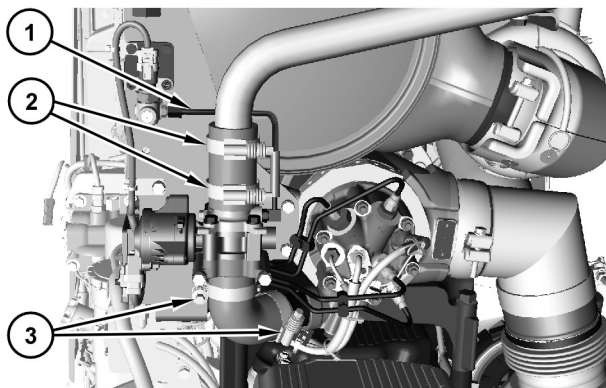


Illustration 47

g02204096

1. Remove tube assembly (1).
2. Loosen clamp assemblies (2) and remove the hose.
3. Loosen clamp assemblies (3) and remove the hose.

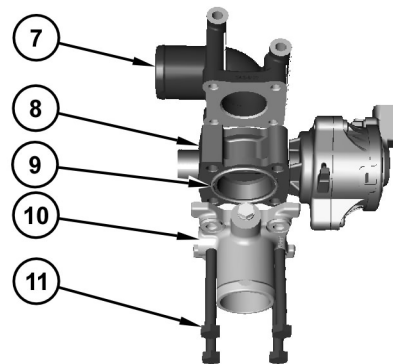


Illustration 49

g02204633

Typical Example

6. Remove bolts (11). Separate housings (10) and (7) from the air control valve actuator (8). Remove both seals (9) from the housings.

## Installation Procedure

1. Install the air control valve in the reverse order.

i04151149

i03513485

## Exhaust Gas Valve (NRS) - Remove and Install

SMCS Code: 108N-010; 5510

### Removal Procedure

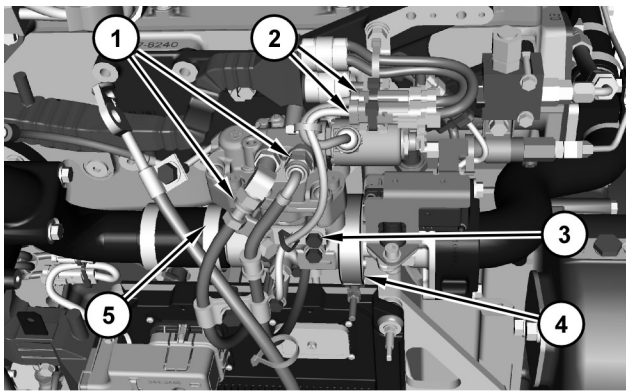


Illustration 50

g02347636

1. Disconnect harness assemblies (2) and disconnect hose assemblies (1). Remove bolt (3) and the bracket.
2. Loosen clamp assemblies (4) and (5).

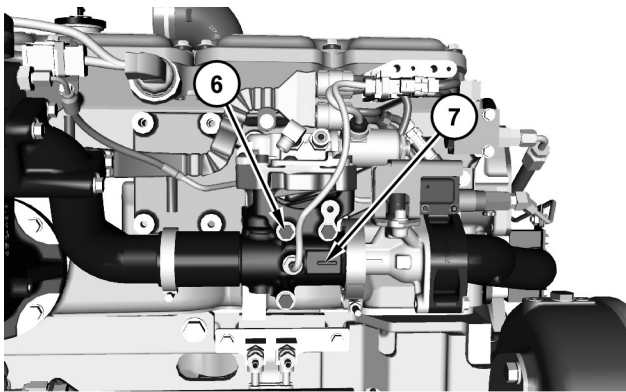


Illustration 51

g02156919

3. Remove three bolts (6). Remove exhaust gas valve (7).

### Installation Procedure

1. Install the exhaust gas valve (7) in reverse order.

## Exhaust Gas Valve (NRS) - Disassemble

SMCS Code: 108N-015; 5510

### Disassembly Procedure

Start By:

- a. Remove the Exhaust Gas Valve.



Illustration 52

g01845346

1. Remove temperature sensor (1).
2. Remove bolts (2). Separate actuator assembly (3) from the valve housing (4).

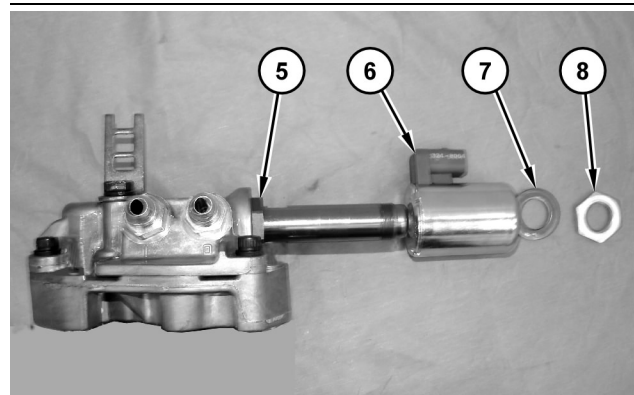


Illustration 53

g01845473

3. Remove nut (8), washer (7), and solenoid (6).
4. Remove spool (5).

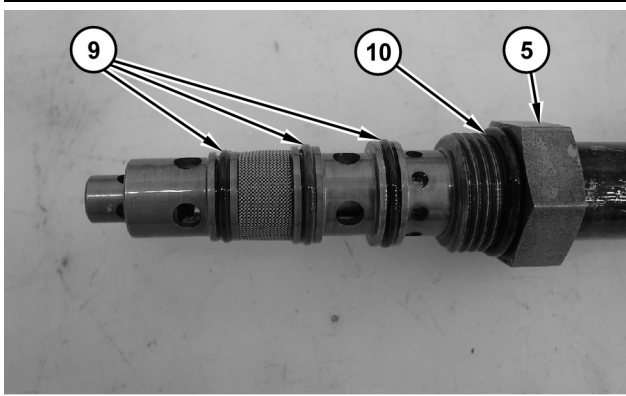


Illustration 54

g01896079

5. Remove O-rings (9) and (10) from spool (5).

i04148533

## Exhaust Gas Valve (NRS) - Assemble

SMCS Code: 108N-016; 5510

### Assembly Procedure

Table 9

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 5P-3931     | Anti-Seize Compound | -   |
| B              | 1P-0808     | Multipurpose Grease | -   |

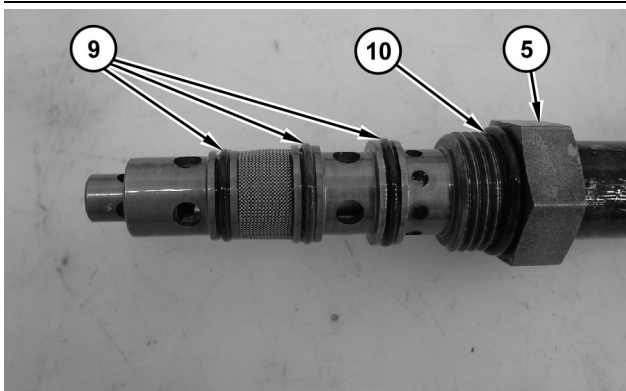


Illustration 55

g01896079

1. Lubricate all of the O-ring seals with the lubricant that is being sealed.

2. Install O-rings (9) and (10) onto spool (5).

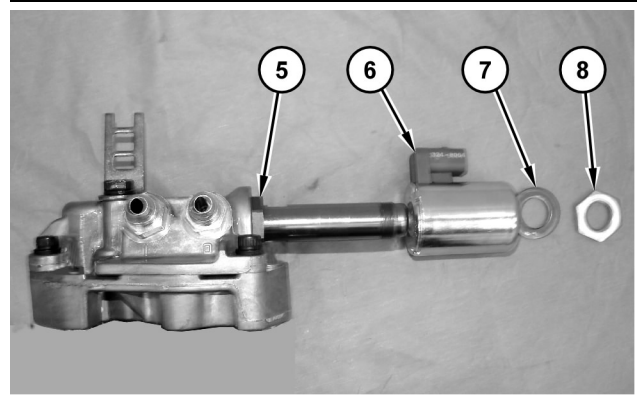


Illustration 56

g01845473

3. Install spool (5) into the actuator housing. Tighten spool (5) to a torque of  $50 \pm 5$  N·m ( $37 \pm 4$  lb ft).

4. Install solenoid (6), washer (7), and nut (8).

5. Tighten nut (8) to a torque of  $20 \pm 2.5$  N·m ( $177 \pm 22$  lb in).

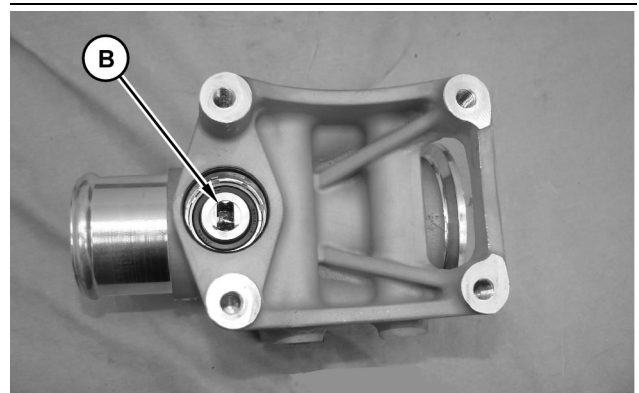


Illustration 57

g01871983

6. Fill the cavity (B) to the halfway mark with Tooling (B). Cavity (B) is found on the valve housing.

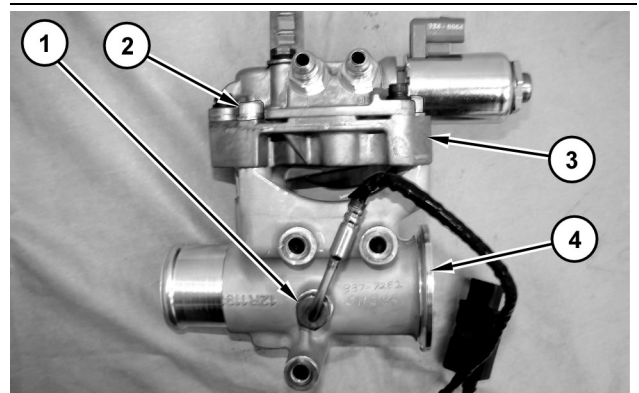


Illustration 58

g01845346

7. Position actuator assembly (3) on valve housing (4). Install bolts (2).

8. Install temperature sensor (1). Apply Tooling (A) to the threads on temperature sensor (1). Tighten temperature sensor (1) to a torque of  $45 \pm 5$  N·m ( $33 \pm 4$  lb ft).

i04023069

## Ignition Coil - Remove and Install (Clean Emissions Module)

SMCS Code: 1554-010

### Removal Procedure

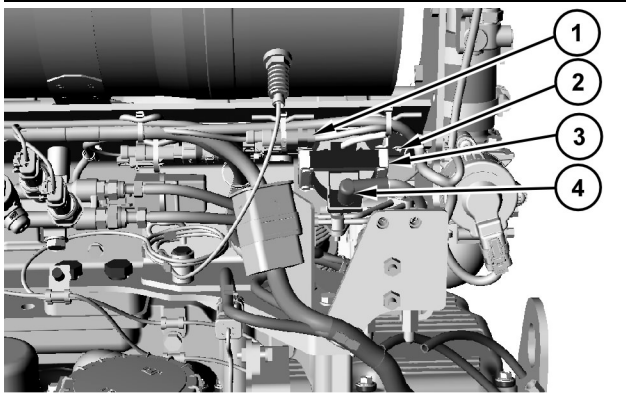


Illustration 59

g02202258

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

1. Disconnect harness assembly (1) and remove the cable straps.
2. Remove cable assembly (4).
3. Remove bolts (2) and remove the ignition coil (3).

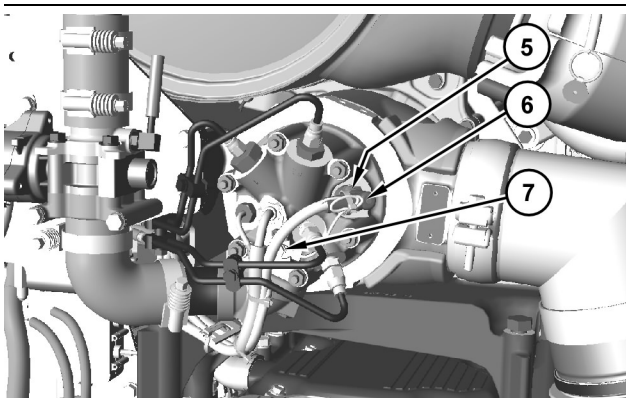


Illustration 60

g02202435

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

4. Disconnect cable assembly (7) and disconnect cable assembly (6).
5. Remove spark plug (5).

### Installation Procedure

1. Install the coil assembly (3) in the reverse order.
  - a. Tighten spark plug (5) to a torque of  $47 \pm 4$  N·m ( $35 \pm 3$  lb ft).

i04023137

## Relay (ARD Nozzle Heater) - Remove and Install (Clean Emissions Module)

SMCS Code: 4493-HTR

### Removal Procedure

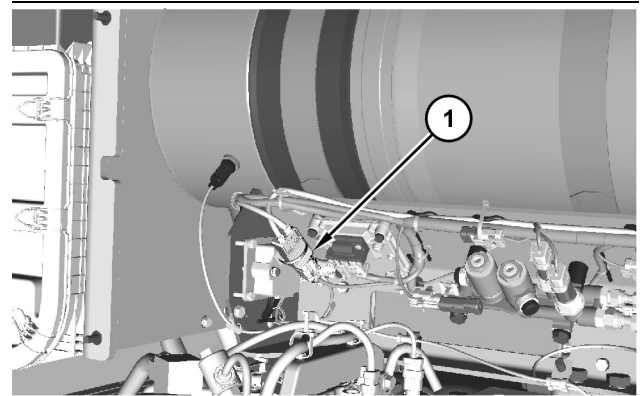


Illustration 61

g02202673

1. Remove the cable straps and position flame detection temperature sensor (1) out of the way.

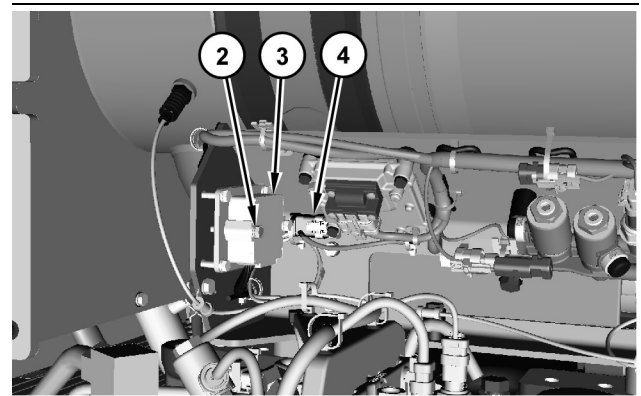


Illustration 62

g02202674

2. Disconnect harness assembly (4).
3. Remove bolts (2) and remove relay (3).

## Installation Procedure

1. Install relay assembly (2) in the reverse order.

i04338310

## Exhaust Manifold - Remove and Install

SMCS Code: 1059-010

## Removal Procedure

Table 10

| Required Tools |             |                       |     |
|----------------|-------------|-----------------------|-----|
| Tool           | Part Number | Part Description      | Qty |
| (A)            | 361-5661    | Bellows Tool Assembly | 1   |

### Start By:

- a. Remove the turbocharger.
- b. Remove the water temperature regulator housing.

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

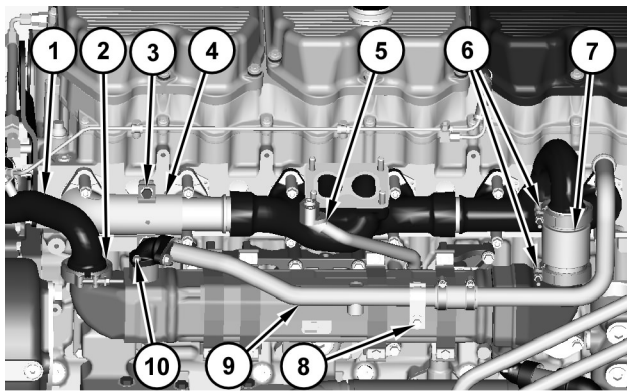


Illustration 63

g02494237

### CAUTION

The ends of the bellows are very sharp. Injury could occur if the bellows are not handled properly. Handle the bellows by the convolutions.

**Note:** Refer to Special Instruction, REHS1728, "Application Guideline for the Bellows" for additional information on handling the bellows.

1. Remove clamp assembly (2) and position tube assembly (1) out of the way.
2. Remove bolts (3) and remove heat shield assembly (4).
3. Remove tube assembly (5).
4. Remove clamp assemblies (6). Use Tooling (A) in order to remove bellows (7).
5. Remove bolts (8) and (10). Remove tube assembly (9).

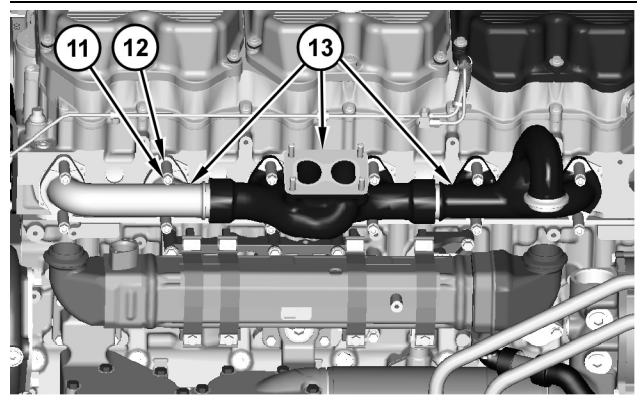


Illustration 64

g02494496

6. Remove nuts (11) and remove spacers (12). Discard nuts (11).
7. Remove exhaust manifold assembly (13) and remove the gaskets.

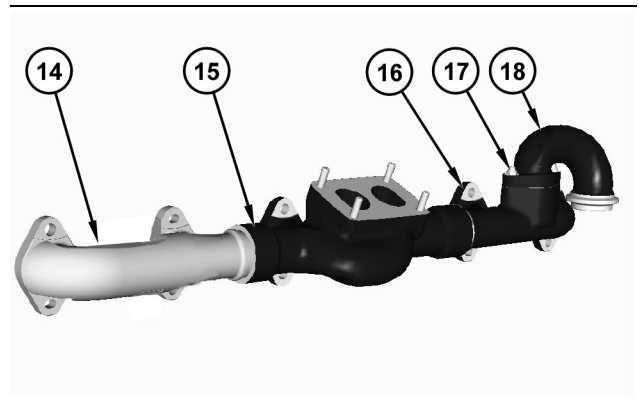


Illustration 65

g02494559

**Note:** Note the orientation of the exhaust manifold sections for use in installation procedure.

8. Remove nuts (17) and discard the nuts. Remove elbow (18) and the gasket. separate exhaust manifold sections (14), (15), and (16).

## Installation Procedure

Table 11

| Required Tools |             |                                 |     |
|----------------|-------------|---------------------------------|-----|
| Tool           | Part Number | Description                     | Qty |
| (A)            | 361 - 5661  | Bellows Tool Assembly           | 1   |
| B              | -           | Anti-Seize Compound             | 1   |
| C              | 2P - 2333   | 3M 1137 High Temperature Sealer | 1   |
| D              | 165 - 4638  | Guide                           | 3   |

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Check the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

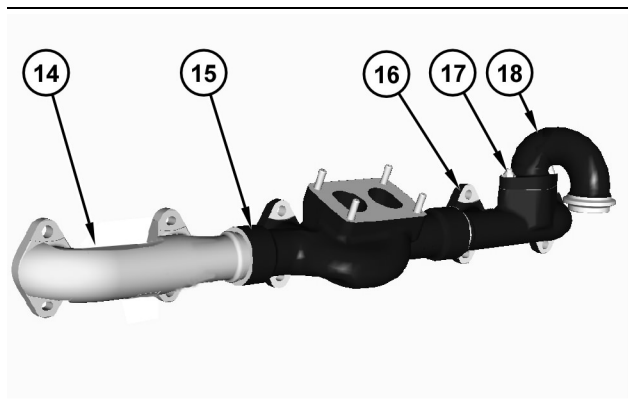


Illustration 66

g02494599

**Note:** Note the orientation of the exhaust manifold sections for use in installation procedure.

**Note:** Cleanliness is an important factor. Before assembly, all parts should be thoroughly cleaned in cleaning fluid. Allow the parts to air dry. Wiping cloths or rags should not be used to dry parts. Lint may be deposited on the parts which may cause later trouble. Inspect all parts. If any parts are worn or damaged, use new parts for replacement.

1. Position elbow (18) and the gasket into position on manifold section (16).
2. Apply Tooling (B) on the threads of nuts (17). Install the nuts. Tighten nuts (17) to a torque of  $70 \pm 5 \text{ N}\cdot\text{m}$  ( $52 \pm 4 \text{ lb ft}$ ).

3. Apply a thin coat of Tooling (C) to the outside of the male ends of manifold sections (14) and (16). Assemble manifold sections (14), (15), and (16), as shown.

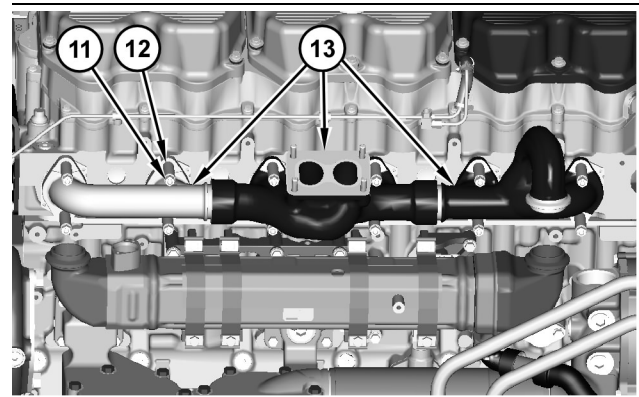


Illustration 67

g02494496

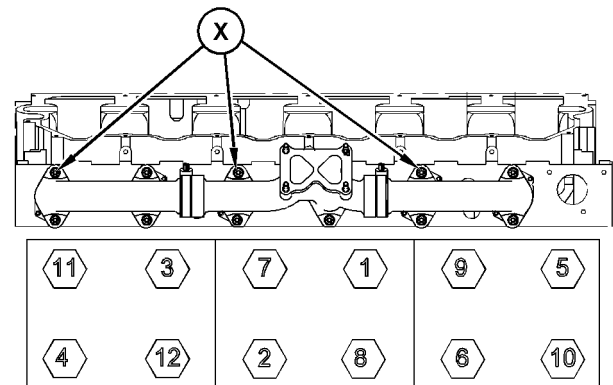


Illustration 68

g01381130

Torque Sequence

4. Position exhaust manifold (13) and the gaskets into position.
5. Apply Tooling (B) on the threads of nuts (11).
6. Install Tooling (D) at Locations (X). Position spacers (12) and install new nuts (11). Hand tighten nuts (11). Remove Tooling (D). Install remaining spacers (12) and nuts (11). Tighten nuts (11) in the above sequence to a torque of  $20 \pm 3 \text{ N}\cdot\text{m}$  ( $15 \pm 2 \text{ lb ft}$ ). Tighten nuts (11) again in the above sequence to a torque of  $50 \pm 5 \text{ N}\cdot\text{m}$  ( $37 \pm 4.0 \text{ lb ft}$ ).

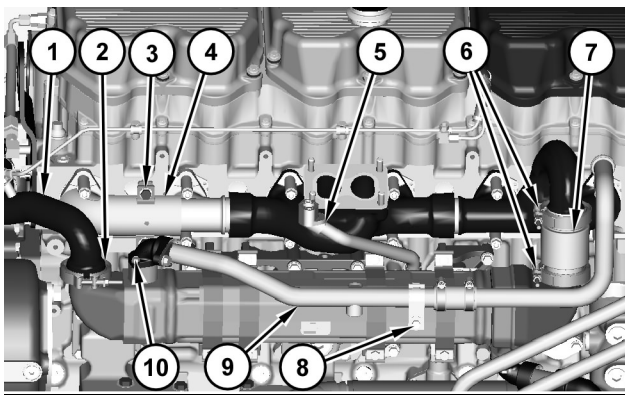


Illustration 69

g02494237

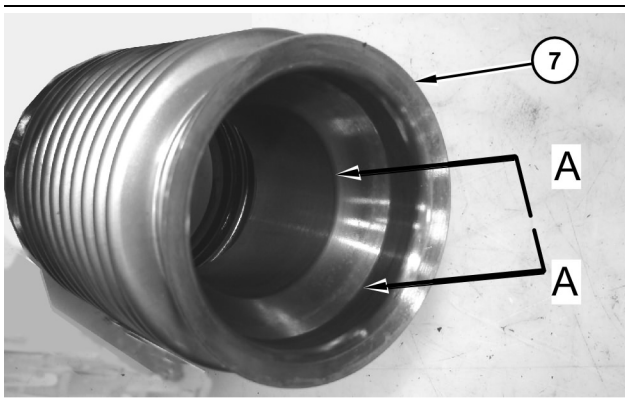


Illustration 70

g02494743

### CAUTION

The ends of the bellows are very sharp. Injury could occur if the bellows are not handled properly. Handle the bellows by the convolutions.

**Note:** Refer to Special Instruction, REHS1728, "Application Guideline for the Bellows" for additional information on handling the bellows.

7. Position heat shield assembly (4) and install bolts (3). Tighten bolts (3) to a torque of  $25 \pm 7$  N·m ( $18 \pm 5$  lb ft).
8. Install tube assembly (5).
9. Position clamp assemblies (6). Use Tooling (A) in order to install bellows (7). Ensure that the end of the bellows with the taper (A-A) is facing the exhaust manifold.
10. Tighten clamp assemblies (6) to a torque of  $7.5 \pm 1$  N·m ( $66 \pm 8$  lb in).
11. Position tube assembly (9) and install bolts (8) and (10).
12. Position tube assembly (1) and install clamp assembly (2). Tighten clamp assembly (2) to a torque of  $7.5 \pm 1$  N·m ( $66 \pm 8$  lb in).

### End By:

- a. Install the turbocharger.
- b. Install the water temperature regulator housing.

i04152917

## Exhaust Elbow - Remove and Install (Clean Emissions Module Inlet)

SMCS Code: 1061-010-E4

### Removal Procedure

1. If reusing the exhaust elbow, refer to Special Instruction, REHS5014, "Reuse Guideline for the Lines Group - Flexpipe on Tier 4 Engines".

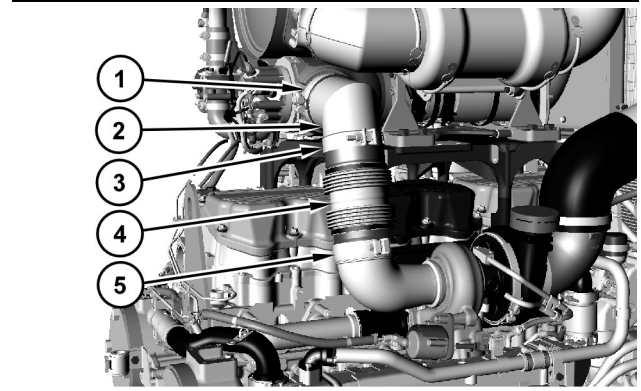


Illustration 71

g02197073

2. Loosen clamp assemblies (1), (3) and (5).
3. Slide elbow (2) into bellows (4) in order to gain clearance. Remove the bellows assembly.

**Note:** All of the parts that have been removed should be discarded. The parts are all one time use parts.

4. Discard clamp assemblies (1), (3), and (5). Discard elbow (2) and bellows (4).

### Installation Procedure

1. If reusing the exhaust elbow, refer to Special Instruction, REHS5014, "Reuse Guideline for the Lines Group - Flexpipe on Tier 4 Engines".

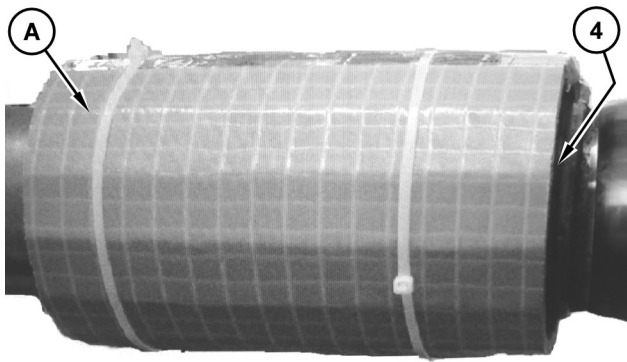


Illustration 72 g02095400

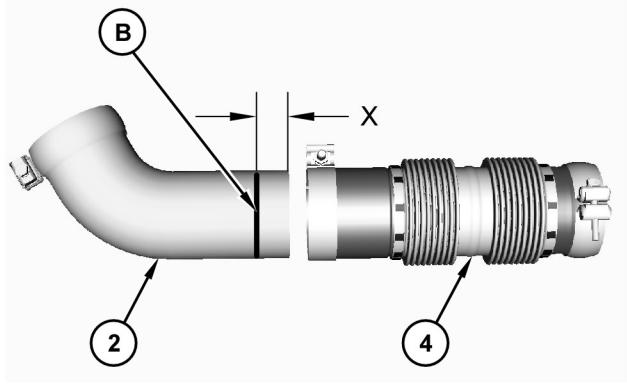


Illustration 73 g02092825

Alignment wrap (A) is not shown for photographic purposes.  
Typical Example

**Note:** Alignment wrap (A) will be included with the new bellows assembly. The Tooling will be pre-installed on the bellows.

**Note:** The alignment wrap (A) should not be removed until Step 11. Bellows (4) should never be flexed during installation.

2. Distance (X) is 40 mm (1.6 inch). Place Mark (B) onto elbow (2). a Distance (X) from the end of elbow (2).
3. Insert elbow (2) into the bellows. The elbow should be inserted as far as possible without using force. This action will minimize the overall length of the bellows assembly and will help with installation.

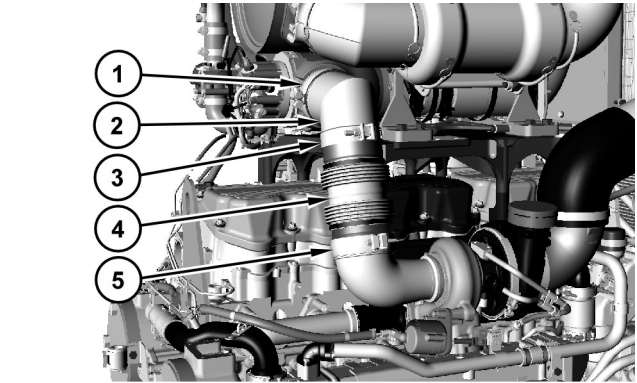


Illustration 74 g02197073

Alignment wrap (A) is not shown for photographic purposes.

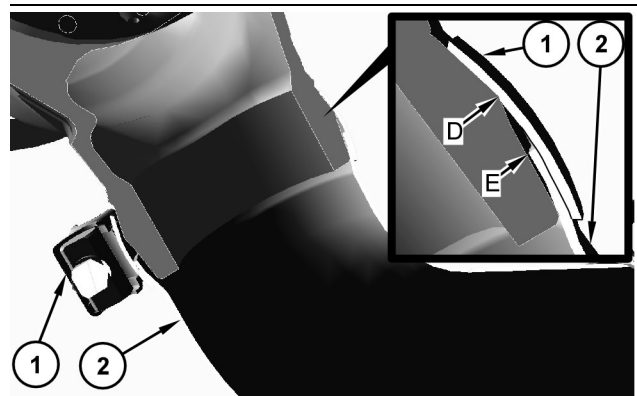


Illustration 75 g02097701

The photo is a cutaway view of the ball clamp assembly which is located near the combustion head group.

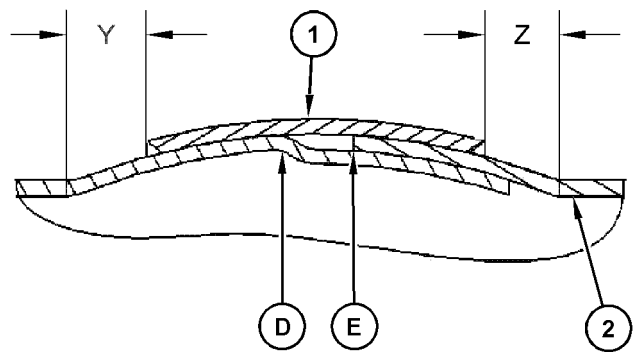


Illustration 76 g02098533

The photo is a cutaway view of the ball clamp assembly.

4. Prior to installation, position both ball clamp assemblies (1) and (5) onto the bellows assembly.
5. Position the bellows assembly between the Clean Emissions Module and the turbocharger adapter. Adjust the length of elbow (2) in the slip joint at clamp assembly (3) in order to position the bellows assembly.

6. Verify that the cup of the ball joint (E) does not touch the radius of the ball (D). Position ball clamp (1) and hand tighten ball clamp (1). Measure Distance (Y) and Distance (Z). The two measurements should be equal. Repeat the measurements every 90° around ball clamp (1). If necessary, adjust ball clamp (1).
7. Repeat Step 6 for ball clamp (5) which is located near the turbocharger.
8. Verify that Mark (B) is not visible at the slip joint that is positioned near clamp assembly (3).

**Note:** Do not use power tools in order to torque clamp assemblies (1), (3), and (5).

9. Torque ball clamp (1) to a torque of  $35 \pm 2$  N·m ( $26 \pm 1$  lb ft).
10. Torque ball clamp (5) to a torque of  $35 \pm 2$  N·m ( $26 \pm 1$  lb ft).
11. Remove alignment wrap (A) from bellows (4).
12. Torque clamp assembly (3) to a torque of  $55 \pm 8$  N·m ( $41 \pm 6$  lb ft).

i04047141

## Exhaust Elbow - Remove and Install (Clean Emissions Module Outlet)

SMCS Code: 1061-010-E4

### Removal Procedure

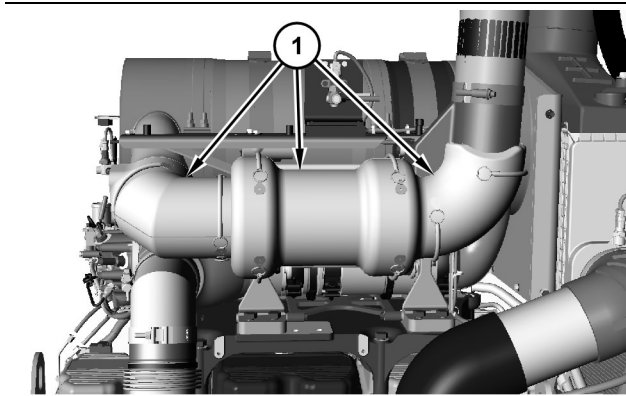


Illustration 77

g02197315

1. Remove heat shields (1).

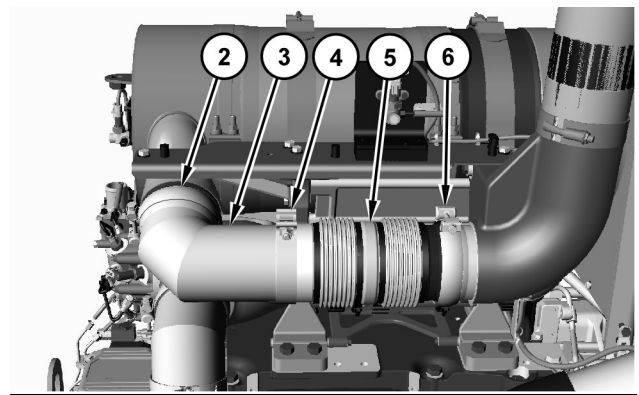


Illustration 78

g02197322

2. Loosen clamp assemblies (2), (4) and (6).
3. Slide elbow (3) into bellows (5) in order to gain clearance. Remove the bellows assembly.

**Note:** All of the below listed parts that have been removed should be discarded. The parts are all one time use parts.

4. Discard clamp assemblies (2), (4), and (6). Discard elbow (3) and bellows (5).

### Installation Procedure

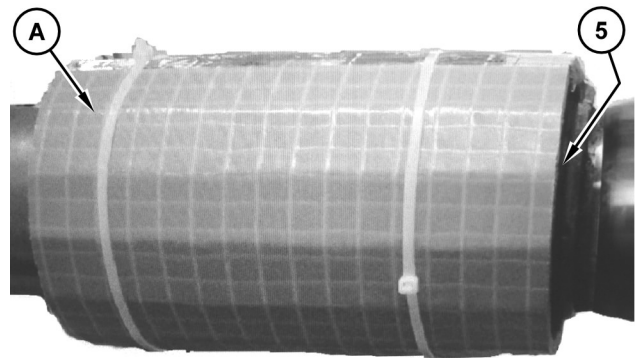


Illustration 79

g02197375

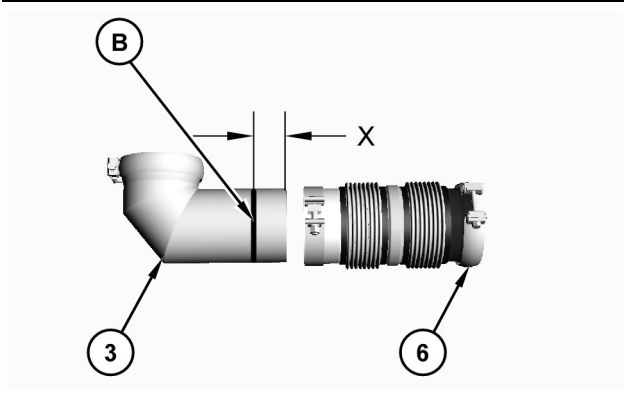


Illustration 80 g02197413

Alignment wrap (A) is not shown for photographic purposes. Typical Example

**Note:** Alignment wrap (A) will be included with the new bellows assembly. The Tooling will be pre-installed on the bellows.

**Note:** The alignment wrap (A) should not be removed until Step 10. Bellows (5) should never be flexed during installation.

1. Distance (X) is 40 mm (1.6 inch). Place Mark (B) onto elbow (3). a Distance (X) from the end of elbow (3).
2. Insert elbow (3) into the bellows. The elbow should be inserted as far as possible without using force. This action will minimize the overall length of the bellows assembly and will help with installation.

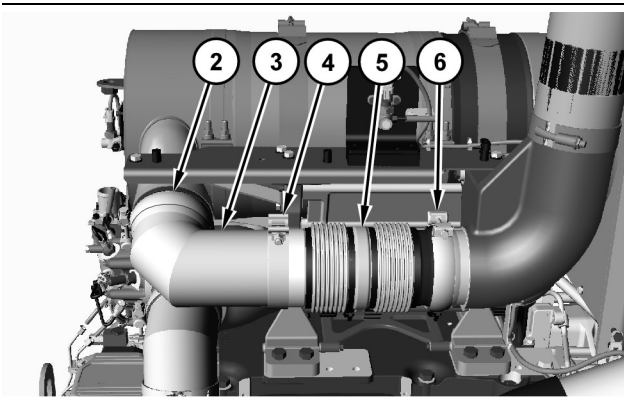


Illustration 81 g02197322

Alignment wrap (A) is not shown for photographic purposes.

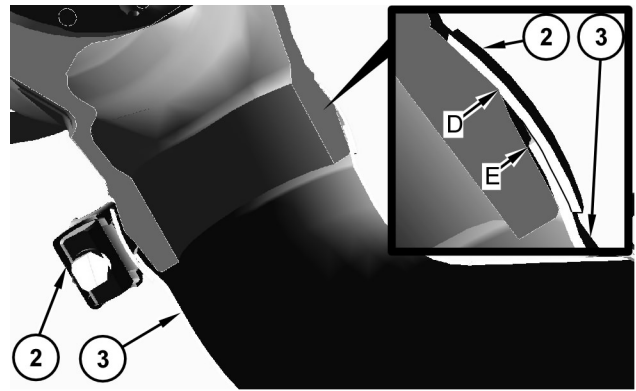


Illustration 82 g02197473

The photo is a cutaway view of the ball clamp assembly which is located near the Clean Emissions Module outlet.

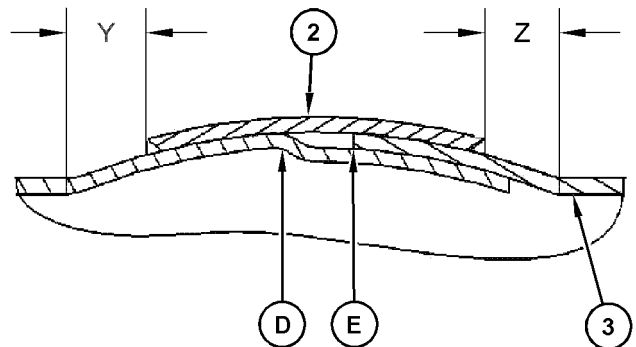


Illustration 83 g02197833

The photo is a cutaway view of the ball clamp assembly.

3. Prior to installation, position both ball clamp assemblies (2) and (6) onto the bellows assembly.
4. Position the bellows assembly between the Clean Emissions Module and the turbocharger adapter. Adjust the length of elbow (3) in the slip joint at clamp assembly (4) in order to position the bellows assembly.
5. Verify that the cup of the ball joint (E) does not touch the radius of the ball (D). Position ball clamp (2) and hand tighten ball clamp (2). Measure Distance (Y) and Distance (Z). The two measurements should be equal. Repeat the measurements every 90° around ball clamp (2). If necessary, adjust ball clamp (2).
6. Repeat Step 5 for ball clamp (6) which is located near the turbocharger.
7. Verify that Mark (B) is not visible at the slip joint that is positioned near clamp assembly (4).

**Note:** Do not use power tools in order to torque clamp assemblies (2), (4), and (6).

8. Torque ball clamp (2) to a torque of  $35 \pm 2$  N·m ( $26 \pm 1$  lb ft).
9. Torque ball clamp (6) to a torque of  $35 \pm 2$  N·m ( $26 \pm 1$  lb ft).
10. Remove alignment wrap (A) from bellows (5).
11. Torque clamp assembly (4) to a torque of  $55 \pm 8$  N·m ( $41 \pm 6$  lb ft).

i04096709

## Diesel Particulate Filter - Remove and Install (Clean Emissions Module)

SMCS Code: 108F-010

### Removal Procedure

Table 12

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 352-5891    | Strap            | 2   |
| B              |             | Loctite 771      | -   |

#### Start By:

- a. Connect the engine to Caterpillar Electronic Technician (Cat ET) before the DPF is removed from the engine. Once the engine is connected to Cat ET, then perform an ash service test. This test is a manual regeneration. Allow the DPF to cool before proceeding.

#### WARNING

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

#### WARNING

Wear goggles, gloves, protective clothing, and a National Institute for Occupational Safety and Health (NIOSH) approved P95 or N95 half-face respirator when handling a used Diesel Particulate Filter or Catalytic Converter Muffler. Failure to do so could result in personal injury.

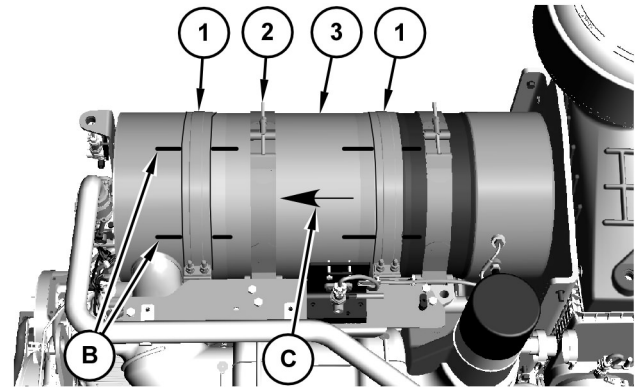


Illustration 84

g02198514

Overhead view of the Diesel Particulate Filter

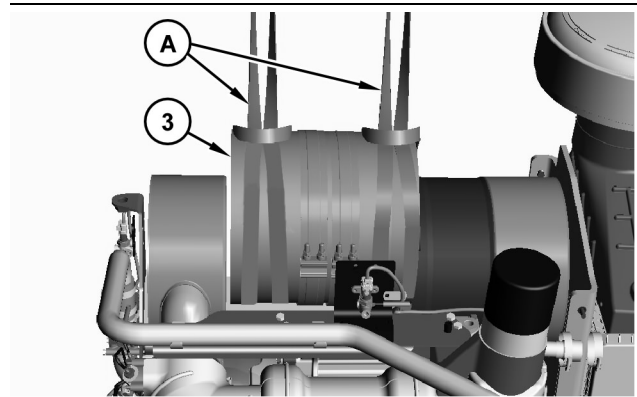


Illustration 85

g02198556

1. Put identification marks (B) on both sides of clamp assemblies (1) for installation purposes.
  2. Put identification mark (C) on the diesel particulate filter (3) for installation purposes. Identification mark (C) is showing the flow of exhaust gases through the diesel particulate filter.
  3. Loosen clamp assemblies (1) and reposition the clamp assemblies toward the center of diesel particulate filter (3). Tighten clamp assemblies (1).
- Note:** Do not allow any objects to contact the internal element of the diesel particulate. Do not shake or bump the filter assembly.
4. Install Tooling (A) onto diesel particulate filter (3). The weight of diesel particulate filter (3) is approximately 27 kg (60 lb).
  5. Loosen clamp assembly (2) and remove diesel particulate filter (3).

