

# Disassembly and Assembly

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## **854E-E34TA, 854F-E34T and 854F-E34TA Industrial Engines**

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JR (Engine)  
JS (Engine)  
JT (Engine)  
JV (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, including human factors that can affect safety. 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 verify that you are authorized to perform this work, and 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 you are authorized to perform this work, and 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.**

**Failure to follow this warning may 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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# Disassembly and Assembly Section

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## Inspection of Parts

### Reuse Guideline for the Flexible Exhaust Pipe

This Information Element will address the following applications for the lines group - flex pipe: the installation, the handling and the reusability. The lines group - flex pipe is defined as the connection between the turbocharger diffuser outlet and the Clean Emissions Module (CEM) inlet.

### Removal of the Lines Group

#### Removal Procedure

#### 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.

#### 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 uniformity of the spacing between the convolutions.

Inspect the bellows for damage prior to installation. If there is any damage to the convolutions, discard the bellows. If there is any difficulty in installation after the repair, discard the bellows.

The alignment of the bellows is important. Improper lateral alignment is two sealing surfaces that do not align with each other. The proper lateral adjustment is shown in Illustration 1 .

Proper alignment means that initial alignment of all components that are held together by the components referenced in Illustration 1 are maintained.

**Note:** Do not force the bellows into the position.

**Note:** Failure to reinstall the bellows into the as removed alignment will result in a failure of the part and a needed replacement.

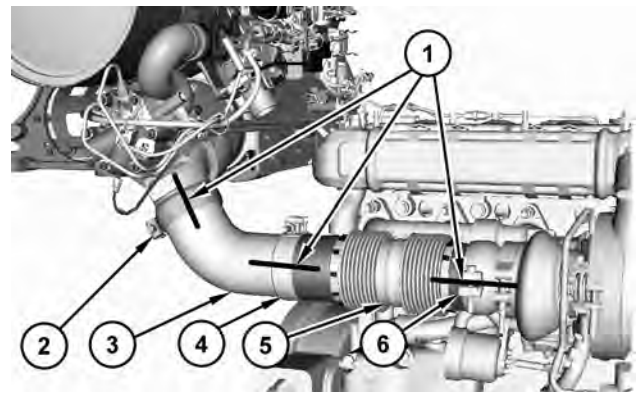


Illustration 1

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#### Typical example

- (1) Alignment marks
- (2) Ball clamp
- (3) Tube
- (4) Slip joint clamp
- (5) Bellows
- (6) Ball clamp

1. Draw alignment marks that will cover both the lines group and the associated clamps. Refer to Illustration 1 .

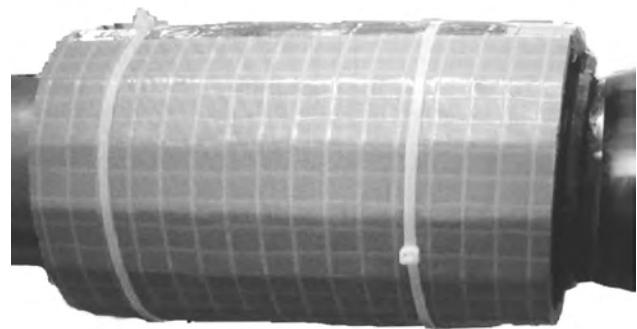


Illustration 2

g02239794

#### Typical example

Bellows with protective covering installed

2. Wrap the bellows with a protective cover to avoid possible damage to the bellows during the removal and installation.
3. Loosen clamp assemblies (2), and (6).
4. Remove the lines group.

**Note:** Removal of the entire line group as a whole is ideal. However, in some applications the assembly must be disassembled further in order for the assembly to be removed.

## Disassembly and Assembly Section

**Note:** Care should be taken when handling the lines group. The slightest bump or drop can result in a misalignment of the bellows and a possible need for replacement.

5. Discard clamp assemblies (2) and (6). The clamp assemblies are a one time use part.

**Note:** Steps 6 through 7 are only necessary if clamp (4) was loosened to remove the entire lines group.

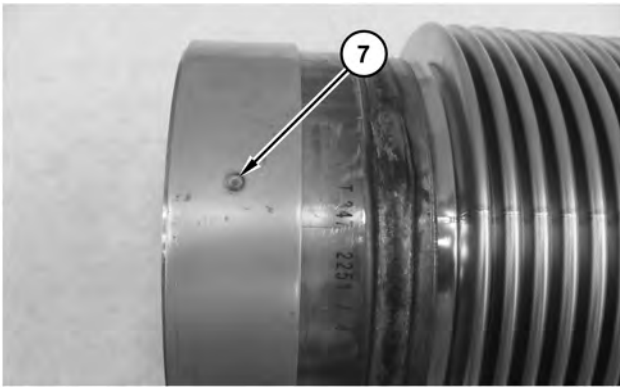


Illustration 3

g02231056

Typical example

(7) Weld

6. Remove clamp (4) from bellows (5) by removing weld (7). Use a grinding device to remove the spot weld.

**Note:** Use care not to remove excessive amounts of material and grind on the bellows.

**Note:** Do not use a vice to secure the lines group. The bellows cannot be damaged in any way during this procedure.

**Note:** Use the proper personal protective equipment when removing clamp (4) from the bellows assembly.



Illustration 4

g02231059

Typical example

Remove the weld from the bellows assembly with a grinding device

7. Inspect the clamping surface on the outside of the bellows. Deburr the surface if necessary.

**Note:** If the bellows assembly is damaged during the removal of clamp (4), replace the bellows assembly.

### Installation

**Note:** Step 1 is only necessary if clamp (4) was loosened to remove the entire lines group.

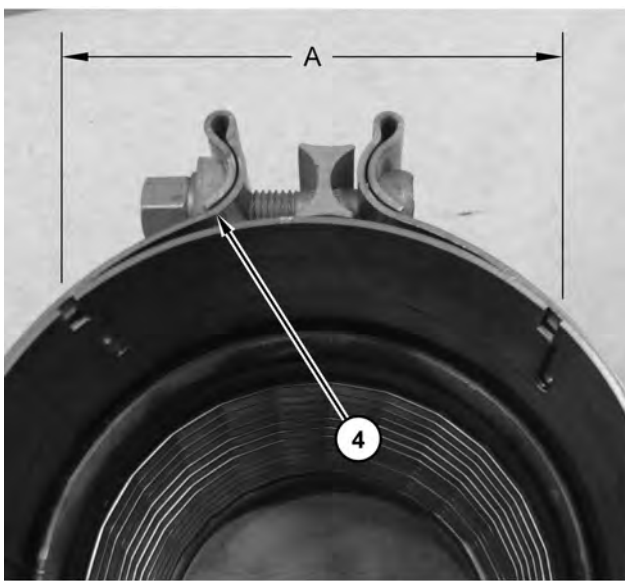


Illustration 5 g02231073

Typical example

1. Install new clamp (4) with the tightening assembly centered between reliefs (A). Do not torque the clamp until Step 12

**Note:** The end of the clamp must be flush with the end of the bellows assembly.

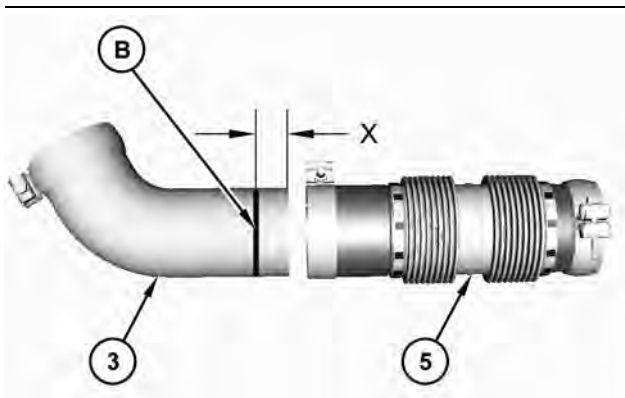


Illustration 6 g02211937

Typical example

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

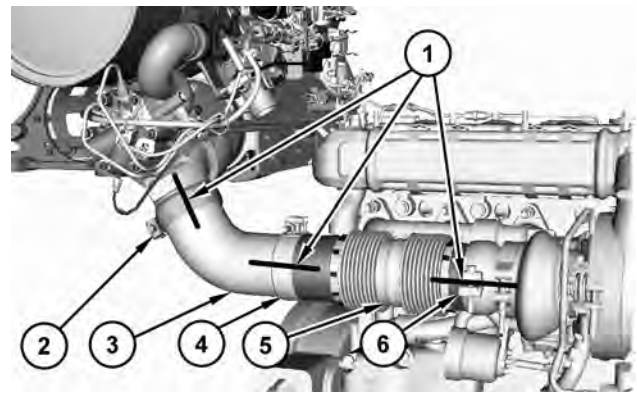


Illustration 7 g02211913

Typical example

Alignment wrap is not shown for photographic purposes.

4. Prior to installation, position both ball clamp assemblies (2) and (6) onto the lines group.
5. Position the lines group between the Clean Emissions Module and the turbocharger adapter. Adjust the length of tube (3) in the slip joint at clamp assembly (4) in order to position the lines group.

**Note:** Do not force any of the components into the position.

**Note:** Make sure that you loosely fit all of the parts before the final torquing is started.

**Note:** Failure to reinstall the bellows into the original alignment will result in a failure of the part and a needed replacement.

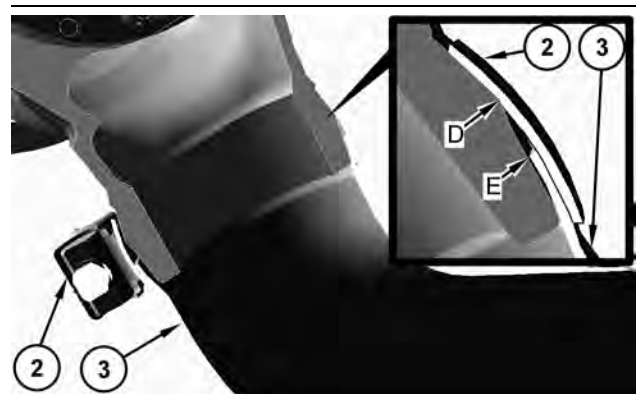


Illustration 8 g02211953

Typical example

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

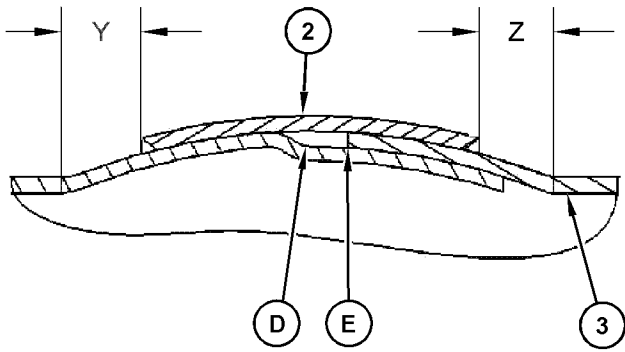


Illustration 9

g02211955

### Typical example

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

- Verify that the cup of the ball joint (E) does not touch the radius of the ball (D). Position ball clamp (2) and loosely tighten ball clamp (2).

**Note:** The ball clamp that is opposite the bellows must always be tightened first. Clamp (2) which can be located at the turbocharger diffuser outlet or the CEM inlet must be tightened first. Refer to Illustration 10 and Illustration 11 for example of the possible placement of clamp (2).

- Verify that the ball clamp is centered. Measurement (Y) and measurement (Z) must be within 2 mm (0.07874 inch) of each other. Refer to Illustration 9.

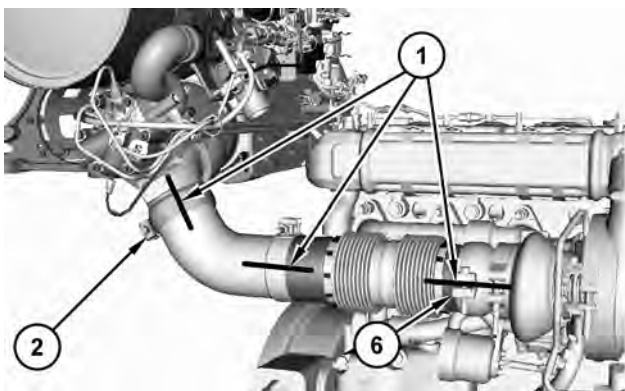


Illustration 10

g02239874

### Typical example

Example of configuration with the bellows located near the turbocharger outlet

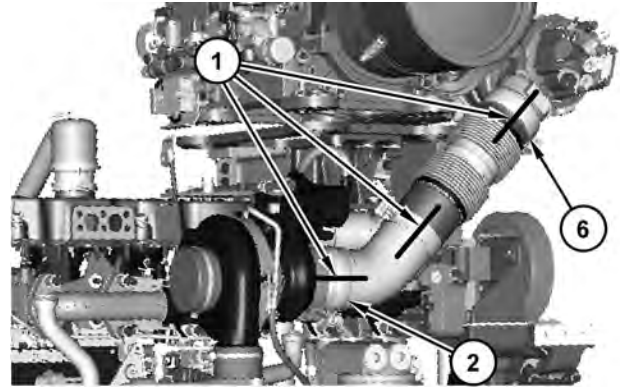


Illustration 11

g02239877

### Typical example

Example of configuration with the bellows located near the CEM inlet

- Repeat Step 6 and 7 for ball clamp (6).
- Verify that Mark (B) is not visible at the slip joint that is positioned near clamp assembly (4).

**Note:** Use hand tools to torque clamps on Steps 10 through 12. Do not use power tools in order to torque clamp assemblies (2), (4), and (6).

**Note:** The ball clamp that is opposite the bellows must always be tightened first. In Illustration 10 the ball clamp that must be tightened first is located at the CEM inlet. In Illustration 11 the ball clamp that must be tightened first is located at the turbocharger diffuser outlet.

- Torque ball clamp (2) to a torque of  $35 \pm 2 \text{ N}\cdot\text{m}$  ( $26 \pm 1 \text{ lb ft}$ ).
- Torque ball clamp (6) to a torque of  $35 \pm 2 \text{ N}\cdot\text{m}$  ( $26 \pm 1 \text{ lb ft}$ ).
- Torque clamp assembly (4) to a torque of  $55 \pm 8 \text{ N}\cdot\text{m}$  ( $41 \pm 6 \text{ lb ft}$ ).
- Remove the protective cover that was installed in Step 2 of the removal section.



## Examples of Possible Misalignment and Results

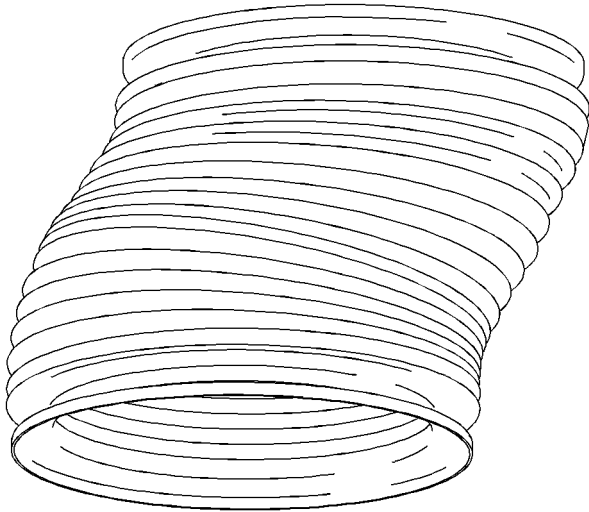


Illustration 12

g01023261

### Typical example

#### Example of lateral misalignment

Lateral misalignment is shown in Illustration 12 . Lateral misalignment on the exhaust bellows can lead to contact between liner and convolutions. The misalignment can cause premature failure.

Lateral misalignment is identified by visually inspecting the convolutions on the bellows. The visual inspection will help ensure an even amount of spacing between each of the convolutions.

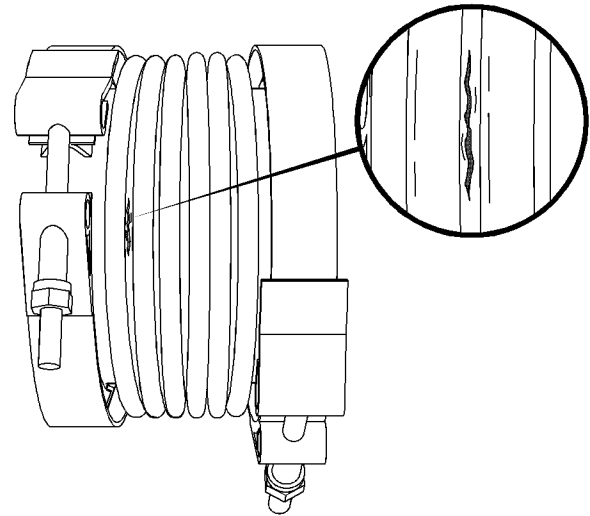


Illustration 13

g01016673

### Typical example

#### Example of premature failure due to lateral misalignment

Improper alignment during installation can lead to premature failure of the bellows. An Example of premature failure is shown in Illustration 13 .

## Handling

Bellows should be handled by the convolutions. The convolutions are the ribbed portion of the bellows. The ends of the bellows could be sharp and the ends should be handled carefully. The bellows can be damaged if the bellows are dropped.

## Reusability

**Note:** If there are any indications of separation of the layers or difficulty with the installation, discard the bellows. Failure to replace the bellows could result in the following problems: improper seating, subsequent air leakage and Exhaust leakage.

The bellows consist of multiple layers of material that are pressed together.

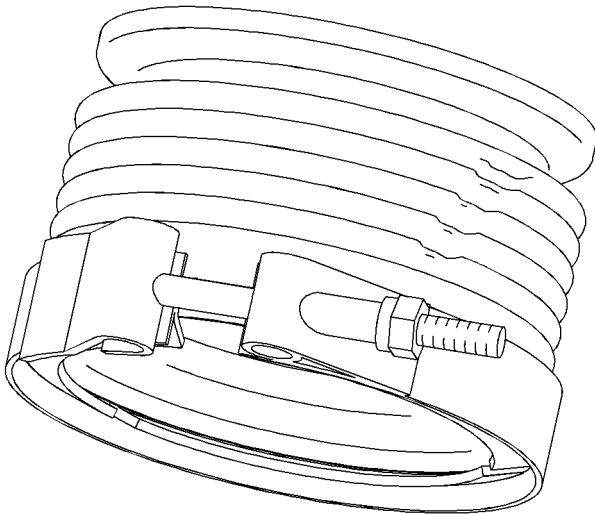


Illustration 14

g01016669

Typical example

Example of damage to the convolutions

Inspect the bellows for damage. The part should be discarded if damage to the convolutions is present. Illustration 14 shows that damage to the convolutions.

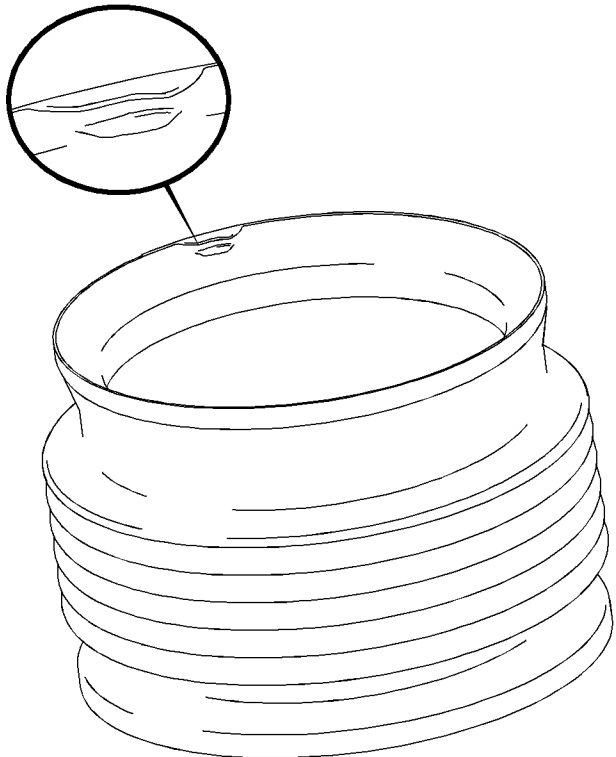


Illustration 15

g02240434

Typical example

Example of a bad edge

If damage has occurred to the edges of the bellows, the bellows must be replaced.