### Installation Procedure

1. Install the diesel particulate filter (3) in the reverse order.

- a. Install new clamp assemblies (1). Use hand tools in order to tighten clamp assemblies (1) to a torque of  $50 \pm 2.5 \text{ N}\cdot\text{m}$  ( $37 \pm 2 \text{ lb ft}$ ).

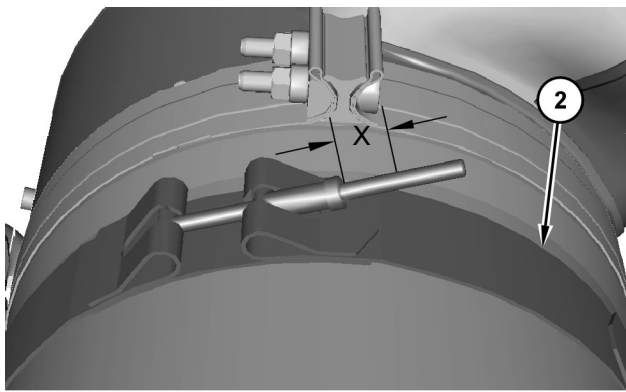


Illustration 86 g02206673

- b. Apply Tooling (B) to the threads of clamp assembly (2) for a Distance (X). Distance (X) is 25 mm (1 inch) above the trunnion. Use hand tools in order to tighten clamp assembly (2). Tighten clamp assembly (2) to a torque of  $15 \pm 3 \text{ N}\cdot\text{m}$  ( $133 \pm 27 \text{ lb in}$ ).

**End By:**

- a. Reset the Engine Ash Model. Refer to Special Instruction, REHS5026.

i04259649

## Catalyst - Remove and Install (Diesel Oxidation Catalyst, Clean Emissions Module)

SMCS Code: 1091-010

### Removal Procedure

Table 13

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 352-5891    | Lifting Strap    | 2   |
| B              |             | Loctite 771      | -   |

**WARNING**

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

**WARNING**

Wear goggles, gloves, protective clothing, and a National Institute for Occupational Safety and Health (NIOSH) approved P95 or N95 half-face respirator when handling a used Diesel Particulate Filter or Catalytic Converter Muffler. Failure to do so could result in personal injury.

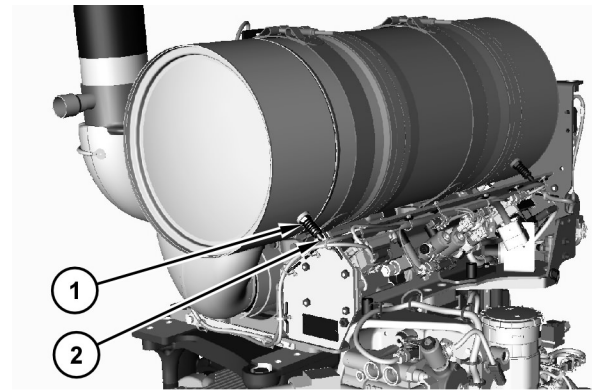


Illustration 87 g02198653

**Note:** Keep the soot antenna and harness assembly connections clean from contaminants. To prevent contaminants from entering the connections, always plug or cap the connections as they are disconnected.

1. Disconnect cable assembly (2) and remove soot antenna (1).

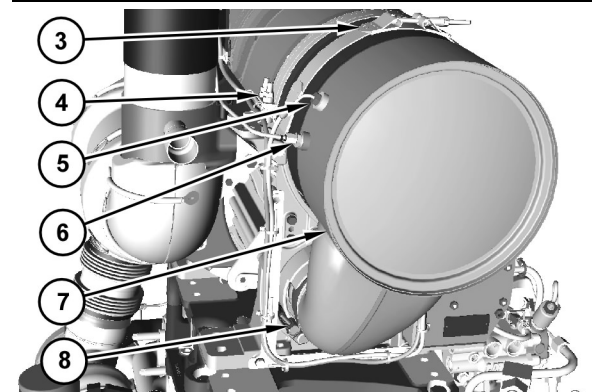


Illustration 88 g02199118

2. Loosen clamp assembly (4) and slide the clamp assembly away from catalyst (7).
3. Disconnect temperature sensor (5) and pressure sensor (6).
4. Position Tooling (A) around catalyst (7). Disconnect clamp assemblies (8) and (3), and remove the catalyst. The weight of the catalyst is approximately 21 kg (46 lb).
5. Discard clamp assembly (4).

## Installation Procedure

1. Install the diesel oxidation catalyst (7) in reverse order.
  - a. Install new clamp assembly (4). Apply Tooling (B) to the threads of clamp assembly (4). Tighten clamp assembly (4) to a torque of  $50 \pm 1 \text{ N}\cdot\text{m}$  ( $37 \pm 1 \text{ lb ft}$ ). Do not use power tools in order to tighten clamp assembly (4).

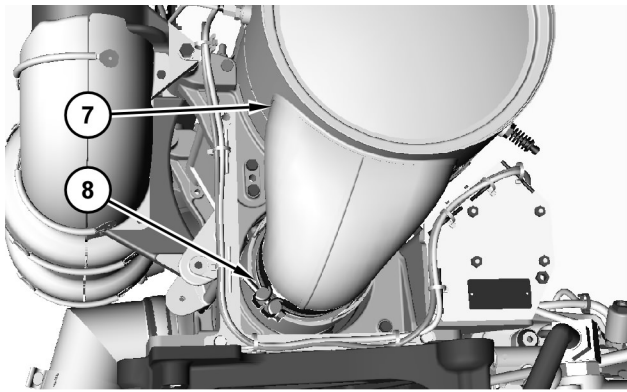


Illustration 89

g02199213

View from below clamp assembly (8).

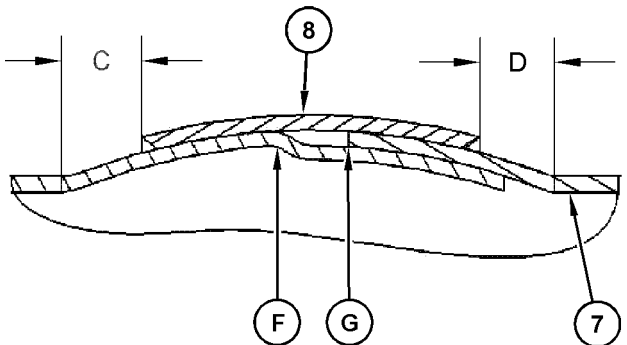


Illustration 90

g02199293

Cutaway view of clamp assembly (8) in position on the assembly.

- b. Verify that the cup of the ball joint (G) does not touch the radius of the ball (F). Position ball clamp (8) and hand tighten ball clamp (8). Ball Clamp (8) should be in the center of the joint. Dimension (C) and Dimension (D) should be equal within 2 mm (0.08 inch). Repeat the measurements every  $90^\circ$  around ball clamp (8). If necessary, adjust ball clamp (8). Do not use power tools in order to torque clamp assembly (8). Torque ball clamp (8) to a torque of  $35 \pm 2 \text{ N}\cdot\text{m}$  ( $26 \pm 1 \text{ lb ft}$ ).

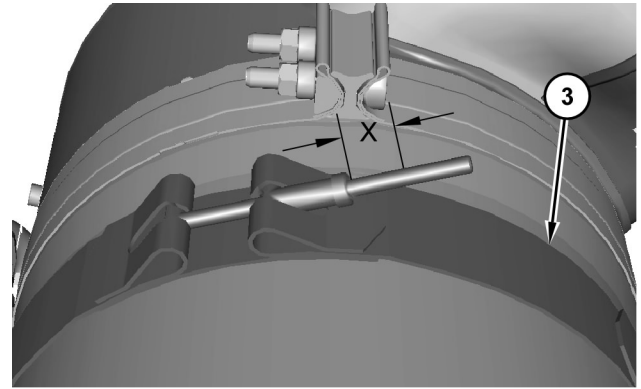


Illustration 91

g02199513

- c. Apply Tooling (B) to the threads of clamp assembly (3) for a Distance (X). Distance (X) is 25 mm (1 inch) above the trunnion. Use hand tools in order to tighten clamp assembly (3). Tighten clamp assembly (3) to a torque of  $16.5 \pm 1.5 \text{ N}\cdot\text{m}$  ( $146 \pm 13 \text{ lb in}$ ).

**Note:** Keep the soot antenna and cable assembly connections clean from contaminants.

- d. Apply Tooling (B) to the threads of temperature sensor (5) and soot sensor (1). Tighten temperature sensor (5) and soot sensor (1) to a torque of  $45 \pm 5 \text{ N}\cdot\text{m}$  ( $33 \pm 4 \text{ lb ft}$ ). Hand tighten the cable assembly (2) when connecting to soot antenna (1).

i03947887

## Air Inlet Elbow - Remove and Install

SMCS Code: 1087-010-E4

### Removal Procedure

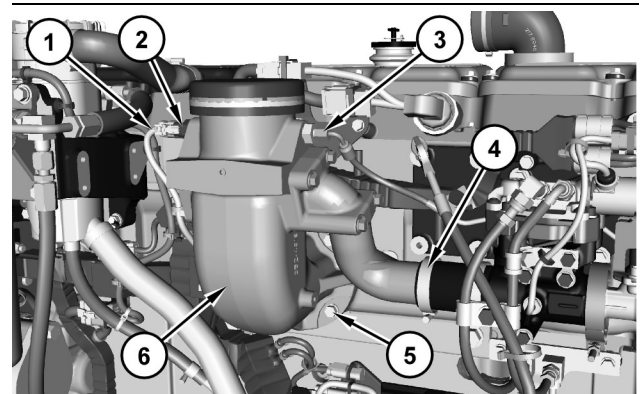


Illustration 92

g02157699

1. Remove harness assembly (1) and remove inlet air temperature sensor (2).

2. Remove hose assembly (3).
3. Remove clamp assemblies (4)
4. Remove bolts (5) and remove air inlet elbow (6).

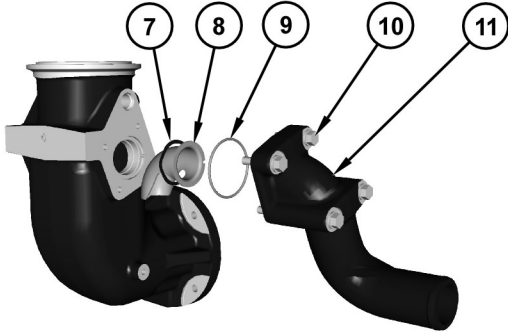


Illustration 93

g02157798

5. Remove bolts (10) and tube (11).
6. Remove O-ring seal (9) from tube (11).
7. Remove spring washer (7), and mixing tube (8).

## Installation Procedure

1. Install the air inlet elbow (6) in the reverse order of removal.
  - a. Tighten inlet air temperature sensor (2) to a torque of  $20 \pm 3 \text{ N}\cdot\text{m}$  ( $177 \pm 27 \text{ lb in}$ ).

i02585135

## Inlet and Exhaust Valve Springs - Remove and Install

SMCS Code: 1108-010

### Removal Procedure

Table 14

| Required Tools |             |                         |     |
|----------------|-------------|-------------------------|-----|
| Tool           | Part Number | Part Description        | Qty |
| A              | 9U-7241     | Valve Spring Compressor | 1   |
| B              | 8S-2263     | Spring Tester           | 1   |

#### Start By:

- a. Remove the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove".

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The following procedure is for the removal of the inlet valve springs and the exhaust valve springs without removing the cylinder head. This procedure can be performed on only one cylinder at a time. This will prevent the inlet valves and the exhaust valves from falling into the cylinder.

1. Position the No. 1 piston at the top center of the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

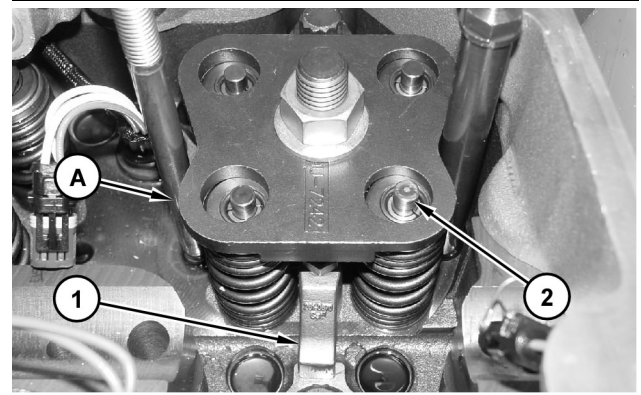


Illustration 94

g01260774

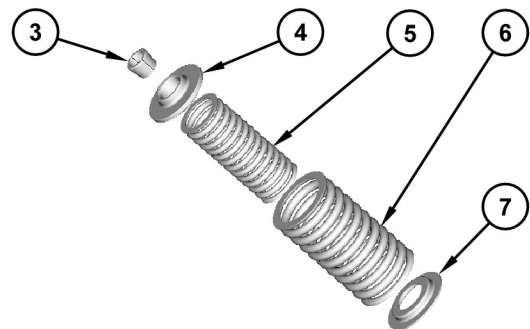


Illustration 95

g01260809

### WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

2. Install Tooling (A) in the electronic unit injector sleeve. Secure Tooling (A) with unit injector clamp (1).
3. Tighten the full nut until valve spring keepers (3) are loose on valve (2).
4. Remove valve spring keepers (3) from the valve.
5. Carefully remove Tooling (A).
6. Remove valve rotator (4).
7. Remove outer valve spring (6) and inner valve spring (5) from the valve.
8. Remove washer (7) from the valve guide.
9. Use Tooling (B) to check the valve springs (spring force). Refer to Specifications, "Cylinder Head Valves" for additional information on the valve springs.

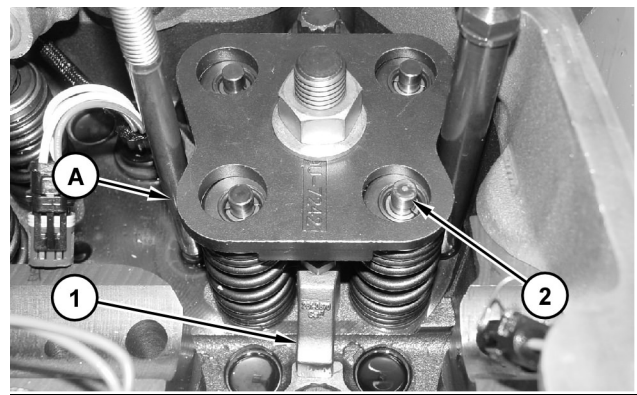


Illustration 97

g01260774

## Installation Procedure

Table 15

| Required Tools |             |                         |     |
|----------------|-------------|-------------------------|-----|
| Tool           | Part Number | Part Description        | Qty |
| A              | 9U-7241     | Valve Spring Compressor | 1   |

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Lubricate the valve stems with clean engine oil.

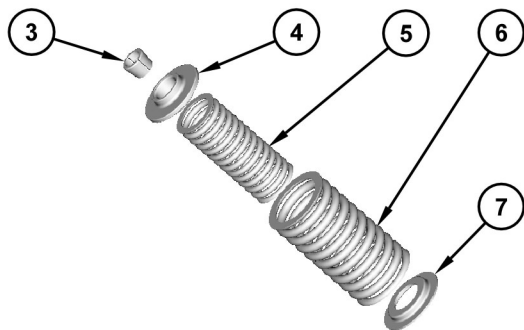


Illustration 96

g01260809

### WARNING

Improper assembly of parts that are spring loaded can cause bodily injury.

To prevent possible injury, follow the established assembly procedure and wear protective equipment.

2. Ensure that washer (7) is installed on the valve guide.
3. Install inner valve spring (5) and outer valve spring (6) on valve (2).
4. Install valve rotator (4) on valve (2).

### WARNING

The valve spring keepers can be thrown from the valve when the valve spring compressor is released. Ensure that the valve spring keepers are properly installed on the valve stem. To help prevent personal injury, keep away from the front of the valve spring keepers and valve springs during the installation of the valves.

5. Use Tooling (A) to compress inner valve spring (5) and outer valve spring (6). Install valve spring keepers (3) on valve (2).
6. Remove unit injector clamp (1) and Tooling (A).

### End By:

- a. Install the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install".

i03637609

## Inlet and Exhaust Valves - Remove and Install

SMCS Code: 1105-010

### Removal Procedure

Table 16

| Required Tools |             |                         |     |
|----------------|-------------|-------------------------|-----|
| Tool           | Part Number | Part Description        | Qty |
| A              | 5S-1330     | Valve Spring Compressor | 1   |
| B              | 8S-2263     | Spring Tester           | 1   |

#### Start By:

- a. Remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove".

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

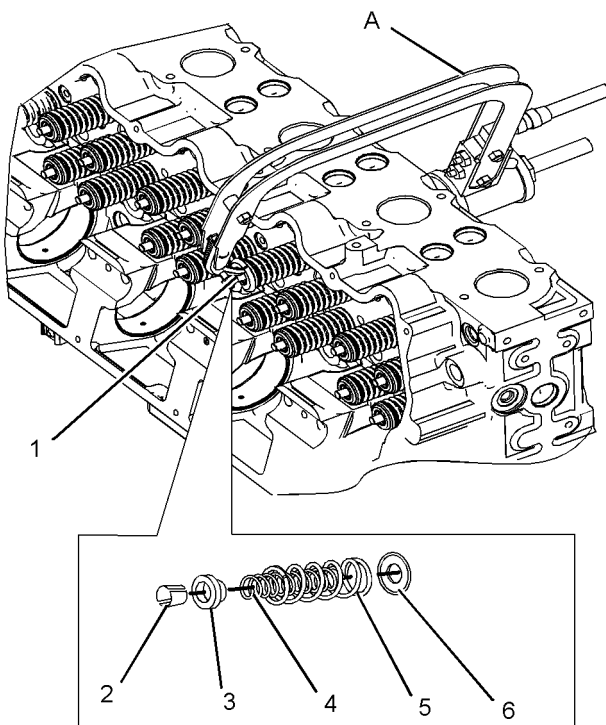


Illustration 98

g01015263

### **! WARNING**

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

1. Install Tooling (A) and compress the valve springs. Remove valve spring keepers (2) from valve (1).
2. Carefully remove Tooling (A) from valve (1).
3. Remove valve rotator (3).
4. Remove outer valve spring (5) and inner valve spring (4) from valve (1).
5. Remove washer (6) and valve (1) from the valve guide.
6. Use Tooling (B) to check the valve springs (spring force). Refer to Specifications, "Cylinder Head Valves" for additional information on the valve springs.
7. Inspect the valves. Refer to Specifications, "Cylinder Head Valves" for additional information on the inlet and exhaust valves.

### Installation Procedure

### **! WARNING**

Improper assembly of parts that are spring loaded can cause bodily injury.

To prevent possible injury, follow the established assembly procedure and wear protective equipment.

### **! WARNING**

The valve spring keepers can be thrown from the valve when the valve spring compressor is released. Ensure that the valve spring keepers are properly installed on the valve stem. To help prevent personal injury, keep away from the front of the valve spring keepers and valve springs during the installation of the valves.

1. Install the Inlet and Exhaust Valves in the reverse order of removal.

**End By:**

- a. Install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

i02109151

## Inlet and Exhaust Valve Guides - Remove and Install

SMCS Code: 1104-010

### Removal Procedure

Table 17

| Required Tools   |             |                    |     |
|------------------|-------------|--------------------|-----|
| Tool             | Part Number | Part Description   | Qty |
| A <sup>(1)</sup> | 9U-6895     | Valve Guide Driver | 1   |

<sup>(1)</sup> Part of 9U-7530 Engine Tool Group

**Start By:**

- a. Remove the inlet and exhaust valves. Refer to Disassembly and Assembly, "Inlet and Exhaust Valves - Remove and Install".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

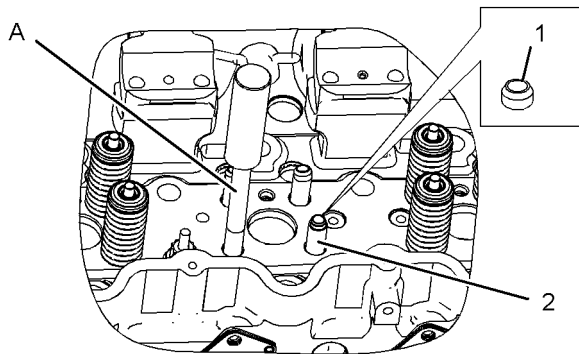


Illustration 99

g01073841

1. Remove valve stem seal (1) from valve guide (2).
2. Use Tooling (A) and a hammer to remove the valve guide from the cylinder head.

### Installation Procedure

Table 18

| Required Tools   |             |                    |     |
|------------------|-------------|--------------------|-----|
| Tool             | Part Number | Part Description   | Qty |
| A <sup>(1)</sup> | 9U-6895     | Valve Guide Driver | 1   |
| B <sup>(1)</sup> | 9U-6894     | Guide Collar       | 1   |

<sup>(1)</sup> Part of 9U-7530 Engine Tool Group

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

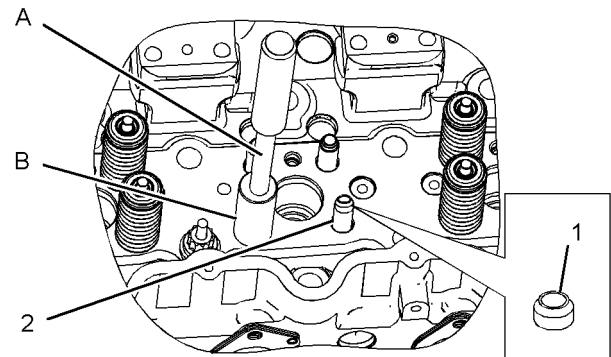


Illustration 100

g01073842

1. Lubricate the bores for the valve guides with clean engine oil.
2. Install valve guide (2) in the cylinder head with Tooling (A) and Tooling (B).

**Note:** Tooling (B) must be used in order to install the valve guide to the correct height.

Height to top of valve guide from cylinder head surface .....  $35.00 \pm 0.50$  mm ( $1.378 \pm 0.020$  inch)

**Note:** For more information, refer to Specifications, "Cylinder Head Valves".

3. Install valve stem seal (1) on the valve guide.

**End By:**

- a. Install the inlet and exhaust valves. Refer to Disassembly and Assembly, "Inlet and Exhaust Valves - Remove and Install".

i02118491

## Inlet and Exhaust Valve Seat Inserts - Remove and Install

SMCS Code: 1103-010

### Removal Procedure

Table 19

| Required Tools |             |                                 |     |
|----------------|-------------|---------------------------------|-----|
| Tool           | Part Number | Part Description                | Qty |
| A              | 166-7441    | Valve Seat Extractor Tool Group | 1   |

#### Start By:

- a. Remove the inlet and exhaust valves. Refer to Disassembly and Assembly, "Inlet and Exhaust Valves - Remove and Install".

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

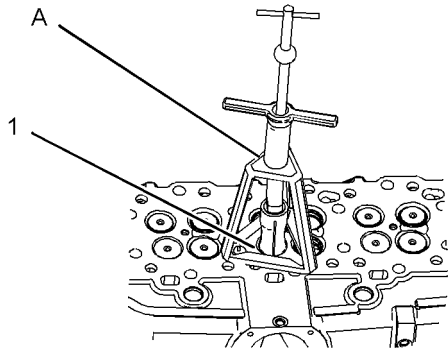


Illustration 101

g01082582

1. Use Tooling (A) to remove valve seat insert (1) from the cylinder head.
2. Clean the bores in the cylinder head for the valve seat inserts. Remove any rough areas from the bores.

### Installation Procedure

Table 20

| Required Tools   |             |                             |     |
|------------------|-------------|-----------------------------|-----|
| Tool             | Part Number | Part Description            | Qty |
| B <sup>(1)</sup> | 9U-6898     | Valve Seat Driver (Exhaust) | 1   |
|                  | 9U-6897     | Valve Seat Driver (Inlet)   | 1   |

(1) Part of 9U-7530 Engine Tool Group

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

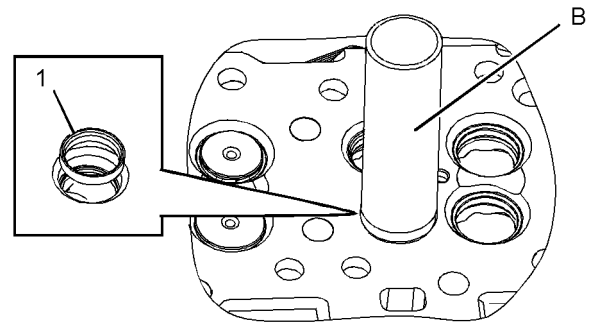


Illustration 102

g01079028

1. Lower the temperature of new valve seat insert (1).
2. Use Tooling (B) to install the new valve seat insert in the cylinder head.

**Note:** Do not machine the prefinished valve seat inserts in order to correct the valve projection. Excessive valve projection indicates that the valve seat insert is not seated or material was not cleaned from the bottom of the counterbore.

#### End By:

- a. Install the inlet and exhaust valves. Refer to Disassembly and Assembly, "Inlet and Exhaust Valves - Remove and Install".

i03948849

# Engine Oil Filter Base - Remove and Install

SMCS Code: 1306-010

## Removal Procedure

Table 21

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 185-3630    | Strap Wrench As  | 1   |

### Start By:

- a. Remove the engine oil cooler.

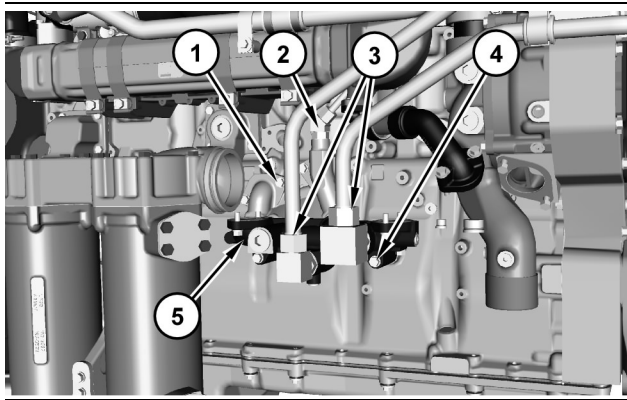


Illustration 103

g02157867

1. Disconnect tube assemblies (3).
2. Disconnect tube assembly (2).
3. Remove four bolts (1).
4. Remove bolts (4) and remove oil filter base (5).

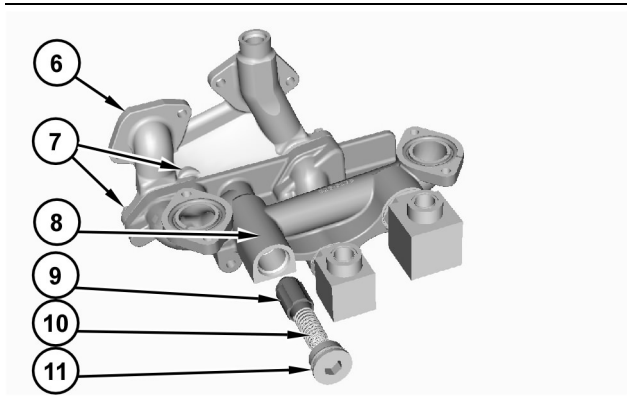


Illustration 104

g02157868

5. Remove four bolts (7) and separate manifold (6) from manifold (8).

## WARNING

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

6. Remove plug (11). Remove spring (10) and plunger (9).

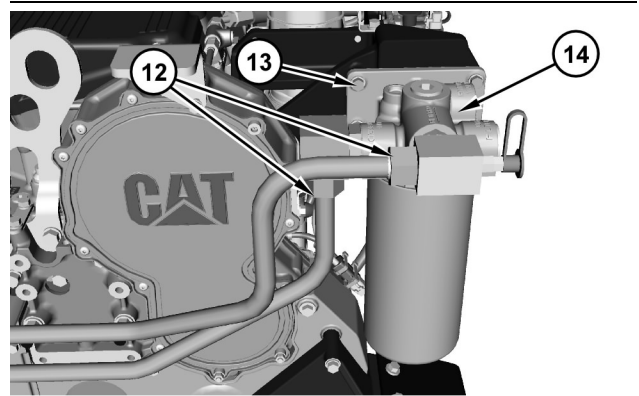


Illustration 105

g02157869

**Note:** Drain the oil from the filter housing into a suitable container for storage or for disposal.

7. Disconnect tube assemblies (12).
8. Remove bolts (13) and remove oil filter base (14).

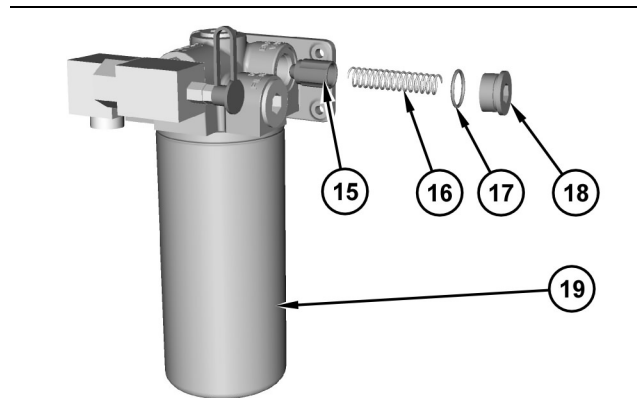


Illustration 106

g02157977

9. Use Tooling (A) to remove filter (19).

**⚠ WARNING**

Personal injury can result from being struck by parts propelled by a released spring force.

Make sure to wear all necessary protective equipment.

Follow the recommended procedure and use all recommended tooling to release the spring force.

10. Remove plug (18), O-ring (17), spring (16), and plunger (15).

### Installation Procedure

**Note:** Check the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

1. Install the engine oil filter base in the reverse order.
  - a. Tighten plug (18) to a torque of  $100 \pm 15$  N·m ( $74 \pm 11$  lb ft).
  - b. Use Tooling (A) to install filter (19). Tighten filter (19) to a torque of  $100 \pm 15$  N·m ( $74 \pm 11$  lb ft).

i03519140

## Engine Oil Cooler - Remove and Install

SMCS Code: 1378-010

### Removal Procedure

1. Drain the coolant into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant (ELC) - Change".

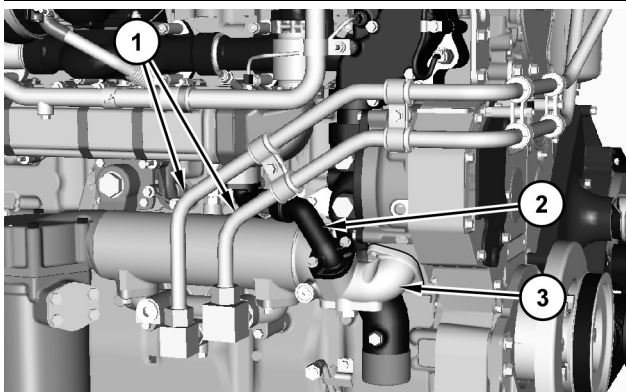


Illustration 107

g01849733

2. Remove tube assemblies (1).

3. Remove both elbow assemblies (2) and (3).

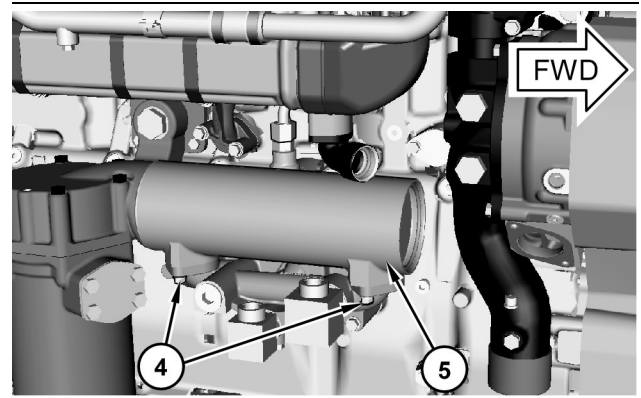


Illustration 108

g01849774

4. Remove four bolts (4). Remove oil cooler (5) and the O-ring seals.

### Installation Procedure

**Note:** Check the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

1. Install the engine oil cooler (5) in reverse order.
2. Change the engine oil. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".

i02115856

## Engine Oil Pump - Remove

SMCS Code: 1304-011

### Removal Procedure

**Start By:**

- a. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

i02020477

**NOTICE**

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Tools and Shop Products Guide" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

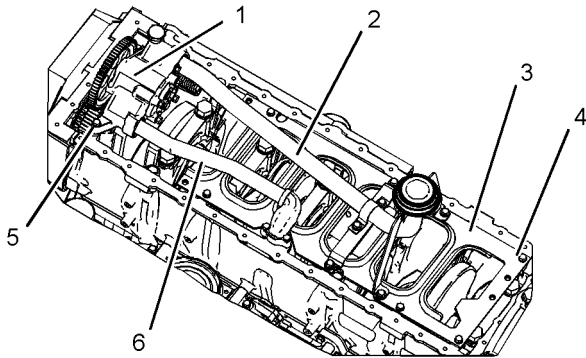


Illustration 109

g01077736

1. Remove tube assembly (6). Remove the O-ring seal from the tube assembly.
2. Remove the suction bell assembly and tube assembly (2). Remove the O-ring seal from the tube assembly.
3. Remove bolts (5) and remove engine oil pump (1) from the cylinder block.
4. If necessary, remove bolts (4) and remove underframe assembly (3).

**Engine Oil Pump - Disassemble**

**SMCS Code:** 1304-015

**Disassembly Procedure**

Table 22

| Required Tools |             |                    |     |
|----------------|-------------|--------------------|-----|
| Tool           | Part Number | Part Description   | Qty |
| A              | 1P-2321     | Combination Puller | 1   |
| B              | 1P-0510     | Driver Group       | 1   |

**Start By:**

- a. Remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

**NOTICE**

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Tools and Shop Products Guide" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

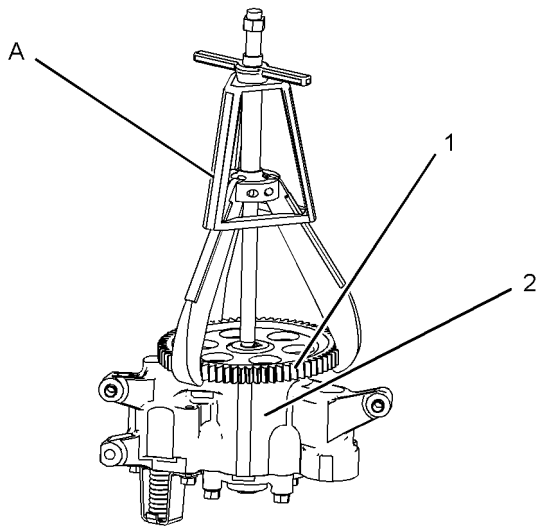


Illustration 110

g01001918

1. Remove the bolt that holds drive gear (1) to the shaft of engine oil pump (2).
2. Use Tooling (A) to remove drive gear (1) from the shaft. Remove the key from the shaft.

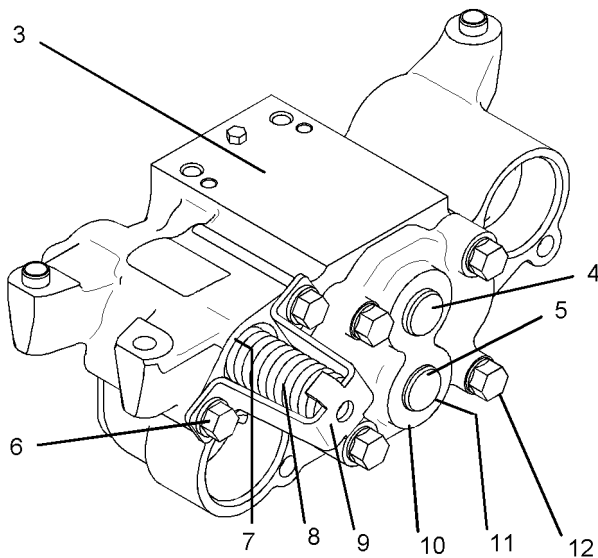


Illustration 111

g01043546

**WARNING**

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

3. Remove bolts (6) that hold retainer (9) to pump body (3).
4. Remove retainer (9), spring (8), and relief plunger (7) from the pump body.
5. Remove bolts (12) and cover (10) from the pump body.

**Note:** Inspect the bores in the cover. The aluminum cover does not have bearings. If the bores in the cover are damaged, replace the cover with a new part.

6. Remove idler gear (5) and drive gear (4) from the pump body.
7. Use Tooling (B) to remove sleeve bearings (11) from pump body (3).

i02020480

## Engine Oil Pump - Assemble

SMCS Code: 1304-016

### Assembly Procedure

Table 23

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| B              | 1P-0510     | Driver Group     | 1   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

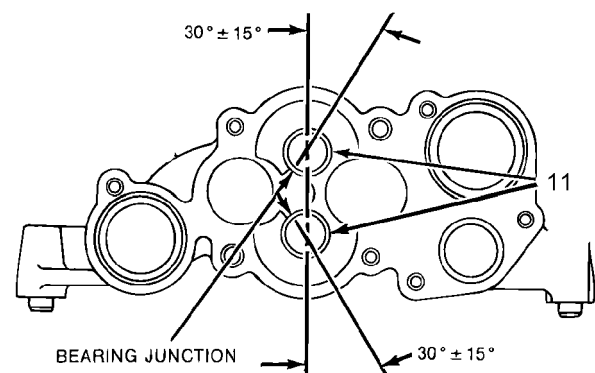


Illustration 112

g01053962

1. Install sleeve bearings (11) in the pump body with Tooling (B). The bearing joint should be  $30 \pm 15$  degrees from the center line of the two bearing bores. Install the sleeve bearings so the sleeve bearings are even with the outside of the pump body.
2. Before final assembly, check the condition and specifications of all of the parts of the engine oil pump. Refer to Specification, "Engine Oil Pump".

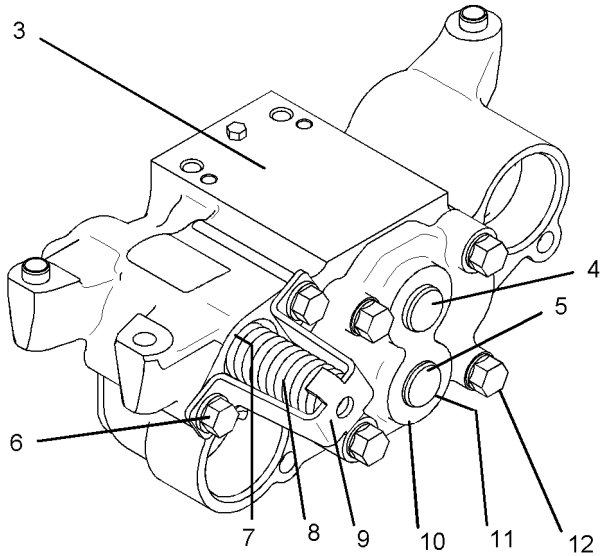


Illustration 113

g01043546

### WARNING

Improper assembly of parts that are spring loaded can cause bodily injury.

To prevent possible injury, follow the established assembly procedure and wear protective equipment.

3. Lubricate the idler gear and the drive gear with clean engine oil. Lubricate sleeve bearings (11) with clean engine oil. Install idler gear (5) and drive gear (4) in pump body (3).
  4. Install cover (10). Install bolts (12) in order to secure the cover to the pump body.
- Note:** The engine oil pump must turn freely after assembly. Turn the engine oil pump by hand. Reposition cover (10) if the engine oil pump does not turn freely.
5. Install relief plunger (7), spring (8), retainer (9), and bolts (6).
  6. Install the key on the shaft.

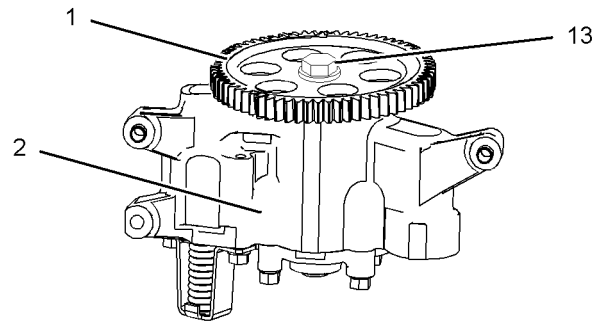


Illustration 114

g01043619

7. Install drive gear (1) on the shaft of engine oil pump (2). Install bolt (13). Tighten the bolt to a torque of  $55 \pm 10$  N·m ( $41 \pm 7$  lb ft).

### End By:

- a. Install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

i02183426

## Engine Oil Pump - Install

SMCS Code: 1304-012

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

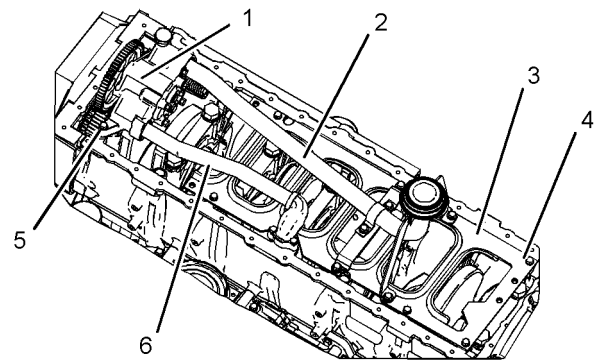


Illustration 115

g01077736

1. Position underframe assembly (3) and install bolts (4).
2. Position engine oil pump (1) on the dowels in the cylinder block. Install bolts (5).

**Note:** Ensure that the engine oil pump is seated on the dowels before the bolts are tightened.

3. Install the O-ring seal on tube assembly (6). Lubricate the bore in the engine oil pump with clean engine oil. Install tube assembly (6).
4. Install the O-ring seal on tube assembly (2). Lubricate the bore in the engine oil pump with clean engine oil. Install the suction bell assembly and tube assembly (2).

**End By:**

- a. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install".

i01965934

## Water Pump - Disassemble

**SMCS Code:** 1361-015

### Disassembly Procedure

Table 24

| Required Tools |             |                      |     |
|----------------|-------------|----------------------|-----|
| Tool           | Part Number | Part Description     | Qty |
| A              | 8S-2264     | Puller Group         | 1   |
|                | 4B-3903     | Bolt                 | 2   |
|                | 1P-0456     | Plate                | 1   |
|                | 4B-4277     | Washer               | 2   |
| B              | 9S-9152     | Bearing Puller Gp    | 1   |
| C              | 9S-5565     | Pin Puller Sleeve As | 1   |

**Start By:**

- a. Remove the water pump. Refer to Disassembly and Assembly, "Water Pump - Remove".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

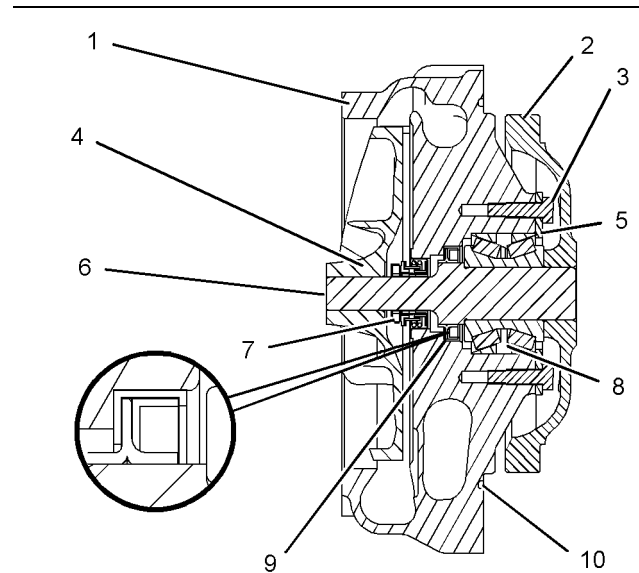


Illustration 116

g01021798

1. Remove O-ring seal (10) from housing (1).
2. Use Tooling (A) to remove impeller (4) from shaft (6).
3. Remove bolts (3) from housing (1). Remove retainer (5) and water pump shaft (6) from the housing.
4. Use Tooling (C) and remove gear (2) from water pump shaft (6).
5. Use a press and Tooling (B) to remove bearing assembly (8) from water pump shaft (6).
6. Invert the housing and drive or press seal group (7) out of the housing.
7. Invert the housing and drive or press lip seal (9) out of the housing.

i04302129

## Water Pump - Assemble

SMCS Code: 1361-016

### Assembly Procedure

Table 25

| Required Tools |                         |                  |     |
|----------------|-------------------------|------------------|-----|
| Tool           | Part Number             | Part Description | Qty |
| D              | 1P-0510                 | Driver Group     | 1   |
| E              | 138-9299 <sup>(1)</sup> | Oil Seal Tool    | 1   |
| E              | FT-3171 <sup>(2)</sup>  | Oil Seal Tool    | 1   |
| F              | 139-0088 <sup>(1)</sup> | Seal Tool        | 1   |
| F              | 325-5756 <sup>(2)</sup> | Seal Tool        | 1   |

<sup>(1)</sup> Use with a 19.1 mm (0.75 inch) shaft<sup>(2)</sup> Use with a 25.4 mm (1.00 inch) shaft

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

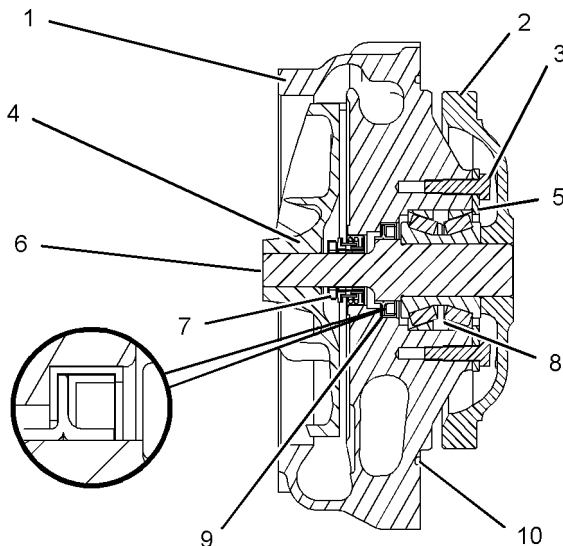


Illustration 117

g01021798

1. Clean water pump shaft (6) and the counterbore for lip seal (9) in housing (1).
2. Use Tooling (D) to install a new lip seal (9) in housing (1).