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## Fuel Priming Pump - Remove and Install

### Removal Procedure

Table 1

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

#### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

#### 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.

Dispose of all fluids according to local regulations and mandates.

1. Turn the fuel supply to the OFF position.

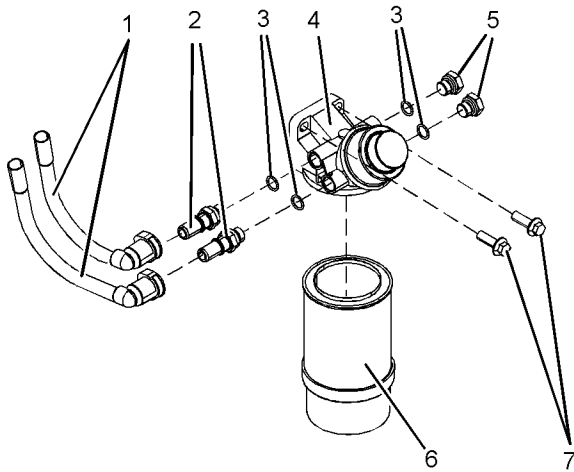


Illustration 16

g02988817

Typical example

2. Make a temporary identification mark on plastic tube assemblies (1) in order to show the correct position of the tube assemblies.
3. Place a suitable container below the fuel priming pump in order to catch any fuel that might be spilled. Drain primary filter (7). Refer to Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace".
4. Disconnect plastic tube assemblies (1). Use Tooling (A) to plug the tube assemblies with new plugs.
5. Use Tooling (A) cap open connectors (2) on the fuel priming pump with new caps.
6. Remove primary filter (6) from fuel priming pump (4). Refer to Operation and Maintenance, "Fuel System Primary Filter (Water Separator) Element - Replace".
7. Remove bolts (7) from fuel priming pump (4). Remove fuel priming pump (4) from the mounting bracket.
8. If necessary, follow Steps 8.a through 8.d in order to disassemble fuel priming pump (4).
  - a. Remove connectors (2) from fuel priming pump (4). Use Tooling (A) to plug fuel priming pump (4).
  - b. Use Tooling (A) to cap connectors (2).
  - c. Remove plugs (5) from fuel priming pump (4). Use Tooling (A) to plug fuel priming pump (4).

- d. Remove O-ring seals (3) from connectors (2) and plugs (5).

## Installation Procedure (Mechanical Priming Pump)

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Ensure that fuel priming pump (4) is clean and free from wear or damage. If necessary, replace the fuel priming pump.

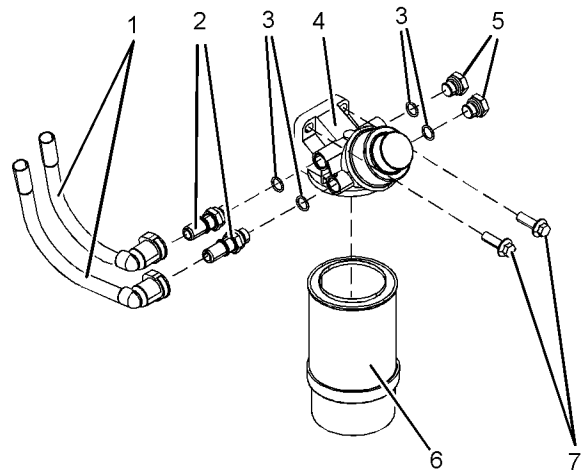


Illustration 17

g02988817

Typical example

2. If necessary, follow Steps 2.a through 2.f in order to assemble fuel priming pump (4).
  - a. Install new O-ring seals (3) to plugs (5).
  - b. Remove caps from connectors (2). Install new O-ring seals (3) connectors (2).
  - c. Remove plugs from fuel priming pump (4).

## Disassembly and Assembly Section

- d. Install connectors (2) to fuel priming pump (4).
  - e. Install plugs (5) to fuel priming pump (4).
  - f. Tighten the plugs and the connectors to a torque of 20 N·m (14 lb ft).
3. Position fuel priming pump (4) on the mounting bracket. Install bolts (7) to the fuel priming pump . Tighten the bolts to a torque of 44 N·m (32 lb ft).
  4. Remove the plugs from the plastic tube assemblies. Remove the caps from the connectors.
  5. Connect plastic tube assemblies (1) to connectors (2).

**Note:** Ensure that the plastic tube assemblies are installed in the original positions.

6. Install a new primary filter (6) to fuel priming pump (4). Refer to Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace".
7. Turn the fuel supply to the ON position.
8. Prime the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime".

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## Flow Control Valve - Remove and Install

### Removal Procedure

Table 2

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

### WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

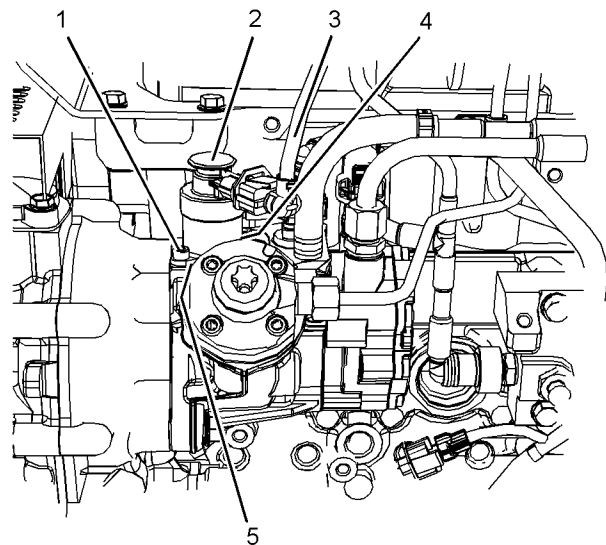


Illustration 18

g02986577

3. Clean the area around flow control valve (2) and fuel injection pump. Ensure that the area is free from contamination before beginning disassembly.
4. Disconnect harness assembly (3) from flow control valve (2).
5. Make temporary marks on the flow control valve and the fuel injection pump for installation purpose.
6. Remove Torx heads screws (1) from the flow control valve.
7. Remove flow control valve (2) from the fuel injection pump.

8. Use Tooling (A) in order to plug the fuel injection pump.
9. Remove O-ring seal (4) (not shown) and O-ring seal (5) (not shown).

## Installation Procedure

1. Ensure that all component at free from wear and damage. If any part of the flow control valve is worn or damaged, the flow control valve must be replaced as an assembly.

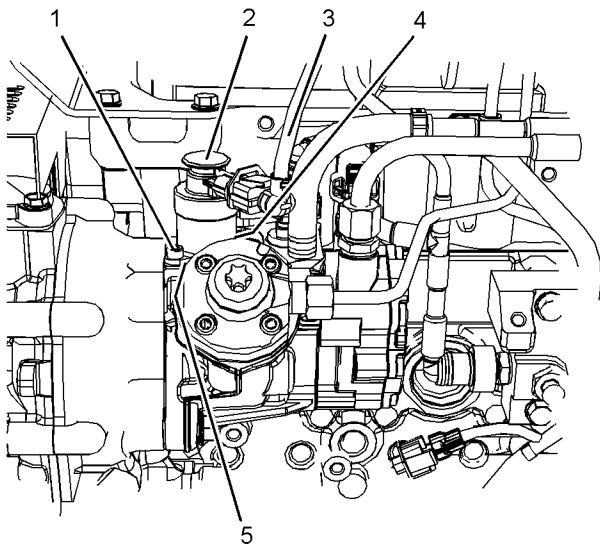


Illustration 19

g02986577

2. Position a new O-ring seal (4) (not shown) and new O-ring seal (5) (not shown) onto the flow control valve assembly.
3. Check O-ring seal (4) (not shown) and O-ring seal (5) (not shown) are correctly positioned. Ensure that O-ring seals are not damaged.
4. Lubricate O-ring seal (4) (not shown) and O-ring seal (5) (not shown) with clean fuel.

**Note:** Ensure that the O-ring seals are not damaged or misaligned.

5. Remove Tooling (A) from the fuel injection pump.
6. Install flow control valve (3) to the fuel injection pump.
7. Install Torx head screws (2) from the flow control valve repair kit.
8. Tighten Torx head screws (2) equally until the flow control valve is seated correctly onto the fuel injection pump.

**Note:** Ensure that the Torx screws are tightened equally. Failure to ensure that the Torx screws are tightened equally will result in damage to the fuel injection pump.

9. Tighten the Torx head screws to a torque of 9 N·m (80 lb in).
10. Connect harness assembly (1) to flow control valve (3).
11. Replace the filters for primary fuel system. Refer to Operation and Maintenance Manual, "Fuel System Primary (Water Separator) Element - Replace" for the correct procedure.
12. Replace the filters for secondary fuel system. Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for the correct procedure.
13. Turn the fuel supply to the ON position.
14. Turn the battery disconnect switch to the ON position.
15. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for more information.

### End By:

- a. After replacement of the flow control valve, the fuel injection pump requires a high-pressure fuel pump calibration procedure to be performed. Refer to Troubleshooting, "Fuel Rail Pressure Problem" for the correct procedure.

i05268269

## Fuel Filter Base - Remove and Install

### Removal Procedure

Table 3

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

**NOTICE**

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

**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.

Dispose of all fluids according to local regulations and mandates.

1. Turn the battery disconnect switch to the OFF position.
2. Turn the fuel supply to the OFF position.
3. Drain the secondary filter. Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for the correct procedure.

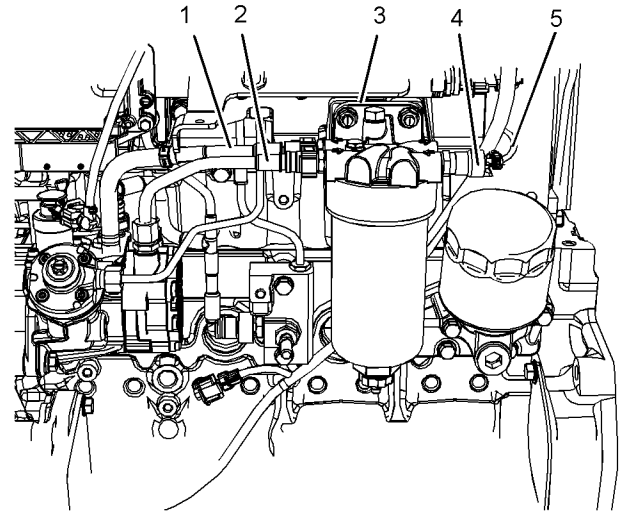


Illustration 20

g03011036

4. Make temporary identification marks on plastic tube assembly (1) and plastic tube assembly (2) in order to show the correct position of the plastic tube assemblies.
5. Place a suitable container below the fuel filter base in order to catch any fuel that might be spilled.
6. Disconnect plastic tube assembly (1) and plastic tube assembly (2) from fuel filter base (3).
7. Use Tooling (A) in order to plug plastic tube assembly (1) and plastic tube assembly (2)
8. Use Tooling (A) in order to cap the connection on fuel filter base (3).
9. Slide locking tab in to the unlock position. Disconnect harness assembly (5) from fuel temperature sensor (4).

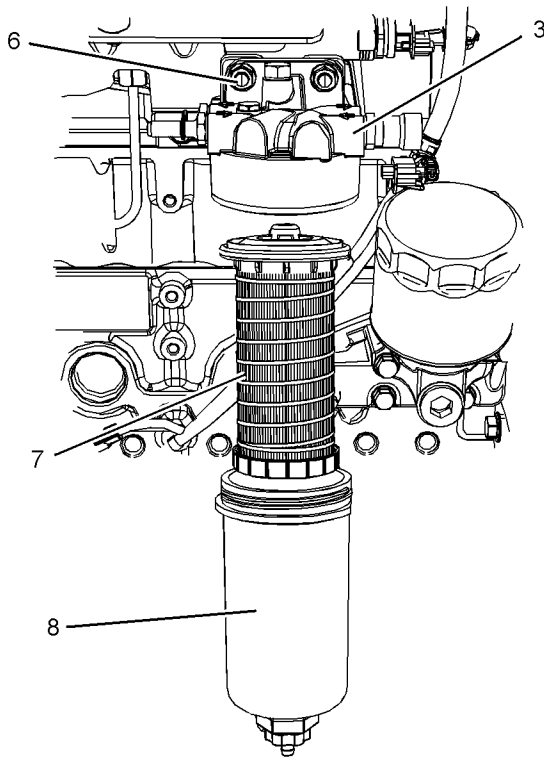


Illustration 21

g03011037

- 10.** Remove cannister (8) from fuel filter base (3). Remove secondary filter (7). Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for the correct procedure.
- 11.** Remove nuts (6) from fuel filter base (3). Remove the fuel filter base from the mounting bracket.

**Note:** Do not disassemble the fuel filter base.

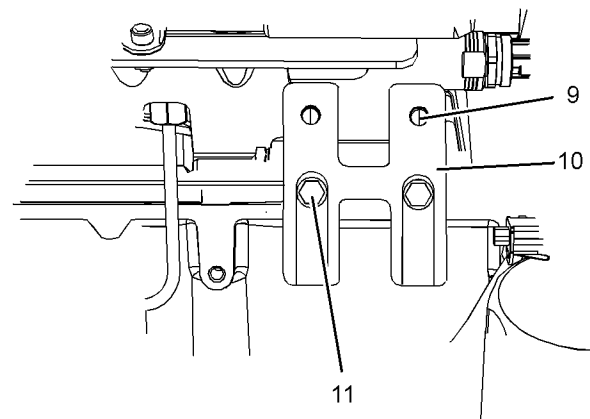


Illustration 22

g03011038

- 12.** If necessary, follow Step 1.c through Step 12.c in order to remove the bracket for secondary fuel filter.
- Remove bolts (11) fuel filter bracket (10).
  - Remove fuel filter bracket (10) from the valve mechanism cover.
  - If necessary, remove studs (9) from fuel filter bracket (10).

## Installation Procedure

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

### NOTICE

Ensure that the wiring harness assembly is correctly routed and the cable straps are not over tightened. Over tightening of the cable straps will damage the wiring harness and the convoluting.

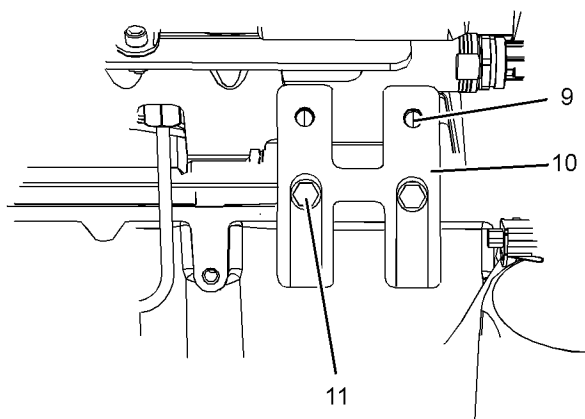


Illustration 23

g03011038

1. If necessary, follow Step 1.a through Step 1.c in order to install the bracket for secondary fuel filter.
  - a. If necessary, install studs (9) to fuel filter bracket (10). Tighten studs (9) to a torque of 18 N·m (159 lb in).
  - b. Position fuel filter bracket (10) onto the valve mechanism cover. Install bolts (11) to fuel filter bracket (10).
  - c. Tighten bolts (11) to a torque of 25 N·m (221 lb in).

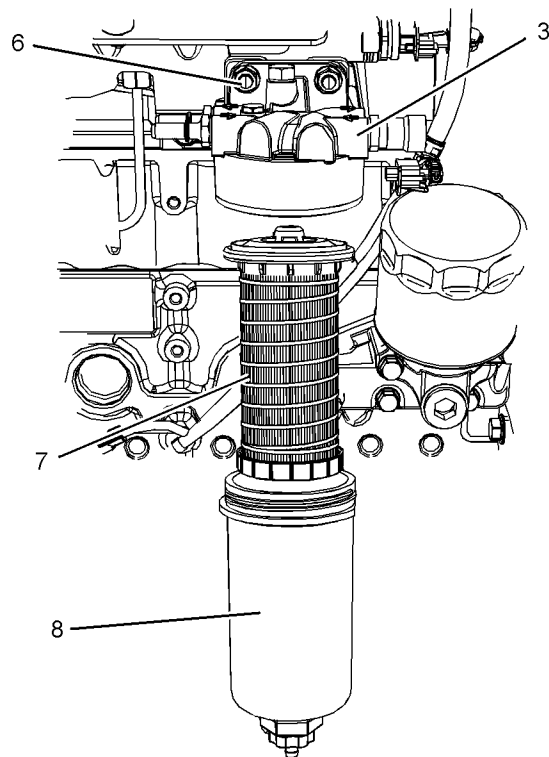


Illustration 24

g03011037

2. Ensure that fuel filter base (3) is clean and free from damage. If necessary, replace the complete fuel filter base and filter assembly.
3. Position fuel filter base (3) on the mounting bracket. Install nuts (6). Tighten the bolts to a torque of 25 N·m (221 lb in).
4. If necessary, install a new fuel filter (7) to canister (8). Install canister (8) to fuel filter base (3). Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for the correct procedure.



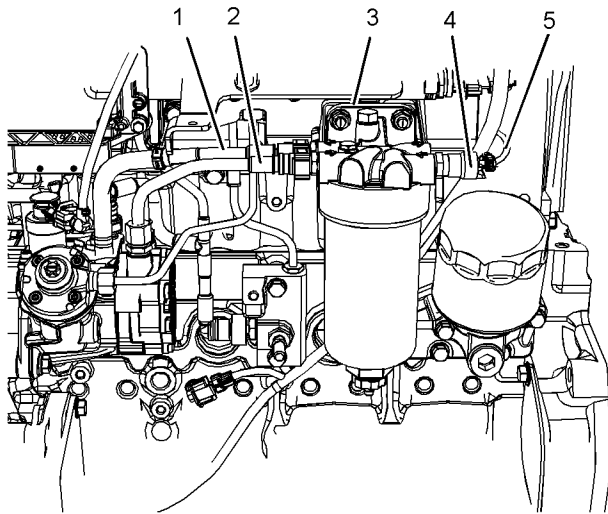


Illustration 25

g03011036

5. Remove the plugs from the plastic tube assemblies. Remove the caps from the ports in the fuel filter base.

#### NOTICE

Ensure that the plastic tube assemblies are installed in the original positions. Failure to connect the plastic tube assemblies to the correct ports will allow contamination to enter the fuel system. Allowing contamination to enter the fuel system will cause serious damage to the engine.

6. Connect plastic tube assembly (1) and plastic tube assembly (2) to the fuel filter base.
7. Connect harness assembly (5) to fuel temperature sensor (4). Slide locking tab in to the lock position.
8. Turn the fuel supply to the ON position.
9. Turn the battery disconnect switch to the ON position.

#### End By:

- a. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.

i05268272

## Water Separator and Fuel Filter (Primary) - Remove and Install

### Removal Procedure

Table 4

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

#### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Turn the battery disconnect switch to the OFF position.
2. Turn the fuel supply to the OFF position.