**Note:** Install the seal with the part number on the metal face of the seal toward the housing. Ensure that the lip seal is flush with the front edge of the counterbore of the housing. Do not lubricate the lip seal. Use a press to install the lip seal. Do not install the lip seal by hand.

3. Install bearing assembly (8) on water pump shaft (6).

4. Place retainer (5) with "OUTSIDE" markings toward the gear end of water pump shaft (6).

5. Use a press and install gear (2) on water pump shaft (6).

**Note:** Install gear (2) against bearing assembly (8).

6. Slide Tooling (E) over shaft (6). The tapered edge will be facing outward.

7. Install gear (2) and the water pump shaft into housing (1). Use care not to damage lip seal (9). Install bolts (3) that hold bearing retainer (5) to the housing.

8. Remove Tooling (E) from water pump shaft (6).

9. Use a press and Tooling (F) to install a new seal group (7) over shaft (6) and into housing (1). Ensure that the outer shell of the seal is fully seated in the housing.

10. Put impeller (4) in position on water pump shaft (6). Use a press and install impeller (4) on the water pump shaft.

**Note:** Install impeller (4) within  $0.00 \pm 0.25$  mm ( $0.000 \pm 0.010$  inch) of the end of the water pump shaft.

11. Install O-ring seal (10) on the housing.

#### End By:

- a. Install the water pump. Refer to Disassembly and Assembly, "Water Pump-Install".

i03962762

## Water Pump - Remove and Install

SMCS Code: 1361-011; 1361-012

### Removal Procedure

Table 26

| Required Tools |             |                          |     |
|----------------|-------------|--------------------------|-----|
| Tool           | Part Number | Part Description         | Qty |
| A              | 1U-6396     | O-Ring Assembly Compound | -   |

#### Start By:

- a. Remove the water temperature regulator housing. Refer to Disassembly and Assembly, "Water Temperature Regulator Housing - Remove".

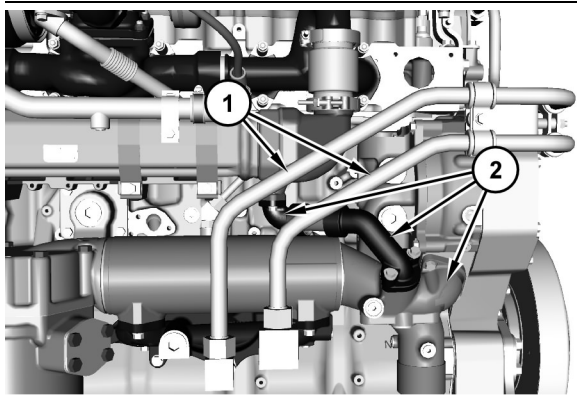


Illustration 118

g02160662

1. Remove tube assemblies (1). Remove elbows (2).

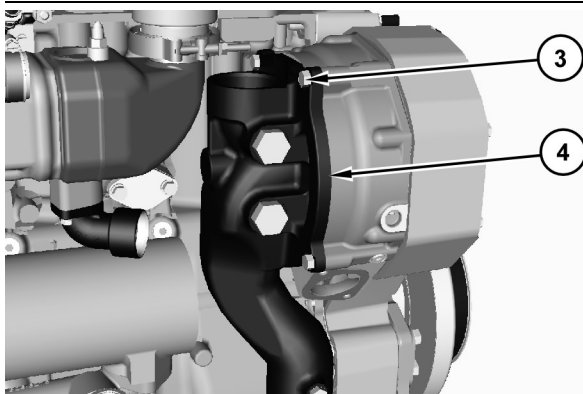


Illustration 119

g01852435

2. Remove bolts (3) and remove the water pump cover (4).

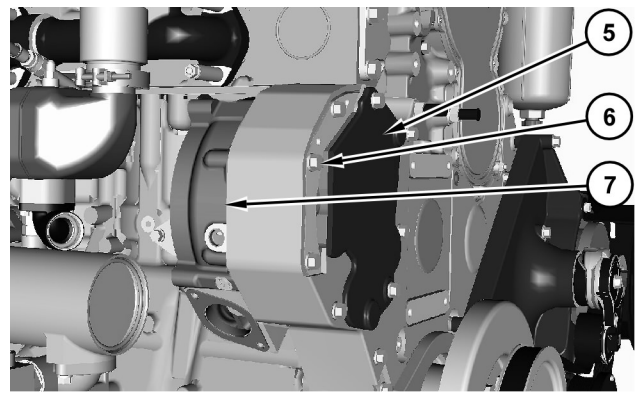


Illustration 120

g01852493

3. Remove two bolts and insulation (5).
4. Remove bolts (6) and remove water pump (7).

### Installation Procedure

**Note:** Check the O-ring seals, the gaskets, and the seals for wear or for damage. Replace the components, if necessary.

1. Install the water pump in reverse order.
  - a. Apply Tooling (A) on all O-ring seals prior to installation.

i03961334

## Water Temperature Regulator Housing - Remove and Install

SMCS Code: 1393-010

### Removal Procedure

1. Drain the coolant from the cooling system into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change".

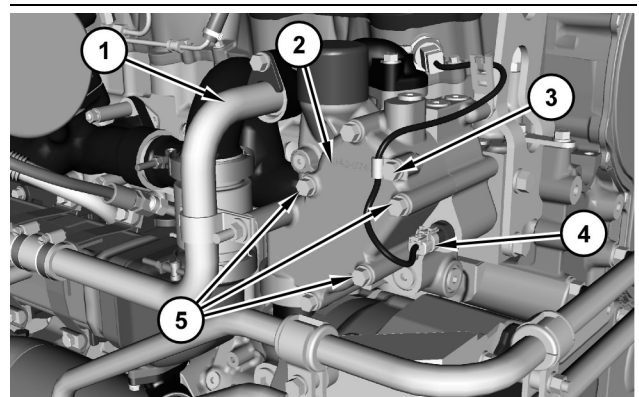


Illustration 121

g02160354

2. Remove tube assemblies (1).
3. Remove bolt (3) and the clip.
4. Disconnect harness assembly (4).
5. Remove bolts (5).
6. Remove the water temperature regulator housing (2).

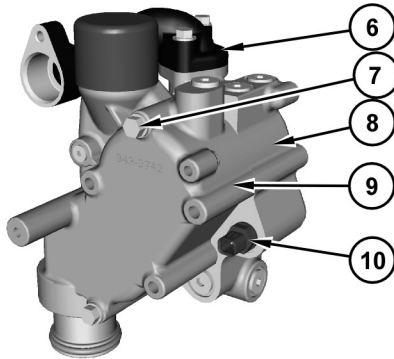


Illustration 122

g02160422

7. Remove elbow (6).
8. Remove the temperature sensor (10).
9. Remove the bolts (7) and separate housing (8) from manifold (9).

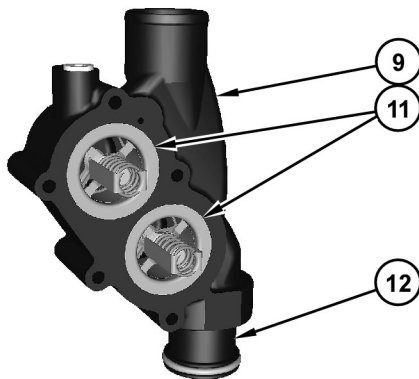


Illustration 123

g01854499

10. Remove water regulators (11) from housing (9).
11. Remove tube (12) and the O-ring seals.

### Installation Procedure

1. Install the water temperature regulator housing in reverse order.
  - a. Tighten water temperature sensor (2) to a torque of  $20 \pm 3$  N·m ( $177 \pm 27$  lb in).

2. Fill the cooling system. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change".

i02115869

### Flywheel - Remove

SMCS Code: 1156-011

### Removal Procedure

Table 27

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 138 - 7573  | Lifting Bracket  | 2   |
| B              | FT2712      | Guide Stud       | 2   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

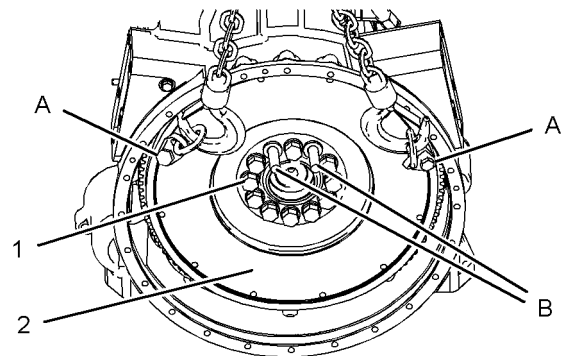


Illustration 124

g01018439

1. Install Tooling (A) on the flywheel. Use a suitable lifting device. The weight of the flywheel is approximately 40 kg (88 lb).
2. Remove two bolts (1). Install Tooling (B).
3. Remove remaining bolts (1) that hold the flywheel to the crankshaft . Remove flywheel (2).

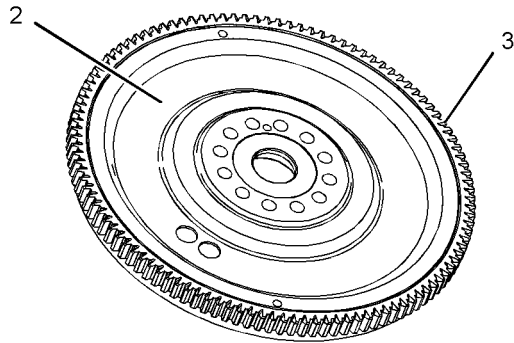


Illustration 125

g01018440

- If necessary, use a hammer and a punch in order to remove ring gear (3) from the flywheel.

i02643003

## Flywheel - Install

SMCS Code: 1156-012

### Installation Procedure

Table 28

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 138-7573    | Lifting Bracket  | 2   |
| B              | FT2712      | Guide Stud       | 2   |

### WARNING

Always wear protective gloves when handling parts that have been heated.

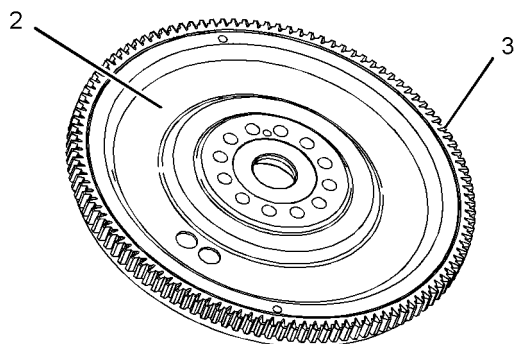


Illustration 126

g01018440

**Note:** Ring gear (3) must be installed with the chamfered side of the teeth upward. The chamfered side of the gear teeth will be facing toward the starting motor when the flywheel is installed. This will ensure that the starting motor will engage correctly.

- Raise the temperature of ring gear (3) and install the ring gear on flywheel (2).

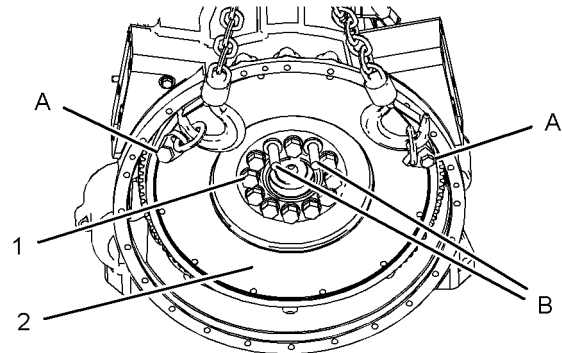


Illustration 127

g01018439

- Install Tooling (B) in the crankshaft.
- Install Tooling (A) on flywheel (2). Use a suitable lifting device. The weight of the flywheel is approximately 40 kg (88 lb). Position flywheel (2) on the crankshaft.
- Apply clean engine oil to the threads of bolts (1).
- Install bolts (1). Remove Tooling (B). Install bolts (1) in place of Tooling (B).
- Tighten bolts (1) to a torque of  $270 \pm 40$  N·m ( $200 \pm 30$  lb ft).
- Remove Tooling (A) from the flywheel.
- Check the flywheel runout. Refer to Testing and Adjusting, "Flywheel - Inspect".

i02519715

## Crankshaft Rear Seal - Remove

SMCS Code: 1161-011

### Removal Procedure

Table 29

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 1U-7600     | Slide Hammer Puller | 1   |

#### Start By:

- Remove the flywheel. Refer to Disassembly and Assembly, "Flywheel - Remove".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The rear seal and the wear sleeve must be replaced at the same time. Once the crankshaft rear seal and the wear sleeve are separated, these components can not be used again.

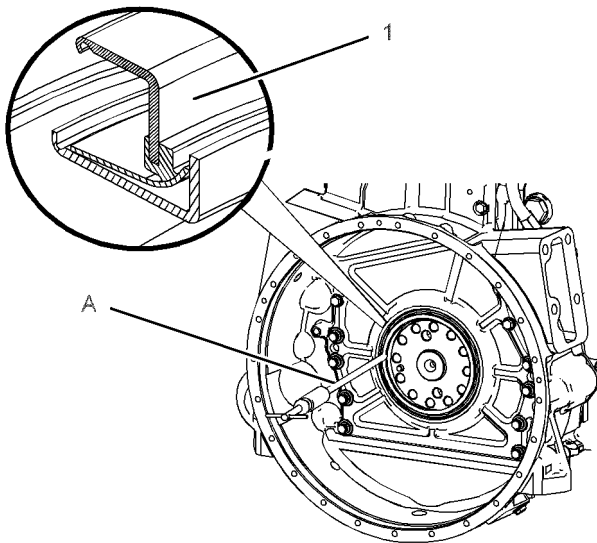


Illustration 128

g01260922

1. Use Tooling (A) or a punch and hammer in order to puncture three or more holes in crankshaft rear seal assembly (1).
2. Use Tooling (A) in order to remove crankshaft rear seal assembly (1).

i02519716

## Crankshaft Rear Seal - Install

**SMCS Code:** 1161-012

### Installation Procedure

Table 30

| Required Tools |             |                      |     |
|----------------|-------------|----------------------|-----|
| Tool           | Part Number | Part Description     | Qty |
| B              | 5P-1733     | Seal Locator         | 1   |
| C              | 5P-1737     | Bolt                 | 3   |
| D              | 9S-8858     | Nut (Seal Installer) | 1   |
| E              | 6V-6143     | Seal Installer       | 1   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

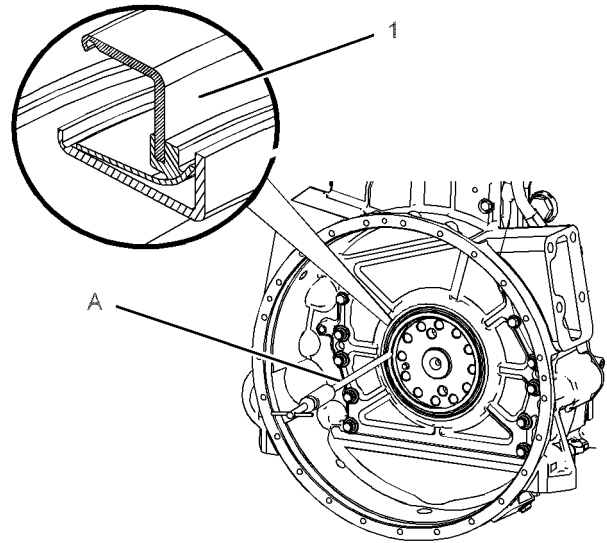


Illustration 129

g01260922

**Note:** Do not use any type of lubricant during the installation of the crankshaft seal and wear sleeve.

1. Before installation of the crankshaft rear seal assembly, inspect the crankshaft for scratches. Also, inspect the crankshaft for any distortion on the surface that may lead to an out of round condition. Use a polishing cloth in order to remove any imperfections on the crankshaft.
  2. Clean the outside diameter of the crankshaft and the inside diameter of the wear sleeve.
  3. Fasten Tooling (B) to the crankshaft with Tooling (C).
- Note:** Install the crankshaft rear seal assembly with the arrow that shows the direction of crankshaft rotation toward the rear of the engine.
4. Position crankshaft rear seal assembly (1) on Tooling (B). Install Tooling (E) on Tooling (B). Lubricate the face of the washer on Tooling (D). Install Tooling (D) on Tooling (B).
  5. Tighten Tooling (D) until Tooling (E) contacts Tooling (B).
  6. Remove Tooling (D) and Tooling (E) from Tooling (B).
  7. Remove Tooling (C) and Tooling (B) from the crankshaft.

8. Check the crankshaft rear seal assembly for the correct installation.

**End By:**

- a. Install the flywheel. Refer to Disassembly and Assembly, "Flywheel - Install".

i02185513

## Flywheel Housing - Remove and Install (Equipped with Rear Power Take-Off)

SMCS Code: 1157-010

### Removal Procedure

Table 31

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 138 - 7574  | Link Bracket     | 2   |

**Start By:**

- a. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove".
- b. Remove the electric starter motor. Refer to Disassembly and Assembly, "Electric Starter Motor - Remove".
- c. Disassemble the power take-off drive. Refer to Disassembly and Assembly, "Power Take-Off Drive Group - Disassemble".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

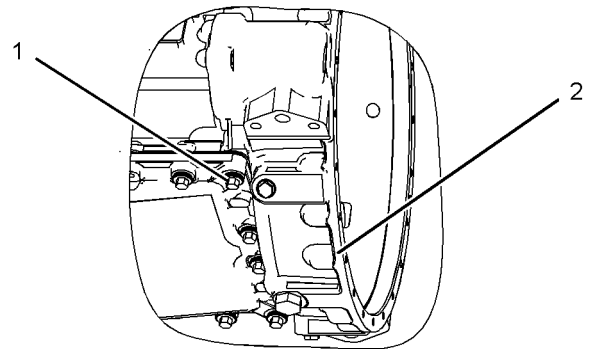


Illustration 130

g01008304

1. Remove bolts (1) that fasten the engine oil pan to flywheel housing (2).

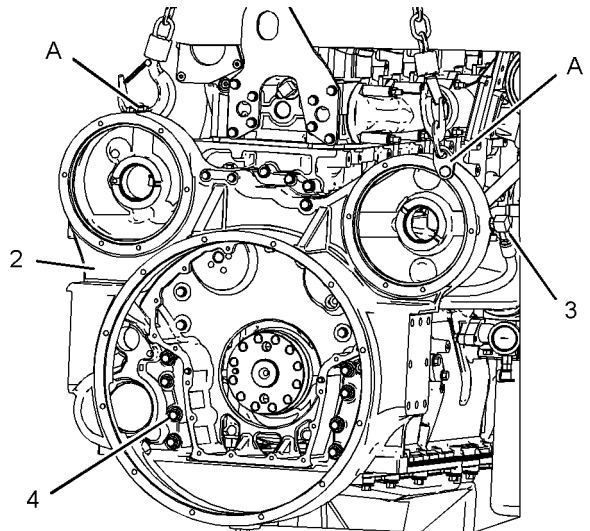


Illustration 131

g01106049

2. Disconnect hose assembly (3) from flywheel housing (2).
3. Install Tooling (A) and a suitable lifting device on flywheel housing (2). The weight of the flywheel housing is approximately 136 kg (300 lb).
4. Remove bolts (4). Remove flywheel housing (2) from the cylinder block.

### Installation Procedure

Table 32

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 138 - 7574  | Link Bracket     | 2   |
| B              | 1U - 8846   | Gasket Sealant   | -   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the mating surfaces of the flywheel housing and the cylinder block.

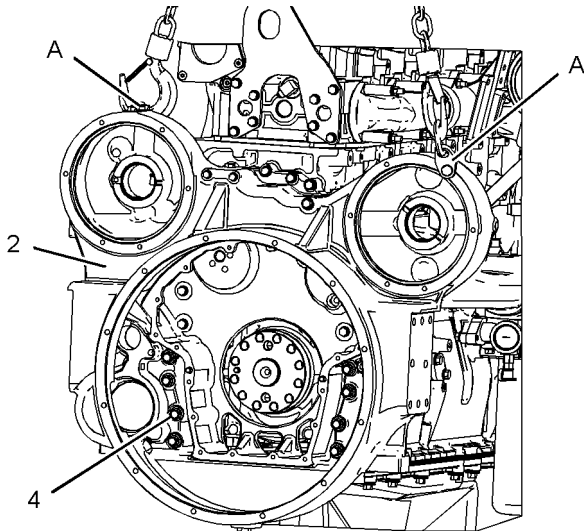


Illustration 132

g01106346

2. Install Tooling (A) on the flywheel housing. Use a suitable lifting device. The weight of the flywheel housing is approximately 136 kg (300 lb).
3. Apply Tooling (B) to the mating surfaces of the cylinder block, the flywheel housing, and the engine oil pan.
4. Position flywheel housing (2) on the cylinder block. Install bolts (4) and remove Tooling (A).

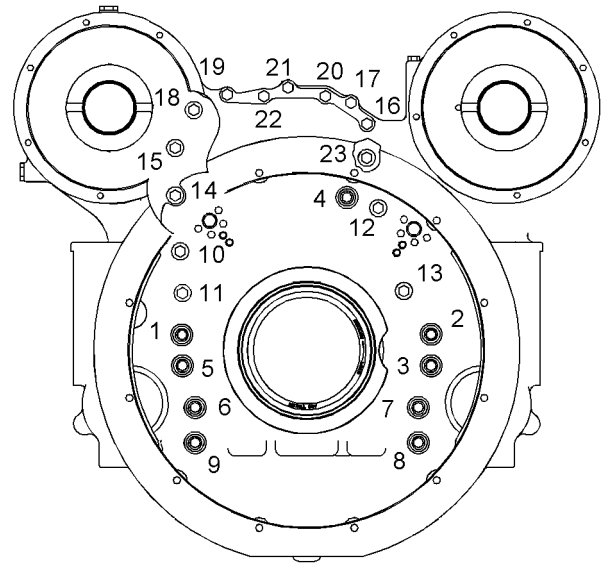


Illustration 133

g01106331

5. Tighten the bolts, as follows:

- a. In a numerical sequence, tighten bolt 1 through bolt 9 to a torque of  $100 \pm 30$  N·m ( $74 \pm 22$  lb ft).
- b. In a numerical sequence, tighten bolt 10 through bolt 23 to a torque of  $40 \pm 10$  N·m ( $30 \pm 7$  lb ft).
- c. In a numerical sequence, again tighten bolt 1 through bolt 9 to a torque of  $135 \pm 20$  N·m ( $100 \pm 15$  lb ft).
- d. In a numerical sequence, again tighten bolt 10 through bolt 23 to a torque of  $55 \pm 10$  N·m ( $41 \pm 7$  lb ft).

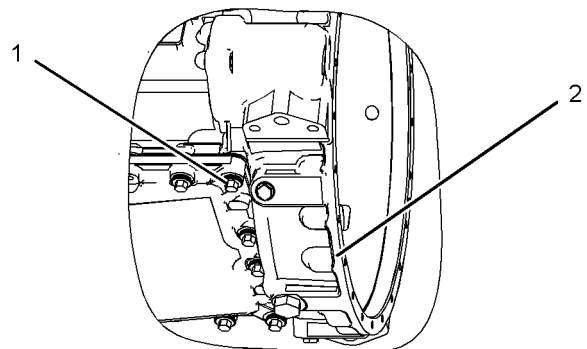


Illustration 134

g01008304

6. Install bolts (1) that fasten the engine oil pan to flywheel housing (2).

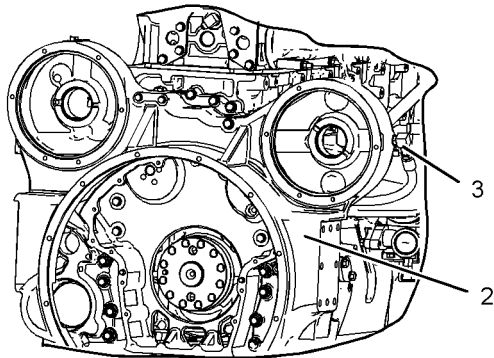


Illustration 135

g01106371

7. Connect hose assembly (3) to flywheel housing (2).

**End By:**

- a. Assemble the power take-off drive. Refer to Disassembly and Assembly, "Power Take-Off Drive Group - Assemble".
- b. Install the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".
- c. Install the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

i03190331

## Flywheel Housing - Remove and Install

**SMCS Code:** 1157-010

### Removal Procedure

Table 33

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 138-7574    | Link Bracket     | 2   |

**Start By:**

- a. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove".
- b. Remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

**NOTICE**

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

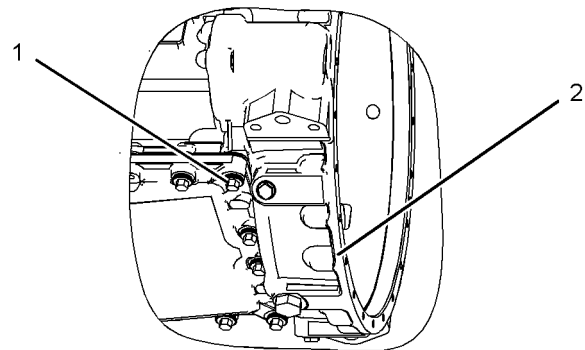


Illustration 136

g01008304

1. Remove bolts (1) that fasten the engine oil pan to flywheel housing (2).

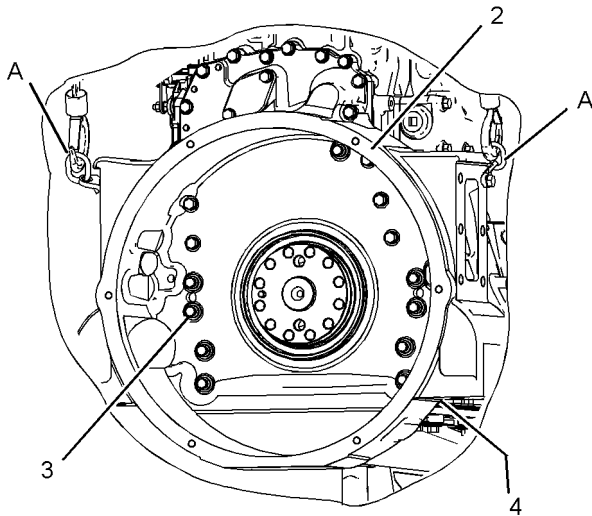


Illustration 137

g01058428

2. Install Tooling (A) and a suitable lifting device on flywheel housing (2). The weight of flywheel housing (2) is approximately 105 kg (230 lb).
3. Remove bolts (3). Remove the flywheel housing from the cylinder block.
4. Remove gasket (4) from the flywheel housing.

### Installation Procedure

Table 34

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 138-7574    | Link Bracket     | 2   |
| B              | 8T-9022     | Silicone Gasket  | -   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the flywheel housing and the rear face of the cylinder block.

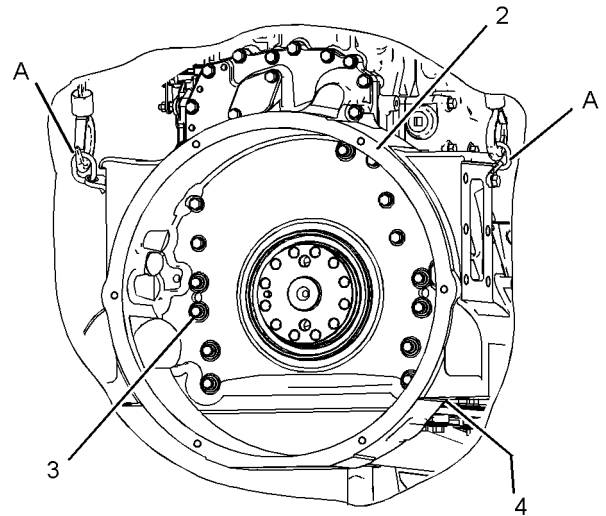


Illustration 138

g01058428

2. Install Tooling (A) and a suitable lifting device on flywheel housing (2). The weight of flywheel housing (2) is approximately 105 kg (230 lb).
3. Install gasket (4) on the dowel pins of the cylinder block. Apply Tooling (B) to the bottom of the gasket in order to fill the space at the cylinder block, the flywheel housing, and the engine oil pan.
4. Position flywheel housing (2) and install bolts (3).

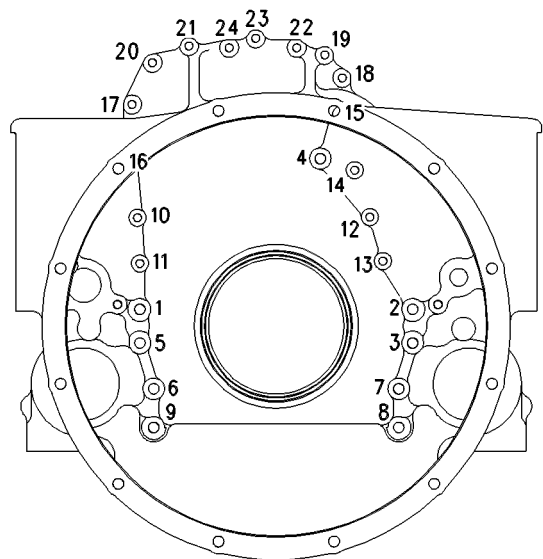


Illustration 139

g00551652

5. Tighten the bolts, as follows:
  - a. In a numerical sequence, tighten Bolt 1 through Bolt 24 to a torque of  $40 \pm 10$  N·m ( $30 \pm 7$  lb ft).

- b. In a numerical sequence, again tighten Bolt 1 through Bolt 9 to a torque of  $135 \pm 20$  N·m ( $100 \pm 15$  lb ft).
- c. In a numerical sequence, again tighten Bolt 10 through Bolt 24 to a torque of  $55 \pm 10$  N·m ( $40 \pm 7$  lb ft).

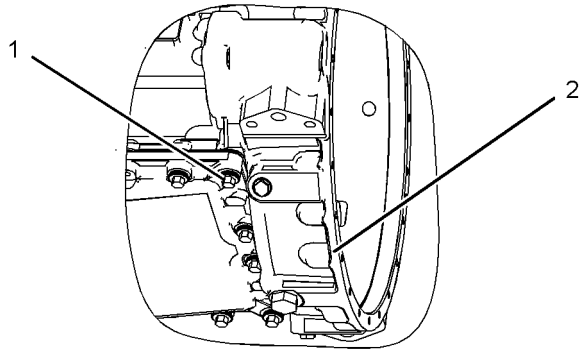


Illustration 140

g01008304

- 6. Install bolts (1) that fasten the engine oil pan to flywheel housing (2).
- 7. Remove Tooling (A).

**End By:**

- a. Install the electric starting motor. Refer to Disassembly and Assembly, “Electric Starting Motor - Remove and Install”.
- b. Install the crankshaft rear seal. Refer to Disassembly and Assembly, “Crankshaft Rear Seal - Install”.

i02187180

## Power Take-Off Drive Group - Disassemble

SMCS Code: 1165-015

### Disassembly Procedure

Table 35

| Required Tools |             |                                |     |
|----------------|-------------|--------------------------------|-----|
| Tool           | Part Number | Part Description               | Qty |
| A              | -           | Guide Stud (5/8 - 18 x 8 inch) | 2   |
| B              | 1P-0520     | Driver Group                   | 2   |

**Start By:**

- a. Remove the flywheel. Refer to Disassembly and Assembly, “Flywheel - Remove”.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

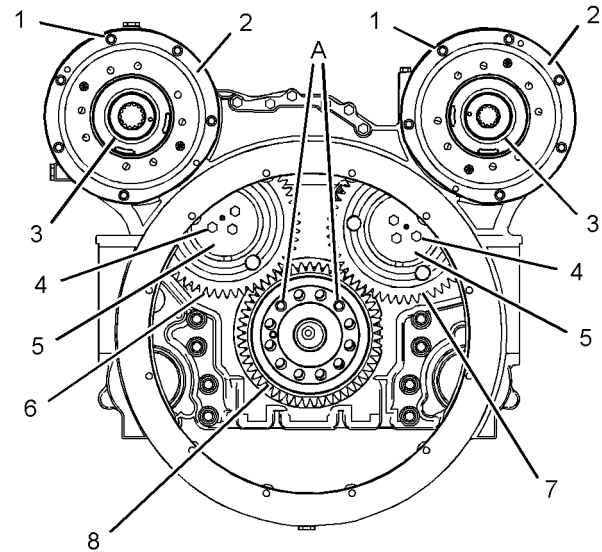


Illustration 141

g01106648

- 1. Remove bolts (1). Remove adapter (2) from the flywheel housing.
- 2. Remove the O-ring seal from adapter (2). Use Tooling (B) to remove sleeve bearing (3) from adapter (2).
- 3. Remove bolts (4). Remove retainer assembly (5) and idler gear (6). Use Tooling (B) and remove the sleeve bearing from idler gear (6).
- 4. Remove bolts (4). Remove retainer assembly (5) and idler gear (7). Use Tooling (B) and remove the sleeve bearing from idler gear (7).
- 5. Remove crankshaft gear (8) from Tooling (A). Remove the O-ring seal from the counterbore of the crankshaft gear.

i02187181

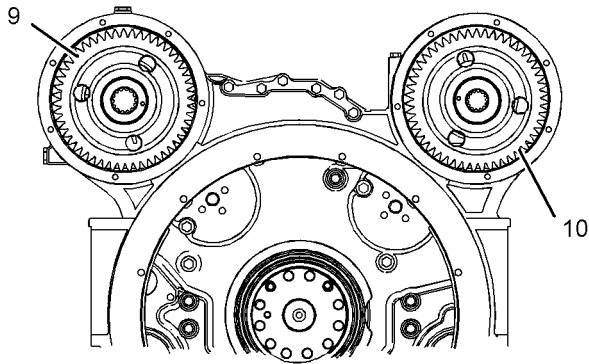


Illustration 142 g01106649

- Remove gear assembly (9) and gear assembly (10) from the flywheel housing.

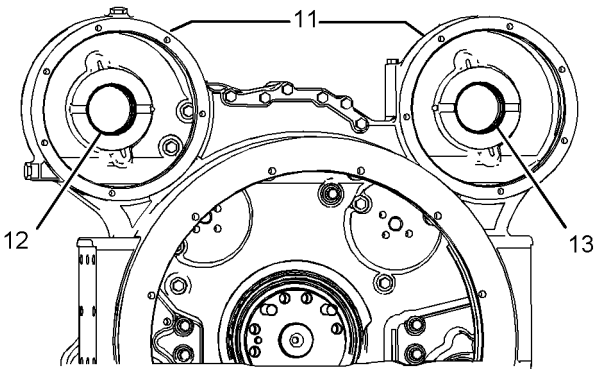


Illustration 143 g01106650

- Remove the bolts and cover (11) from the back side of the flywheel housing. Remove the O-ring seal from the cover. Use Tooling (A) and remove sleeve bearing (12) from the flywheel housing.
- Remove the bolts and cover (11) from the back side of the flywheel housing. Remove the O-ring seal from the cover. Use Tooling (A) and remove sleeve bearing (13) from the flywheel housing.

## Power Take-Off Drive Group - Assemble

SMCS Code: 1165-016

### Assembly Procedure

Table 36

| Required Tools |             |                                |     |
|----------------|-------------|--------------------------------|-----|
| Tool           | Part Number | Part Description               | Qty |
| A              | -           | Guide Stud (5/8 - 18 x 8 inch) | 2   |
| B              | 1P-0520     | Driver Group                   | 2   |
| C              | 9S-3263     | Thread Lock Compound           | -   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

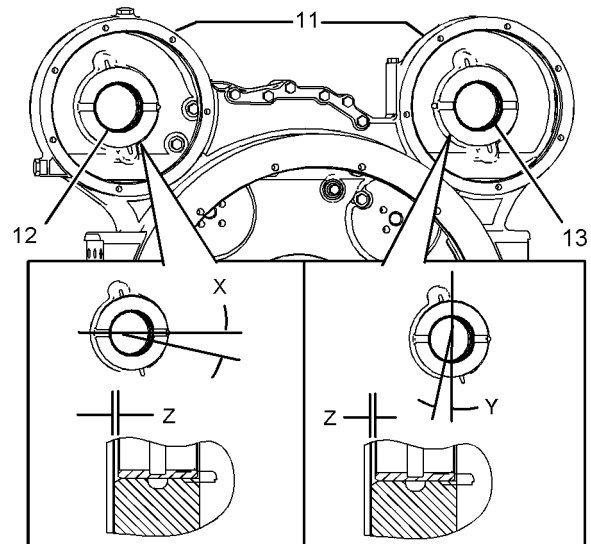


Illustration 144 g01106888

- Install sleeve bearing (13) in the flywheel housing with Tooling (B). The split in the sleeve bearing should be located at Angle (Y), which is  $15 \pm 1$  degrees from the horizontal centerline. The bearing should be installed to Depth (Z), which is  $2.0 \pm 0.5$  mm ( $0.08 \pm 0.02$  inch).
- Install sleeve bearing (12) in the flywheel housing with Tooling (B). The split in the sleeve bearing should be located at Angle (X), which is  $15 \pm 1$  degrees from the vertical centerline. The bearing should be installed to Depth (Z), which is  $2.0 \pm 0.5$  mm ( $0.08 \pm 0.02$  inch).

3. Install the O-ring seal on cover (11). Install cover (11) and the bolts on the back side of the flywheel housing.

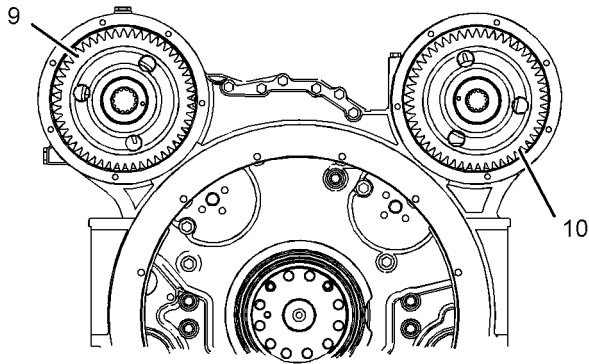


Illustration 145

g01106649

4. Position gear assembly (9) and gear assembly (10) in the flywheel housing.

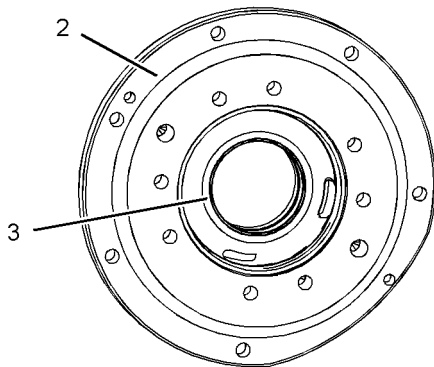


Illustration 146

g01106948

5. Use Tooling (B) and install sleeve bearing (3) in adapter (2). Install the O-ring seal on adapter (2).

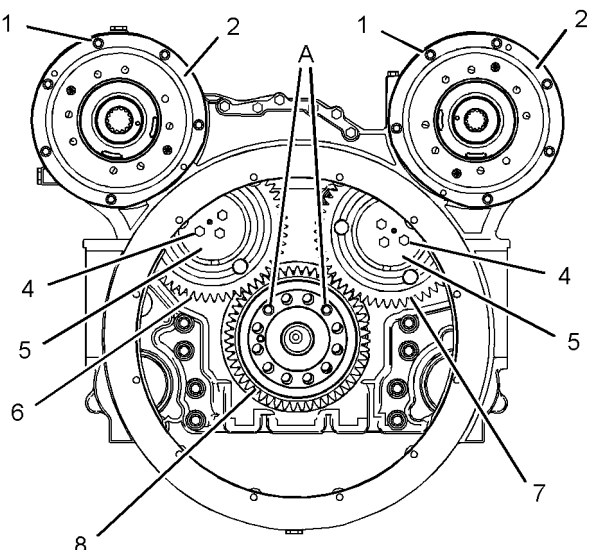


Illustration 147

g01106976

6. Align the relief groove in the sleeve bearing with the relief groove in the idler gear (6). Use Tooling (B) to install the sleeve bearing in idler gear (6).
7. Position idler gear (6) and retainer (5). Install bolts (4).
8. Align the relief groove in the sleeve bearing with the relief groove in the idler gear (7). Use Tooling (B) to install the sleeve bearing in idler gear (7).
9. Position idler gear (7) and retainer (5). Install bolts (4).
10. Install the O-ring seal in the counterbore of crankshaft gear (8). Lubricate the O-ring seal with clean engine oil. Install crankshaft gear (8) on Tooling (A).
11. Position adapter (2) on the flywheel housing. Apply Tooling (C) to the threads of bolts (1) and install the bolts.

**End By:**

- a. Install the flywheel. Refer to Disassembly and Assembly, "Flywheel - Install".

i03963669

## Vibration Damper and Pulley - Remove and Install

SMCS Code: 1205-010

### Removal Procedure

Table 37

| Required Tools |             |                                     |     |
|----------------|-------------|-------------------------------------|-----|
| Tool           | Part Number | Part Description                    | Qty |
| A              | -           | Guide Bolt<br>5/8 - 18 NF by 7 inch | 1   |
| B              | 4C-5593     | Thread Lubricant                    | -   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

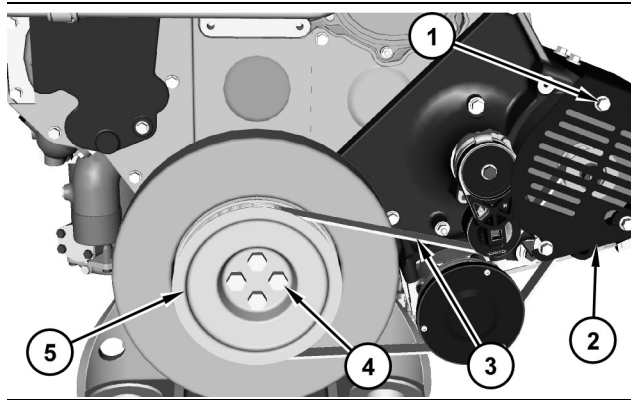


Illustration 148 g02160891

1. Remove bolts (1) and remove guard (2).
2. Release the tension on the belt tensioner in order to position belt (3) out of the way.
3. Remove bolts (4) and remove pulley (5).

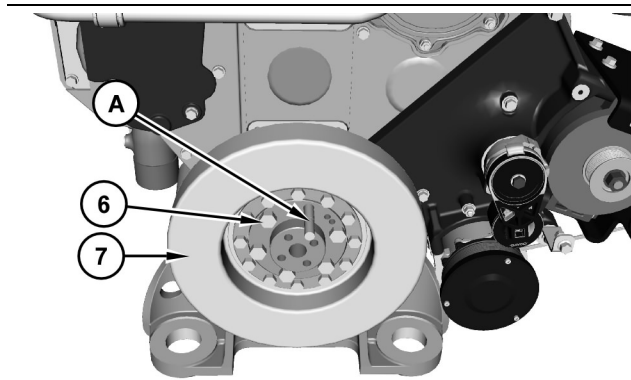


Illustration 149 g02160924

4. Remove one bolt (6) and install Tooling (A).
5. Remove remaining bolts (6). Use two people in order to remove vibration damper assembly (7). The weight of vibration damper assembly (2) is approximately 46 kg (100 lb).