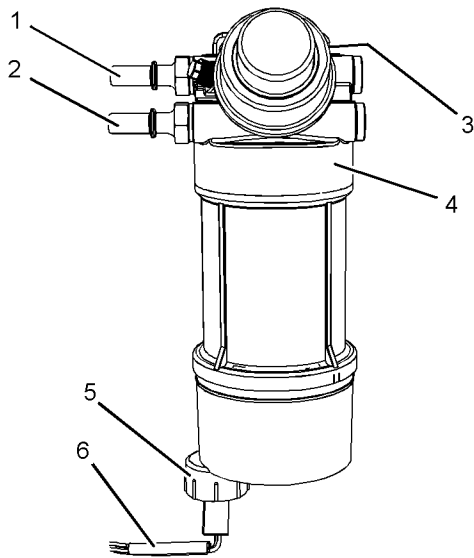


Illustration 26

g03011667

3. Make temporary identification marks on plastic tube assemblies in order to show the correct position of the plastic tube assemblies.
4. Place a suitable container below the fuel filter base in order to catch any fuel that might be spilled.
5. Disconnect the plastic tube assembly from connecting (1). Use Tooling (A) in order to plug the plastic tube assemblies. Use Tooling (A) in order to cap connection (1).
6. Disconnect the plastic tube assembly from connecting (2). Use Tooling (A) in order to plug the plastic tube assemblies. Use Tooling (A) in order to cap connection (2).
7. Disconnect the Original Equipment Manufactures (OEM) harness assembly (6) from water in fuel sensor (5).
8. Remove bolts (2) (not shown) and remove the assembly of primary fuel filter (4) from the mounting bracket.

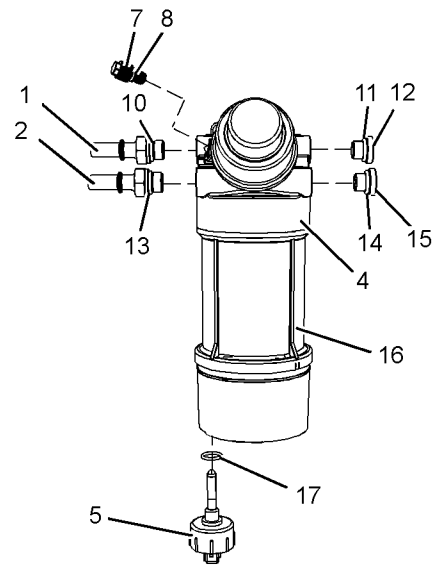


Illustration 27

g03011668

9. If necessary, follow Step 9.a through Step 9.g in order to disassembly the assembly of primary fuel filter (4).
  - a. Remove vent screw assembly (7) and remove O-ring seal (8). Use Tooling (A) in order to plug the primary fuel filter (4). Use Tooling (A) in order to cap vent screw assembly (7).
  - b. Remove connection (1) and remove O-ring seal (10). Use Tooling (A) in order to plug primary fuel filter (4). Use Tooling (A) in order to cap connection (1).
  - c. Remove connection (2) and remove O-ring seal (13). Use Tooling (A) in order to plug primary fuel filter (4). Use Tooling (A) in order to cap connection (1).
  - d. Remove plug (12) and remove O-ring seal (13). Use Tooling (A) in order to plug primary fuel filter (4).
  - e. Remove plug (15) and remove O-ring seal (14). Use Tooling (A) in order to plug primary fuel filter (4).
  - f. Remove water in fuel sensor (6) and remove O-ring seal (17).
  - g. Remove the filter element from fuel filter canister (16). Refer to Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace" for the correct procedure.

## Installation Procedure

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Ensure that the fuel filter base is clean and free from damage. If necessary, replace the complete fuel filter base and filter assembly.

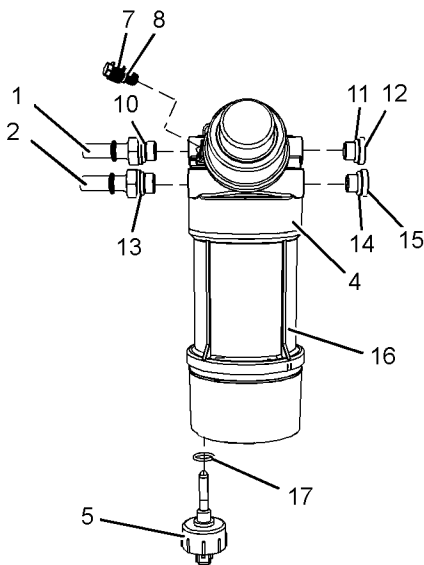


Illustration 28

g03011668

2. If necessary, follow Step 2.a through Step 2.i in order to assemble primary fuel filter (1).
  - a. Install a new filter element to fuel filter canister (16). Refer to Operation and Maintenance Manual, "Fuel System Primary Filter (Water Separator) Element - Replace" for the correct procedure.
  - b. Remove cap from connection (1). Install a new O-ring seal (10) to connection (1).
  - c. Remove plug from primary fuel filter (4). Install connection (1) to primary fuel filter (4). Tighten the connection to a torque of 20 N·m (177 lb in).

- d. Remove cap from connection (2). Install a new O-ring seal (13) to connection (2).
- e. Remove plug from primary fuel filter (4). Install connection (2) to primary fuel filter (4). Tighten the connection to a torque of 20 N·m (177 lb in).
- f. Install a new O-ring seal (13) to plug (12). Install plug (12) to primary fuel filter (4). Tighten the plug to a torque of 20 N·m (177 lb in).
- g. Install a new O-ring seal (14) to plug (15). Install plug (15) to primary fuel filter (4). Tighten the plug to a torque of 20 N·m (177 lb in).
- h. Remove cap from vent screw assembly (7). Install a new O-ring seal (8) to vent screw assembly (7). Install vent screw assembly (7) to primary fuel filter (4). Tighten the vent screw assembly securely.
- i. Install a new O-ring seal (17) to water in fuel sensor (5). Install water in fuel sensor (5) to primary fuel filter (4). Tighten water in fuel sensor (5) hand tight.

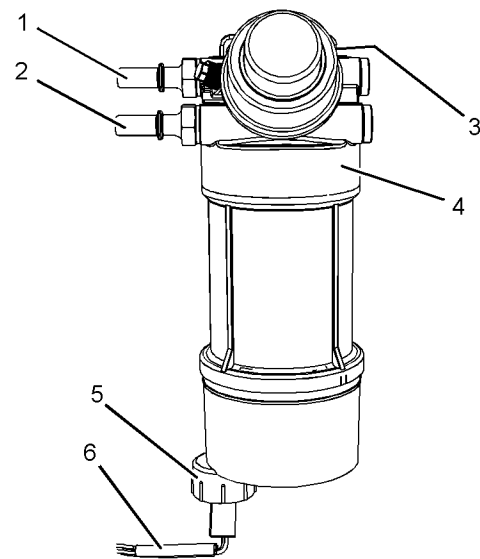


Illustration 29

g03011667

3. Position the assembly of primary fuel filter (4) onto the mounting bracket.
4. Install bolts (3) (not shown) to the assembly of primary fuel filter (4). Tighten the bolts to a torque of 50 N·m (37 lb ft).

**NOTICE**

Ensure that the plastic tube assemblies are installed in the original positions. Failure to connect the plastic tube assemblies to the correct ports will allow contamination to enter the fuel system. Serious damage to the engine will result if contaminated fuel enters the fuel system.

5. Remove plug from the plastic tube assembly. Remove cap from connecting (1) on primary fuel filter (4). Connect the plastic tube assembly to connecting (1) on primary fuel filter (4).
6. Remove plug from the plastic tube assembly. Remove cap from connecting (2) on primary fuel filter (4). Connect the plastic tube assembly to connecting (2) on primary fuel filter (4).
7. Connect the OEM harness assembly (6) to water in fuel sensor (5).
8. Turn the fuel supply to the ON position.
9. Turn the battery disconnect switch to the ON position.

**End By:**

- a. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.

i05268273

## Fuel Manifold (Rail) - Remove and Install

### Removal Procedure

Table 5

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

**Start By:**

- a. Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove" for the correct procedure.


**WARNING**

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

**NOTICE**

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

**Note:** Plug or cap all open ports with new plugs or new caps.

1. Thoroughly clean the area around fuel manifold (12).

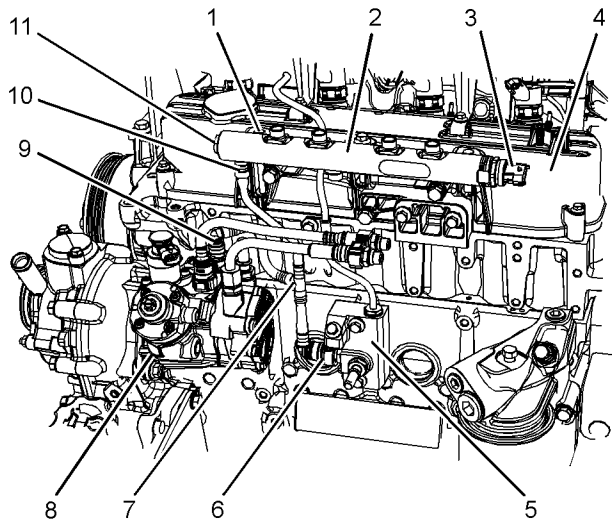


Illustration 30

g02652897

- a. Release hose clamp (9) on plastic tube assembly (6).
- b. Disconnect plastic tube assembly (6) from the fuel manifold (2).
- c. Use Tooling (A) to cap the open port in fuel manifold (2) with a new cap.
- d. Remove seal (10).
- e. Use Tooling (A) to plug the open end of plastic tube assembly (6) with a new plug.

## Installation Procedure

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

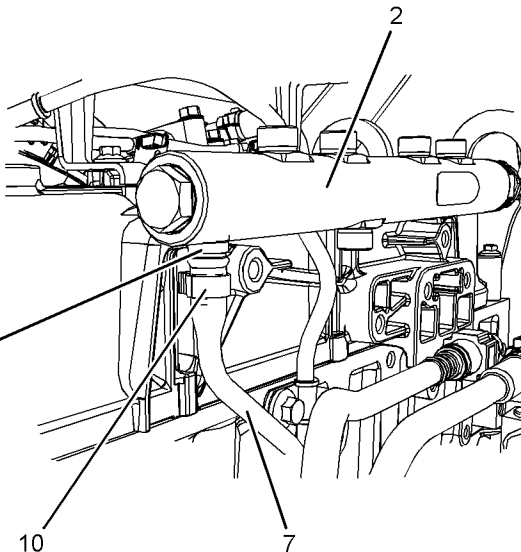


Illustration 31

g02856697

2. Disconnect hose assembly connection (8) from fuel injection pump (7).
3. Disconnect hose assembly connection (5) from fuel distribution block (4).
4. Remove bolts (1) from fuel manifold (2). Remove the fuel manifold from the valve mechanism cover (3).
5. If necessary, follow Step 5.a through Step 5.e in order to remove plastic tube assembly (6).