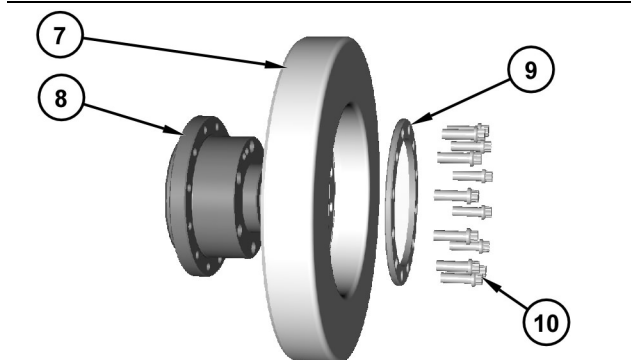


Illustration 150 g02161096

6. Remove bolts (10) and remove spacer (9).
7. Separate damper (7) from adapter (8).

### Installation Procedure

1. Install vibration damper (7) in the reverse order.
  - a. Apply Tooling (B) to bolts (6).

i02507762

## Crankshaft Front Seal - Remove

SMCS Code: 1160-011

### Removal Procedure

Table 38

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 1U-7600     | Slide Hammer Puller | 1   |

#### Start By:

- a. Remove the vibration damper and the pulley. Refer to Disassembly and Assembly, "Vibration Damper and Pulley - Remove and Install".

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

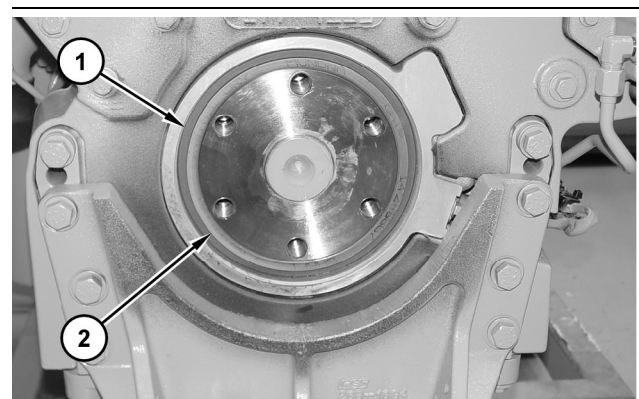


Illustration 151 g01255652

1. If necessary, use Tooling (A) or a punch and hammer in order to puncture three or more holes in wear sleeve (1).
2. If necessary, use Tooling (A) in order to remove wear sleeve (1).

- Use Tooling (A) or a punch and hammer in order to puncture three or more holes in crankshaft front seal (2).
- Use Tooling (A) in order to remove crankshaft front seal (2).

i02507763

## Crankshaft Front Seal - Install

SMCS Code: 1160-012

### Installation Procedure

Table 39

| Required Tools |             |                      |     |
|----------------|-------------|----------------------|-----|
| Tool           | Part Number | Part Description     | Qty |
| B              | 5P-1733     | Seal Locator         | 1   |
| C              | 5P-1737     | Bolt                 | 3   |
| D              | 9S-8858     | Nut (Seal Installer) | 1   |
| E              | 6V-6142     | Seal Installer       | 1   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Do not use any type of lubricant during the installation of the crankshaft front seal and the wear sleeve.

- Before installation of the crankshaft front seal and the wear sleeve, inspect the crankshaft for scratches. Also, inspect the crankshaft for any distortion on the surface that may lead to an out of round condition. Use a polishing cloth in order to remove any imperfections on the crankshaft.
- Clean the outside diameter of the crankshaft.

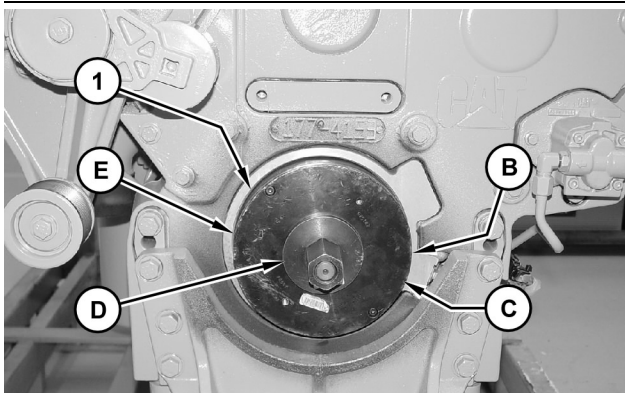


Illustration 152

g01255654

- Use Tooling (C) in order to attach Tooling (B) to the crankshaft.

**Note:** Install the crankshaft front seal with the arrow that shows the direction of crankshaft rotation toward the front of the engine.

- Position wear sleeve (2) and crankshaft front seal (1) as a unit on Tooling (B). Install Tooling (E) on Tooling (B). Lubricate the face of the washer on Tooling (D). Install Tooling (D) on Tooling (B).
- Tighten Tooling (D) until Tooling (E) contacts Tooling (B).
- Remove Tooling (D) and Tooling (E) from Tooling (B).
- Remove Tooling (C) and Tooling (B) from the crankshaft.

#### End By:

- Install the vibration damper and the pulley. Refer to Disassembly and Assembly, "Vibration Damper and Pulley - Remove and Install".

i03966429

## Front Cover - Remove and Install

SMCS Code: 1166-010

### Removal Procedure

Table 40

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 193-9199    | Socket As        | 1   |
| B              | -           | Loctite 271      | -   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

i02519560

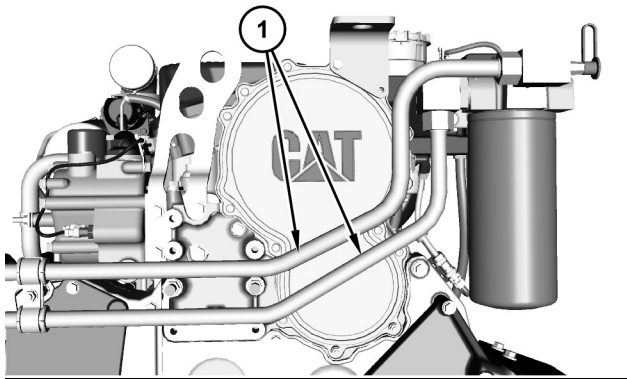


Illustration 153

g02161453

1. Remove tube assemblies (1).

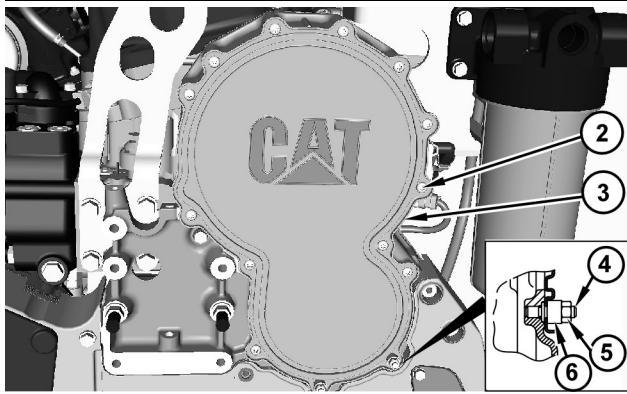


Illustration 154

g01865343

2. Use Tooling (A) to remove button head screws (2).
3. Remove nuts (5) and spacers (6) from studs (4).
4. Remove front cover (3) from the front housing.  
Remove the seal from the front cover.

## Installation Procedure

1. Install the front cover in reverse order.
  - a. Tighten button head screws (2) to a torque of  $21 \pm 3$  N·m ( $186 \pm 27$  lb in).
  - b. Apply Tooling (B) to studs (4) prior to installation.

## Gear Group (Front) - Remove

SMCS Code: 1206-011

### Removal Procedure

Table 41

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 1P-0510     | Driver Group     | 1   |

#### Start By:

- a. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".
- b. Remove the air compressor, if necessary. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".
- c. Remove the water pump, if necessary. Refer to Disassembly and Assembly, "Water Pump - Remove".

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

#### NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

**Note:** Be sure to mark the orientation of each of the gears for installation purposes.

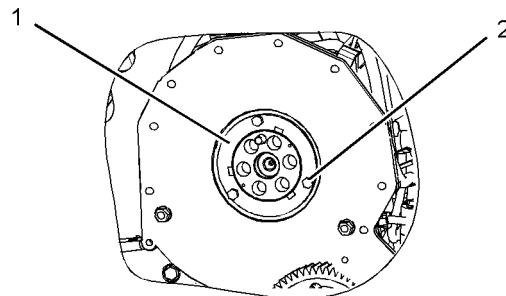


Illustration 155

g01008429

1. Remove bolts (2) and thrust plate (1).

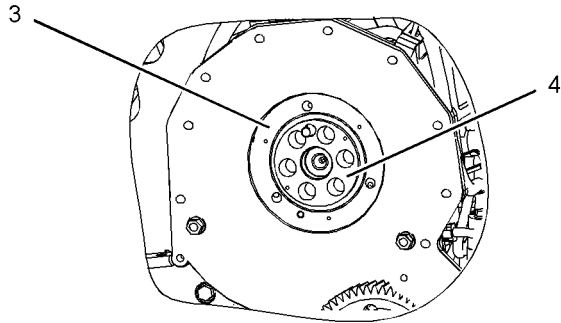


Illustration 156

g01008430

2. Remove sealing plate (3) and adapter (4).

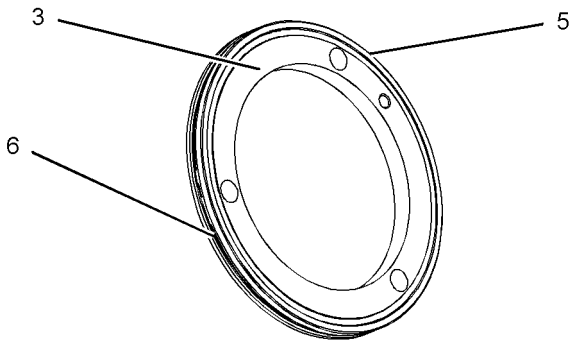


Illustration 157

g01008431

3. Remove O-ring seal (5) and O-ring seal (6) from sealing plate (3).

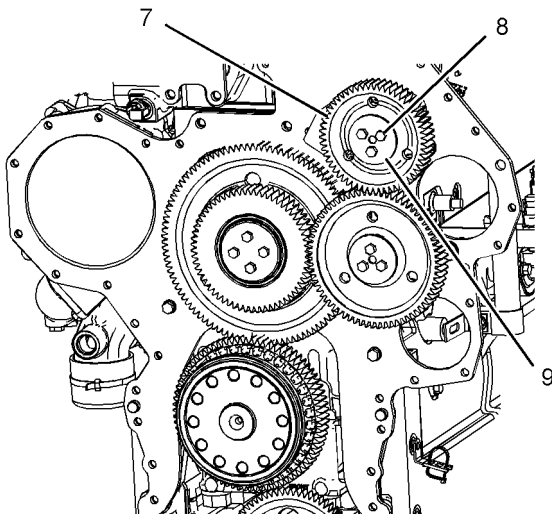


Illustration 158

g01101536

4. Remove bolts (8), plate (9), and adjustable idler gear assembly (7).

5. Use Tooling (A) and remove the sleeve bearing from adjustable idler gear assembly (7).

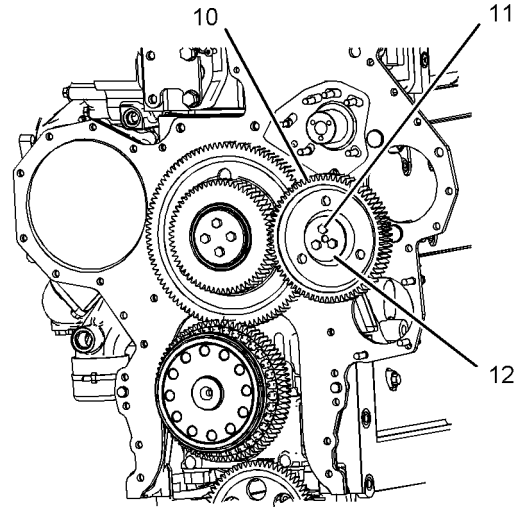


Illustration 159

g01101045

6. Remove bolts (11), plate (12), and idler gear assembly (10).
7. Use Tooling (A) and remove the sleeve bearing from idler gear assembly (10).

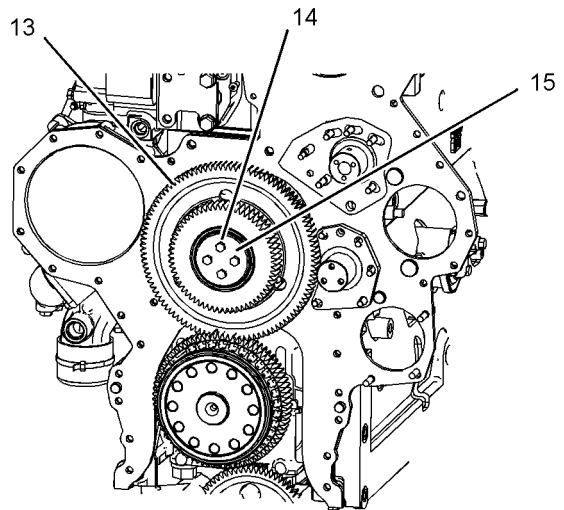


Illustration 160

g01101048

8. Remove bolts (14), plate (15), and cluster gear assembly (13).
9. Use Tooling (A) and remove the sleeve bearing from cluster gear assembly (13).

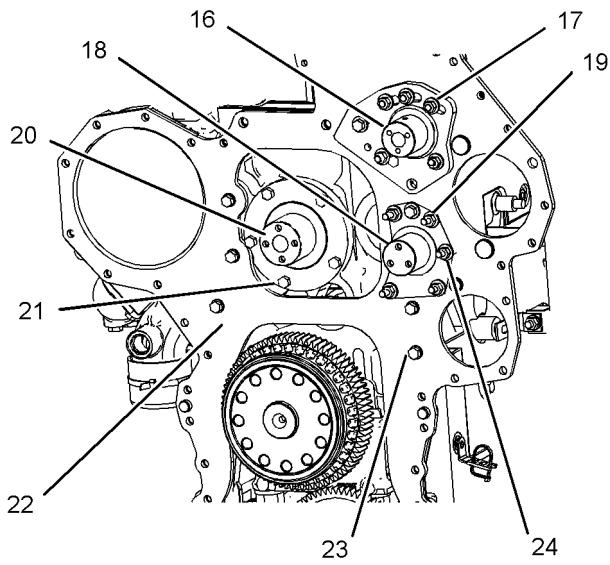


Illustration 161

g01101050

**Note:** Stub shaft assembly (16) must be removed in order to remove plate (22). The backlash for the camshaft gear and the adjustable idler gear assembly will need to be readjusted at assembly.

10. Remove nuts (17) and remove stub shaft assembly (16).

**Note:** Stub shaft (18) must be removed in order to remove plate (22).

11. Remove nuts (19) and remove stub shaft (18).

12. Remove bolts (21) and remove stub shaft (20).

13. Remove bolts (23) that hold plate (22) to the cylinder block. Remove plate (22).

14. If studs (24) are loose or the threads are damaged, remove the studs from the front plate.

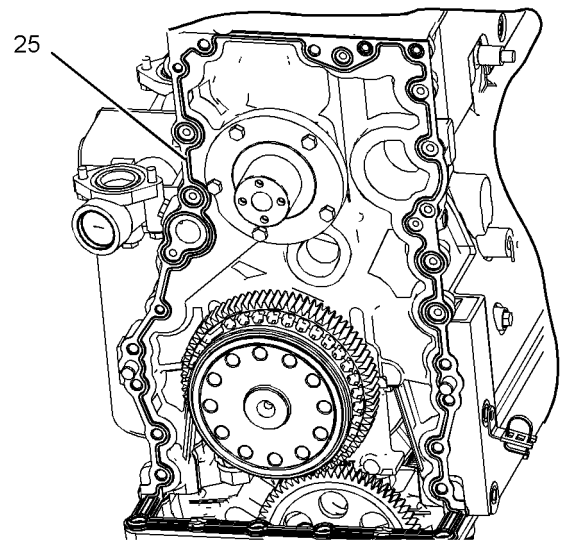


Illustration 162

g01101052

15. Remove integral seal (25) from the cylinder block.

i02519562

## Gear Group (Front) - Install

SMCS Code: 1206-012

### Installation Procedure

Table 42

| Required Tools |             |                      |     |
|----------------|-------------|----------------------|-----|
| Tool           | Part Number | Part Description     | Qty |
| A              | 1P-0510     | Driver Gp            | 1   |
| B              | 8T-2998     | Lubricant            | -   |
| C              | 8T-9022     | Silicone Gasket      | -   |
| D              | 9S-3263     | Thread Lock Compound | -   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

#### NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

1. Thoroughly clean the gasket material from the cylinder block and both sides of the plate.

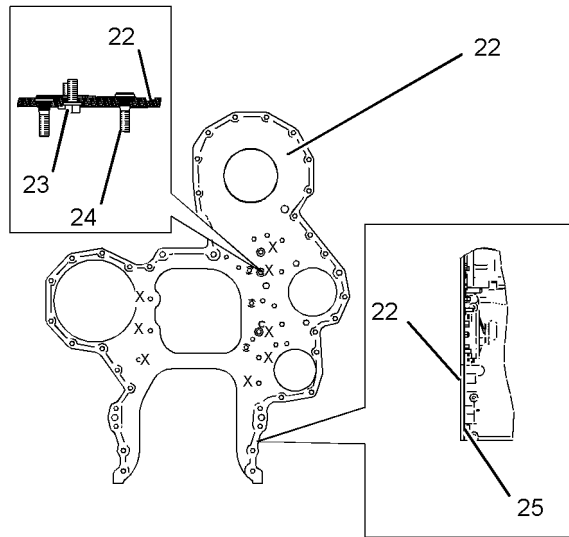


Illustration 163

g01101567

2. If studs (24) are loose or the threads are damaged, install new studs (24) in the front plate. Apply Tooling (D) to the serrations of studs (24). Install studs (24) in the front plate.

3. Install integral seal (25) on the dowel pins on the cylinder block.

**Note:** Apply Tooling (C) to the bottom of integral seal (25) in order to fill the space at the cylinder block, the front housing and the engine oil pan.

4. Install plate (22) on the dowel pins on the cylinder block. Install new locking bolts (23) (Marked "X") in order to fasten the front plate to the cylinder block. Tighten locking bolts (23) to a torque of 55 N·m (41 lb ft).

**Note:** Clean the old sealant from the bolts and apply Tooling (D) to the bolts.

5. Tighten locking bolts (23) again to a torque of 55 N·m (41 lb ft).

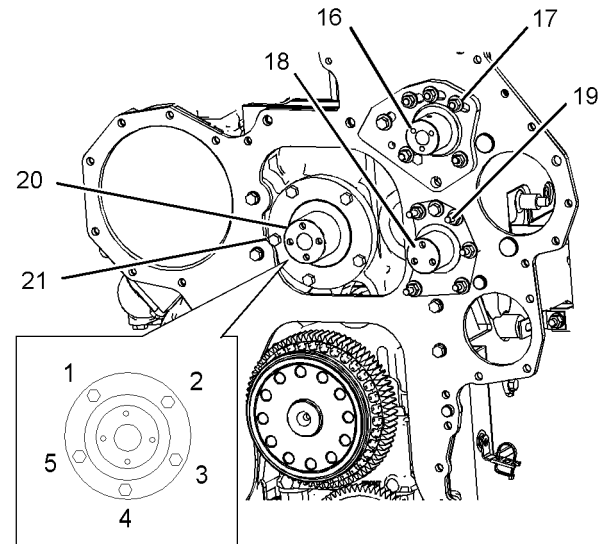


Illustration 164

g01101565

6. Install stub shaft (18). Apply Tooling (D) to the studs and the bolt for stub shaft (18). Tighten nuts (19) and the bolt to a torque of  $55 \pm 10$  N·m ( $41 \pm 7$  lb ft).

7. Install stub shaft assembly (16). Apply Tooling (D) to the studs and the bolt for stub shaft assembly (16). Do not tighten nuts (17) and the bolt for stub shaft assembly (16) at this time. Nuts (17) and the bolt for stub shaft assembly (16) will need to be tightened when the backlash is adjusted.

8. Adjust the backlash between the camshaft gear and the adjustable idler gear assembly. The backlash should be  $0.216 \pm 0.114$  mm ( $0.0085 \pm 0.0045$  inch). Refer to Testing and Adjusting, "Gear Group (Front) - Time" for the backlash adjustment procedure. Tighten nuts (17) and the bolt to a torque of  $55 \pm 10$  N·m ( $41 \pm 7$  lb ft).

9. Install stub shaft (20). Apply Tooling (D) to bolts (21). Install bolts (21) and tighten in a numeric sequence 1, 3, 4, 5, 2, 1, 2, 3, 4, 5, 1 to a torque of  $55 \pm 10$  N·m ( $41 \pm 7$  lb ft).

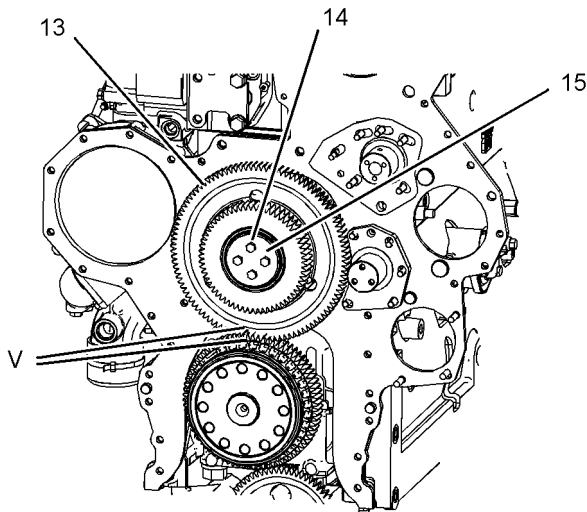


Illustration 165

g01101161

- 10. Use Tooling (A) to install the sleeve bearing in cluster gear assembly (13).
- 11. Put cluster gear assembly (13) on the stub shaft. Ensure that Timing Marks (V) are aligned on the cluster gear assembly and the crankshaft gear.
- 12. Position plate (15) with the oil groove toward the face of the gear. Apply Tooling (D) to bolts (14). Install bolts (14). Tighten bolts (14) to a torque of  $30 \pm 7$  N·m ( $22 \pm 5$  lb ft).

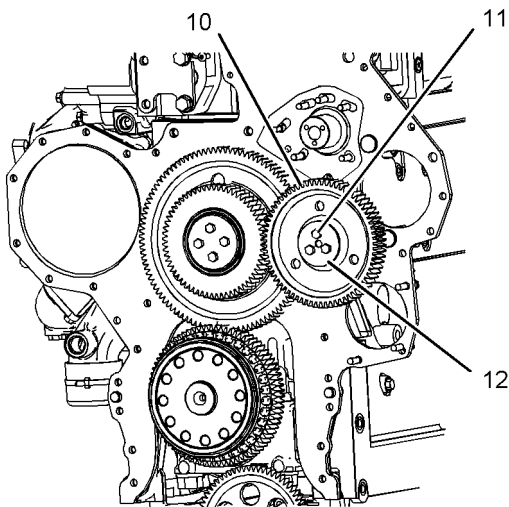


Illustration 166

g01101045

- 13. Use Tooling (A) to install the sleeve in idler gear (10).

- 14. Put idler gear assembly (10) on the stub shaft. Install plate (12) with the oil groove toward the gear face. Apply Tooling (D) to bolts (11). Install bolts (11). Tighten bolts (11) to a torque of  $30 \pm 7$  N·m ( $22 \pm 5$  lb ft).

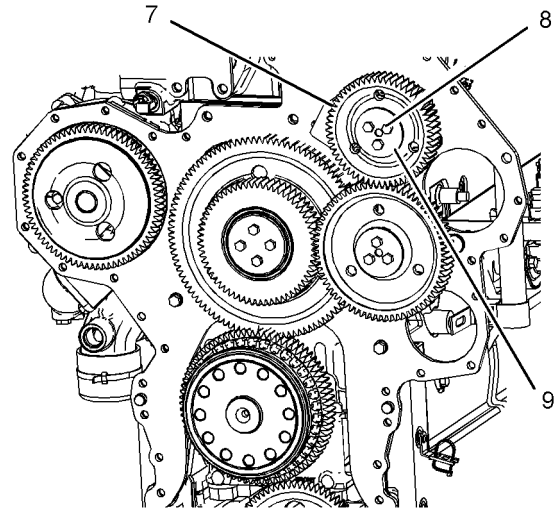


Illustration 167

g01008436

- 15. Use Tooling (A) to install the sleeve bearing in adjustable idler gear (7).
- Note:** Align the oil hole in the bearing with the oil hole in the adjustable idler gear.
- 16. Put adjustable idler gear assembly (7) on the stub shaft assembly. Position plate (9) with the oil groove toward the face of the gear. Apply Tooling (D) to bolts (8). Install bolts (8). Tighten bolts (8) to a torque of  $30 \pm 7$  N·m ( $22 \pm 5$  lb ft).

**Note:** Check the backlash for the camshaft gear and the adjustable idler gear assembly. The camshaft gear must be installed and the adjustable idler gear assembly must be removed in order to perform the backlash adjustment procedure. Refer to Testing and Adjusting, "Gear Group (Front) - Time".

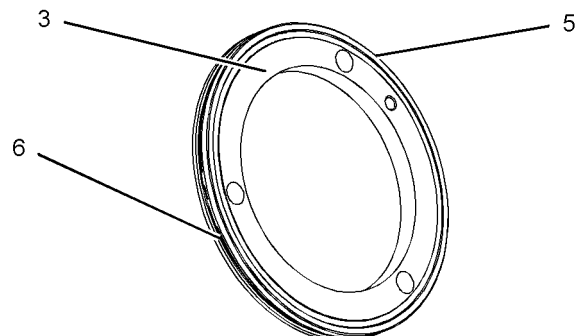


Illustration 168

g01008431

17. Install O-ring seal (5) and O-ring seal (6) in sealing plate (3). Lubricate O-ring seal (6) with a 50/50 mixture of Tooling (B) and clean engine oil.

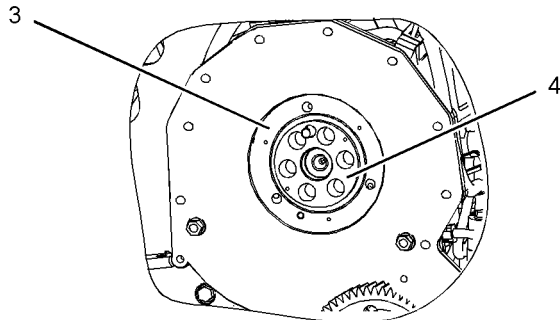


Illustration 169

g01008430

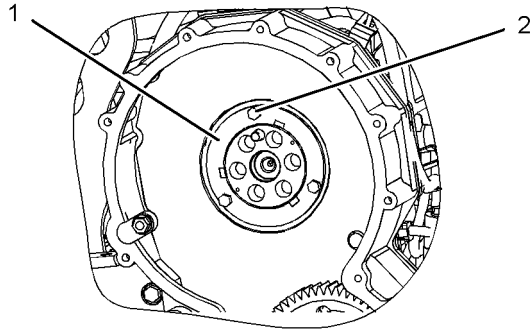


Illustration 170

g01010256

18. Install adapter (4). Ensure that the dowel in the adapter engages the hole in the camshaft.
19. Install sealing plate (3) and thrust plate (1). Ensure that the dowel in the adapter engages the hole in the thrust plate. Apply Tooling (D) to bolts (2). Install bolts (2). Evenly tighten bolts (2) in order to ensure that sealing plate (3) and O-ring seal (5) are seated against the cylinder head.
20. Adjust the backlash for the camshaft gear and the adjustable idler gear, if necessary. Refer to Testing and Adjusting, "Gear Group (Front) - Time".

**Note:** The camshaft gear must be installed and the adjustable idler gear must be removed in order to perform the backlash adjustment procedure.

**End By:**

- a. Install the water pump. Refer to Disassembly and Assembly, "Water Pump - Install".
- b. Install the air compressor, if necessary. Refer to Disassembly and Assembly, "Air Compressor - Remove and Install".

- c. Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install".

i02519539

## Housing (Front) - Remove

SMCS Code: 1151-011

### Removal Procedure

**Start By:**

- a. Remove the camshaft position sensor. Refer to Disassembly and Assembly, "Camshaft Position Sensor - Remove and Install".
- b. Remove the crankshaft position sensor. Refer to Disassembly and Assembly, "Crankshaft Position Sensor - Remove and Install".
- c. Remove the engine support. Refer to Disassembly and Assembly, "Engine Support (Front) - Remove and Install".
- d. Remove the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install".
- e. Remove the crankshaft front seal. Refer to Disassembly and Assembly, "Crankshaft Front Seal - Remove".

#### NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

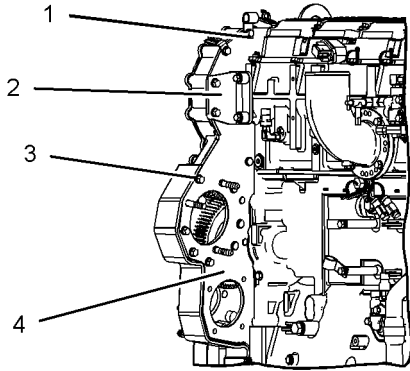


Illustration 171 g01078059

1. Remove the bolts and clips (1).
2. Remove bracket (2) from plate (4) and the cylinder head.
3. Remove bolts (3).

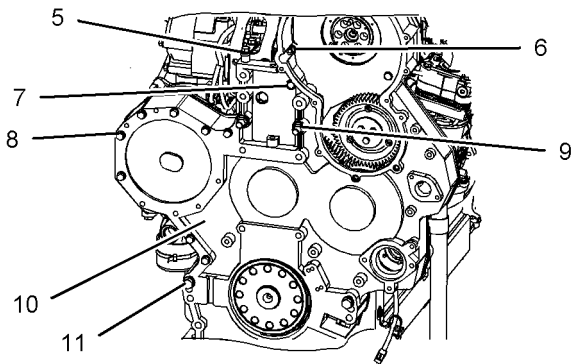


Illustration 172 g01078084

4. Remove cable strap (5) from the cylinder head and front housing (10).
5. Remove bolt (7) and nut (6) from the front housing.
6. Remove bolts (8) and nuts (9) from the front housing.
7. Remove bolts (11) from the front housing.

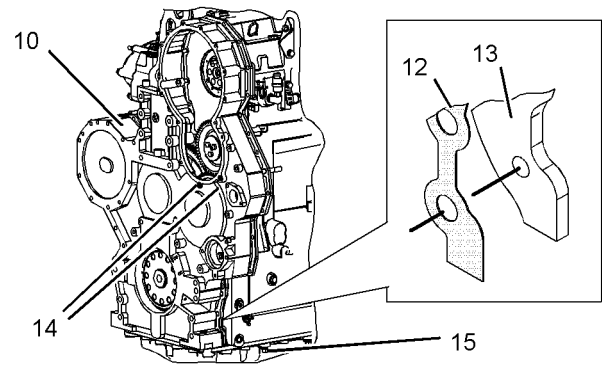


Illustration 173 g01078119

8. Loosen bolts (15) from the engine oil pan.
- Note:** It is not necessary to remove the engine oil pan from the engine.
9. Remove front housing (10).
  10. If necessary, remove studs (14) and the O-ring seals from the front housing.
  11. Remove gasket (12) from plate (13) and the front housing.

i02519540

## Housing (Front) - Install

SMCS Code: 1151-012

### Installation Procedure

Table 43

| Required Tools |             |                      |     |
|----------------|-------------|----------------------|-----|
| Tool           | Part Number | Part Description     | Qty |
| A              | 154-9731    | Thread Lock Compound | -   |
| B              | 8T-9022     | Silicone Gasket      | -   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

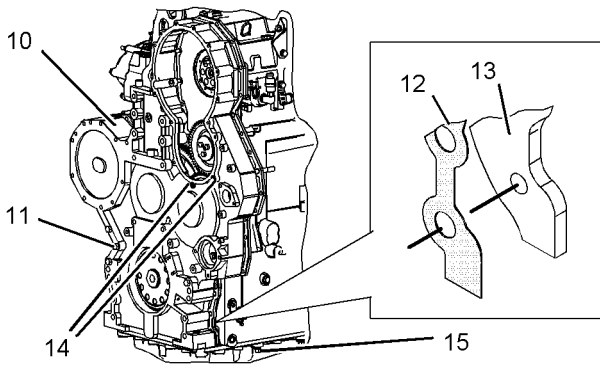


Illustration 174

g01078406

1. If studs (14) are loose or the threads are damaged, install new studs in front housing (10). Apply Tooling (A) to the threads of studs (14). Install the O-ring seals on the studs and install the studs in the front housing.
  2. Thoroughly clean the mating surfaces of plate (13) and front housing (10).
  3. Install gasket (12) on plate (13).
- Note:** Trim the gasket even with the bottom of the front housing after assembly.
4. Apply Tooling (B) to the bottom of gasket (12) in order to fill the space at the front housing and the engine oil pan.
  5. Install front housing (10) on the dowel pins on the cylinder block.
  6. Install bolts (11) in front housing (10).
  7. Tighten bolts (15).

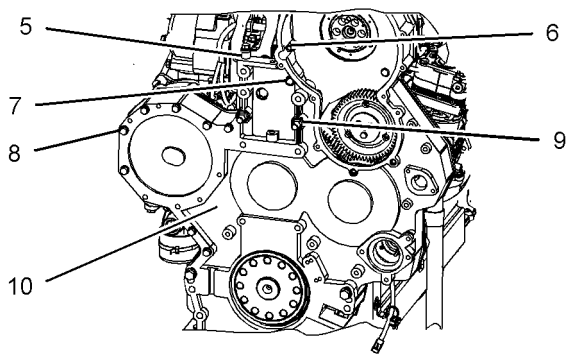


Illustration 175

g01078272

8. Install bolt (7) and nuts (6).
9. Install bolts (8) and nuts (9).

10. Install cable strap (5) on the front housing and on the cylinder head.

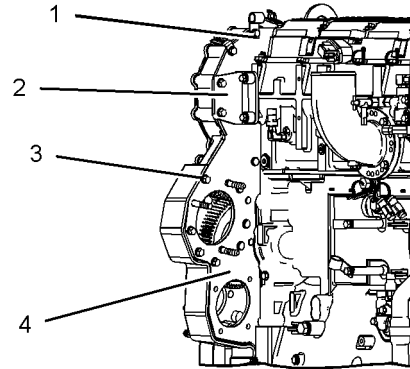


Illustration 176

g01078059

11. Install the bolts and clips (1).
12. Install bolts (3).
13. Install bracket (2) on plate (4) and the front housing.

**End By:**

- a. Install the crankshaft front seal and the wear sleeve. Refer to Disassembly and Assembly, "Crankshaft Front Seal - Install".
- b. Install the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install".
- c. Install the engine support. Refer to Disassembly and Assembly, "Engine Support (Front) - Remove and Install".
- d. Install the camshaft position sensor. Refer to Disassembly and Assembly, "Camshaft Position Sensor - Remove and Install".
- e. Install the crankshaft position sensor. Refer to Disassembly and Assembly, "Crankshaft Position Sensor - Remove and Install".

i02117416

## Valve Mechanism Cover - Remove and Install

SMCS Code: 1107-010

### Removal Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

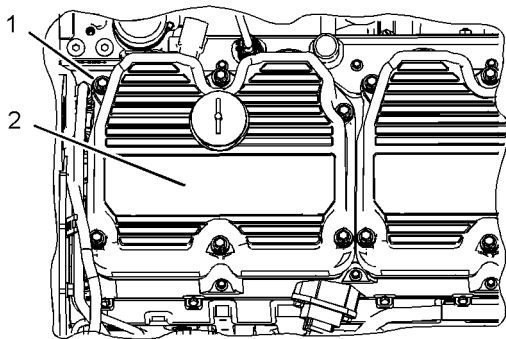


Illustration 177

g01078498

1. Remove bolts (1).
2. Remove valve mechanism cover (2).

### Installation Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

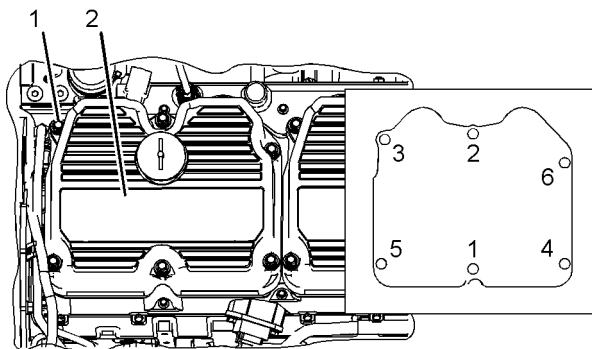


Illustration 178

g01078533

1. Position valve mechanism cover (2) on the valve cover base. Tighten bolts (1) to a torque of  $18 \pm 3 \text{ N}\cdot\text{m}$  ( $13 \pm 2 \text{ lb ft}$ ) in the numerical sequence that is shown in Illustration 178.

i03537469

## Valve Mechanism Cover Base - Remove and Install

SMCS Code: 1120-010

### Removal Procedure

Start By:

- a. Remove the valve mechanism cover.

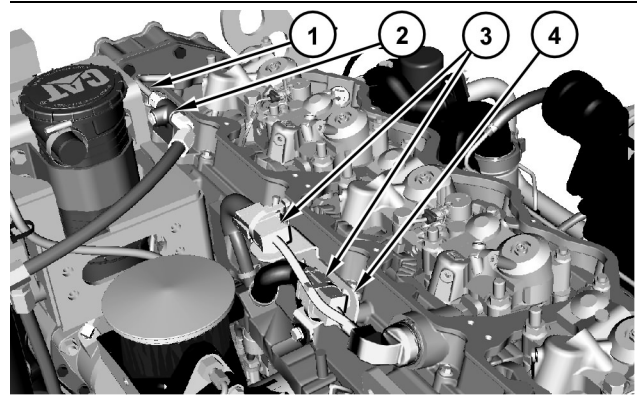


Illustration 179

g01865954

1. Remove tube assembly (1) and remove union (2).
2. Disconnect harness assemblies (3) and remove bracket (4).

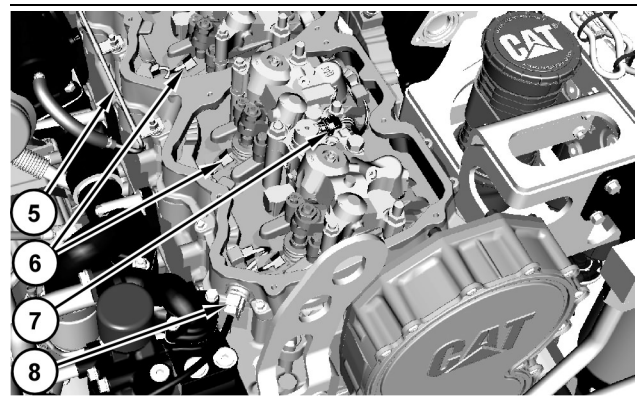


Illustration 180

g01866024

3. Remove tube assembly (5).
4. Disconnect six harness assemblies (6).
5. Disconnect three harness assemblies (7) and disconnect harness assembly (8).

i02521249

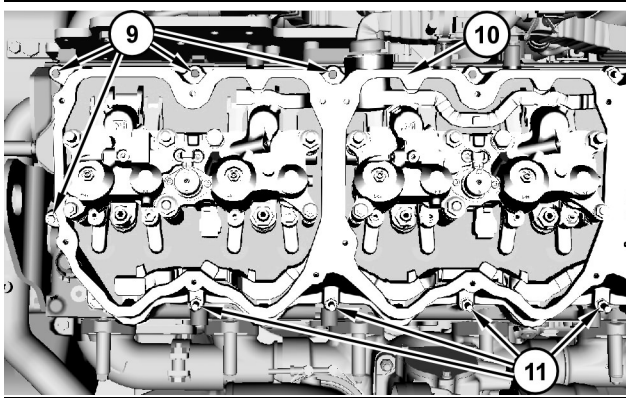


Illustration 181 g01866533

6. Remove bolts (9) and studs (11).
7. Remove the valve mechanism cover base (10).

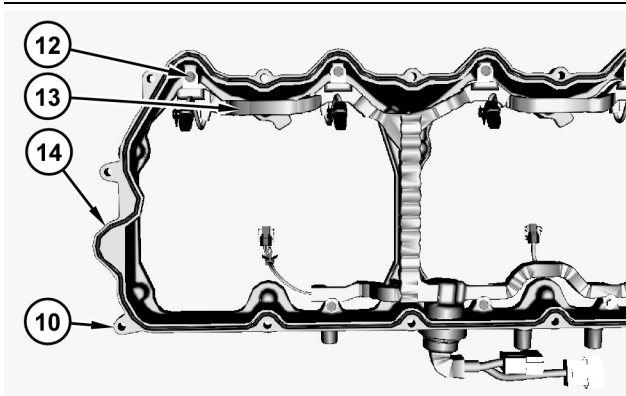


Illustration 182 g01866653

8. Remove bolts (12) and remove harness assembly (13).
9. Remove seal (14) from valve mechanism cover base (10).

## Installation Procedure

1. Install the valve mechanism cover base (10) in the reverse order.

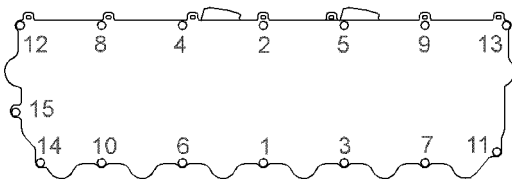


Illustration 183 g01866736

Tightening sequence

- a. Tighten bolts (9) and studs (11) to a torque of  $25 \pm 6$  N·m ( $18 \pm 4$  lb ft) in the numerical sequence that is shown in Illustration 183.

## Valve Actuator (Variable) - Remove

SMCS Code: 1105-011

### Removal Procedure

Start By:

- a. Remove the valve mechanism cover. Refer to the Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

**Note:** DO NOT disassemble the variable valve actuator after the component has been removed. Any attempt to disassemble the variable valve actuator will void the warranty of the component.

#### NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

i03022214

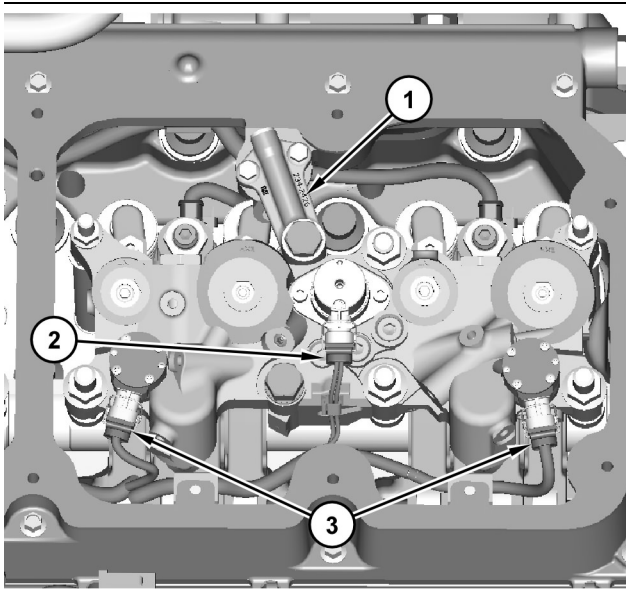


Illustration 184

g01261947

1. Remove engine oil connector (1). Remove the O-ring seals from the engine oil connector.
2. Disconnect harness assembly (2). Disconnect harness assemblies (3).

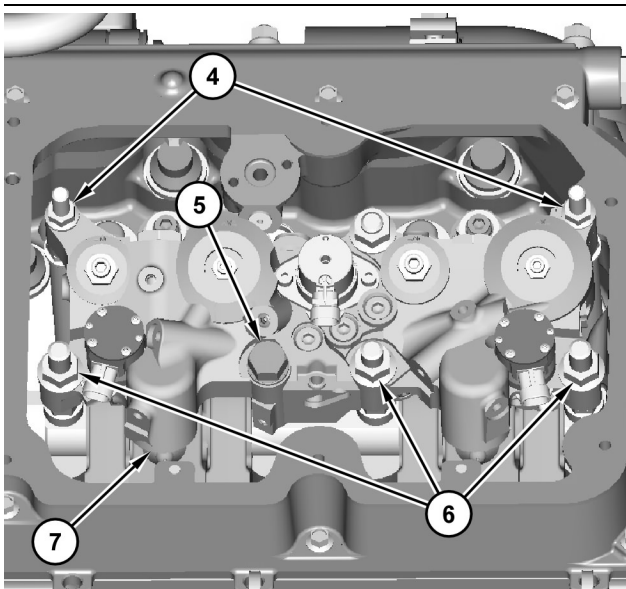


Illustration 185

g01261951

3. Remove nuts (4). Remove bolt (5). Remove nuts (6).
4. Remove valve actuator (7).

## Valve Actuator (Variable) - Install

SMCS Code: 1105-012

### Installation Procedure

Table 44

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 5P-3975     | Rubber Lubricant | -   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

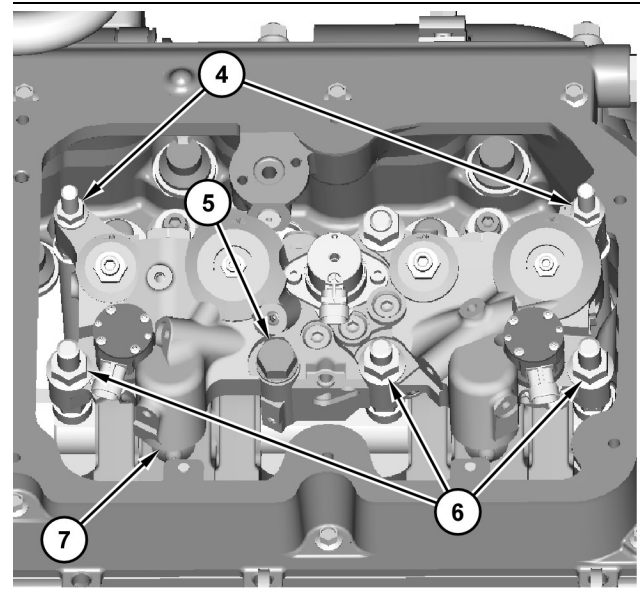


Illustration 186

g01261951

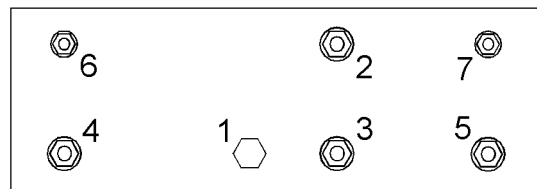


Illustration 187

g01527985

1. If necessary, install the studs at Locations (3), (4), and (5). Tighten the studs to a torque of  $50 \pm 5$  N·m ( $37 \pm 4$  lb ft). Tighten the studs for an additional  $45 \pm 5$  degrees. Install the stud at Location (2) and tighten the stud to a torque of  $65 \pm 10$  N·m ( $48 \pm 7$  lb ft). Install the support over the stud. Install the studs at Locations (6) and (7). Tighten the studs to a torque of  $47 \pm 9$  N·m ( $35 \pm 7$  lb ft).

2. Install valve actuator (7).
3. Install nuts (6). Install bolt (5). Install nuts (4).

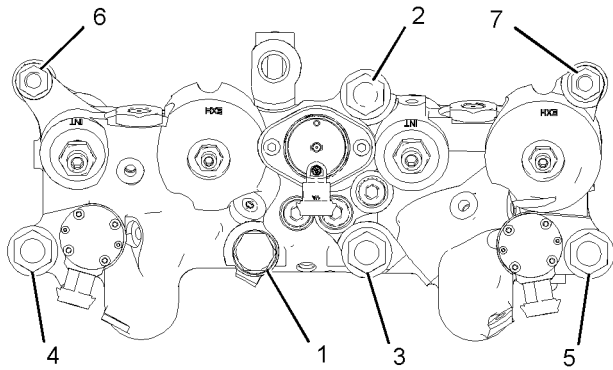


Illustration 188 g01261984

4. Tighten the bolt and tighten the nuts in the sequence that is shown.

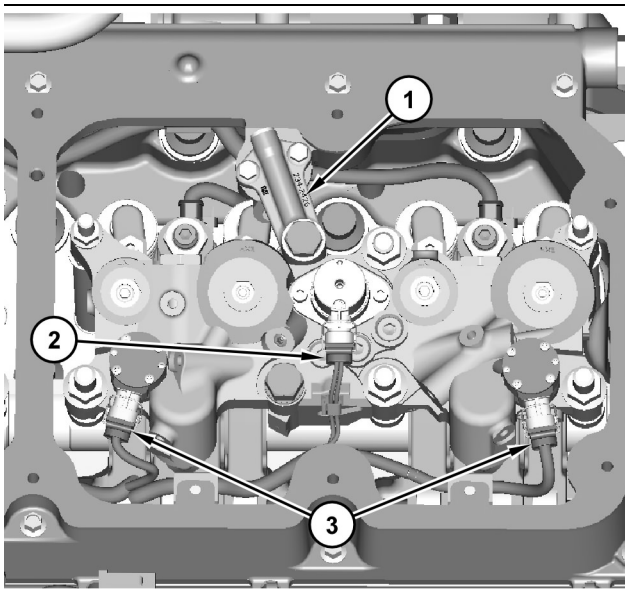


Illustration 189 g01261947

5. Install the O-ring seals in engine oil connector (1). Apply Tooling (A) on the mounting surface of the variable valve actuator and the engine oil connector.
6. Install engine oil connector (1).
7. Connect harness assembly (2). Connect harness assemblies (3).

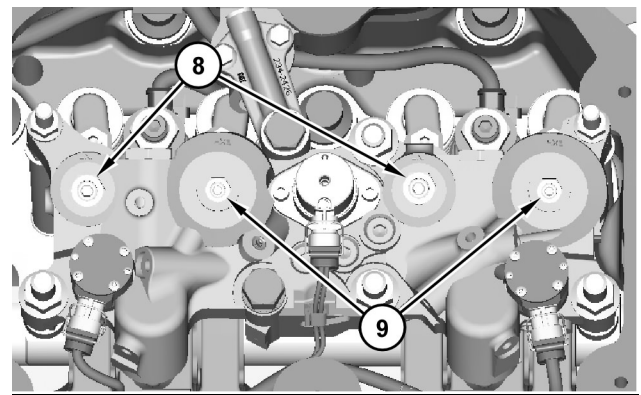


Illustration 190 g01261994

8. Adjust the lash for the variable valve actuators. Refer to Testing and Adjusting, "Variable Valve Actuators - Inspect/Adjust" for more information on adjusting the variable valve actuators. Tighten jam nut (8) to a torque of  $50 \pm 10$  N·m ( $37 \pm 7$  lb ft).
9. Adjust the lash for the compression brake. Refer to Testing and Adjusting, "Slave Piston Lash - Adjust" for more information on adjusting the lash for the compression brake. Tighten jam nut (9) to a torque of  $15 \pm 3$  N·m ( $11 \pm 2$  lb ft).

**End By:**

- a. Install the valve mechanism cover. Refer to the Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".

102517779

## Rocker Arm and Shaft - Remove

SMCS Code: 1102-011

### Removal Procedure

Table 45

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 124 - 2946  | Lifting Bracket  | 1   |

**Start By:**

- a. Remove the variable valve actuator. Refer to Disassembly and Assembly, "Valve Actuator (Variable) - Remove".

i02451112

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

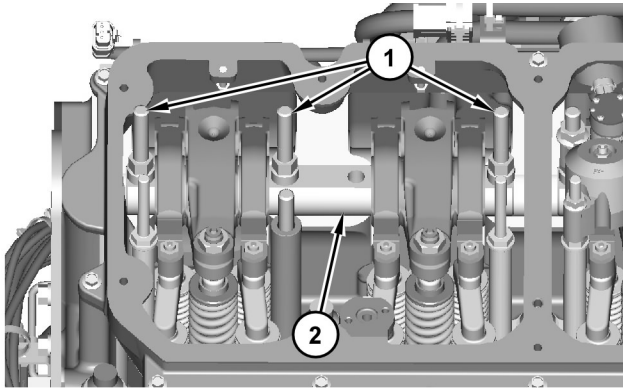


Illustration 191

g01259735

**WARNING**

Valve rocker arms and unit injector rocker arms can move on the shaft after the bolts have been removed. The shaft should be kept level when removed from the cylinder head. To avoid possible personal injury, keep fingers clear of the valve rocker arms and the unit injector rocker arms when lifting the assembly from the cylinder head.

1. Remove studs (1) from rocker arm shaft assembly (2).

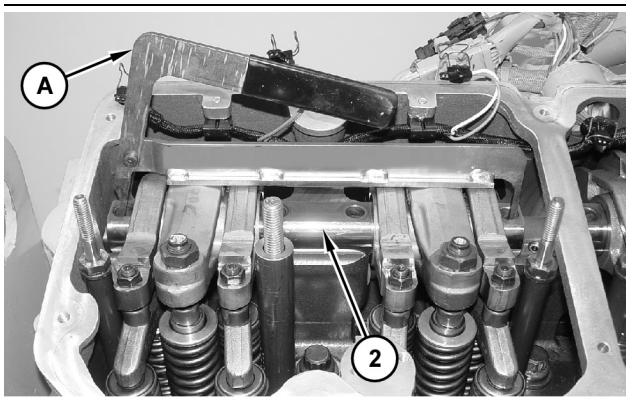


Illustration 192

g01262841

2. Use Tooling (A) in order to remove rocker arm shaft assembly (2).

**Rocker Arm - Disassemble**

**SMCS Code:** 1123-015

**Disassembly Procedure****Start By:**

- a. Remove the rocker arms and the rocker shaft. Refer to Disassembly and Assembly, "Rocker Arm and Shaft - Remove".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

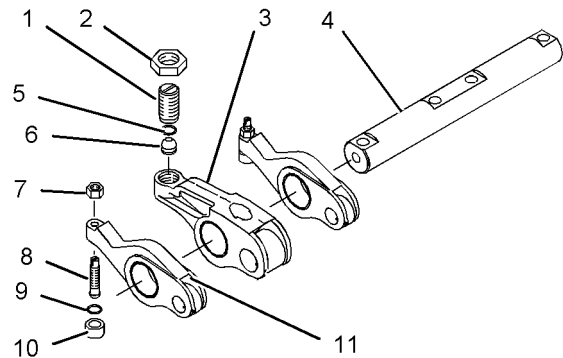


Illustration 193

g01047557

1. Remove valve rocker arms (11) and electronic unit injector rocker arm (3) from rocker shaft assembly (4).
2. Remove jam nut (7) from adjustment screw (8).
3. Remove adjustment screw (8) from valve rocker arms (11).
4. Remove button (10) from adjustment screw (8). Remove O-ring seal (9) from the adjustment screw.
5. Remove jam nut (2) from unit injector adjustment screw (1).
6. Remove unit injector adjustment screw (1) from electronic unit injector rocker arm (3).
7. Remove button (6) from unit injector adjustment screw (1). Remove O-ring seal (5) from the unit injector adjustment screw.

i02451120

## Rocker Arm - Assemble

SMCS Code: 1123-016

### Assembly Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

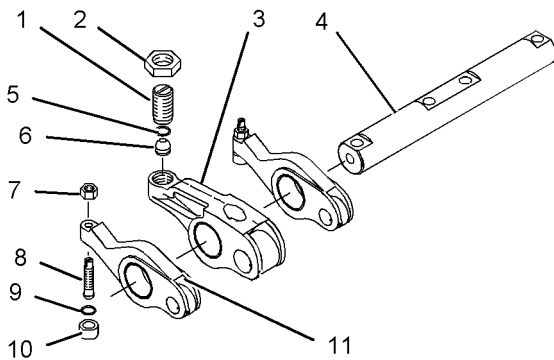


Illustration 194

g01047557

**Note:** Do not reuse the O-ring seal on the adjustment screw if the button is removed from the adjustment screw.

1. Install O-ring seal (9) in button (10).
2. Use a soft hammer to seat button (10) on adjustment screw (8).
3. Install adjustment screw (8) in valve rocker arms (11). Install jam nut (7) on the adjustment screw.
4. Install O-ring seal (5) in button (6).
5. Use a soft hammer to seat button (6) on unit injector adjustment screw (1).
6. Install unit injector adjustment screw (1) in electronic unit injector rocker arm (3). Install jam nut (2) on the unit injector adjustment screw.
7. Lubricate rocker shaft assembly (4) with clean engine oil.
8. Install valve rocker arms (11) and electronic unit injector rocker arm (3) on rocker shaft assembly (4).

### End By:

- a. Install the rocker arms and the rocker shaft. Refer to Disassembly and Assembly, "Rocker Arm and Shaft - Install".

i03288323

## Rocker Arm and Shaft - Install

SMCS Code: 1102-012

### Installation Procedure

Table 46

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 124 -2946   | Lifting Bracket  | 1   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

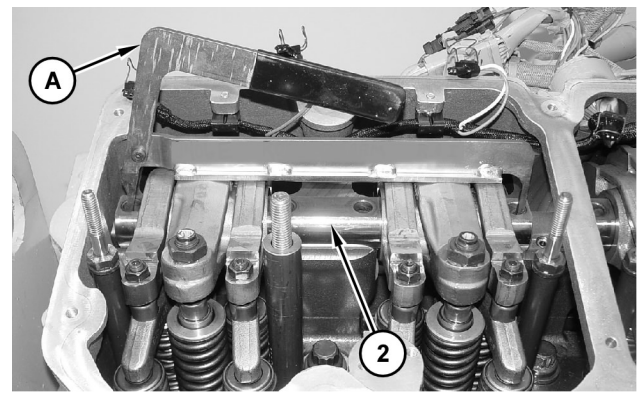


Illustration 195

g01262841

1. Use Tooling (A) in order to install rocker arm shaft assembly (2).

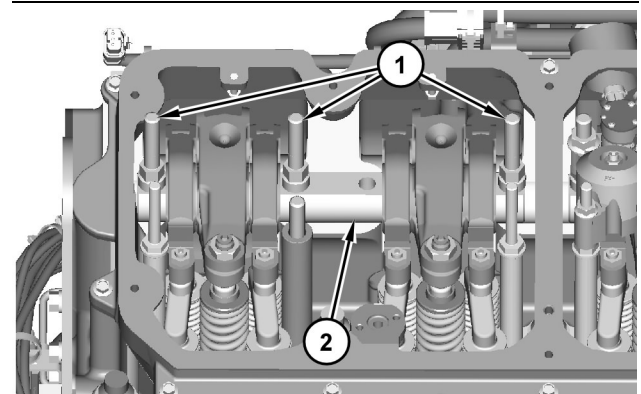


Illustration 196

g01259735

**⚠ WARNING**

Valve rocker arms and unit injector rocker arms can move on the shaft after the bolts have been removed. The shaft should be kept level when removed from the cylinder head. To avoid possible personal injury, keep fingers clear of the valve rocker arms and the unit injector rocker arms when lifting the assembly from the cylinder head.

2. Install studs (1) onto rocker arm shaft assembly (2). Tighten studs to a torque of  $50 \pm 5$  N·m ( $37 \pm 4$  lb ft). Turn the studs by an additional  $45 \pm 5$  degrees.
3. Adjust the electronic unit injectors. Refer to Testing and Adjusting, "Electronic Unit Injector - Adjust".
4. Adjust the engine valve lash. Refer to Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

**End By:**

- a. Install the variable valve actuator. Refer to Disassembly and Assembly, "Valve Actuator (Variable) - Install".

i03538103

## Cylinder Head - Remove and Install

SMCS Code: 1100-010

### Removal Procedure

Table 47

| Required Tools |             |                      |     |
|----------------|-------------|----------------------|-----|
| Tool           | Part Number | Part Description     | Qty |
| A              | 4C-5592     | Anti-Seize Compound  | -   |
| B              | 8T-2998     | Lubricant            | -   |
| C              | 9S-3263     | Thread Lock Compound | -   |
| D              | 5P-3931     | Anti-Seize Compound  | -   |

**Start By:**

- a. Remove the camshaft gear.
- b. Remove the electronic unit injectors.
- c. Remove all of the rocker arm shafts.
- d. Remove the valve mechanism cover base.
- e. Remove the exhaust manifold.
- f. Remove the fuel filter base.

- g. Remove the fumes disposal group.
- h. Remove the exhaust gas induction valve.
- i. Remove the engine oil filter base.
- j. Remove the wastegate valve.
- k. Remove the boost pressure sensor.

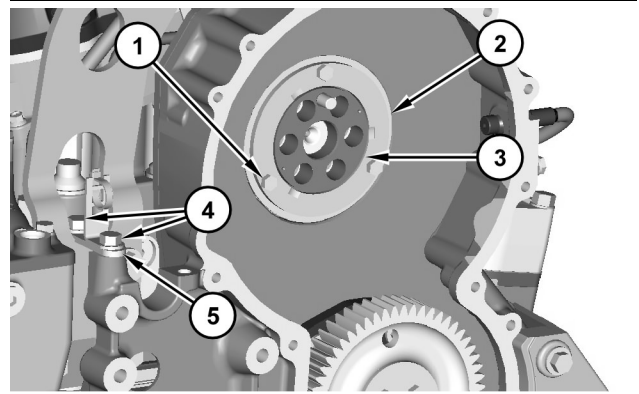


Illustration 197

g01377731

1. Remove bolt (1) and thrust plate (2) in order to remove adapter (3).
2. Remove bolts (4) and plate (5).

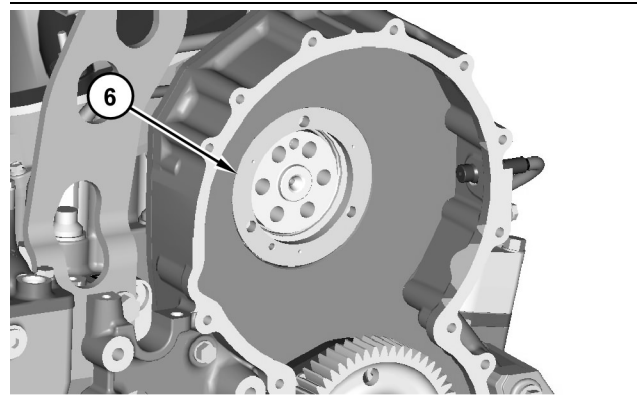


Illustration 198

g01377738

3. Remove sealing plate (6).

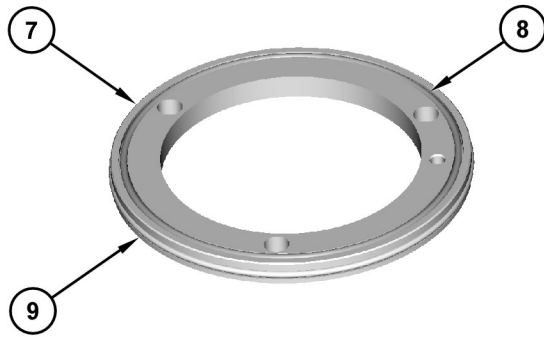


Illustration 199

g01377739

4. Remove O-ring seal (8) and O-ring seal (9) from sealing plate (7).

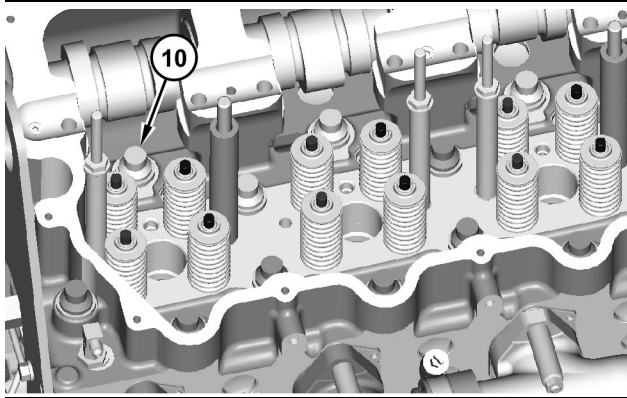


Illustration 200

g01867334

5. Remove bolts (10).

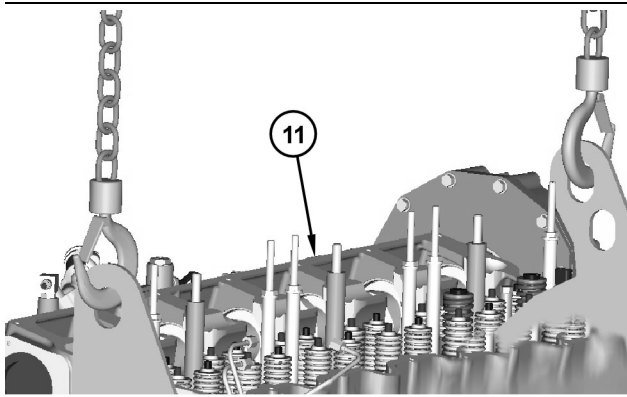


Illustration 201

g01867354

6. Use a suitable lifting device in order to remove cylinder head (11). The weight of cylinder head (11) is approximately 293 kg (645 lb).

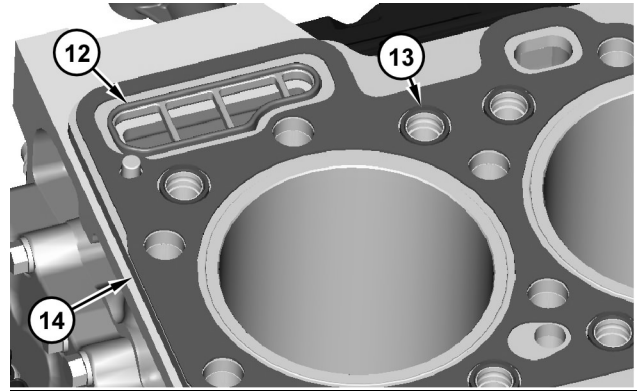


Illustration 202

g01867473

7. Remove oil seal (12), water seals (13), and gasket (14), from the cylinder block.

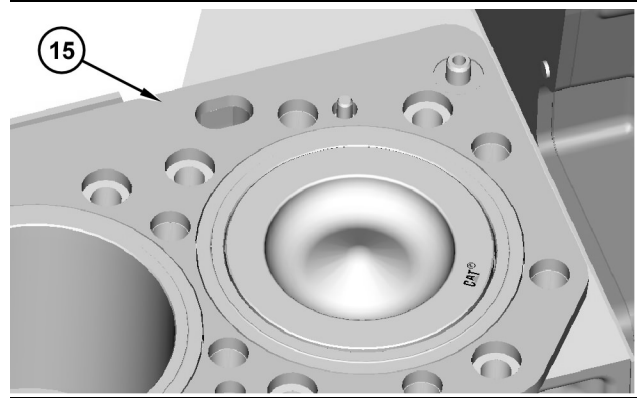


Illustration 203

g01867515

8. Remove spacer plate (15) from the cylinder block.

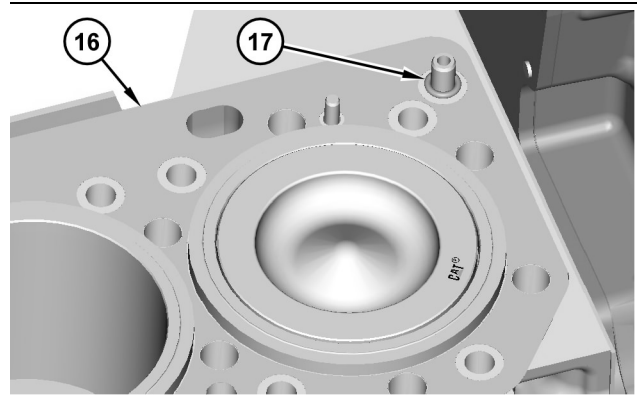


Illustration 204

g01867534

9. Remove gasket (16) from the cylinder block.
10. Remove O-ring seal (17) from the dowel in the cylinder block.

## Installation Procedure

1. Install the cylinder head in reverse order.

- a. Apply Tooling (A) to the threads of cylinder head bolts (10) and the washers.

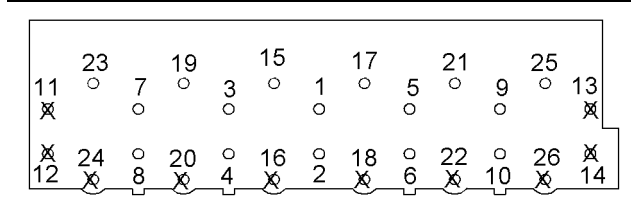


Illustration 205

g01072801

**Note:** The bolts that are marked “x” are 216 mm (8.5 inch) long: 11, 12, 13, 14, 16, 18, 20, 22, 24, and 26. The remaining bolts are 194 mm (7.6 inch) long.

- b. Tighten the cylinder head bolts according to the following procedure.

- Tighten bolts 1 through 26 to a torque of  $270 \pm 15$  N·m ( $200 \pm 11$  lb ft) in a numerical sequence.
- Tighten bolts 1 through 26 to a torque of  $450 \pm 15$  N·m ( $330 \pm 11$  lb ft) in a numerical sequence.
- Tighten bolts 1 through 26 again to a torque of  $450 \pm 15$  N·m ( $330 \pm 11$  lb ft) in a numerical sequence.

- c. Apply a 50/50 mixture of Tooling (B) and clean engine oil onto O-ring seal (8) and O-ring seal (9) prior to assembly.

- d. Apply Tooling (C) onto the threads of bolts (1).

i02037044

## Camshaft - Remove

SMCS Code: 1210-011

### Removal Procedure

Table 48

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 9U-7257     | Cradle           | 1   |
| B              | 9U-7256     | Guide            | 1   |
| C              | 9U-7225     | Camshaft Pilot   | 2   |
| D              | 9U-7240     | Camshaft Hook    | 2   |

#### Start By:

- a. Remove the camshaft gear. Refer to Disassembly and Assembly, “Camshaft Gear - Remove and Install”.

- b. Remove the rocker arms and the rocker shafts. Refer to Disassembly and Assembly, “Rocker Arm and Shaft - Remove”.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

#### NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

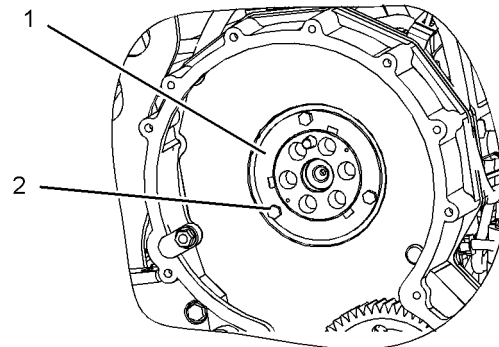


Illustration 206

g01056681

1. Remove bolts (2) and thrust plate (1).

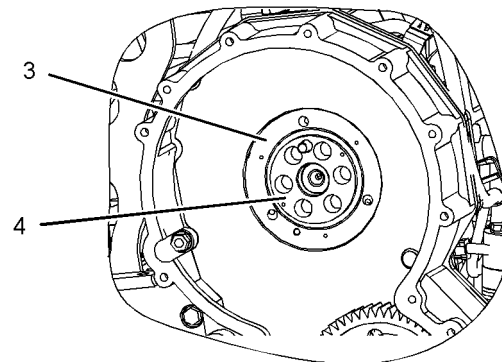


Illustration 207

g01071487

2. Remove sealing plate (3) from the front housing. Remove adapter assembly (4) from the crankshaft.

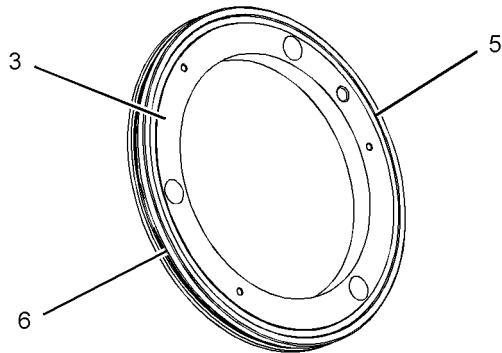


Illustration 208

g01056684

- Remove O-ring seal (5) and O-ring seal (6) from sealing plate (3).

#### NOTICE

Care must be used when removing or installing the camshaft. Do not damage the finished surfaces of the camshaft or the camshaft bearings.

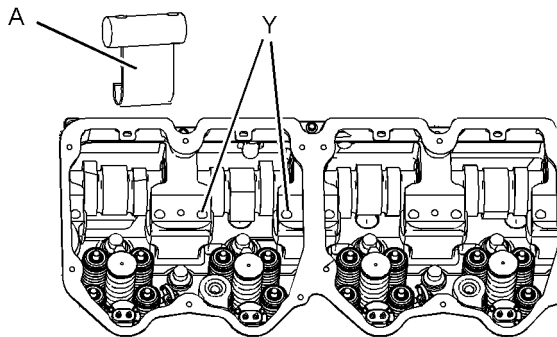


Illustration 209

g01056704

- Use the bolts for the rocker arm shaft assembly to install Tooling (A) at Location (Y).

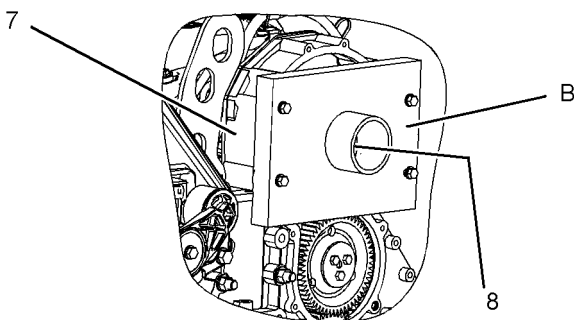


Illustration 210

g01047945

- Install Tooling (B) on front housing (7). Tooling (B) is used to support camshaft (8). Do not tighten the bolts for Tooling (B) at this time.

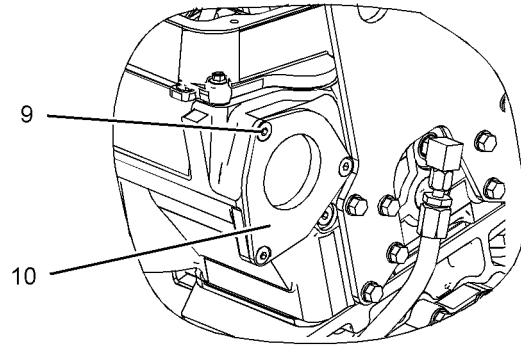


Illustration 211

g01056675

- Remove flat head screws (9) and cover (10). Remove the O-ring seal from the cover.

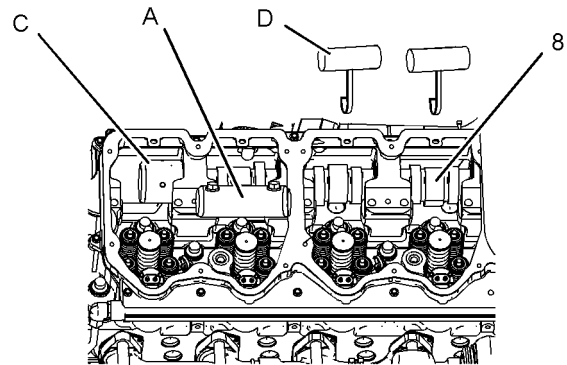


Illustration 212

g01047961

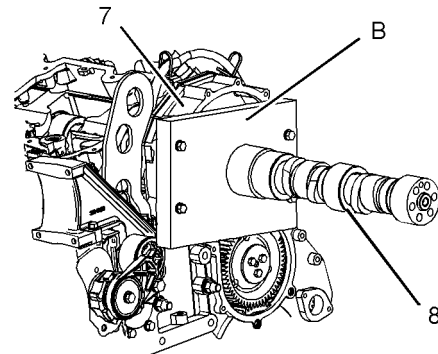


Illustration 213

g01047996

**Note:** It is necessary to install Tooling (C) on the camshaft. Tooling (C) will support the rear of the camshaft as the camshaft is moved out of the cylinder head and into Tooling (B). Align camshaft (8) with the bore of Tooling (B). Tighten the bolts that hold Tooling (B) to front housing (7).

- Move camshaft (8) forward and install one Tooling (C) in the end of the camshaft. Again, move the camshaft forward and install remaining Tooling (C) into the back of first Tooling (C).

**Note:** Avoid lifting the camshaft with Tooling (D). The camshaft should rest on Tooling (A). Lifting of the camshaft can cause misalignment as the camshaft is removed, resulting in damage to the camshaft bearings.

8. Use Tooling (D) to move camshaft (8) toward the front of the engine. Reposition Tooling (D), as needed.
9. Carefully slide the camshaft to the front of the engine for removal. Use two technicians to remove the camshaft. Keep the camshaft level while the camshaft is being removed from the cylinder head. The weight of the camshaft is approximately 39 kg (86 lb).

**Note:** Rotate the camshaft during removal. This will prevent the camshaft from binding in the camshaft bearings.

10. Remove Tooling (C) from the camshaft.
11. Remove Tooling (B) from front housing (7).
12. Remove Tooling (A) from the cylinder head.

### Alternative Removal Procedure

Table 49

| Required Tools   |             |                  |     |
|------------------|-------------|------------------|-----|
| Tool             | Part Number | Part Description | Qty |
| E <sup>(1)</sup> | 177-8001    | Sleeve           | 1   |
| F                | 177-8002    | Adapter          | 1   |
| G                | 6L-4697     | Bolts            | 3   |

<sup>(1)</sup> Part of 177-8003 Engine Tool Group

#### Start By:

- a. Remove the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install".
- b. Remove the rocker arms and the rocker shafts. Refer to Disassembly and Assembly, "Rocker Arm and Shaft - Remove".

**Note:** This is an optional procedure to remove the camshaft. The preceding tool list shows the required tooling for removing the camshaft from the front of the engine or the rear of the engine.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

#### NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

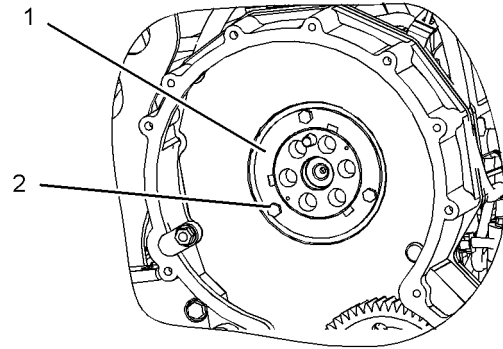


Illustration 214

g01056681

1. Remove bolts (2) and thrust plate (1).

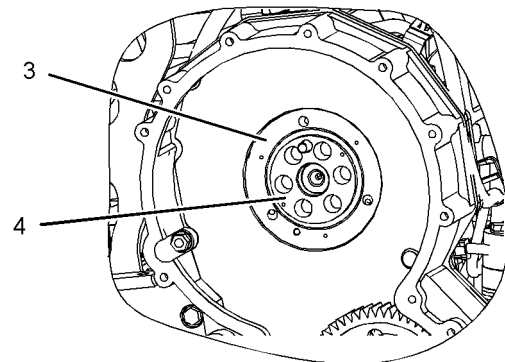


Illustration 215

g01071487

2. Remove sealing plate (3) from the front housing. Remove adapter assembly (4) from the crankshaft.

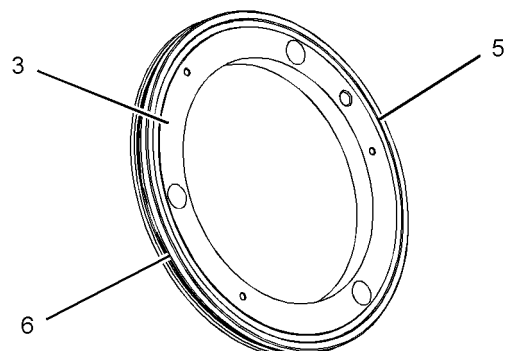


Illustration 216

g01056684

3. Remove O-ring seals (5) and (6) from sealing plate (3).

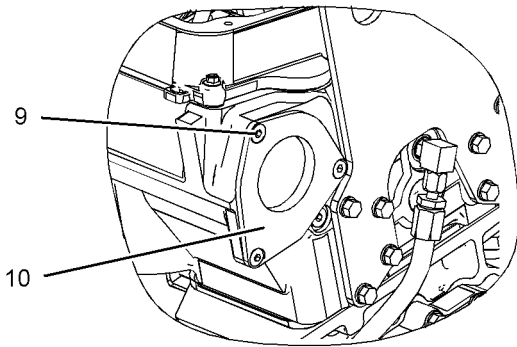


Illustration 217 g01056675

4. Remove flat head screws (9) and cover (10). Remove the O-ring seal from the cover.

**NOTICE**

Care must be used when removing or installing the camshaft. Do not damage the finished surfaces of the camshaft or the camshaft bearings.

5. To remove the camshaft from the rear of the engine, go to Step 6 through Step 9. To remove the camshaft from the front of the engine, go to Step 10 through Step 13.

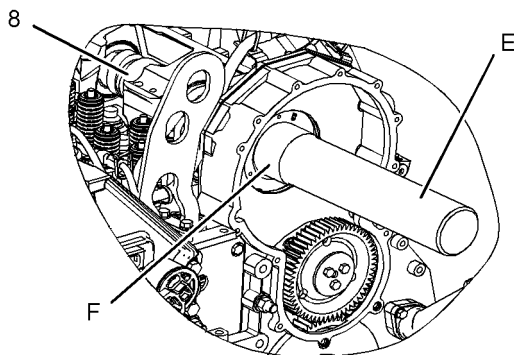


Illustration 218 g01056714  
Removal of the camshaft from the rear of the engine

6. To remove the camshaft from the rear of the engine, install Tooling (F) on the front of camshaft (8) with Tooling (G).

**Note:** Carefully align Tooling (F) with the end of camshaft (8). If the adapter and the camshaft are not aligned, the camshaft may not be removed. The adapter and camshaft bearing will interfere.

7. Install Tooling (E) on Tooling (F).

8. Carefully slide the camshaft to the rear of the engine for removal. Use two technicians to remove the camshaft. Keep the camshaft level while the camshaft is being removed from the cylinder head. The weight of the camshaft is approximately 39 kg (86 lb).

**Note:** Rotate the camshaft during removal. This will prevent the camshaft from binding in the camshaft bearings.

9. Remove Tooling (E), Tooling (F), and Tooling (G) from the camshaft.

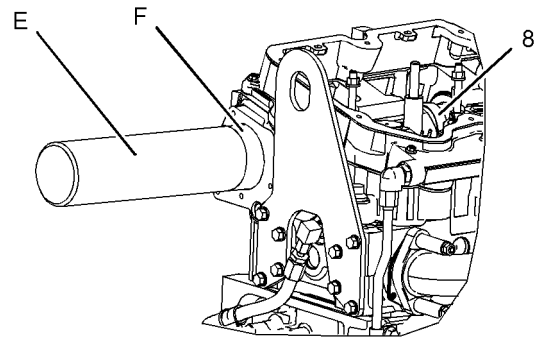


Illustration 219 g01056717  
Remove the camshaft from the front of the engine.

10. To remove the camshaft from the front of the engine, install Tooling (F) on the rear of camshaft (8) with Tooling (G).

**Note:** Carefully align Tooling (F) with the end of camshaft (8). If the adapter and the camshaft are not aligned, the camshaft may not be removed. The adapter and camshaft bearing will interfere.

11. Install Tooling (E) on Tooling (F).

12. Carefully slide the camshaft to the front of the engine for removal. Use two technicians to remove the camshaft. Keep the camshaft level while the camshaft is being removed from the cylinder head. The weight of the camshaft is approximately 39 kg (86 lb).

13. Remove Tooling (E), Tooling (F), and Tooling (G) from the camshaft.

i02107136

# Camshaft - Install

SMCS Code: 1210-012

## Installation Procedure

Table 50

| Required Tools |             |                      |     |
|----------------|-------------|----------------------|-----|
| Tool           | Part Number | Part Description     | Qty |
| A              | 9U-7257     | Cradle               | 1   |
| B              | 9U-7256     | Guide                | 1   |
| C              | 9U-7225     | Camshaft Pilot       | 2   |
| D              | 9U-7240     | Camshaft Hook        | 2   |
| H              | 9U-7243     | Alignment Sleeve     | 1   |
| J              | 8T-2998     | Lubricant            | -   |
| K              | 9S-3263     | Thread Lock Compound | -   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

**NOTICE**

Care must be used when removing or installing the camshaft. Do not damage the finished surfaces of the camshaft or the camshaft bearings.

1. Ensure that the camshaft and camshaft bearings are thoroughly clean. Lubricate the camshaft lobes with a 50/50 mixture of Tooling (J) and clean engine oil. Apply a thin coat of clean engine oil on the camshaft bearings.

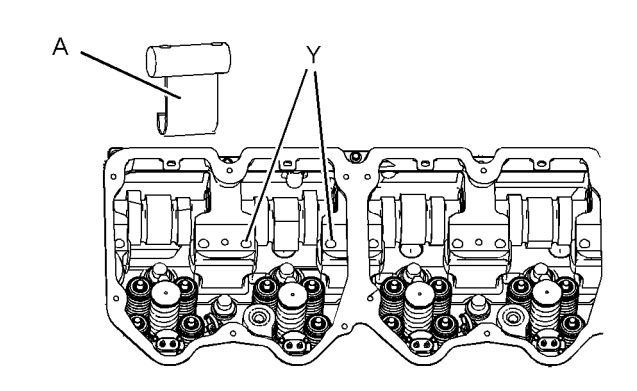


Illustration 220 g01056704

2. Install Tooling (A) on the cylinder head at Location (Y).

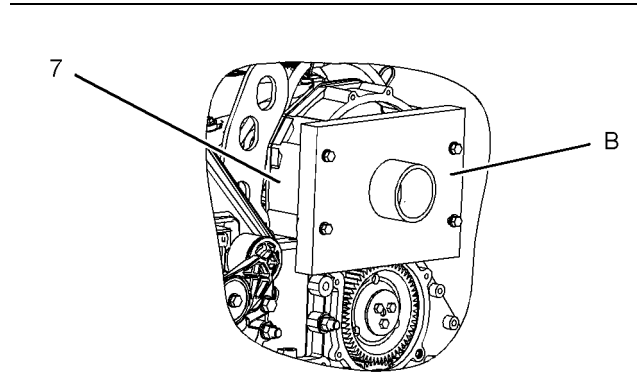


Illustration 221 g01056901

3. Install Tooling (B) on front housing (7). Do not tighten the bolts that hold Tooling (B) to front housing (7) at this time.
4. Use Tooling (H) to align Tooling (B) with the camshaft bearings. Tighten the bolts that hold Tooling (B) to front housing (7). Remove Tooling (H).

**Note:** Tooling (H) should move freely from the bore of Tooling (B).

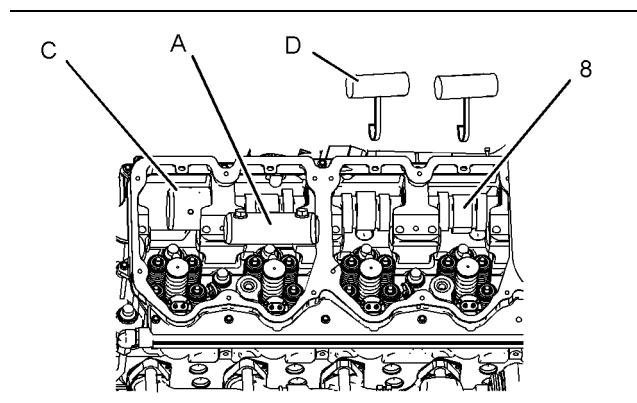


Illustration 222 g01047961

5. Install Tooling (C) on the rear of the camshaft.
6. Use two technicians to install the camshaft. Use Tooling (D) to assist in aligning camshaft (8) with the camshaft bearings. Carefully slide the camshaft into the cylinder head from the front of the engine. Keep the camshaft level while the camshaft is being installed in the cylinder head. The weight of the camshaft is approximately 39 kg (86 lb).

**Note:** Rotate the camshaft during installation. This will prevent the camshaft from binding in the camshaft bearings.

7. Remove Tooling (C) and finish installing camshaft (8) in the bore.

**Note:** Tooling (C) must be removed before the camshaft can be completely installed in the cylinder head.

8. Remove Tooling (A) from the cylinder head.
9. Remove Tooling (B) from the front housing.

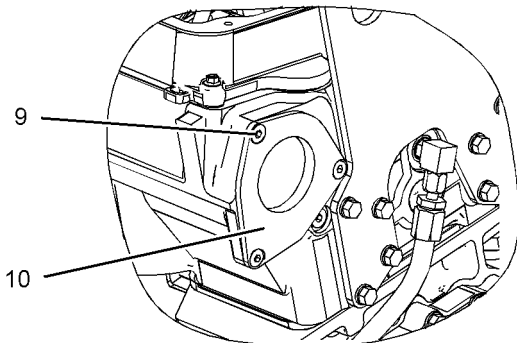


Illustration 223 g01056675

10. Install the O-ring seal on cover (10). Position the cover on the rear of the cylinder head. Install flat head screws (9) and tighten to a torque of  $13 \pm 3$  N·m ( $10 \pm 2$  lb ft).

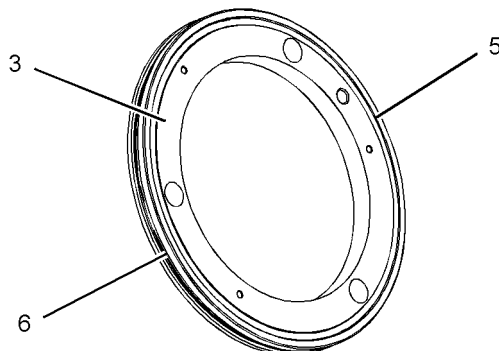


Illustration 224 g01056684

11. Install O-ring seals (5) and (6) in sealing plate (3). Lubricate O-ring seal (6) with a 50/50 mixture of Tooling (J) and clean engine oil.