1. Ensure that all ports on the fuel manifold are capped. Ensure that the fuel manifold is externally clean and free from damage.

**Note:** Do not install a fuel manifold that has not been plugged. All plugs and caps must be left in place until the fuel injection lines are about to be installed.

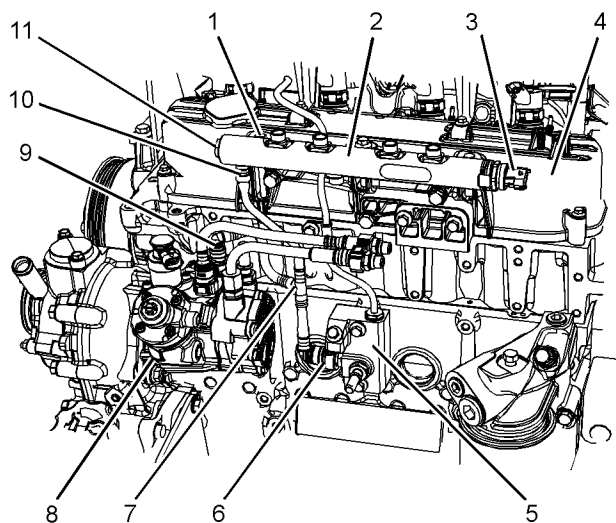


Illustration 32

g02652897

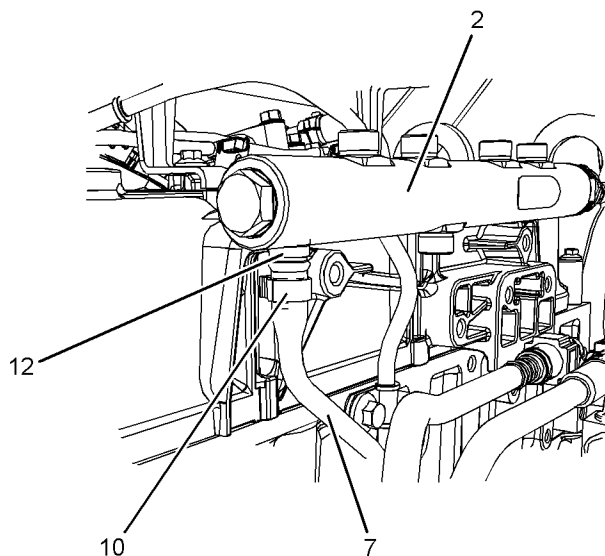


Illustration 33

g02856697

2. If necessary, follow Step 2.a through Step 2.d in order to install tube assembly (6) to fuel manifold (2).
  - a. Position hose clamp (9) onto plastic tube assembly (6).
  - b. Install new seal (10) into plastic tube assembly (6).
  - c. Install plastic tube assembly (6) to fuel manifold (2).

**Note:** Ensure that the plastic tube assembly is correctly orientated.

d. Tighten hose clamp (9) securely.

3. Position fuel manifold (2) onto valve mechanism cover (3). Install bolts (1) to fuel manifold (2) finger tight.
4. Install new fuel injection lines finger tight. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for the installation procedure.

**Note:** Do not torque the nuts for the fuel injection lines at this stage of the assembly procedure.

5. Tighten bolts (1) to a torque of 27 N·m (239 lb in).
6. Tighten the nuts for the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for the correct torque.
7. Remove the plug from connection (8) and install plastic tube assembly (6) to the fuel injection pump (7).
8. Remove the plug from connection (5) and install plastic tube assembly (6) to distribution block (4).
9. For the remaining installation procedure for the fuel injection lines, refer to Disassembly and Assembly, "Fuel Injection Lines - Install".

**End By:**

- a. If a new fuel manifold is installed, it will be necessary to use the electronic service tool in order to perform the "Rail Pressure Valve Learn Reset" procedure.

i05268277

## Fuel Injection Lines - Remove

### Removal Procedure

Table 6

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1
B	-	LASER 4920 1/2 Inch Drive HP Fuel Line Socket Set	1

## ⚠ WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

### 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.

Dispose of all fluids according to local regulations and mandates.

**Note:** Put identification marks on all hoses on all hose assemblies and on wires and all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. Plugging all hose assemblies and tube assemblies will help to prevent fluid loss and helps to keep contaminants from entering the system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.
3. If necessary, remove the Diesel Particulate Filter (DPF). Refer to Disassembly and Assembly, "Diesel Particulate Filter - Remove" for the correct procedure.

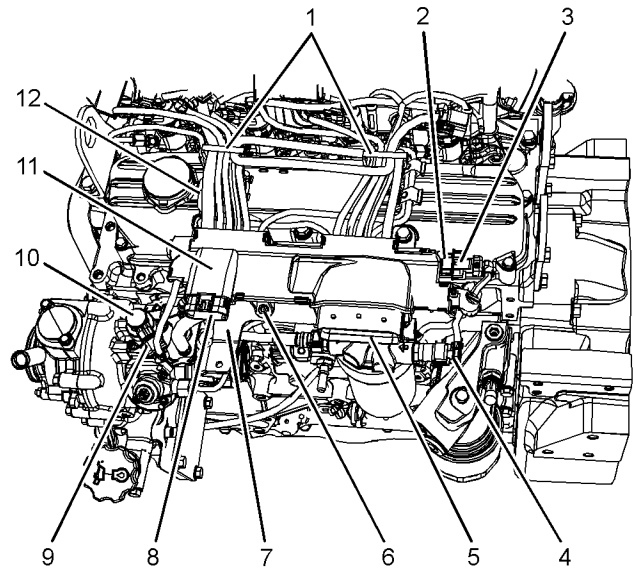


Illustration 34

g02656817

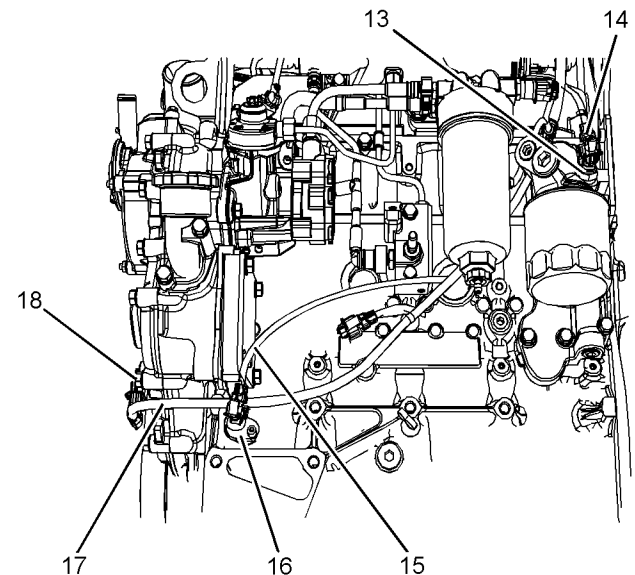


Illustration 35

g02683476

4. Disconnect the Original Equipment Manufacturers (OEM) wiring harness assembly from connection (5) and connection (8).
5. Cut cable straps (1) from the wiring harness assemblies.
6. Slide the locking tab for wiring harness assembly (3) into the unlocked position. Disconnect wiring harness assembly (3) from pressure sensor (2).
7. Disconnect wiring harness assembly (14) from oil pressure switch (13).

## Disassembly and Assembly Section

8. If necessary, cut cable straps in order to remove the wiring harness assemblies.
9. Slide the locking tab for wiring harness assembly (15) into the unlocked position. Disconnect wiring harness assembly (15) from crankshaft position sensor (16).
10. Slide the locking tab for wiring harness assembly (17) into the unlocked position. Disconnect wiring harness assembly (17) from camshaft position sensor (18).
11. Slide the locking tab for wiring harness assembly (9) into the unlocked position. Disconnect wiring harness assembly (9) from fuel metering valve (10).
12. Disconnect the wiring harness assembly from fuel temperature sensor (4).
13. Remove bolt (6) from wiring harness assembly (11).
14. Position wiring harness assembly (11) away from fuel injection lines (12).

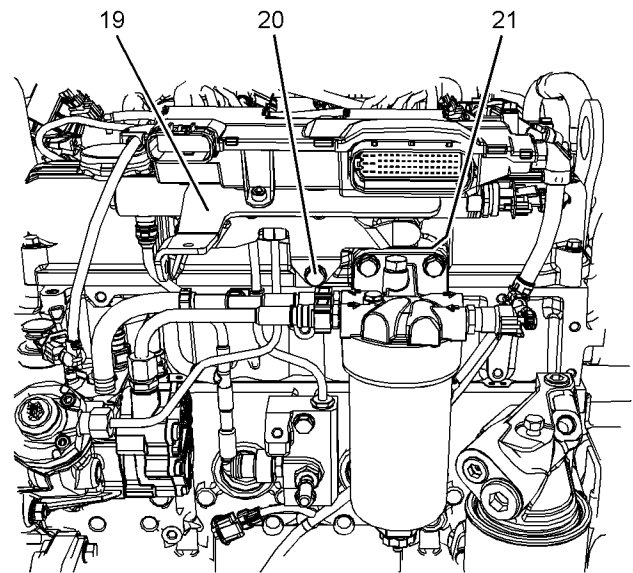


Illustration 36

g02848956

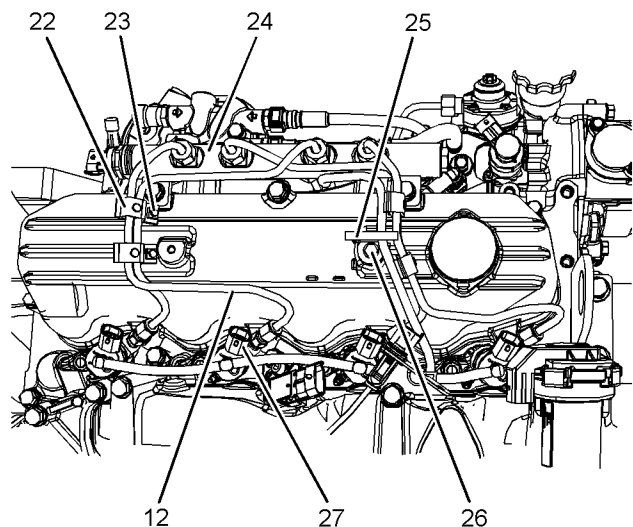


Illustration 37

g02683858

15. Remove fuel filter base mounting bracket (21) (not shown). Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install" for the correct procedure.
  16. Remove bolt (23) from tube clamp (22). Remove tube clamp (22) from fuel injection lines (12).
- Note:** Make temporary marks to identify the position of the tube clamps.
17. Repeat Step 16 in order to remove the remaining tube clamps.