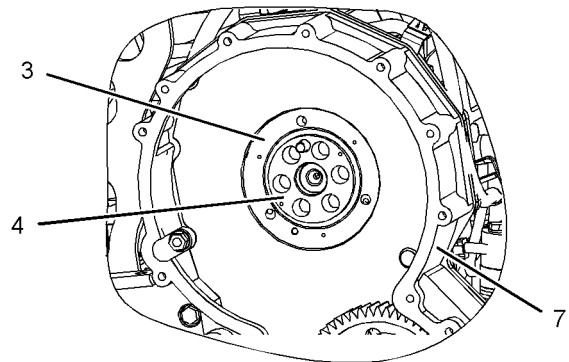


Illustration 225 g01056682

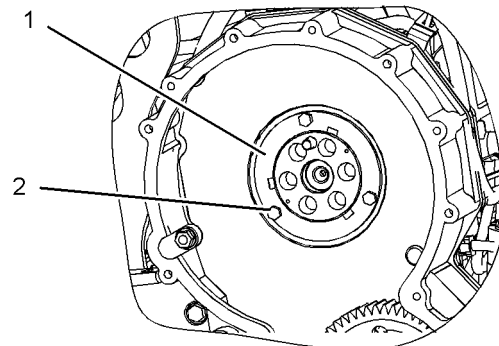


Illustration 226 g01056681

12. Install sealing plate (3) in front housing (7). Install adapter assembly (4) in the sealing plate. Ensure that the dowel in adapter assembly (4) engages the hole in the camshaft.

13. Install thrust plate (1). Apply Tooling (K) to bolts (2). Hold the thrust plate in position and install bolts (2). Evenly tighten bolts (2) until sealing plate (3) and the O-ring seal are seated against the cylinder head.

**Note:** Ensure that the O-ring seal stays in the groove in sealing plate (3).

**End By:**

- a. Install the rocker arms and the rocker shafts. Refer to Disassembly and Assembly, "Rocker Arms and Shaft - Install".
- b. Install the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install".

## Alternative Installation Procedure

Table 51

| Required Tools   |             |                      |     |
|------------------|-------------|----------------------|-----|
| Tool             | Part Number | Part Description     | Qty |
| E <sup>(1)</sup> | 177-8001    | Sleeve               | 1   |
| F                | 177-8002    | Adapter              | 1   |
| G                | 6L-4697     | Bolts                | 3   |
| J                | 8T-2998     | Lubricant            | -   |
| K                | 9S-3263     | Thread Lock Compound | -   |

(1) Part of 177-8003 Engine Tool Group

**Note:** This is an optional procedure to install the camshaft. The preceding tool list shows the required tooling for installing the camshaft from the front of the engine or the rear of the engine.

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

### NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

### NOTICE

Care must be used when removing or installing the camshaft. Do not damage the finished surfaces of the camshaft or the camshaft bearings.

1. Ensure that the camshaft and camshaft bearings are thoroughly clean. Lubricate the camshaft lobes with a 50/50 mixture of Tooling (J) and clean engine oil. Apply a thin coat of clean engine oil on the camshaft bearings.
2. To install the camshaft from the rear of the engine, go to Step 3 through Step 6. To install the camshaft from the front of the engine, go to Step 7 through Step 10.

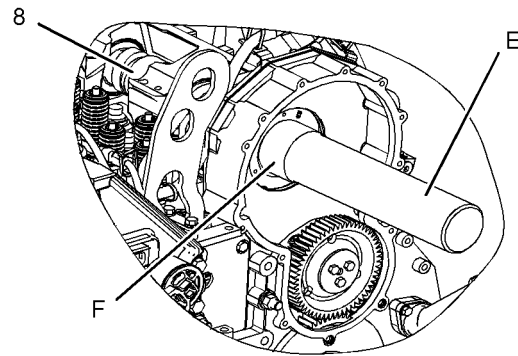


Illustration 227

g01056714

Install the camshaft from the rear of the engine.

3. To install the camshaft from the rear of the engine, install Tooling (F) on the front of camshaft (8) with Tooling (G).

**Note:** Carefully align Tooling (F) with the end of camshaft (8). If the adapter and the camshaft are not aligned, the camshaft may not be removed. The adapter and camshaft bearing will interfere.

4. Install Tooling (E) on Tooling (F).

5. Use two technicians to install the camshaft. Carefully slide the camshaft into the cylinder head from the rear of the engine. Keep the camshaft level while the camshaft is being installed in the cylinder head. The weight of the camshaft is approximately 39 kg (86 lb).

**Note:** Rotate the camshaft during installation. This will prevent the camshaft from binding in the camshaft bearings.

6. Remove Tooling (E), Tooling (F) and Tooling (G) from the camshaft.

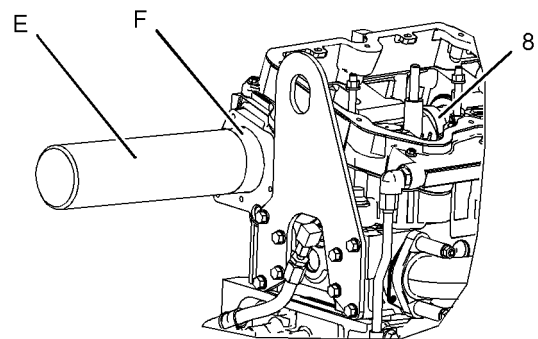


Illustration 228

g01056717

Install the camshaft from the front of the engine.

7. To install the camshaft from the front of the engine, install Tooling (F) on the rear of camshaft (8) with Tooling (G).

**Note:** Carefully align Tooling (F) with the end of camshaft (8). If the adapter and the camshaft are not aligned, the camshaft may not be removed. The adapter and camshaft bearing will interfere.

8. Install Tooling (E) on Tooling (F).

9. Use two technicians to install the camshaft. Carefully slide the camshaft into the cylinder head from the front of the engine. Keep the camshaft level while the camshaft is being installed in the cylinder head. The weight of the camshaft is approximately 39 kg (86 lb).

**Note:** Rotate the camshaft during installation. This will prevent the camshaft from binding in the camshaft bearings.

10. Remove Tooling (E), Tooling (F), and Tooling (G) from the camshaft.

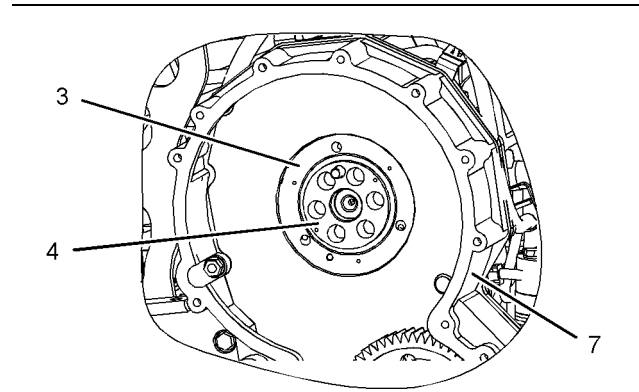


Illustration 231

g01056682

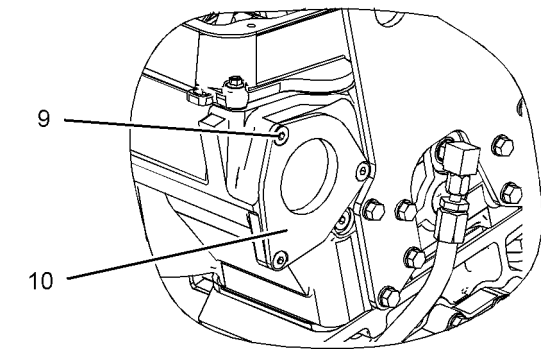


Illustration 229

g01056675

11. Install the O-ring seal on cover (10). Position the cover on the rear of the cylinder head. Install flat head screws (9) and tighten to a torque of  $13 \pm 3$  N·m ( $10 \pm 2$  lb ft).

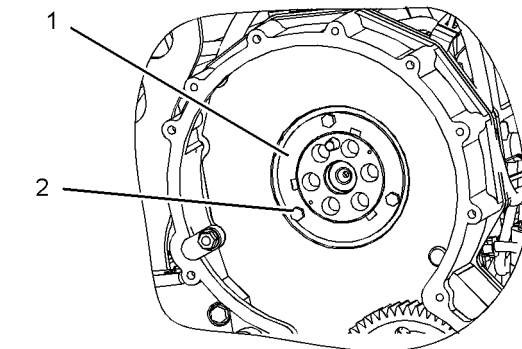


Illustration 232

g01056681

13. Install sealing plate (3) in front housing (7). Install adapter assembly (4) in the sealing plate. Ensure that the dowel in adapter assembly (4) engages the hole in the camshaft.

14. Install thrust plate (1). Apply Tooling (K) to bolts (2). Hold the assembly in position and install bolts (2). Evenly tighten bolts (2) until sealing plate (3) and the O-ring seal are seated against the cylinder head.

**Note:** Ensure that the O-ring seal stays in the groove in sealing plate (3).

**End By:**

- a. Install the rocker arms and the rocker shafts. Refer to Disassembly and Assembly, "Rocker Arms and Shaft - Install".
- b. Install the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install".

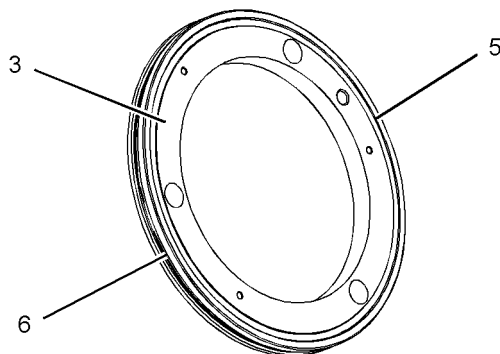


Illustration 230

g01056684

12. Install O-ring seal (5) and O-ring seal (6) in sealing plate (3). Lubricate O-ring seal (6) with a 50/50 mixture of Tooling (J) and clean engine oil.

i02172172

## Camshaft Gear - Remove and Install

**SMCS Code:** 1210-010-GE

### Removal Procedure

#### Start By:

- a. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove".

---

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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#### NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

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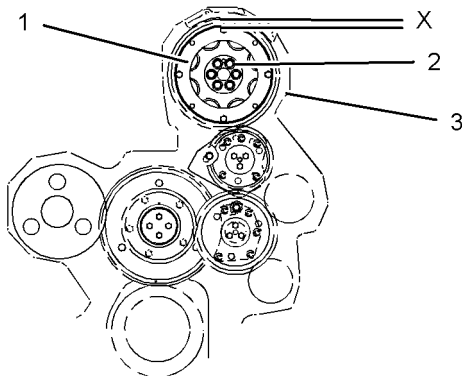


Illustration 233

g01010536

1. Position the No. 1 piston at the top center of the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".
2. Verify that the timing mark on camshaft gear (1) is aligned with Timing Mark (X) on front housing (3).
3. Remove bolts (2) and remove camshaft gear (1).

## Installation Procedure

---

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

#### NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

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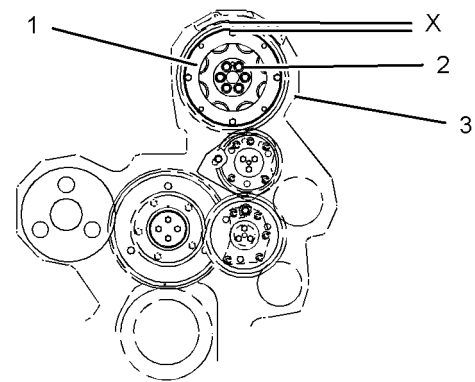


Illustration 234

g01010536

1. Align the hole in the back of camshaft gear (1) with the dowel in the adapter. Install camshaft gear (1).

**Note:** Camshaft timing is critical. The timing mark on the camshaft gear must be aligned with the timing mark on the front cover when the No. 1 piston is at the top center of the compression stroke. Refer to Testing and Adjusting, "Gear Group (Front) - Time".

2. Verify that the timing mark on camshaft gear (1) is aligned with Timing Mark (X) on front housing (3).

**Note:** If the timing marks are not aligned, remove camshaft gear (1) and rotate the camshaft until the timing marks are aligned.

3. Install bolts (2).

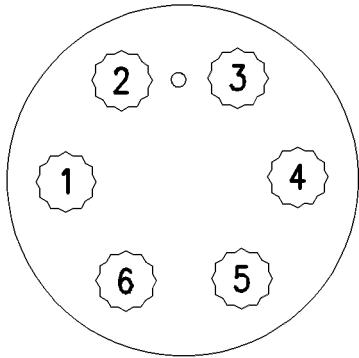


Illustration 235 g00593987

Torque sequence for the camshaft gear

4. Tighten the bolts for the camshaft gear in a numeric sequence 1, 4, 2, 5, 3, 6, 1, 4 to a torque of  $240 \pm 40$  N·m ( $180 \pm 30$  lb ft).
5. Check the backlash between the camshaft gear and the adjustable idler gear. The backlash should be  $0.216 \pm 0.114$  mm ( $0.0085 \pm 0.0045$  inch). Refer to Testing and Adjusting, "Gear Group (Front) - Time" for the backlash adjustment procedure.

**End By:**

- a. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Install".

i02451045

## Camshaft Bearings - Remove

SMCS Code: 1211-011

### Removal Procedure

Table 52

| Required Tools |             |   |     |
|----------------|-------------|---|-----|
| Tool           | Part Number | Part Description                          | Qty |
| A              | 8S-2241     | Camshaft Bearing Tool Group               | 1   |
| B              | 9U-7222     | Camshaft Bearing Pilot                    | 1   |
|                | 8M-8778     | Taperlock Stud<br>1/2 - 13 by 1 9/16 inch | 1   |
| C              | 9U-7210     | Puller Plate                              | 1   |

**Start By:**

- a. Remove the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

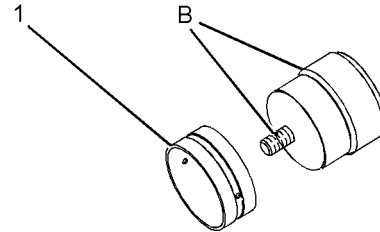


Illustration 236 g01159745

1. Remove the No. 7 camshaft bearing (rear). Work from the rear of the engine to the front of the engine.
  2. Install the small end of Tooling (B) in camshaft bearing (1).
  3. Position Tooling (C) over Tooling (A). Install Tooling (A) through the cylinder head on Tooling (B).
- Note:** Tooling (C) is installed on the outside of the cylinder head. Tooling (C) is required in order to remove all the camshaft bearings from the cylinder head.
4. Use Tooling (A) to remove camshaft bearing (1) from the cylinder head.
  5. Remove Tooling (B) from Tooling (A) and remove the camshaft bearing.

i02451063

# Camshaft Bearings - Install

SMCS Code: 1211-012

## Installation Procedure

Table 53

| Required Tools |             |   |     |
|----------------|-------------|---|-----|
| Tool           | Part Number | Part Description                          | Qty |
| A              | 8S-2241     | Camshaft Bearing Tool Group               | 1   |
| B              | 9U-7222     | Camshaft Bearing Pilot                    | 1   |
|                | 8M-8778     | Taperlock Stud<br>1/2 - 13 by 1 9/16 inch | 1   |
| C              | 9U-7210     | Puller Plate                              | 1   |
| D              | 9U-7223     | Alignment Bushing                         | 1   |
| E              | 9U-7213     | Backup Plate                              | 1   |
|                | 0S-1621     | Bolt<br>1/2 - 13 by 1 inch                | 1   |
| F              | 9U-7214     | Spacer Plate                              | 1   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

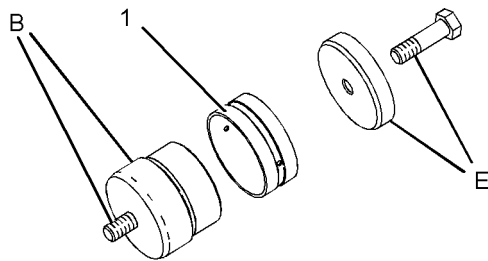


Illustration 237

g01159754

1. Install the No. 7 camshaft bearing (rear), as follows:

- a. Insert the large end of Tooling (B) into the No. 7 camshaft bore.
- b. Position Tooling (C) over Tooling (A). Install Tooling (A) through the cylinder head on Tooling (B).
- c. Position camshaft bearing (1) on Tooling (B). Install Tooling (E) on Tooling (B).

**Note:** Refer to Specifications, "Cylinder Head" for appropriate information for the orientation of the camshaft bearings in the cylinder head.

- d. Use Tooling (A) in order to pull camshaft bearing (1) into the camshaft bore.

**Note:** When the chamfer of Tooling (E) contacts the face of the camshaft bore, the camshaft bearing is properly installed.

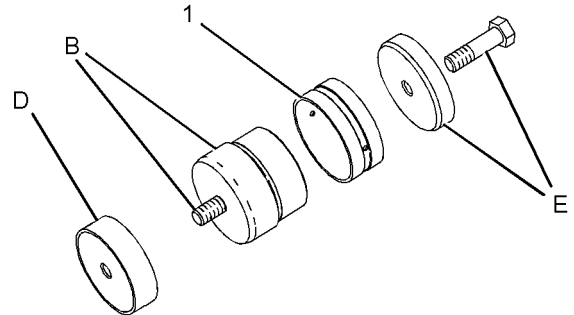


Illustration 238

g01159756

2. Install the No. 6 through No. 2 camshaft bearings, as follows:

- a. Insert the large end of Tooling (B) into the camshaft bore.

**Note:** Use Tooling (D) to align Tooling (A) and Tooling (B) with the camshaft bearing bores. Install Tooling (D) in the inside diameter of any installed camshaft bearing between Tooling (A) and Tooling (B).

- b. Install Tooling (A) on Tooling (B). Position camshaft bearing (1) on Tooling (B). Install Tooling (E) on Tooling (B).

**Note:** Refer to Specifications, "Cylinder Head" for appropriate information for the location and the orientation of the camshaft bearings in the cylinder head.

- c. Use Tooling (A) in order to pull camshaft bearing (1) into the camshaft bore.

**Note:** When the chamfer of Tooling (E) contacts the face of the camshaft bore, the camshaft bearing is properly installed.

i04513250

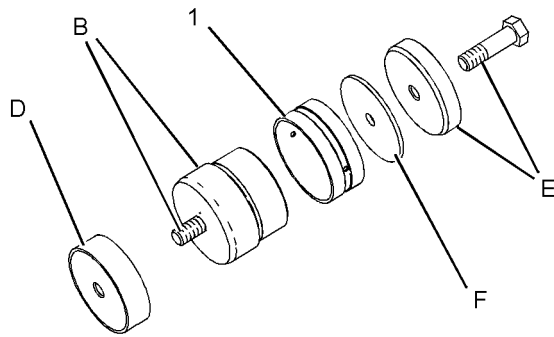


Illustration 239

g01159758

3. Install the No. 1 camshaft bearing (front), as follows:
  - a. Insert the large end of Tooling (B) into the No. 1 camshaft bore. Assemble Tooling (A) and Tooling (D) on Tooling (B).
  - b. Position camshaft bearing (1) on Tooling (B). Install Tooling (E) and Tooling (F) on Tooling (B).
  - c. Use Tooling (A) in order to pull the No. 1 camshaft bearing into the No. 1 camshaft bore. When the chamfer of Tooling (E) contacts the face of the camshaft bore, the camshaft bearing is properly installed.

**Note:** Refer to Specifications, “Cylinder Head” for appropriate information for the location and the orientation of the camshaft bearings in the cylinder head.

**Note:** Tooling (F) is used to seat the No. 1 camshaft bearing to the correct depth in the camshaft bore.

**End By:**

- a. Install the camshaft. Refer to Disassembly and Assembly, “Camshaft - Install”.

## Engine Oil Pan - Remove and Install (C18 Engine)

SMCS Code: 1302-010

### Removal Procedure

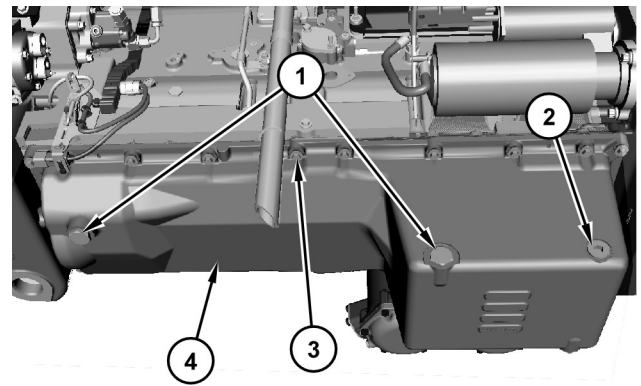


Illustration 240

g02162853

1. Remove drain plugs (1) and (2). Drain the engine oil into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, “Engine Oil and Filter - Change”. Remove the O-ring seal from the drain plugs.
2. Remove bolts (3) and remove oil pan (4).

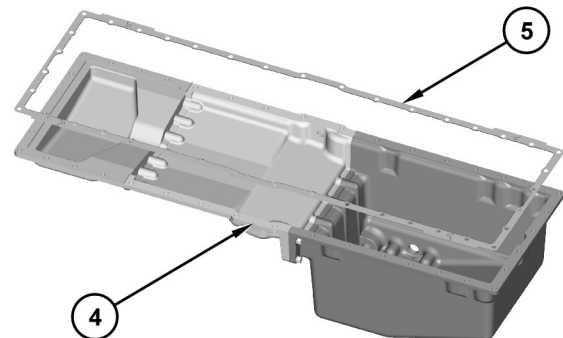


Illustration 241

g02691058

3. Remove gasket (5) from oil pan (4).

### Installation Procedure

Table 54

| Required Tools |             |                           |     |
|----------------|-------------|---------------------------|-----|
| Tool           | Part Number | Part Description          | Qty |
| A              | -           | Loctite Blue RTV Silicone | -   |
| B              | 1Y-3904     | Adhesive                  | -   |

**Note:** Installation of the next steps should be performed within 10 minutes of applying Tooling (A).

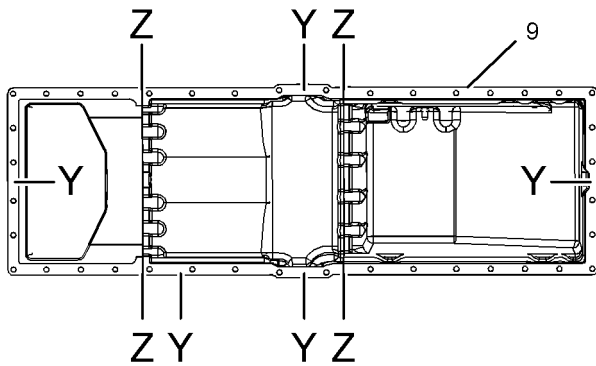


Illustration 242

g02689277

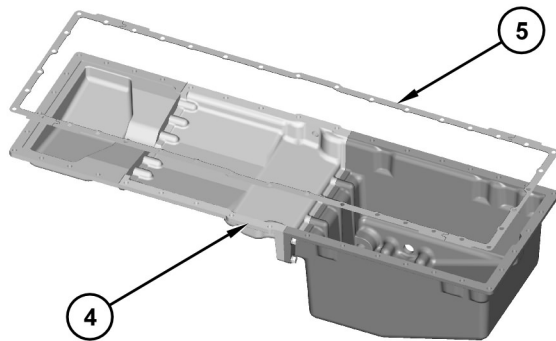
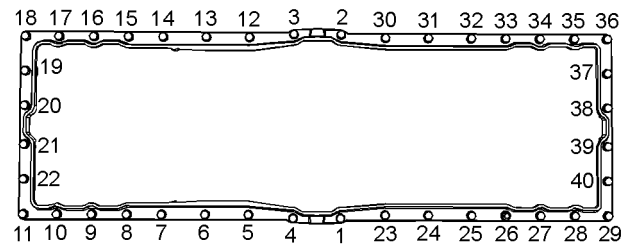


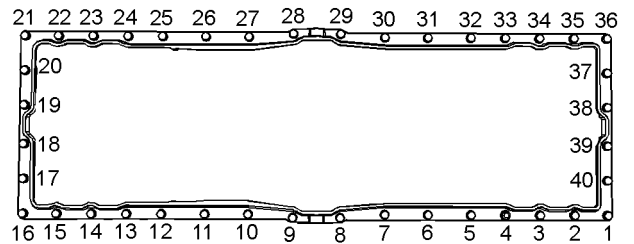
Illustration 243

g02691058

1. Apply Tooling (A) to cover the joints at Locations (Z).
2. Apply Tooling (B) to Locations (Y).
3. Install a new gasket (5) to oil pan (4). Apply Tooling (A) to Locations (Z).



SEQUENCE A



SEQUENCE B

Illustration 244

g02463392

Torque sequences for bolts (3).

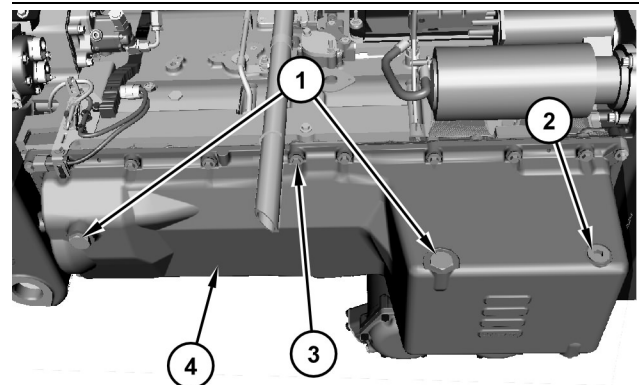


Illustration 245

g02162853

4. Install oil pan (4). Install bolts (3) and hand tighten.
5. Tighten bolts (3) to a torque of  $40 \pm 5$  N·m ( $30 \pm 4$  lb ft) according to Sequence (A) in Illustration 244.
6. Retighten bolts (3) to a torque of  $47 \pm 5$  N·m ( $35 \pm 4$  lb ft) according to Sequence (B) in Illustration 244.
7. Tighten drain plugs (1) to a torque of  $70 \pm 15$  N·m ( $52 \pm 11$  lb ft).
8. Tighten drain plugs (2) to a torque of  $90 \pm 15$  N·m ( $66 \pm 11$  lb ft).
9. Fill the engine oil pan to the correct level that is indicated on the engine oil level gauge. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations" for the lubrication system capacity of the engine.

i04513249

## Engine Oil Pan - Remove and Install (C15 Engine)

SMCS Code: 1302-010

### Removal Procedure

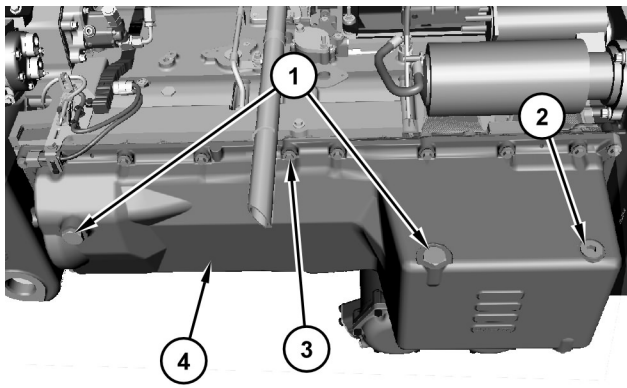


Illustration 246

g02162853

1. Remove drain plugs (1) and (2). Drain the engine oil into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change". Remove the O-ring seal from the drain plugs.
2. Remove bolts (3) and remove oil pan (4).

### Installation Procedure

1. Install the engine oil pan (4) in reverse order.

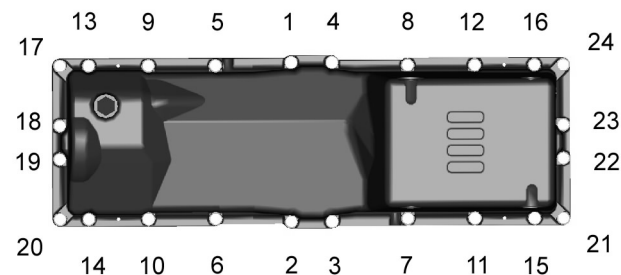


Illustration 247

g02164497

- a. Tightening sequence for the engine oil pan.
- b. Tighten drain plugs (1) to a torque of  $70 \pm 15$  N·m ( $52 \pm 11$  lb ft).
- c. Tighten drain plugs (2) to a torque of  $90 \pm 15$  N·m ( $66 \pm 11$  lb ft).

2. Fill the engine oil pan to the correct level that is indicated on the engine oil level gauge. Refer to the Operation and Maintenance Manual, "Refill Capacities and Recommendations" for the lubrication system capacity of the engine.

i03871869

## Cylinder Liner - Remove

SMCS Code: 1216-011

### Removal Procedure

Table 55

| Required Tools |                        |                          |     |
|----------------|------------------------|--------------------------|-----|
| Tool           | Part Number            | Part Description         | Qty |
| A              | 5P-8665 <sup>(1)</sup> | Cylinder Liner Puller Gp | 1   |

<sup>(1)</sup> The 6V-9448 Cylinder Pack Puller is an optional Tool for 137 mm (5.4 inch) and 140 mm (5.5 inch) bore diameters.

#### Start By:

- a. Remove the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Remove".

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

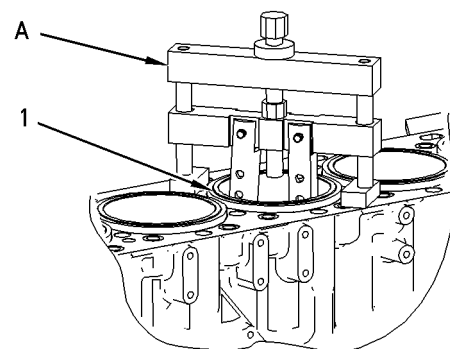


Illustration 248

g01005579

1. Remove cylinder liner (1) with Tooling (A).

i02110914

# Cylinder Liner - Install

SMCS Code: 1216-012

## Installation Procedure

Table 56

| Required Tools |             |                          |     |
|----------------|-------------|--------------------------|-----|
| Tool           | Part Number | Part Description         | Qty |
| B              | 2P-8260     | Cylinder Liner Installer | 1   |
| C              | 5P-3975     | Rubber Lubricant         | 1   |

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Check the cylinder liner projection. Refer to Testing and Adjusting, "Cylinder Liner Projection - Inspect".

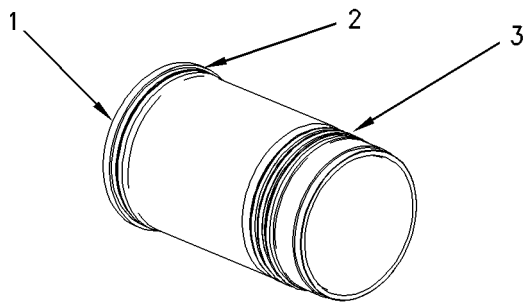


Illustration 249

g01004993

2. Install liner seals (3) in the respective grooves.
3. Apply Tooling (C) on the cylinder block liner bore surfaces and liner seals (3).
4. Dip filler band (2) in clean engine oil for a moment. Install filler band (2) and install cylinder liner (1) immediately.

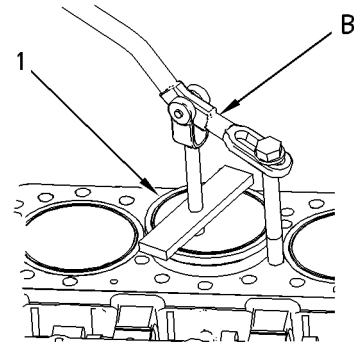


Illustration 250

g01005003

5. Use Tooling (B) to install cylinder liner (1) in the cylinder block. Ensure that any marks in relation to the cylinder liner projection are in alignment.

**Note:** Refer to Special Instruction, SEHS9564 for more information about cylinder liner installation.

**End By:**

- a. Install the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Install".

i02643038

# Piston Cooling Jets - Remove and Install

SMCS Code: 1331-010

## Removal Procedure

Table 57

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 9S-9082     | Engine Turning Tool | 1   |

**Start By:**

- a. Remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

**NOTICE**

Special care must be taken not to bend the piston cooling jets because the piston cooling jets are precision aligned with a coolant passage in the pistons.

There is only one position for each cooling jet. The notch in the bottom of the piston allows clearance for the piston cooling jet when the piston is at bottom dead center.

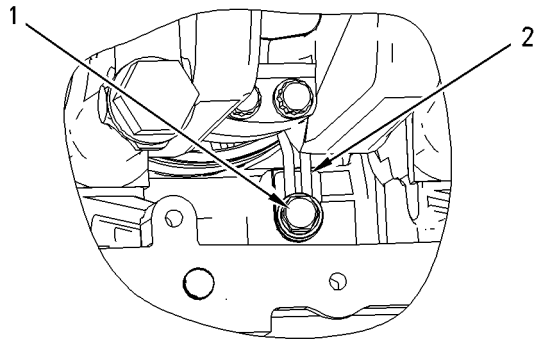


Illustration 251

g01004705

1. Use Tooling (A) to rotate the crankshaft in order to gain access to the piston cooling jet.
2. Remove bolt (1) and piston cooling jet (2).

## Installation Procedure

Table 58

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 9S-9082     | Engine Turning Tool | 1   |

### NOTICE

Special care must be taken not to bend the piston cooling jets because the piston cooling jets are precision aligned with a coolant passage in the pistons.

There is only one position for each cooling jet. The notch in the bottom of the piston allows clearance for the piston cooling jet when the piston is at bottom dead center.

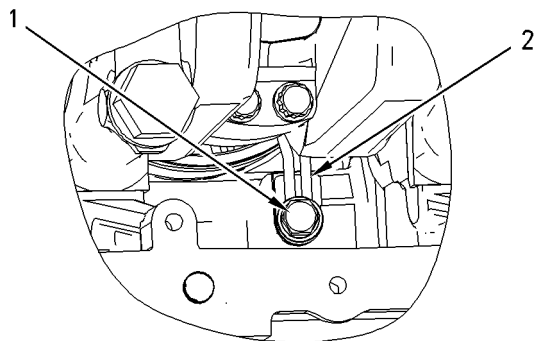


Illustration 252

g01004705

1. Use Tooling (A) to rotate the crankshaft in order to gain access to the piston cooling jet.

2. Position piston cooling jet (2) in the cylinder block. Install bolt (1). Tighten the bolt to a torque of  $40 \pm 8 \text{ N}\cdot\text{m}$  ( $30 \pm 6 \text{ lb ft}$ ).

### End By:

- a. Install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

i02038820

## Pistons and Connecting Rods - Remove

SMCS Code: 1225-011

## Removal Procedure

Table 59

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 9S-9082     | Engine Turning Tool | 1   |

### Start By:

- a. Remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove".
- b. Remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".
- c. Remove the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

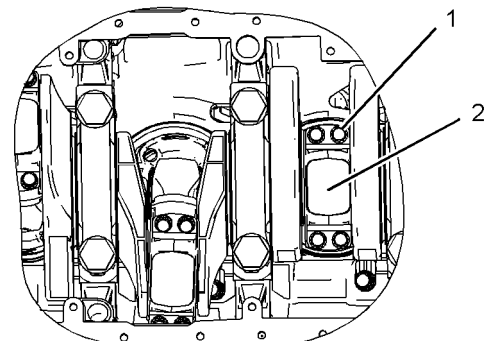


Illustration 253

g00998389

1. Use Tooling (A) to rotate the crankshaft until the piston is at the bottom center.
2. Remove the carbon ridge from the top inside surface of the cylinder liner.
3. Inspect the connecting rod and connecting rod cap for the proper identification mark. The connecting rod and the connecting rod cap should have an etched number on the side. The number should match the cylinder number. Mark the connecting rod and the connecting rod cap, if necessary.

**Note:** Do not stamp the connecting rod assembly. Stamping or punching the connecting rod assembly could cause the connecting rod to fracture.

4. Remove bolts (1) and connecting rod bearing cap (2). Push the connecting rod until the piston rings are out of the cylinder liner.

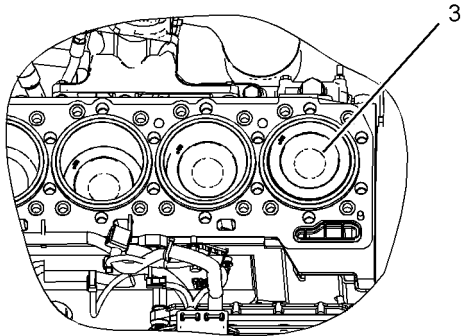


Illustration 254

g00998390

5. Remove piston (3) and the connecting rod from the cylinder liner.

**Note:** Be careful not to damage the cylinder liner or the crankshaft journal during the removal of the piston and the connecting rod.

i02532973

## Pistons and Connecting Rods - Disassemble

**SMCS Code:** 1225-015

### Disassembly Procedure

Table 60

| Required Tools |             |                         |     |
|----------------|-------------|-------------------------|-----|
| Tool           | Part Number | Part Description        | Qty |
| A              | 6V-6192     | Pliers                  | 1   |
| B              | 7M-3978     | Piston Ring Expander Gp | 1   |

### Start By:

- a. Remove the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Remove".

**Note:** Mark the components of each piston and connecting rod assembly. The components must be reinstalled in the original location. Do not interchange components.

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

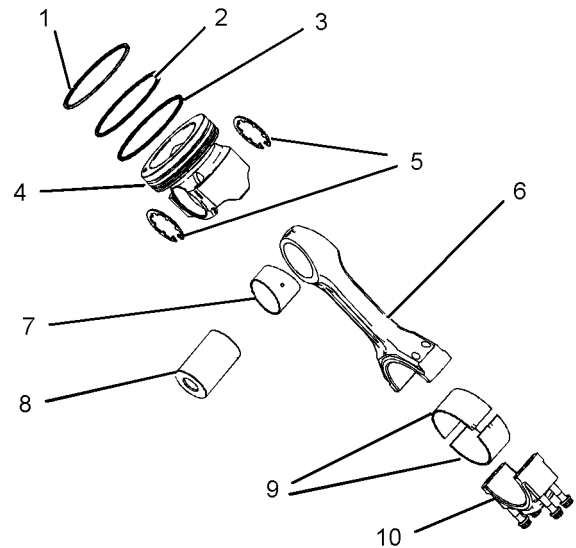


Illustration 255

g01017728

1. Remove connecting rod bearing (9) from connecting rod bearing cap (10). Remove connecting rod bearing (9) from connecting rod (6).
2. Use Tooling (A) to remove pin retainer (5) from piston body assembly (4).
3. Remove connecting rod pin (8) and connecting rod (6) from piston body assembly (4).
4. Use Tooling (B) to remove piston rings (1), (2), and (3) from piston body assembly (4).
5. Do not remove bearing (7) from connecting rod (6) at this time.

i03742620

# Pistons and Connecting Rods - Assemble

SMCS Code: 1225-016

## Assembly Procedure

Table 61

| Required Tools |             |  |     |
|----------------|-------------|--|-----|
| Tool           | Part Number | Part Description                         | Qty |
| A              | 6V-6192     | Pliers                                   | 1   |
| B              | 7M-3978     | Piston Ring Expander Gp                  | 1   |
| C              | 5P-8639     | Hydraulic Press (Connecting Rod Bearing) | 1   |
|                | 8F-0024     | Hose Assembly                            | 1   |
|                | 1P-2375     | Connecting Coupler                       | 1   |
|                | 1P-2376     | Connecting Coupler                       | 1   |
|                | 5P-8651     | Spacer                                   | 1   |
|                | 5P-8649     | Adapter                                  | 1   |
|                | 5P-8650     | Bushing Adapter                          | 1   |
|                | 9U-6600     | Hydraulic Pump                           | 1   |

**Note:** Prior to removal from the engine, the pistons and connecting rod assemblies were marked. The components must be reassembled together. The components must be installed in the original location in the engine. Do not interchange any of the components.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

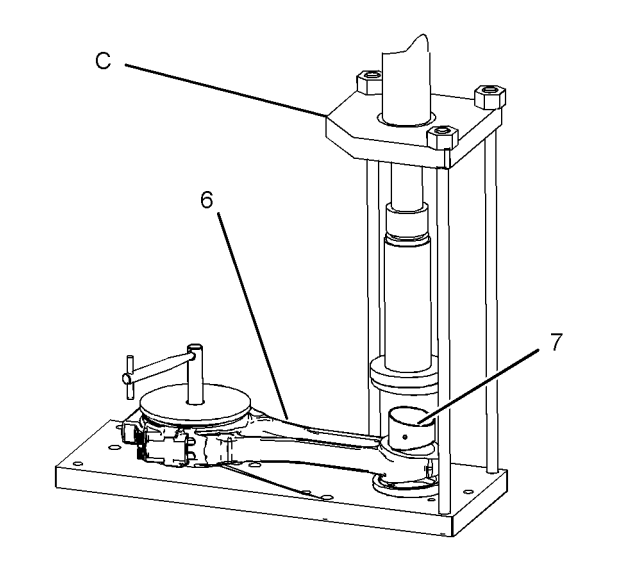


Illustration 256

g01018268

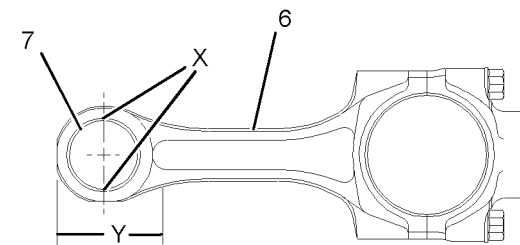


Illustration 257

g01017742

1. Use Tooling (C) to remove the old bearing and install the new bearing (7) at the same time. The adapter of Tooling (C) should make full contact with the surfaces of connecting rod (6).

**Note:** Orient the bearing joint within  $\pm 5$  degrees of either Location (X).

**NOTICE**

The connecting rod must be heated for the installation of the piston pin bearing. Do not use a torch.

- a. Raise the temperature of connecting rod (6) along Length (Y).  
  
(Y) Maximum Length for heating the connecting rod ..... 93 mm (3.7 inch)
  - b. Allow the connecting rod and the bearing to cool to room temperature.
2. Use a pin boring machine to machine the bore of bearing (7) to the correct diameter.

Diameter of bearing bore .....  $60.035 \pm 0.008$  mm  
( $2.3636 \pm 0.0003$  inch)

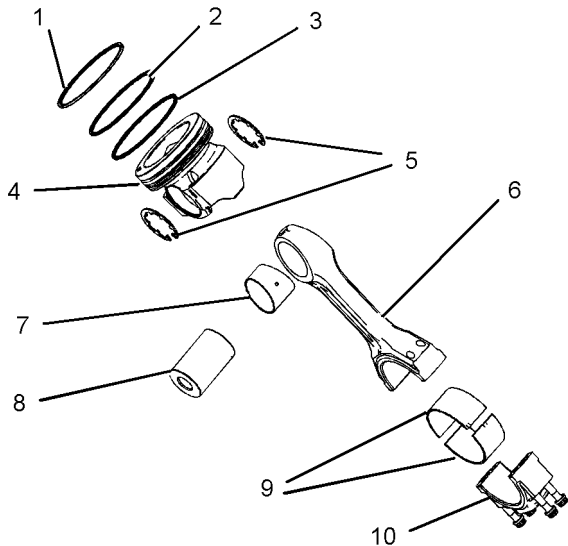


Illustration 258

g01017728

3. Position the spring for the oil control ring in the oil ring groove in the piston body assembly.
4. Position oil control ring (3) over the spring. Position the oil control ring so that the gap is 180 degrees from the joint in the spring. Install the oil control ring on the piston with Tooling (B).
5. Use Tooling (B) to install intermediate piston ring (2) with the side that has the identification "UP-2" toward the top of the piston.
6. Use Tooling (B) to install top piston ring (1) with the side that has the identification "UP-1" toward the top of the piston.
7. Position piston rings (1), (2), and (3) so the gaps are 120 degrees from each other.
8. Check the clearance between the ends of piston rings (1), (2), and (3). Refer to the Specifications Manual, "Pistons And Rings" for the specifications.
9. Put piston body assembly (4) in position on connecting rod (6). Apply clean engine oil to connecting rod pin (8) and install connecting rod pin (8). Install pin retainer (5) with Tooling (A). Make sure that pin retainers (5) are fully seated in the grooves of piston body assembly (4).
10. Install connecting rod bearings (9) in connecting rod (6) and connecting rod cap (10). Make sure that rod bearings (9) are installed so that the bearing tabs fit into the notches in connecting rod (6) and in connecting rod cap (10).

11. Ensure that the dowels are installed in connecting rod cap (10).

**End By:**

- a. Install the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Install".

i02842731

## Pistons and Connecting Rods - Install

SMCS Code: 1225-012

### Installation Procedure

Table 62

| Required Tools   |             |                        |     |
|------------------|-------------|------------------------|-----|
| Tool             | Part Number | Part Description       | Qty |
| A                | 9S-9082     | Engine Turning Tool    | 1   |
| B <sup>(1)</sup> | 5P-3526     | Piston Ring Compressor | 1   |
| B <sup>(2)</sup> | 200-3914    | Piston Ring Compressor | 1   |
| C                | 8T-3052     | Degree Wheel           | 1   |

(1) For use with the C15 engine.

(2) For use with the C18 engine.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Install the connecting rod bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, "Bearing Clearance - Check". Apply clean engine oil on the connecting rod bearings for final assembly.

1. Apply clean engine oil to the cylinder liner bore, to the piston rings, and to the outer surface of the piston.

**Note:** The piston and connecting rod are matched to a specific cylinder. Ensure that the connecting rod and pistons are installed in the correct cylinder.

2. Use Tooling (A) to rotate the crankshaft until the connecting rod journal is at the bottom center.

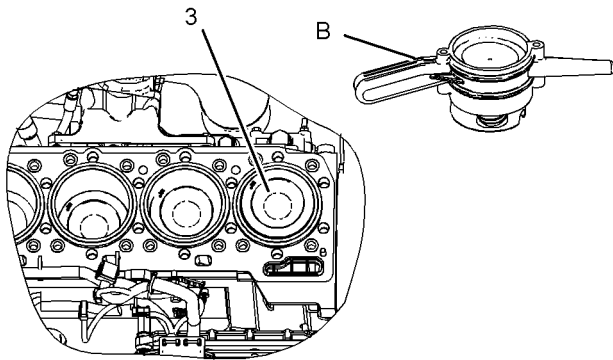


Illustration 259

g01048560

**Note:** Be careful not to damage the cylinder liner, the crankshaft journal during installation of the piston and the connecting rod.

3. Use Tooling (B) to install piston (3) and the connecting rod in the cylinder liner.

**Note:** Install the connecting rod so that the bearing tab is located on the side of the piston cooling jet.

4. Install the upper connecting rod bearing in the connecting rod.

**Note:** Ensure that the connecting rod bearing is installed so that the bearing tab fits into the notch in the connecting rod.

5. Lubricate the connecting rod bearing with clean engine oil and pull the connecting rod onto the crankshaft journal.

6. Install the lower connecting rod bearing in the connecting rod bearing cap.

**Note:** Ensure that the connecting rod bearing is installed so that the bearing tab fits into the notch in the connecting rod.

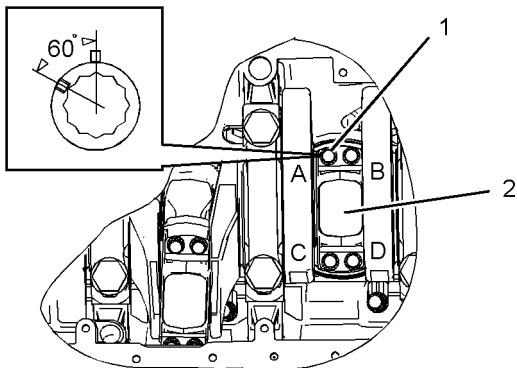


Illustration 260

g01016640

7. Position connecting rod bearing cap (2) on the connecting rod.

**Note:** Ensure that the number on the side of the connecting rod bearing cap is on the same side as the number on the connecting rod. The bearing tabs of the connecting rod bearing cap and the connecting rod are located on the side of the piston cooling jet.

8. Lubricate the threads of bolts (1) with clean engine oil and install bolts (1).

9. Tighten bolts (1), as follows:

- a. Tighten Bolt (A) and Bolt (C) to a torque of  $70 \pm 4 \text{ N}\cdot\text{m}$  ( $52 \pm 3 \text{ lb ft}$ ).
- b. Tighten Bolt (B) and Bolt (D) to a torque of  $70 \pm 4 \text{ N}\cdot\text{m}$  ( $52 \pm 3 \text{ lb ft}$ ).
- c. Turn Bolt (B) and Bolt (D) for an additional  $60 \pm 5$  degrees ( $1/6$  turn).

**Note:** If Tooling (C) is not used, place an index mark on each bolt.

- d. Tighten Bolt (A) and Bolt (C) to a torque of  $70 \pm 4 \text{ N}\cdot\text{m}$  ( $52 \pm 3 \text{ lb ft}$ ).
- e. Turn Bolt (A) and Bolt (C) for an additional  $60 \pm 5$  degrees ( $1/6$  turn).

**Note:** If Tooling (C) is not used, place an index mark on each bolt.

- f. Rotate the crankshaft in order to ensure that the crankshaft turns freely.

#### End By:

- a. Install the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".
- b. Install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".
- c. Install the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Install".

i02038671

## Connecting Rod Bearings - Remove

SMCS Code: 1219-011

### Removal Procedure

Table 63

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 9S-9082     | Engine Turning Tool | 1   |

#### Start By:

- a. Remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

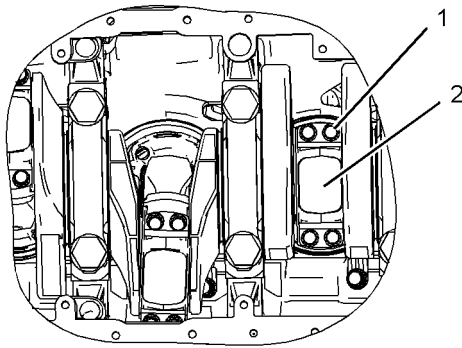


Illustration 261

g00998459

1. Use Tooling (A) to rotate the crankshaft until the connecting rod is at the bottom center.
2. Inspect the connecting rod and connecting rod cap for the proper identification mark. The connecting rod and the connecting rod cap should have an etched number on the side. The number should match the cylinder number. Mark the connecting rod and the connecting rod cap, if necessary.

**Note:** Do not stamp the connecting rod assembly. Stamping or punching the connecting rod assembly could cause the connecting rod to fracture.

3. Remove bolts (1) and connecting rod bearing cap (2) from the connecting rod.

4. Remove the lower half of the connecting rod bearing from the connecting rod bearing cap.
5. Push the connecting rod away from the crankshaft. Remove the upper half of the connecting rod bearing from the connecting rod.

i02221853

## Connecting Rod Bearings - Install

SMCS Code: 1219-012

### Installation Procedure

Table 64

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 9S-9082     | Engine Turning Tool | 1   |
| B              | 8T-3052     | Degree Wheel        | 1   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Install the connecting rod bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, "Bearing Clearance - Check". Apply clean engine oil on the connecting rod bearings for final assembly.

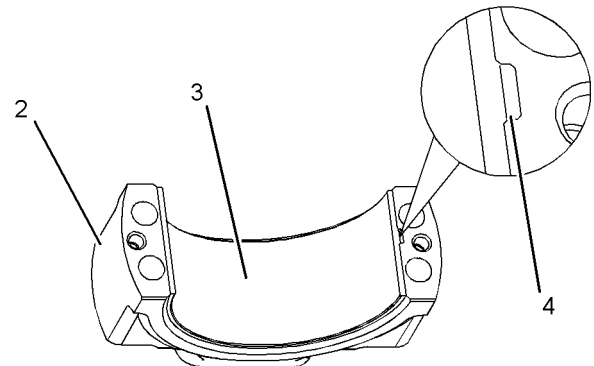


Illustration 262

g00998730

1. Use Tooling (A) to rotate the crankshaft until the connecting rod journal is at the bottom center.
2. Install a new lower half connecting rod bearing (3) in connecting rod bearing cap (2).

**Note:** Ensure that bearing locking tab (4) is located in the notch of the connecting rod bearing cap.

3. Install a new upper half connecting rod bearing in the connecting rod.

**Note:** Ensure that the bearing locking tab is located in the notch of the connecting rod.

4. Pull the connecting rod onto the crankshaft.

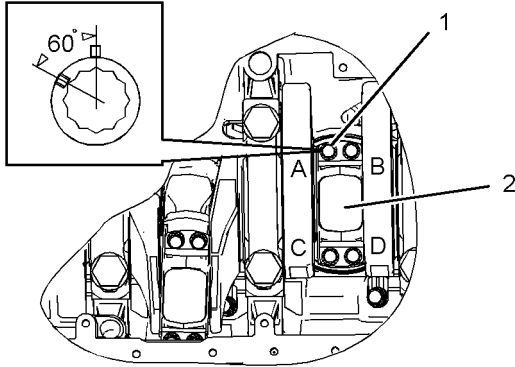


Illustration 263

g01016640

5. Position connecting rod bearing cap (2) on the connecting rod.

**Note:** Ensure that the number on the side of the connecting rod bearing cap is on the same side as the number on the connecting rod. The bearing tabs of the connecting rod bearing cap and the connecting rod are located on the side of the piston cooling jet.

6. Lubricate the threads of bolts (1) with clean engine oil. Install the bolts.

7. Tighten bolts (1), as follows:

- a. Tighten Bolt (A) and Bolt (C) to a torque of  $70 \pm 4$  N·m ( $52 \pm 3$  lb ft).
- b. Tighten Bolt (B) and Bolt (D) to a torque of  $70 \pm 4$  N·m ( $52 \pm 3$  lb ft).
- c. Turn Bolt (B) and Bolt (D) for an additional  $60 \pm 5$  degrees ( $1/6$  turn).

**Note:** If Tooling (B) is not used, place an index mark on each bolt.

- d. Tighten Bolt (A) and Bolt (C) again to a torque of  $70 \pm 4$  N·m ( $52 \pm 3$  lb ft).
- e. Tighten Bolt (A) and Bolt (C) for an additional  $60 \pm 5$  degrees ( $1/6$  turn).

**Note:** If Tooling (B) is not used, place an index mark on each bolt.

- f. Rotate the crankshaft in order to ensure that the crankshaft turns freely.

**End By:**

- a. Install the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

i02535015

## Crankshaft Main Bearings - Remove

SMCS Code: 1203-011

### Removal Procedure

Table 65

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 2P-5518     | Bearing Tool     | 1   |

**Start By:**

- a. Remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Check the main bearing caps for identification of the location and check the direction of the main bearing caps in relation to the cylinder block. The main bearing caps must be installed in the original location and the original direction.

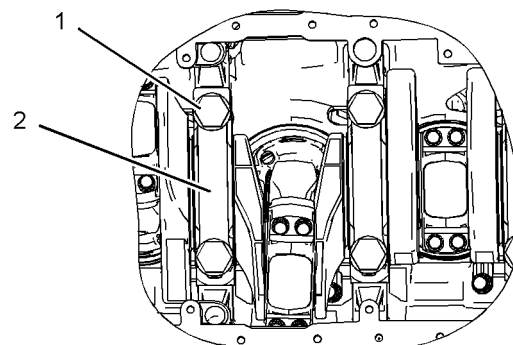


Illustration 264

g00996899

2. Remove bolts (1) from No. 2 through No. 6 main bearing caps (2).

**Note:** Remove No. 1 and No. 7 main bearing caps (2) after No. 2 through No. 6 main bearing caps have been installed.

i03136200

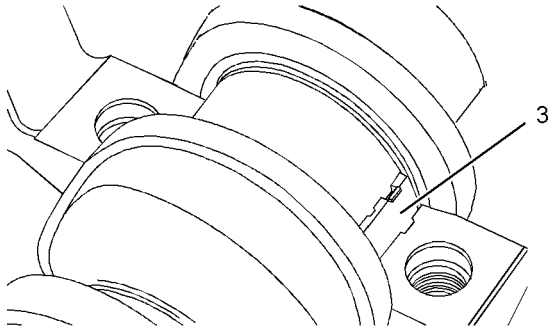


Illustration 265

g01020288

3. Install Tooling (A) in the oil hole of the crankshaft. Carefully rotate the crankshaft in order to remove upper main bearing (3) from the cylinder block.

**Note:** Push the upper main bearing from the opposite side of the bearing tab with Tooling (A). If the crankshaft is turned in the wrong direction, the tab on the bearing will be pushed between the crankshaft and the bearing area of the cylinder block. This can result in damage to the cylinder block and/or the crankshaft.

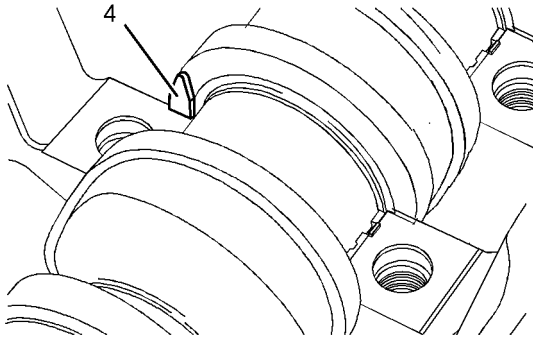


Illustration 266

g01134355

4. Remove thrust plates (4) from each side of the No. 4 main bearing.
5. Remove the lower halves of the main bearings from the main bearing caps.

## Crankshaft Main Bearings - Install

SMCS Code: 1203-012

### Installation Procedure

Table 66

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 2P-5518     | Bearing Tool     | 1   |
| B              | 8T-5096     | Dial Indicator   | 1   |
| C              | 8T-3052     | Degree Wheel     | 1   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Install the main bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, "Bearing Clearance - Check". Apply clean engine oil on the main bearings for final assembly.

**Note:** Ensure that the main bearings are installed so that bearing tabs fit into the notch in the cylinder block. The upper halves of the main bearings have the oil groove and the oil hole.

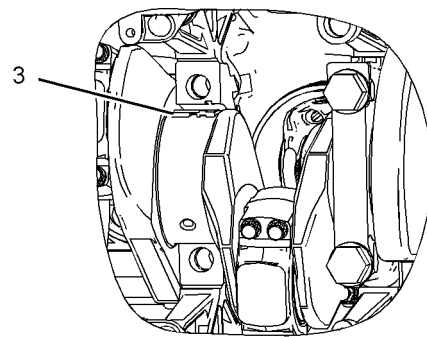


Illustration 267

g01020300

1. Position the new upper main bearing (3) on the crankshaft. Insert the end of the upper main bearing that does not have the tab into the cylinder block. Install Tooling (A) in the oil hole of the crankshaft. Carefully rotate the crankshaft in order to push the upper main bearing into the cylinder block.

**Note:** Push the upper main bearing from the side of the bearing tab with Tooling (A). If the crankshaft is turned in the wrong direction, the tab on the bearing will be pushed between the crankshaft and the bearing area of the cylinder block. This can result in damage to the cylinder block and/or the crankshaft.

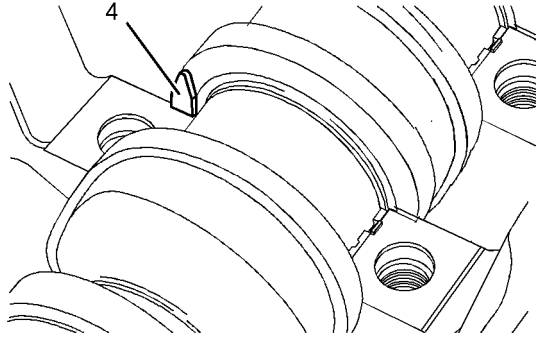


Illustration 268

g01134355

2. Install thrust plates (4) on each side of the No. 4 main bearing.

**Note:** Install the thrust plates with the words “Block Side” toward the cylinder block.

3. Install the lower halves of the crankshaft main bearings in the main bearing caps.

**Note:** Ensure that the main bearings are installed so that bearing tabs fit into the notch in the main bearing caps.

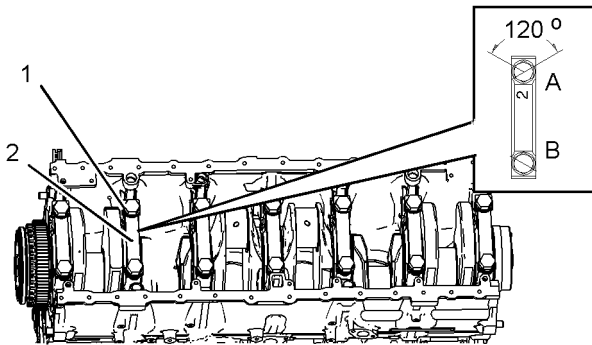


Illustration 269

g01018383

4. Position main bearing caps (2) on the crankshaft.

**Note:** Ensure that the numbers on the main bearing caps match the numbers on the cylinder block. Also ensure that the “FRONT” on the main bearing cap is installed toward the front of the cylinder block.

5. Lubricate the threads of bolts (1) with clean engine oil. Install the bolts.

6. Tighten bolts (1) for the main bearing caps, as follows:

- a. Tighten Bolt (A) to a torque of  $258 \pm 14$  N·m ( $190 \pm 10$  lb ft).

**Note:** Bolt (A) is on the bearing tab side of the main bearing cap.

- b. Tighten Bolt (B) to a torque of  $258 \pm 14$  N·m ( $190 \pm 10$  lb ft).

**Note:** Bolt (B) is on the opposite side of the bearing tab of the main bearing cap.

- c. Tighten Bolt (B) for an additional  $120 \pm 5$  degrees (2 flats).

**Note:** If Tooling (C) is not used, place an index mark on the bolt and the main bearing cap.

- d. Tighten Bolt (A) for an additional  $120 \pm 5$  degrees (2 flats).

**Note:** If Tooling (C) is not used, place an index mark on the bolt and the main bearing cap.

- e. Rotate the crankshaft in order to ensure that the crankshaft turns freely.

7. Use Tooling (B) to check the crankshaft end play. Ensure that Tooling (B) is against a machined surface. The end play is controlled by the thrust plates of No. 4 main bearing (center). Refer to Specifications, “Crankshaft” for the crankshaft end play.

#### End By:

- a. Install the engine oil pump. Refer to Disassembly and Assembly, “Engine Oil Pump - Install”.

i02533916

# Crankshaft - Remove

SMCS Code: 1202-011

## Removal Procedure

Table 67

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 138-7575    | Link Bracket        | 2   |
| B              | 1H-3110     | Bearing Puller      | 1   |
|                | 8B-7560     | Step Plate          | 1   |
|                | 9U-6600     | Hand Hydraulic Pump | 1   |
|                | 1H-3108     | Push-Puller Leg     | 2   |
|                | 1H-3107     | Bearing Puller      | 1   |
|                | 3H-0468     | Puller Plate        | 5   |
|                | 3H-0465     | Push-Puller Plate   | 2   |
|                | 1P-0820     | Hydraulic Puller    | 1   |
|                | 5B-0637     | Nut                 | 1   |
|                | 8S-6586     | Forcing Screw       | 1   |
| C              | 5P-0944     | Dowel Puller Group  | 1   |
|                | 5P-0939     | Dowel Extractor     | 1   |

### Start By:

- a. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove".
- b. Remove the flywheel housing. Refer to Disassembly and Assembly, "Flywheel Housing - Remove and Install".
- c. Remove the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Check the main bearing caps for identification for the location and the direction in the cylinder block. The identification marks on the main bearing caps must be installed in the same direction prior to removal.
2. Check the connecting rod and the connecting rod bearing caps for identification and the location in the cylinder block.

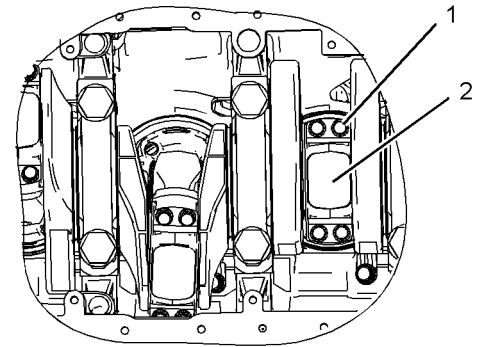


Illustration 270

g01017945

3. Remove bolts (1) for connecting rod bearing cap (2). Remove the connecting rod bearing caps.

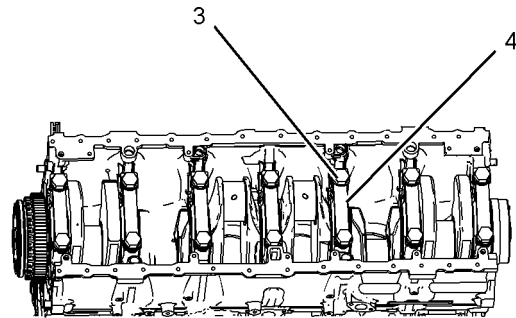


Illustration 271

g01020310

4. Remove bolts (3) for main bearing cap (4). Remove the main bearing caps.

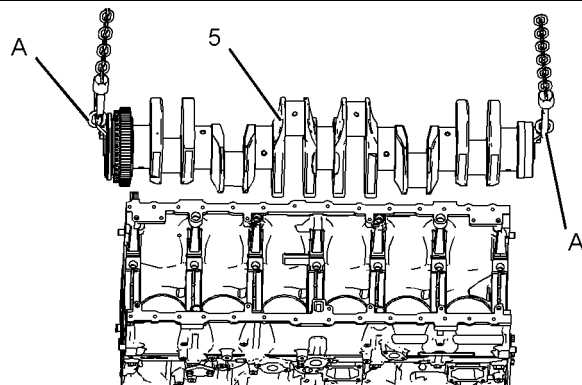


Illustration 272

g00996555

5. Install Tooling (A) and a suitable lifting device on each end of crankshaft (5). The weight of crankshaft (5) is approximately 177 kg (390 lb).
6. Remove the crankshaft from the cylinder block.
7. Remove the thrust plates from each side of the No. 4 main bearing.

i04089170

8. Remove the lower main bearings from the main bearing caps. Remove the upper main bearings from the cylinder block.

**Note:** Mark the used main bearings or identify the used main bearings for installation if the main bearings will be used again.

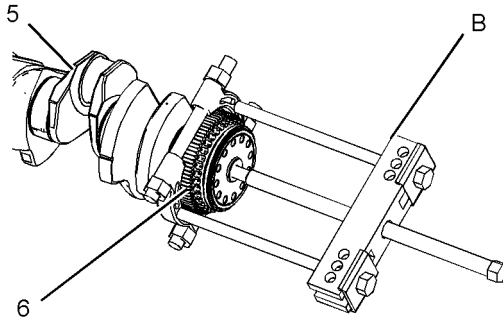


Illustration 273

g00996556

9. Use Tooling (B) to remove crankshaft gear (6) from crankshaft (5).

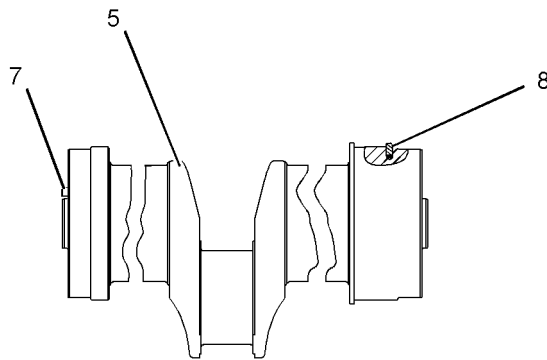


Illustration 274

g01056151

10. If necessary, use Tooling (C) to remove dowel (7) and dowel (8) from crankshaft (5).

## Crankshaft - Install

**SMCS Code:** 1202-012

### Installation Procedure

Table 68

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | Qty |
| A              | 138-7575    | Link Bracket     | 2   |
| D              | 8T-5096     | Dial Indicator   | 1   |
| E              | 8T-3052     | Degree Wheel     | 1   |

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

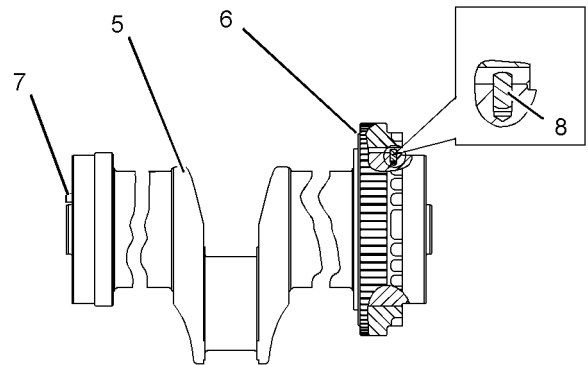


Illustration 275

g01018035

1. Install dowel (7) in the crankshaft.

Protrusion of dowel (7) from the crankshaft face ..... 6.4 mm (0.25 inch)

2. Install dowel (8) in the crankshaft.

Protrusion of dowel (8) from the crankshaft .....  $4.1 \pm 0.5$  mm ( $0.16 \pm 0.02$  inch)

**Note:** Do not use a torch to heat the crankshaft gear. Overheating of the crankshaft gear will cause premature failure.

3. Raise the temperature of crankshaft gear (6) to a maximum temperature of 233° C (451° F). Install crankshaft gear (6) on the crankshaft with the keyway in alignment with dowel (8). The Timing Mark "V" of the gear should face away from crankshaft (5). If necessary, use a suitable brass drift and a suitable hammer to seat the crankshaft gear against the shoulder of the crankshaft.

4. Clean the cylinder block and the main bearing caps thoroughly.

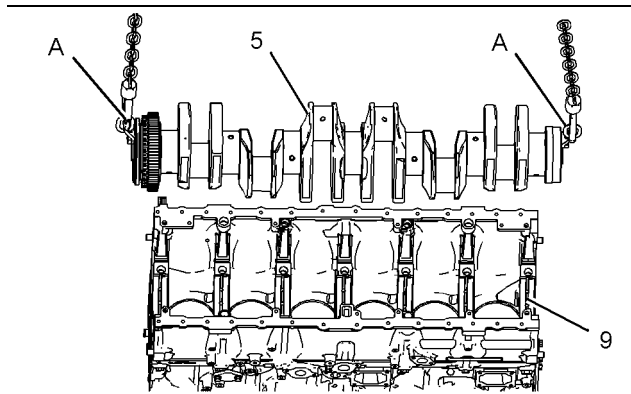


Illustration 276

g01048335

**Note:** Install the main bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, "Bearing Clearance - Check". Apply clean engine oil on the face of the main bearings for final assembly.

5. Install the upper halves of main bearings (9) in the cylinder block.

**Note:** Ensure that the main bearings are installed so that the bearing tabs fit into the notch in the cylinder block. The upper halves of the main bearings have the oil groove and the oil hole.

6. Install Tooling (A) and a suitable lifting device on crankshaft (5). The weight of crankshaft (5) is approximately 177 kg (390 lb).

7. Install crankshaft (5) with the Timing Mark "V" on the crankshaft gear in alignment with the Timing Mark "V" on the cluster gear.

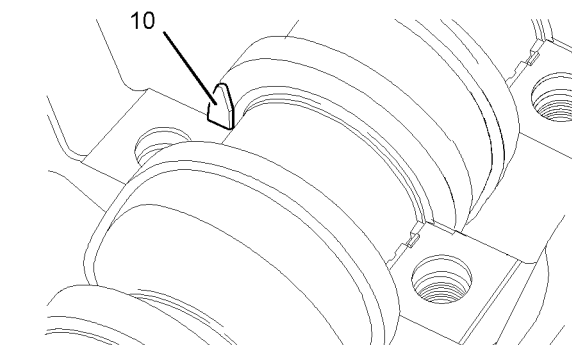


Illustration 277

g01048338

8. Install thrust plates (10) on each side of the No. 4 main bearing.

**Note:** Install the thrust plates with the words "Block Side" toward the cylinder block.

9. Install the lower halves of the crankshaft main bearings in the main bearing caps.

**Note:** Ensure that the main bearings are installed so that the bearing tabs fit into the notch in the main bearing cap.

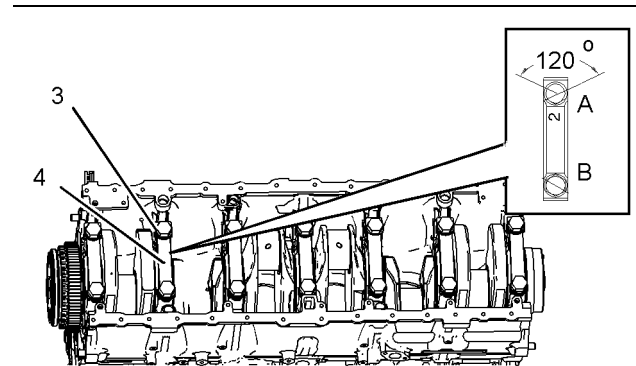


Illustration 278

g01020434

10. Position main bearing caps (4) on the crankshaft.

**Note:** Ensure that the numbers on the main bearing caps match the numbers on the cylinder block. Also ensure that the "FRONT" on the main bearing cap is installed toward the front of the cylinder block.

11. Lubricate the threads of bolts (3) with clean engine oil. Install the bolts.

12. Tighten bolts (3) for the main bearing caps, as follows:

- a. Tighten Bolt (A) to a torque of  $258 \pm 14$  N·m ( $190 \pm 10$  lb ft).

**Note:** Bolt (A) is on the bearing tab side of the main bearing cap.

- b. Tighten Bolt (B) opposite the bearing tab side to a torque of  $258 \pm 14$  N·m ( $190 \pm 10$  lb ft).

**Note:** Bolt (B) is on the opposite side of the bearing tab of the main bearing cap.

- c. Tighten Bolt (B) for an additional  $120 \pm 5$  degrees (2 flats).

**Note:** If Tooling (E) is not used, place an index mark on the bolt and the main bearing cap.

- d. Tighten Bolt (A) for an additional  $120 \pm 5$  degrees (2 flats).

**Note:** If Tooling (E) is not used, place an index mark on the bolt and the main bearing cap.

- e. Rotate the crankshaft in order to ensure that the crankshaft turns freely.

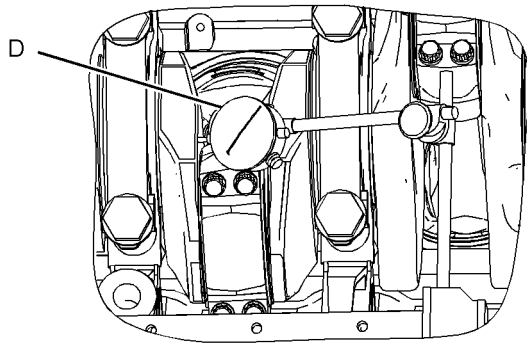


Illustration 279

g01103661

**13.** Use Tooling (D) to check the crankshaft end play. Ensure that Tooling (D) is against a machined surface. The end play is controlled by the thrust plates of No. 4 main bearing (center). Refer to Specifications, "Crankshaft" for the crankshaft end play.

**Note:** Install the connecting rod bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, "Bearing Clearance - Check". Apply clean engine oil on the face of the connecting rod bearings for final assembly.

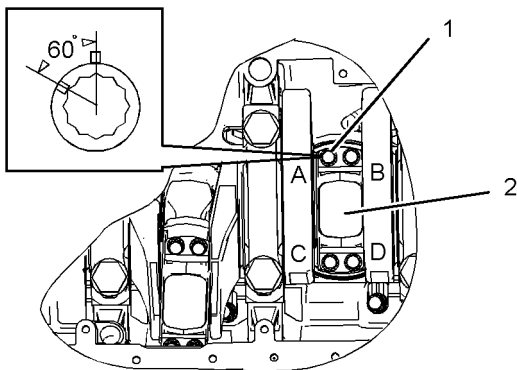


Illustration 280

g01020428

**14.** Position the connecting rod against the crankshaft. Install connecting rod bearing cap (2) on the connecting rod.

**Note:** Ensure that the number on the side of the connecting rod bearing cap is on the same side as the number on the connecting rod. The bearing tabs of the connecting rod bearing cap and the connecting rod are located on the side of the piston cooling jet.

**15.** Lubricate the threads of bolts (1) with clean engine oil. Install the bolts.

**16.** Tighten bolts (1), as follows:

- a. Tighten Bolt (A) and Bolt (C) to a torque of  $70 \pm 4$  N·m ( $52 \pm 3$  lb ft).

- b. Tighten Bolt (B) and Bolt (D) to a torque of  $70 \pm 4$  N·m ( $52 \pm 3$  lb ft).

- c. Turn Bolt (B) and Bolt (D) for an additional  $60 \pm 5$  degrees ( $1/6$  turn).

**Note:** If Tooling (E) is not used, place an index mark on each bolt and connecting rod cap.

- d. Tighten Bolt (A) and Bolt (C) to a torque of  $70 \pm 4$  N·m ( $52 \pm 3$  lb ft).

- e. Turn Bolt (A) and Bolt (C) for an additional  $60 \pm 5$  degrees ( $1/6$  turn).

**Note:** If Tooling (E) is not used, place an index mark on each bolt and connecting rod cap.

- f. Rotate the crankshaft in order to ensure that the crankshaft turns freely.

**End By:**

- a. Install the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

- b. Install the flywheel housing. Refer to Disassembly and Assembly, "Flywheel Housing - Remove and Install".

- c. Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install".

i02717761

## Bearing Clearance - Check

**SMCS Code:** 1203-535; 1219-535

### Measurement Procedure

Table 69

| Required Tools |             |  |     |
|----------------|-------------|--|-----|
| Tool           | Part Number | Part Description   | Qty |
| A              | 198-9142    | Plastic Gauge (Green)<br>0.025 to 0.076 mm<br>(0.001 to 0.003 inch)  | 1   |
|                | 198-9143    | Plastic Gauge (Red)<br>0.051 to 0.152 mm<br>(0.002 to 0.006 inch)    | 1   |
|                | 198-9144    | Plastic Gauge (Blue)<br>0.102 to 0.229 mm<br>(0.004 to 0.009 inch)   | 1   |
|                | 198-9145    | Plastic Gauge (Yellow)<br>0.230 to 0.510 mm<br>(0.009 to 0.020 inch) | 1   |

**Note:** Plastic gauge may not be necessary when the engine is in the chassis.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Caterpillar does not recommend the checking of the actual bearing clearances particularly on small engines. This is because of the possibility of obtaining inaccurate results and the possibility of damaging the bearing or the journal surfaces. Each Caterpillar engine bearing is quality checked for specific wall thickness.

**Note:** The measurements should be within specifications and the correct bearings should be used. If the crankshaft journals and the bores for the block and the rods were measured during disassembly, no further checks are necessary. However, if the technician still wants to measure the bearing clearances, Tooling (A) is an acceptable method. Tooling (A) is less accurate on journals with small diameters if clearances are less than 0.10 mm (0.004 inch).

#### NOTICE

Lead wire, shim stock or a dial bore gauge can damage the bearing surfaces.

The technician must be very careful to use Tooling (A) correctly. The following points must be remembered:

- Ensure that the backs of the bearings and the bores are clean and dry.
- Ensure that the bearing locking tabs are properly seated in the tab grooves.
- The crankshaft must be free of oil at the contact points of Tooling (A).

1. Put a piece of Tooling (A) on the crown of the bearing that is in the cap.

**Note:** Do not allow Tooling (A) to extend over the edge of the bearing.

2. Use the correct torque-turn specifications in order to install the bearing cap. Do not use an impact wrench. Be careful not to dislodge the bearing when the cap is installed.

**Note:** Do not turn the crankshaft when Tooling (A) is installed.

3. Carefully remove the cap, but do not remove Tooling (A). Measure the width of Tooling (A) while Tooling (A) is in the bearing cap or on the crankshaft journal. Refer to Illustration 281.

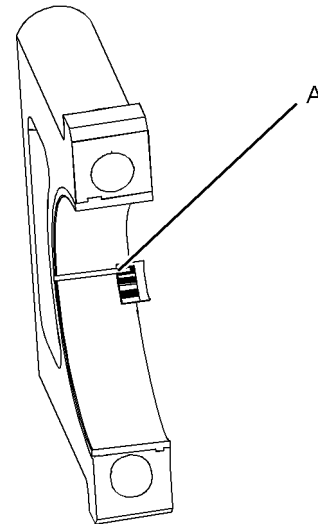


Illustration 281

g01152855

Typical Example

4. Remove all of Tooling (A) before you install the bearing cap.

**Note:** When Tooling (A) is used, the readings can sometimes be unclear. For example, all parts of Tooling (A) are not the same width. Measure the major width in order to ensure that the parts are within the specification range. Refer to Specifications Manual, "Connecting Rod Bearing Journal" and Specifications Manual, "Main Bearing Journal" for the correct clearances.

i03539018

## Atmospheric Pressure Sensor - Remove and Install

SMCS Code: 1923-010

### Removal Procedure

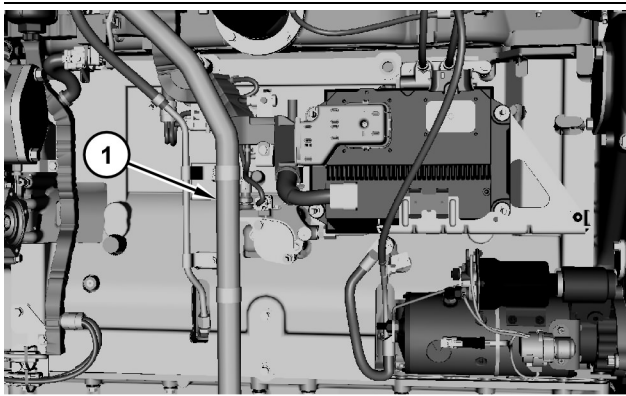


Illustration 282

g01868533

1. Remove hose assembly (1).

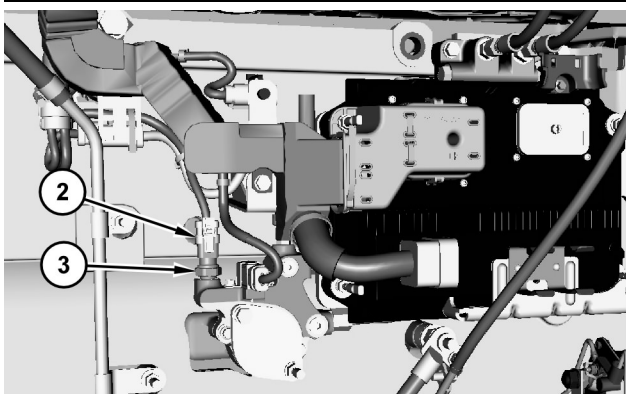


Illustration 283

g01868513

2. Disconnect harness assembly and remove atmospheric pressure sensor (3).

### Installation Procedure

1. Install atmospheric pressure sensor (3) in reverse order.

- a. Tighten atmospheric pressure sensor (3) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).

i03974312

## Camshaft Position Sensor - Remove and Install

SMCS Code: 1912-010

### Removal Procedure

1. Remove the engine oil filter. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change".

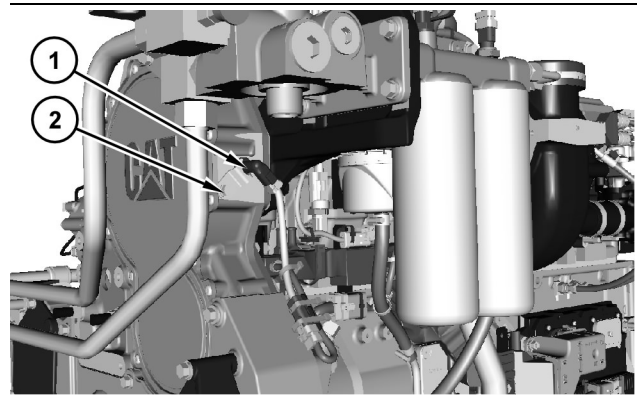


Illustration 284

g02163447

2. Disconnect the harness assembly and remove bolt (2). Remove camshaft position sensor (1) and the O-ring seal.

### Installation Procedure

1. Install the camshaft position sensor (1) in the reverse order.
  - a. Lubricate the O-ring seal with the lubricant that is being sealed prior to the installation of the camshaft position sensor (1).

i03976010

## Crankshaft Position Sensor - Remove and Install

SMCS Code: 1912-010

### Removal Procedure

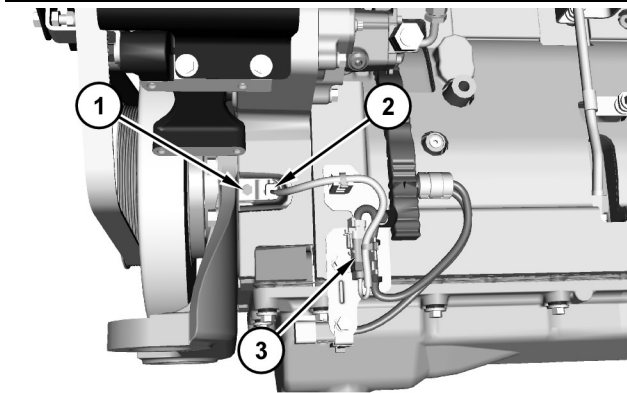


Illustration 285

g02163782

1. Disconnect harness assembly (3). Remove bolt (1) and crankshaft position sensor (2). Remove the O-ring seal from the crankshaft position sensor.

### Installation Procedure

1. Install the crankshaft position sensor (2) in the reverse order.
  - a. Lubricate the O-ring seal with the lubricant that is being sealed prior to the installation of crankshaft position sensor (2).

i03541175

## Coolant Temperature Sensor - Remove and Install

SMCS Code: 1906-010

### Removal Procedure

**Note:** The coolant temperature sensor is located in the water temperature regulator housing.

1. Drain the coolant from the cooling system to a level below the coolant temperature sensor into a suitable container for storage or disposal.

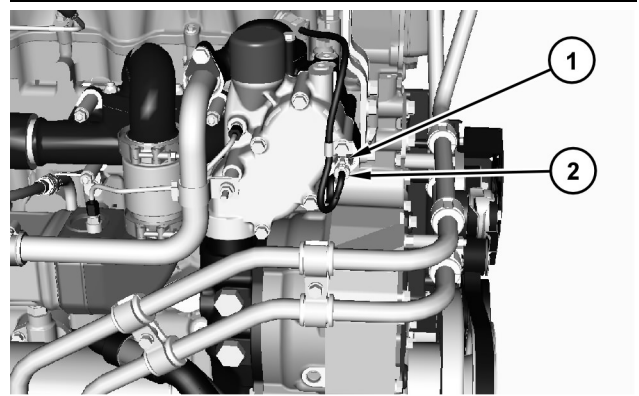


Illustration 286

g01869661

2. Disconnect harness assembly (2) and remove coolant temperature sensor (1).
3. Remove the O-ring seal from the coolant temperature sensor.

### Installation Procedure

1. Install the coolant temperature sensor in the reverse order.
  - a. Tighten coolant temperature sensor (1) to a torque of  $20 \pm 3$  N·m ( $177 \pm 27$  lb in).
2. Fill the cooling system with coolant. Refer to Operation and Maintenance, "Refill Capacities" for the cooling system capacity.

i03977430

## Engine Oil Pressure Sensor - Remove and Install

SMCS Code: 1924-010

### Removal Procedure

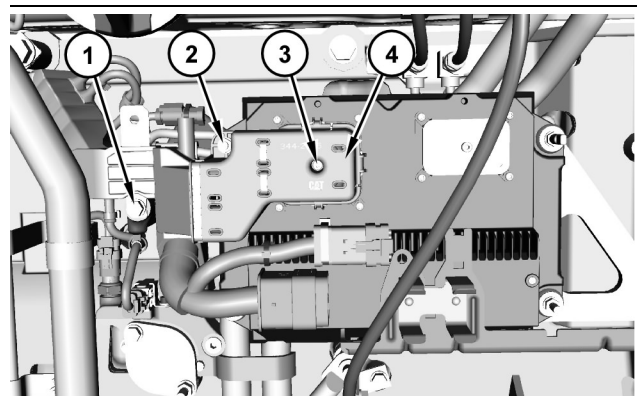


Illustration 287

g02164146

1. Remove bolts (1) and (2). Loosen bolt (3). Disconnect the harness assemblies and position harness assembly (4) out of the way.

i03539123

## Crankcase Pressure Sensor - Remove and Install

SMCS Code: 1916-010

### Removal Procedure

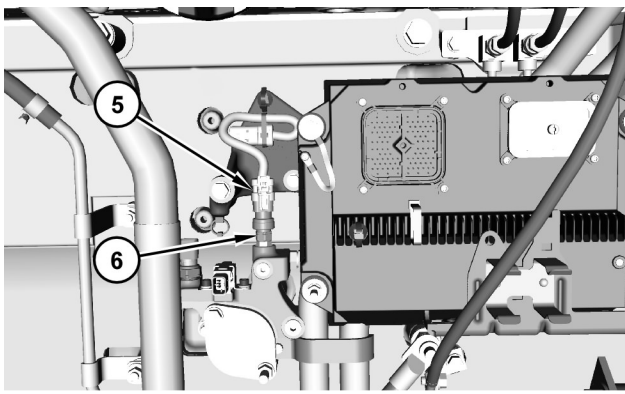


Illustration 288

g02164147

2. Disconnect harness assembly (5) and remove engine oil pressure sensor (6).
3. Remove the O-ring seal from the engine oil pressure sensor.