18. Remove bolt (26). Remove bracket (25) from the valve mechanism cover.
19. Clean the area around the nuts for fuel injection lines (12). Ensure that the area is free from contamination before beginning disassembly.
20. Use Tooling (B) in order to disconnect fuel injection line (12) from electronic unit injector (27).

**Note:** It may be necessary to remove the front engine lifting eye in order to gain access to number one high-pressure pipe nut.

21. Use Tooling (B) in order to disconnect fuel injection line (12) from fuel manifold (24).
22. Remove fuel injection line (12). **Discard the fuel injection lines.**
23. Use Tooling (A) in order to cap all open ports immediately in fuel manifold (24) and electronic unit injectors (27).
24. Repeat Step 19 through Step 23 in order to remove the remaining fuel injection lines from the fuel manifold to the electronic unit injectors.

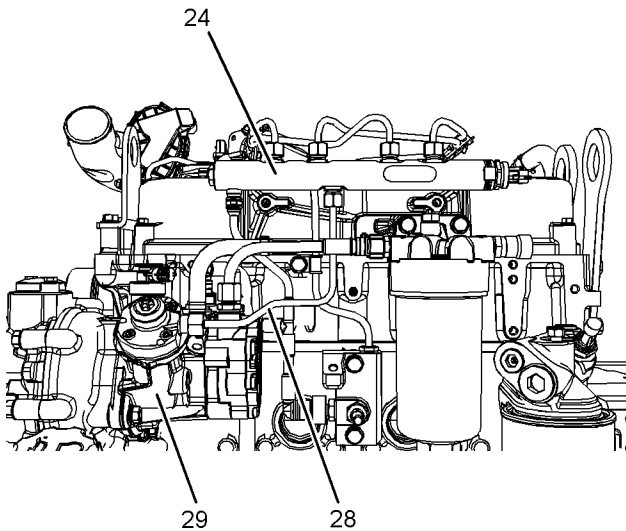


Illustration 38

g02688011

25. Clean the area around the nuts for fuel injection line (28). Ensure that the area is free from contamination before beginning disassembly.
26. Disconnect fuel injection line (28) from fuel injection pump (29).
27. Disconnect fuel injection line (28) from fuel manifold (24).
28. Remove fuel injection line (28). **Discard the fuel injection line.**

29. Use Tooling (A) in order to cap all open ports immediately in fuel manifold (24) and in fuel injection pump (29).

i05268279

## Fuel Injection Lines - Install

### Installation Procedure

Table 7

Required Tools			
Tool	Part Number	Part Description	Qty
B	-	LASER 4920 1/2 Inch Drive HP Fuel Line Socket Set	1

#### NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.**

**Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

**Note:** The following procedure should be adopted in order to install the fuel injection lines when the electronic unit injectors or the fuel manifold have not been removed. If the electronic unit injectors or the fuel manifold have been removed, refer to Disassembly and Assembly, "Electronic Unit Injector - Install" and Disassembly and Assembly, "Fuel Manifold - Install" for more information.

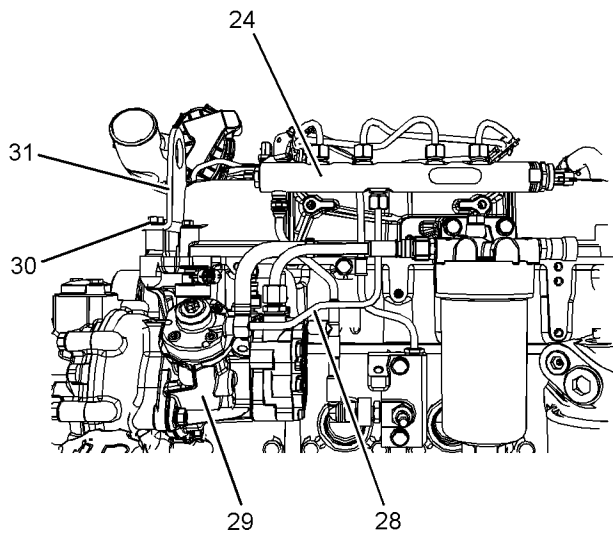


Illustration 39

g02699457

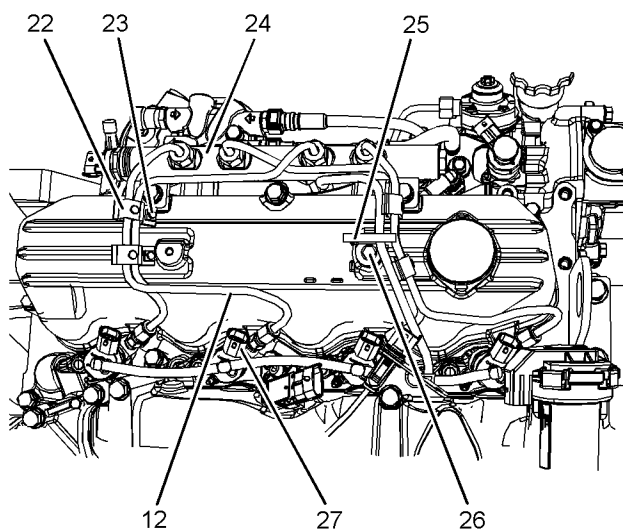


Illustration 40

g02849442

1. Remove the relevant plug from fuel manifold (24) and fuel injection pump (29).
2. Remove the caps from new fuel injection line (28).
3. Position fuel injection line (28) onto fuel injection pump (29) and fuel manifold (24). Loosely install nuts for the fuel injection line onto the fuel manifold and the fuel injection pump.
4. Use Tooling (B) to tighten the nuts on fuel injection line (23) to a torque of 25 N·m (221 lb in).

**Note:** Ensure that fuel injection lines do not contact any other engine component.

5. Remove the caps from the port of the electronic unit injector and from the appropriate port in fuel manifold (16).
  6. Loosely connect the nuts at both ends of fuel injection line (12) to the electronic unit injector and to the appropriate port in fuel manifold (16). Ensure that the ends of the fuel injection line are correctly seated in the electronic unit injector and in the fuel manifold.
  7. Repeat Step 5 through Step 6 in order to install the remaining fuel injection lines.
  8. Position clamp (22) onto fuel injection lines (12) and install clamp bolt (20). Tighten the bolt to a torque of 10 N·m (89 lb in).
- Note:** Ensure that the rubber separator is correctly installed around the fuel injection lines. Ensure that fuel injection lines do not contact any other engine component.
9. Repeat Step 8 for the remaining fuel injection lines.
  10. Use Tooling (B) to tighten the nuts on fuel injection line (12) to a torque of 25 N·m (221 lb in).
  11. Position bracket (25) onto the valve mechanism cover. Install bolt (26) and tighten the bolt to a torque of 10 N·m (89 lb in).
  12. If necessary, reinstall the front engine lifting eye (31). Install bolts (30) and tighten the bolts to a torque of 45 N·m (33 lb ft).