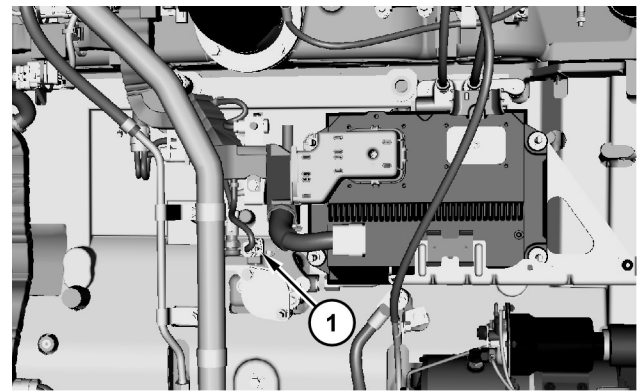


Illustration 289

g01868599

Location of crankcase pressure sensor

### Installation Procedure

1. Install the engine oil pressure sensor (6) in the reverse order.
  - a. Tighten the engine oil pressure sensor (6) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).
  - b. Tighten bolt (3) to a torque of  $7.0 \pm 0.5$  N·m ( $62 \pm 4.5$  lb in).

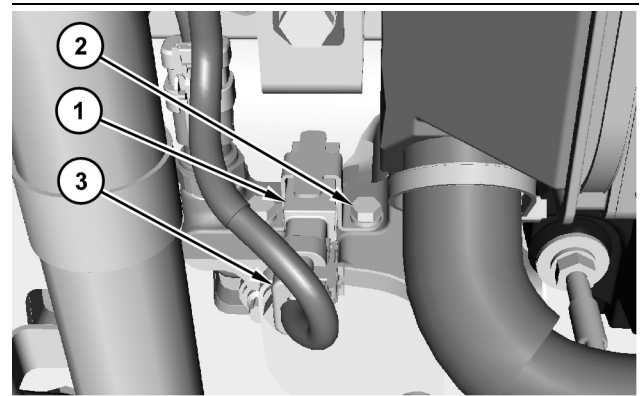


Illustration 290

g01868636

1. Disconnect harness assembly (3) and remove bolts (2).
2. Remove crankcase pressure sensor (1) and remove the O-ring seals.

### Installation Procedure

1. Install the crankcase pressure sensor in reverse order.

i03931098

## Fuel Pressure Sensor - Remove and Install

SMCS Code: 7414-010

### Removal Procedure

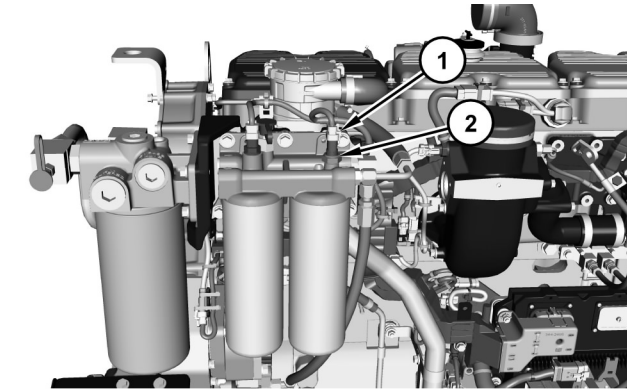


Illustration 291

g02154154

1. Disconnect harness assembly (1) and remove fuel pressure sensor (2).

### Installation Procedure

1. Install fuel pressure sensor (2) in the reverse order.
  - a. Tighten fuel pressure sensor (1) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).

i03931111

## Fuel Temperature Sensor - Remove and Install

SMCS Code: 1922-010

### Removal Procedure

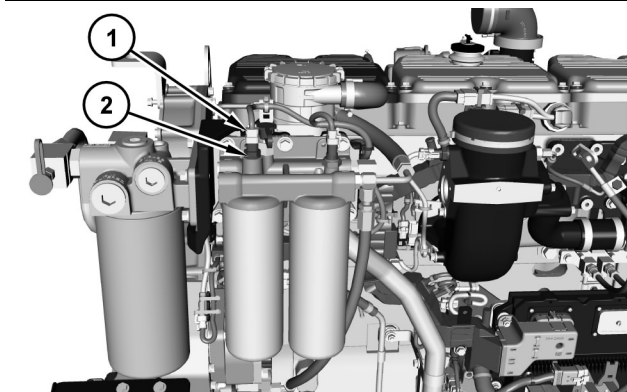


Illustration 292

g02154478

1. Disconnect harness assembly (1) and remove fuel temperature sensor (2).

### Installation Procedure

1. Install the fuel temperature sensor (2) in the reverse order.
  - a. Tighten fuel temperature sensor (2) to a torque of  $20 \pm 3$  N·m ( $177 \pm 27$  lb in).

i04024228

## Pressure Sensor (ARD Combustion Air) - Remove and Install (Clean Emissions Module)

SMCS Code: 1439-010

### Removal Procedure

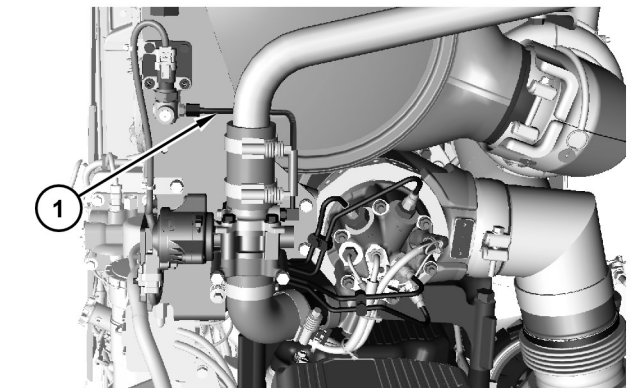


Illustration 293

g02204679

1. Remove tube assembly (1).

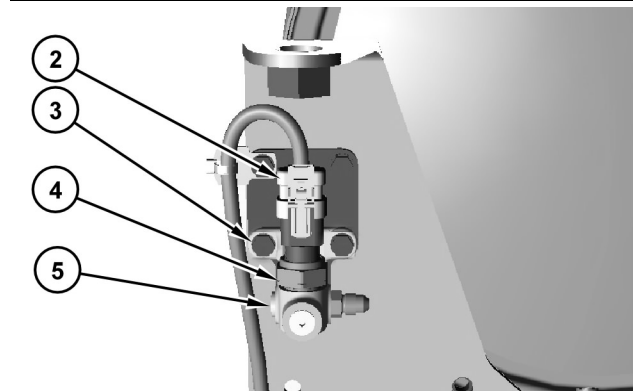


Illustration 294

g02204680

2. Disconnect harness assembly (2).
3. Remove pressure sensor (4) and remove the O-ring seal (not shown).

4. Remove bolts (3) and remove manifold (5).

## Installation Procedure

1. Install pressure sensor (4) in reverse order.
  - a. Tighten pressure sensor (4) to a torque of  $10 \pm 2$  N·m ( $89 \pm 17$  lb in).

i04259669

## Soot Antenna - Remove and Install (Clean Emissions Module)

SMCS Code: 108F-010-NS; 1335-010-SOT

### Removal Procedure

Table 70

| Required Tools |             |                  |     |
|----------------|-------------|------------------|-----|
| Tool           | Part Number | Part Description | QTY |
| A              | -           | Loctite 771      | -   |

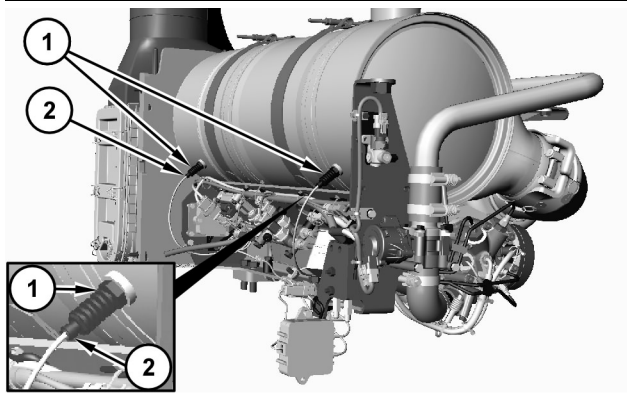


Illustration 295

g02204834

Typical Example

**Note:** Keep the soot antenna and harness assembly connections clean from contaminants. To prevent contaminants from entering the connections, always plug or cap the connections when disconnected.

1. Disconnect harness assemblies (2) from soot antennas (1).
2. Remove soot antennas (1) from the clean emissions module.

### Installation Procedure

1. Install the soot antenna (1) in reverse order.

- a. Apply Tooling (A) to the threads on soot antenna (1). Torque soot antenna (1) to a torque of  $45 \pm 5$  N·m ( $33 \pm 4$  lb ft).

**Note:** Keep the soot antenna and harness assembly connections clean from contaminants.

- b. Hand tighten harness assemblies (2) when connecting to soot antenna (2).

i04024294

## Soot Sensor - Remove and Install

SMCS Code: 108F-010-NS; 1439-010-SOT

### Removal Procedure

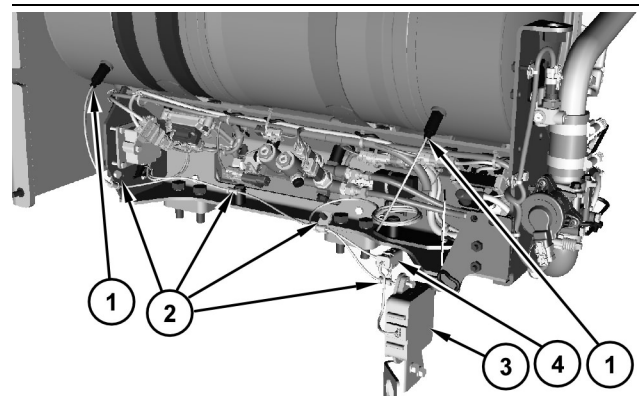


Illustration 296

g02205113

**Note:** Keep the soot antenna and harness assembly connections clean from contaminants. To prevent contaminants from entering the connections, always plug or cap the connections.

1. Disconnect both harness assemblies (1) from the soot antenna.
2. Remove loop clips (2).
3. Disconnect harness assembly (4). Remove the bolts and remove Soot Sensor (3).

### Installation Procedure

1. Install the Soot Sensor in the reverse order.

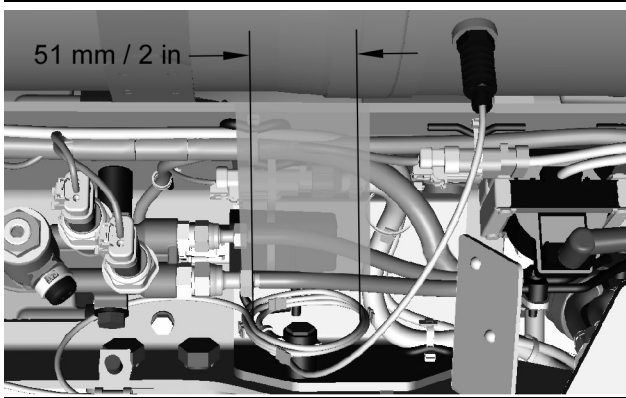


Illustration 297 g02205253

- a. Keep a minimum diameter bend of 51 mm (2 inch) when installing harness assemblies (1).

**Note:** Keep the soot antenna and harness assembly connections clean from contaminants.

- b. Hand tighten harness assemblies (1).

i04022888

## Flame Detection Temperature Sensor - Remove and Install (Clean Emissions Module)

**SMCS Code:** 1439-010-TA; 1919-010

### Removal Procedure

Table 71

| Required Tools |             |                                 |     |
|----------------|-------------|---------------------------------|-----|
| Tool           | Part Number | Part Description                | Qty |
| A              | -           | Loctite 771 Anti-Seize Compound | -   |

1. Turn the fuel supply to the OFF position and turn the power disconnect switch to the OFF.
2. Drain the coolant from the cooling system into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change".

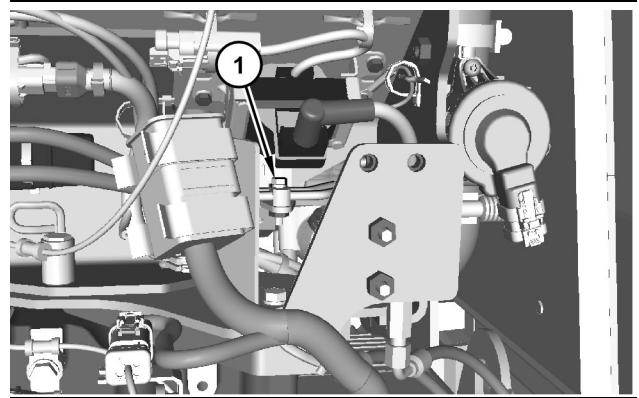


Illustration 298 g02201253

This is a view of the engine compartment from the left side of the machine.

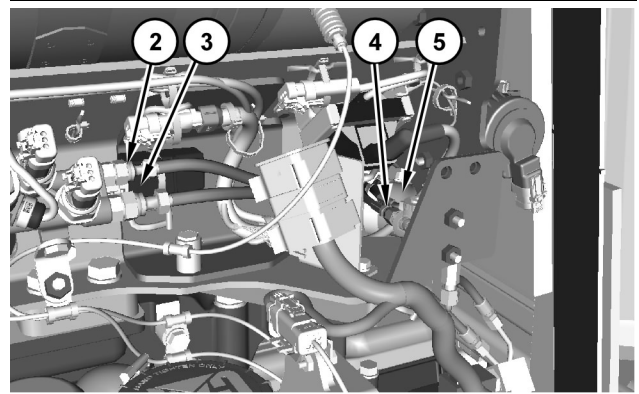


Illustration 299 g02201257

3. Remove bolt (1).

**Note:** Cap all tube assemblies and fittings that are disconnected in order to prevent fluid loss. This will also keep contaminants out of the systems.

4. Disconnect tube assemblies (2), (3), (4), and (5).

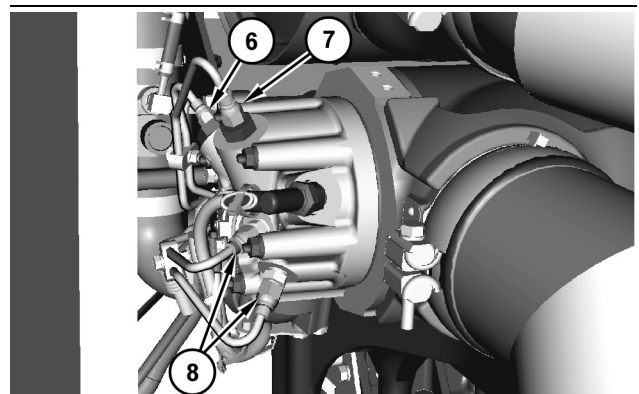


Illustration 300 g02201258

**Note:** Cap all tube assemblies and fittings that are disconnected in order to prevent fluid loss. This will also keep contaminants out of the systems.

5. Disconnect tube assemblies (6), (7), and (8).

- Carefully remove the tube assemblies as one unit from the right side of the machine.

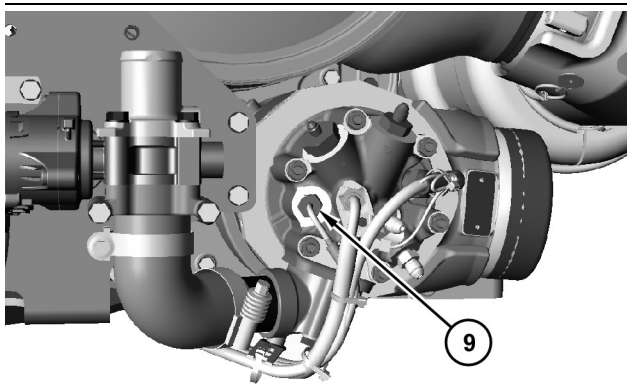


Illustration 301

g02199957

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

- Remove cable straps and remove flame detection temperature sensor (9).

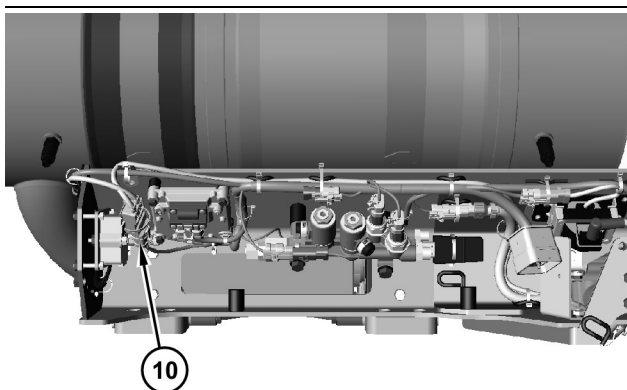


Illustration 302

g02201433

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

- Disconnect the harness assembly that attaches to flame detection temperature sensor (10). Remove all cable straps that secure the sensor.

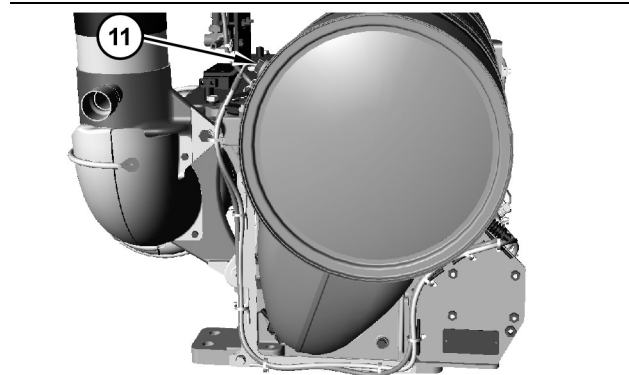


Illustration 303

g02201534

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

- Remove the inlet temperature sensor (11).

## Installation Procedure

- Install the flame detection temperature sensor in the reverse order.
  - Apply Tooling (A) to the threads on flame detection temperature sensor (9) and to the threads of inlet temperature sensor (11). Tighten the flame detection temperature sensor (9) and the inlet temperature sensor (11) to a torque of  $45 \pm 5$  N·m ( $33 \pm 4$  lb ft).
  - Tighten tube assemblies (8) to a torque of  $16 \pm 2$  N·m ( $142 \pm 18$  lb in).
  - Tighten tube assembly (6) to a torque of  $11 \pm 2$  N·m ( $97 \pm 18$  lb in).
  - Tighten tube assembly (7) to a torque of  $16 \pm 2$  N·m ( $142 \pm 18$  lb in).
  - Tighten tube assembly (5) to a torque of  $20 \pm 2$  N·m ( $177 \pm 18$  lb in).
  - Tighten tube assembly (4) to a torque of  $16 \pm 2$  N·m ( $142 \pm 18$  lb in).
  - Tighten tube assembly (3) to a torque of  $43 \pm 4$  N·m ( $32 \pm 3$  lb ft).
  - Tighten tube assembly (2) to a torque of  $27 \pm 3$  N·m ( $239 \pm 27$  lb in).

i04022211

# Temperature Sensor (DPF) - Remove and Install (Clean Emissions Module)

SMCS Code: 1919-F1

## Removal Procedure

Table 72

| Required Tools |             |                                 |     |
|----------------|-------------|---------------------------------|-----|
| Tool           | Part Number | Part Description                | Qty |
| A              | -           | Loctite 771 Anti-Seize Compound | -   |

1. Turn the fuel supply to the OFF position and turn the power disconnect switch to the OFF.
2. Drain the coolant from the cooling system into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change".

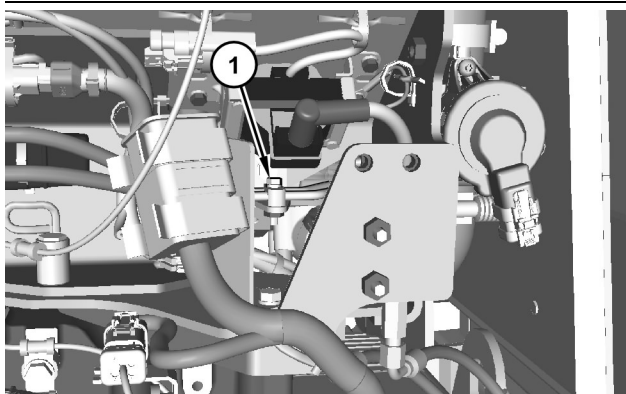


Illustration 304

g02201253

This is a view of the engine compartment from the left side of the machine.

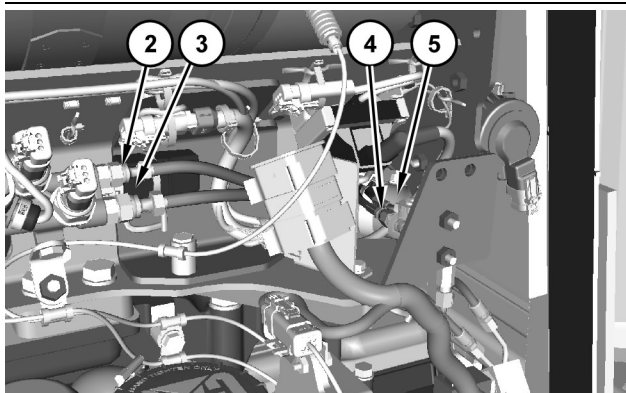


Illustration 305

g02201257

3. Remove bolt (1).

**Note:** Cap all tube assemblies and fittings that are disconnected in order to prevent fluid loss. This will also keep contaminants out of the systems.

4. Disconnect tube assemblies (2), (3), (4), and (5).

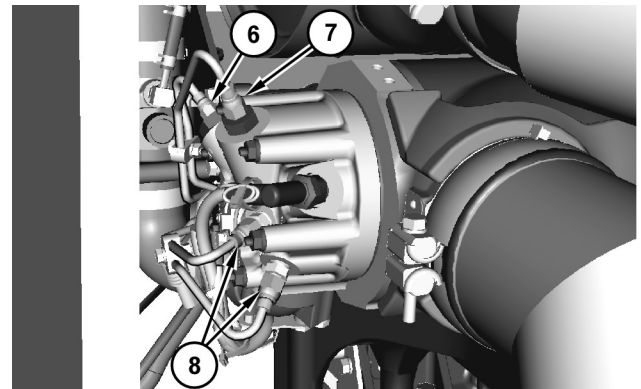


Illustration 306

g02201258

**Note:** Cap all tube assemblies and fittings that are disconnected in order to prevent fluid loss. This will also keep contaminants out of the systems.

5. Disconnect tube assemblies (6), (7), and (8).
6. Carefully remove the tube assemblies as one unit from the right side of the machine.

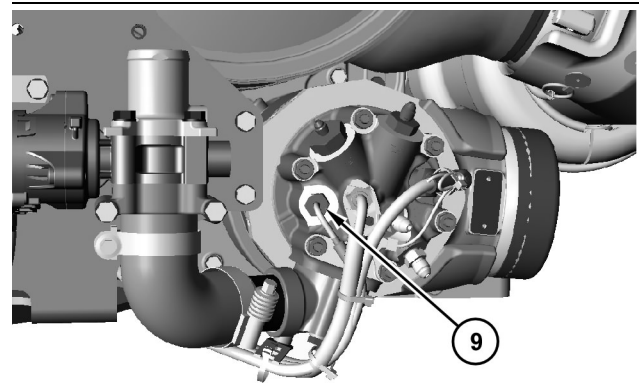


Illustration 307

g02199957

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

7. Remove cable straps and remove flame detection temperature sensor (9).

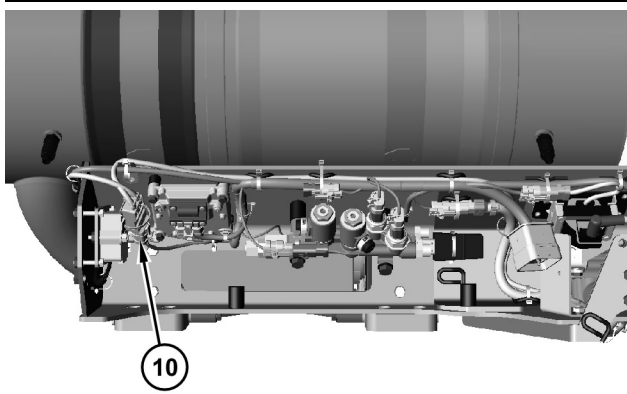


Illustration 308

g02201433

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

8. Disconnect the harness assembly that attaches to flame detection temperature sensor (10). Remove all cable straps that secure the sensor.

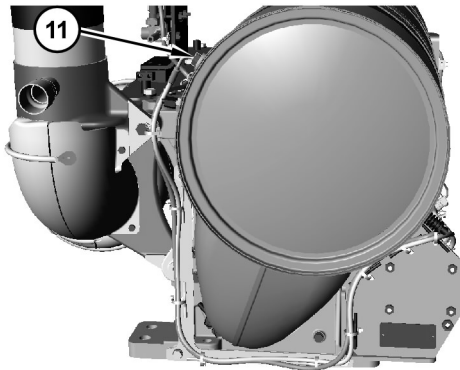


Illustration 309

g02201534

**Note:** Put orientation and location marks on all cable strap locations and on all insulation wraps for installation purposes.

9. Remove the inlet temperature sensor (11).

## Installation Procedure

1. Install the flame detection temperature sensor in the reverse order.
  - a. Apply Tooling (A) to the threads on flame detection temperature sensor (9) and to the threads of inlet temperature sensor (11). Tighten the flame detection temperature sensor (9) and the inlet temperature sensor (11) to a torque of  $45 \pm 5$  N·m ( $33 \pm 4$  lb ft).
  - b. Tighten tube assemblies (8) to a torque of  $16 \pm 2$  N·m ( $142 \pm 18$  lb in).

- c. Tighten tube assembly (6) to a torque of  $11 \pm 2$  N·m ( $97 \pm 18$  lb in).
- d. Tighten tube assembly (7) to a torque of  $16 \pm 2$  N·m ( $142 \pm 18$  lb in).
- e. Tighten tube assembly (5) to a torque of  $20 \pm 2$  N·m ( $177 \pm 18$  lb in).
- f. Tighten tube assembly (4) to a torque of  $16 \pm 2$  N·m ( $142 \pm 18$  lb in).
- g. Tighten tube assembly (3) to a torque of  $43 \pm 4$  N·m ( $32 \pm 3$  lb ft).
- h. Tighten tube assembly (2) to a torque of  $27 \pm 3$  N·m ( $239 \pm 27$  lb in).

i04022133

## Pressure Sensor (DPF) - Remove and Install (Clean Emissions Module)

SMCS Code: 1439-PXS

### Removal Procedure

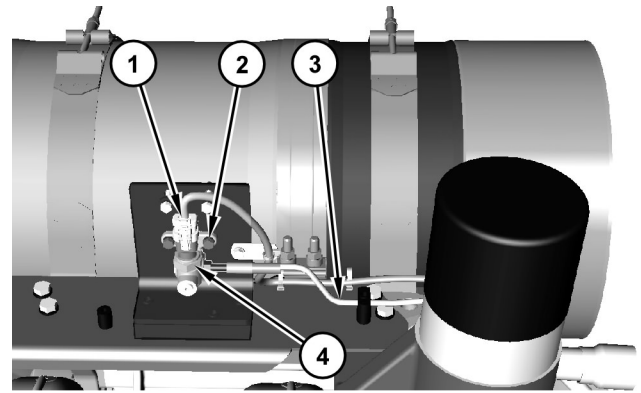


Illustration 310

g02199679

Overhead view of the Diesel Particulate Filter Assembly showing the location of the pressure sensor.

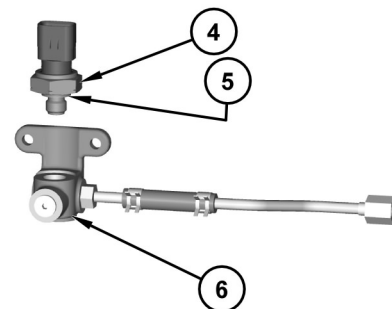


Illustration 311

g02199681

i04152020

1. Disconnect harness assembly (1).
2. Disconnect tube assembly (3).
3. Remove bolts (2) and remove pressure sensor (4).
4. Remove pressure sensor (4) and remove O-ring seal (5) from manifold (6).

### Installation Procedure

1. Install pressure sensor (4) in reverse order.
  - a. Tighten pressure sensor (4) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).

i03544394

### Temperature Sensor (Cooled Exhaust Gas) - Remove and Install

SMCS Code: 1439; 1919; 1921

### Removal Procedure

Table 73

| Required Tools |             |                     |     |
|----------------|-------------|---------------------|-----|
| Tool           | Part Number | Part Description    | Qty |
| A              | 5P-3931     | Anti-Seize Compound | -   |

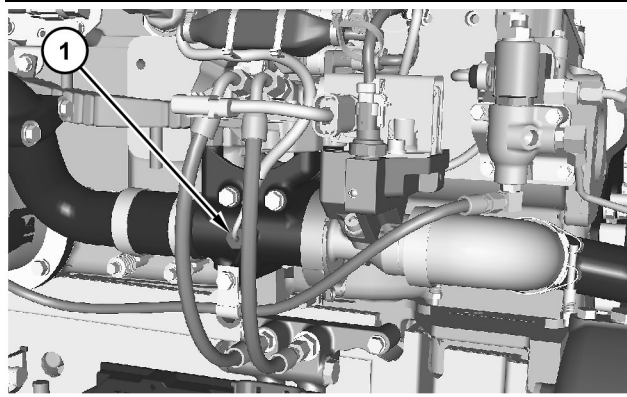


Illustration 312

g01872335

1. Disconnect the harness assembly and remove the temperature sensor (1).

### Installation Procedure

1. Install the temperature sensor (1) in reverse order.
  - a. Apply Tooling (A) to the threads of temperature sensor (1). Tighten the sensor to a torque of  $45 \pm 5$  N·m ( $33 \pm 4$  lb ft).

### Pressure Sensor (Cooled Exhaust Gas) - Remove and Install (Outlet Pressure)

SMCS Code: 1439

### Removal Procedure

Start By:

- a. Remove the fumes disposal group.

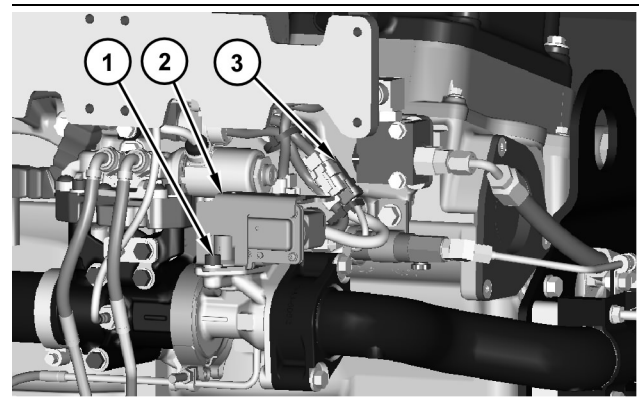


Illustration 313

g02348357

1. Disconnect the cable strap and disconnect harness assembly (3). Remove bolts (1) and remove differential pressure sensor (2). Remove the two O-ring seals (not shown).

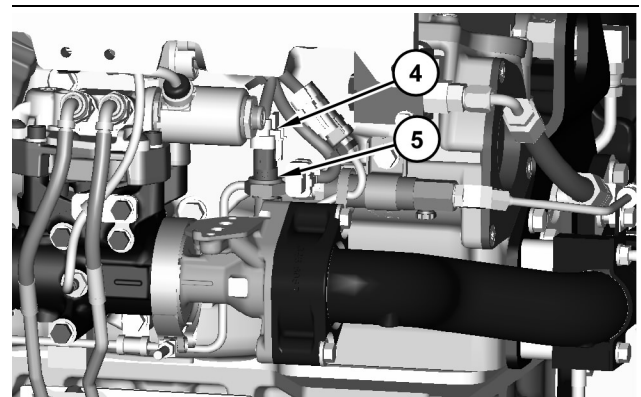


Illustration 314

g02348582

2. Disconnect harness assembly (4) and remove outlet pressure sensor (5). Remove the O-ring seal (not shown).

### Installation Procedure

1. Install the outlet pressure sensor (5) in the reverse order.

- a. Tighten outlet pressure sensor (5) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).
- b. Tighten bolts (1) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).

i03536313

## Pressure Sensor (Cooled Exhaust Gas) - Remove and Install (Differential Pressure)

i04151870

SMCS Code: 1439

### Removal Procedure

Start By:

- a. Remove the fumes disposal group.

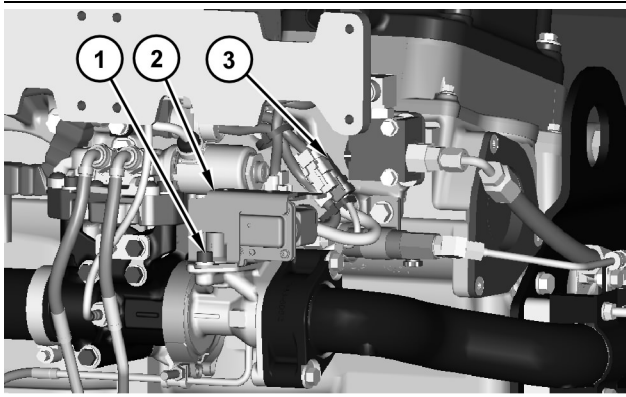


Illustration 315

g02348357

1. Disconnect the cable strap and disconnect harness assembly (3). Remove bolts (1) and remove differential pressure sensor (2). Remove the two O-ring seals (not shown).

### Installation Procedure

1. Install the differential pressure sensor (2) in the reverse order.
  - a. Tighten bolts (1) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).

## Boost Pressure Sensor - Remove and Install

SMCS Code: 1917-010

### Removal Procedure

Start By:

- a. Remove the fumes disposal group.

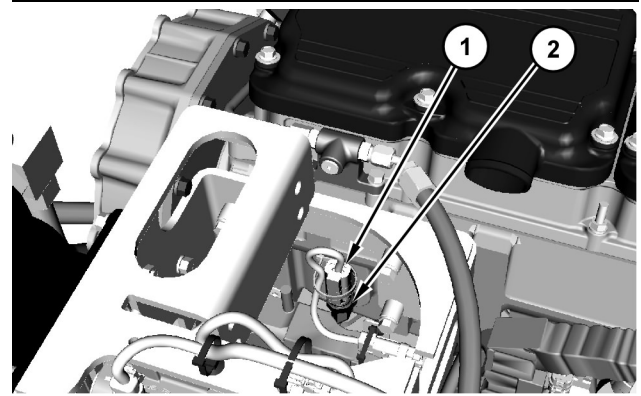


Illustration 316

g01864394

1. Disconnect harness assembly (1) and remove boost pressure sensor (2).

### Installation Procedure

1. Install boost pressure sensor (2) in reverse order.
  - a. Tighten boost pressure sensor (2) to a torque of  $10 \pm 2$  N·m ( $89 \pm 18$  lb in).

i03535343

## Inlet Air Temperature Sensor - Remove and Install

SMCS Code: 1921-010

### Removal Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

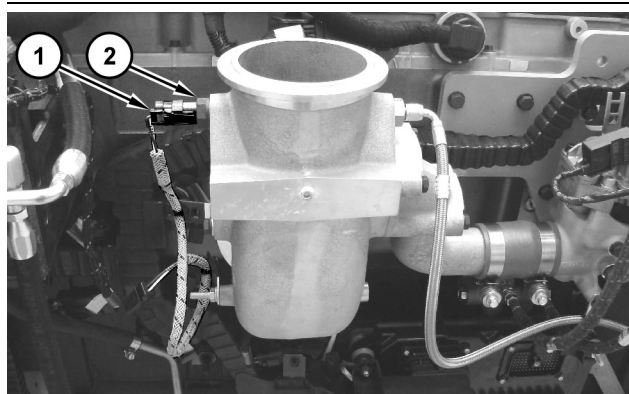


Illustration 317

g01863364

1. Disconnect harness assembly (1). Remove inlet air temperature sensor (2).

## Installation Procedure

1. Install the inlet air temperature sensor (2) in reverse order.
  - a. Tighten air temperature sensor (2) to a torque of  $20 \pm 5$  N·m ( $177 \pm 44$  lb in).

i03536083

## Inlet Manifold Temperature Sensor - Remove and Install

SMCS Code: 1921-010

### Removal Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

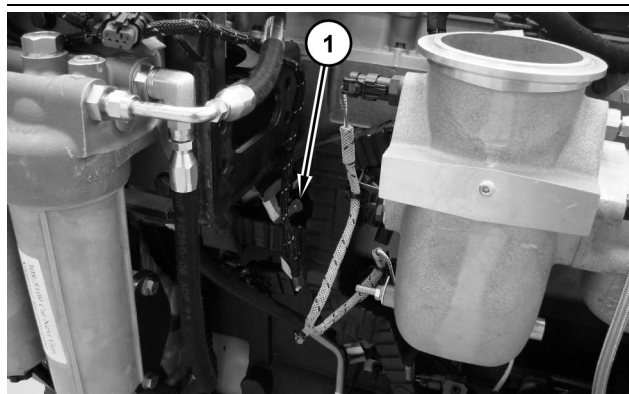


Illustration 318

g01864033

Showing the general location of the sensor

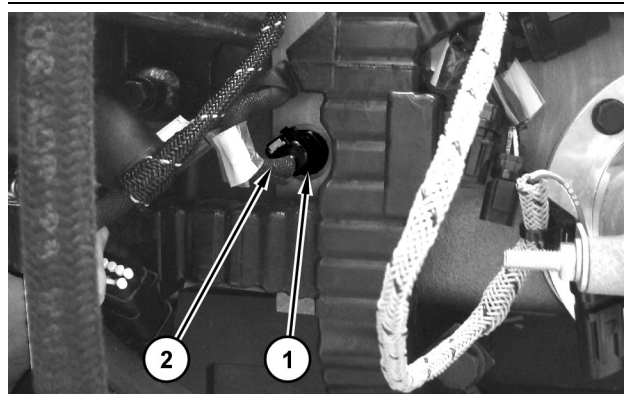


Illustration 319

g01864073

1. Disconnect harness assembly (1). Remove inlet manifold temperature sensor (2).

## Installation Procedure

1. Install the inlet manifold temperature sensor in reverse order.
  - a. Tighten inlet manifold temperature sensor (1) to a torque of  $20 \pm 5$  N·m ( $15 \pm 4$  lb ft).

i03541700

## Belt Tensioner - Remove and Install

SMCS Code: 1358-010

### Removal Procedure

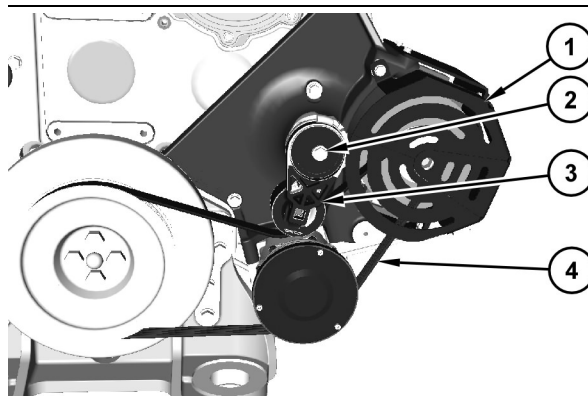


Illustration 320

g01870374

1. Remove guard (1).
2. Release the spring tension on belt tensioner (3) and remove belt (4).
3. Remove bolt (2) and remove belt tensioner (3).

## Installation Procedure

1. Install the belt tensioner (3) in reverse order.

i03859512

## Engine Control Module - Remove and Install

SMCS Code: 1901-010

### Removal Procedure

1. Disconnect the battery. Refer to Operation and Maintenance Manual, "Battery or Battery Cable - Disconnect".

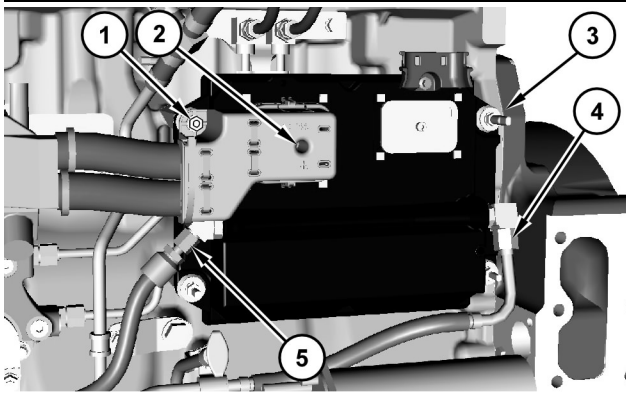


Illustration 321

g02103128

2. Remove nut (1).
3. Loosen allen head bolt (2) and position the harness assembly out of the way.
4. Disconnect hose assemblies (4) and (5).
5. Remove studs (3). Remove the engine control module, the washers, and the isolation mounts.

### Installation Procedure

1. Install the engine control module in reverse order.
  - a. Tighten allen head bolt (2) to a torque of  $6 \pm 1 \text{ N}\cdot\text{m}$  ( $53 \pm 9 \text{ lb in}$ ).

i02154932

## Electric Starting Motor - Remove and Install

SMCS Code: 1453-010

### Removal Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

#### WARNING

Accidental engine starting can cause injury or death to personnel working on the equipment.

To avoid accidental engine starting, disconnect the battery cable from the negative (-) battery terminal. Completely tape all metal surfaces of the disconnected battery cable end in order to prevent contact with other metal surfaces which could activate the engine electrical system.

Place a Do Not Operate tag at the Start/Stop switch location to inform personnel that the equipment is being worked on.

1. Disconnect the batteries.
2. Put an index mark on all of the harness assemblies that are connected to the electric starting motor and the solenoid.

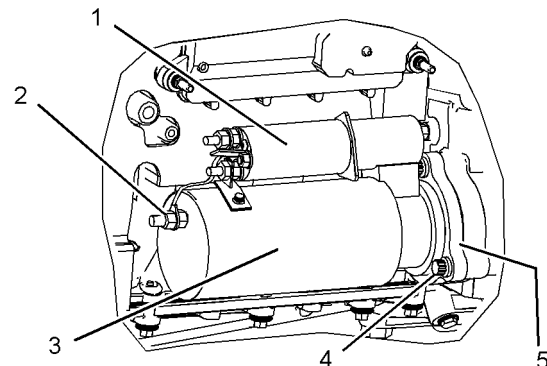


Illustration 322

g01100842

3. Disconnect the harness assemblies from solenoid (1).
4. Disconnect harness assembly (2).
5. Fasten a suitable lifting device to electric starting motor (3). The weight of the electric starting motor is approximately 26 kg (57 lb).

- Remove bolts (4). Remove electric starting motor (3) and gasket (5) from the flywheel housing.

## Installation Procedure

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

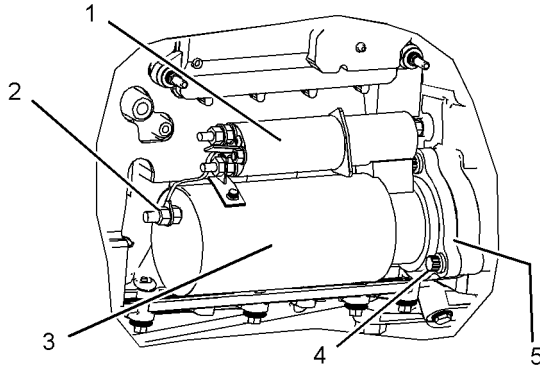


Illustration 323

g01100842

- Fasten a suitable lifting device to electric starting motor (3). The weight of electric starting motor is approximately 26 kg (57 lb).
- Position electric starting motor (3) and gasket (5) on the flywheel housing. Install bolts (4). Remove the lifting device from the electric starting motor.
- Position the harness assembly on the electric starting motor and install nut (2). Tighten the nut to a torque of  $31 \pm 4$  N·m ( $23 \pm 3$  lb ft).

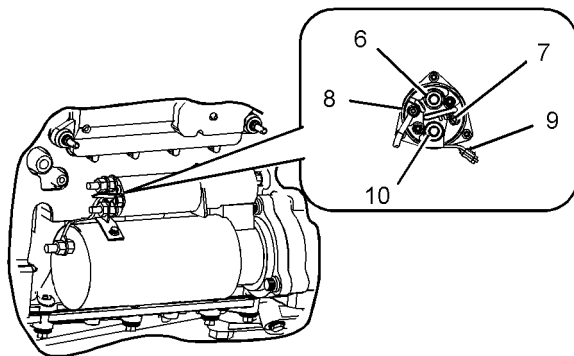


Illustration 324

g01100656

- Position the harness assembly on the solenoid and install nut (8). Tighten the nut to a torque of  $31 \pm 4$  N·m ( $23 \pm 3$  lb ft).
- Position the harness assembly on the solenoid and install nut (8). Tighten the nut to a torque of  $2.25 \pm 0.25$  N·m ( $20 \pm 2$  lb in).

- Position the harness assembly to the solenoid and install nut (7). Tighten the nut to a torque of  $2.25 \pm 0.25$  N·m ( $20 \pm 2$  lb in).
- If necessary, install the connector and install nut (10) and bolt (9). Tighten the nut and the bolt to a torque of  $31 \pm 4$  N·m ( $23 \pm 3$  lb ft).
- Connect the batteries.

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