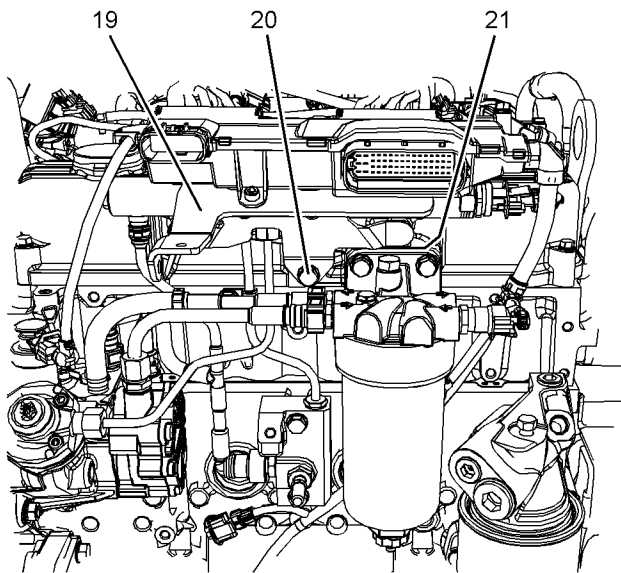


Illustration 41

g02849446

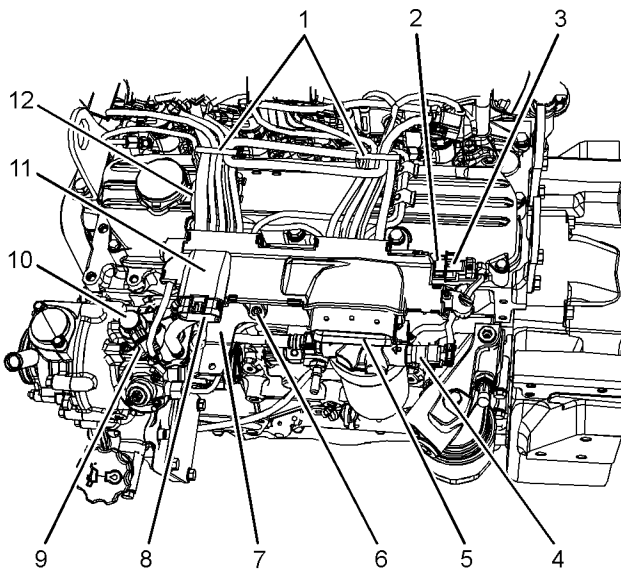


Illustration 42

g02699461

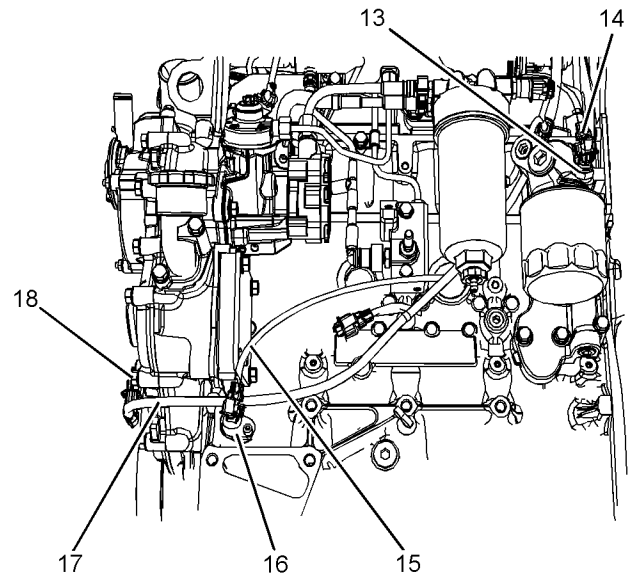


Illustration 43

g02699462

- 13.** Position bracket (19) onto the valve mechanism cover. Install bolts (20) and tighten the bolts to a torque of 25 N·m (221 lb in).
- 14.** Install the fuel filter base mounting bracket (21) (not shown). Refer to Disassembly and Assembly, "Fuel Filter Base - Remove and Install" for the correct procedure.
- 15.** Position the wiring harness assembly (11) over fuel injection lines (12).
- 16.** Install bolt (6) to wiring harness assembly (11). Tighten the bolt to a torque of 10 N·m (89 lb in)
- 17.** Install cable straps (1) to the wiring harness and brackets (25). Ensure that the cable straps meet the Original Equipment Manufactures (OEM) specifications.
- 18.** Connect wiring harness assembly (9) to fuel metering valve (10). Slide the locking tab for wiring harness assembly (9) into the locked position.
- 19.** Connect wiring harness assembly (14) to oil pressure switch (13).
- 20.** Connect wiring harness assembly (3) to pressure sensor (2). Slide the locking tab for wiring harness assembly (3) into the locked position.
- 21.** Connect wiring harness assembly to fuel temperature sensor (4). Slide the locking tab for wiring harness assembly into the locked position.
- 22.** Connect wiring harness assembly (15) to crankshaft position sensor (16). Slide the locking tab for wiring harness assembly (15) into the locked position.

23. Connect wiring harness assembly (17) to camshaft position sensor (18). Slide the locking tab for wiring harness assembly (17) into the locked position.
24. Install cable straps to the wiring harness assembly in the relevant positions. Ensure that the cable straps meet the OEM specifications.
25. Install the OEM wiring harness assembly to connection (5) and connection (8).
26. If necessary, install the Diesel Particulate Filter (DPF). Refer to Disassembly and Assembly, "Diesel Particulate Filter - Install" for the correct procedure.
27. Turn the fuel supply to the ON position.
28. Turn the battery disconnect switch to the ON position.
29. Remove trapped air from the fuel system. Refer to the Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.

i05268286

## Exhaust Cooler (NRS) - Remove and Install

### Removal Procedure

#### Start By:

- a. 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" for the correct procedure.

#### WARNING

Sulfuric Acid Burn Hazard may cause serious personal injury or death.

The exhaust gas cooler may contain a small amount of sulfuric acid. The use of fuel with sulfur levels greater than 15 ppm may increase the amount of sulfuric acid formed. The sulfuric acid may spill from the cooler during service of the engine. The sulfuric acid will burn the eyes, skin and clothing on contact. Always wear the appropriate personal protective equipment (PPE) that is noted on a material safety data sheet (MSDS) for sulfuric acid. Always follow the directions for first aid that are noted on a material safety data sheet (MSDS) for sulfuric acid.

**Note:** Plug or cap all open ports with new plugs or caps.

1. If necessary, remove the diesel particulate filter mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.

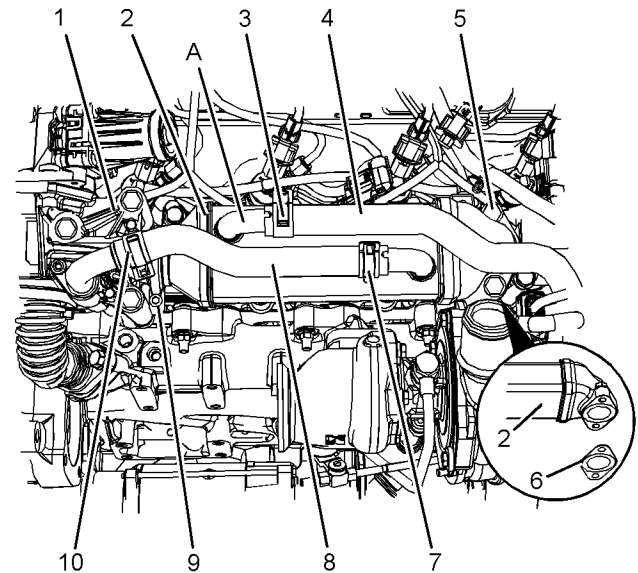


Illustration 44

g02717244

2. Position hose clamp (3) away from the coolant inlet in Position (A). Disconnect hose (4) from exhaust cooler assembly (2).
3. Reposition hose clamp (7) and hose clamp (10) in order to allow removal of hose (8). Disconnect hose (8) from exhaust cooler assembly (2).
4. Loosen V-band clamp (9) and position the clamp away from the Exhaust Gas Recirculation (EGR) valve assembly (1).
5. Remove bolts (5) from exhaust cooler assembly (2).
6. Remove exhaust cooler assembly (2) from the induction manifold.
7. Remove gasket (6).
8. Remove clamp (9) from the exhaust cooler assembly.

### Installation Procedure

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.

**Note:** Remove plugs and caps that were previously installed prior to assembly.

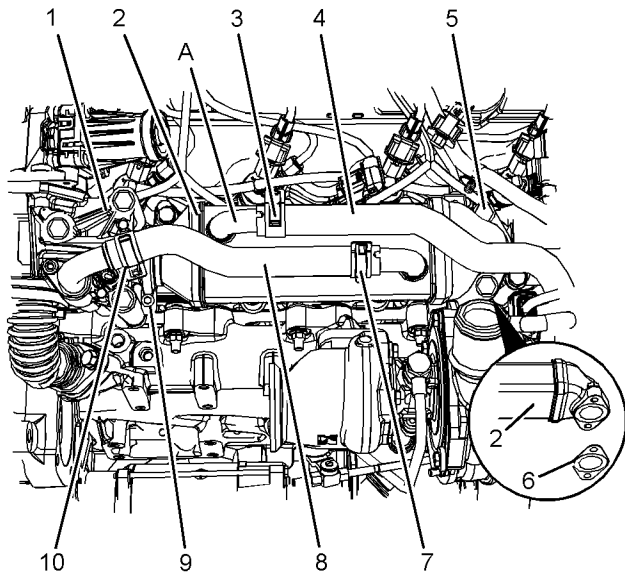


Illustration 45

g02717358

11. If necessary, install the diesel particulate filter mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.

2. Ensure that the NRS exhaust cooler is free from restriction and external damage. Ensure that the NRS exhaust cooler and tube assemblies are free from wear and damage. Refer to Systems Operation Testing and Adjusting, "Exhaust Cooler (NRS) - Test" for the correct inspection procedure.

**Note: The NRS exhaust cooler should not be internally cleaned.**

3. Clean the sealing face on the EGR valve assembly (1) is clean and free from damage.
4. Install a new clamp (9) to NRS mixer chamber (1).

**Note:** Ensure that the clamp is correctly orientated to prevent contact with any other engine components.

5. Position a new gasket (6) onto the inlet manifold.
6. Position exhaust cooler assembly (2) onto the induction manifold. Install bolts (5) finger tight.

**Note:** Ensure that the exhaust cooler assembly (2) can still move freely.

7. Tighten clamp (9) to a torque of 10 N·m (89 lb in)
8. Tighten bolts (5) to a torque of 25 N·m (221 lb in)
9. Connect hose (4) to exhaust cooler assembly (2) in Position (A). Position hose clamp (3) onto the coolant inlet.
10. Install hose assembly (8) to exhaust cooler assembly (2). Position hose clamp (7) and position hose clamp (10) and tighten securely.

**End By:**

- a. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

i05268287

## Throttle Valve (Intake Air) - Remove and Install (Rear Facing Inlet Elbow)

### Removal Procedure

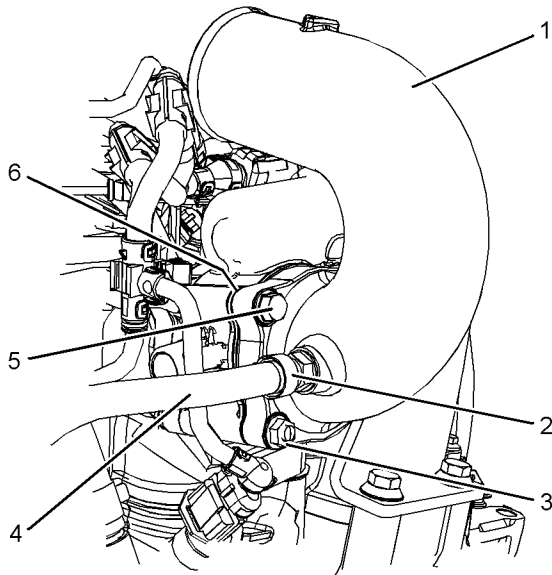


Illustration 46

g02906277

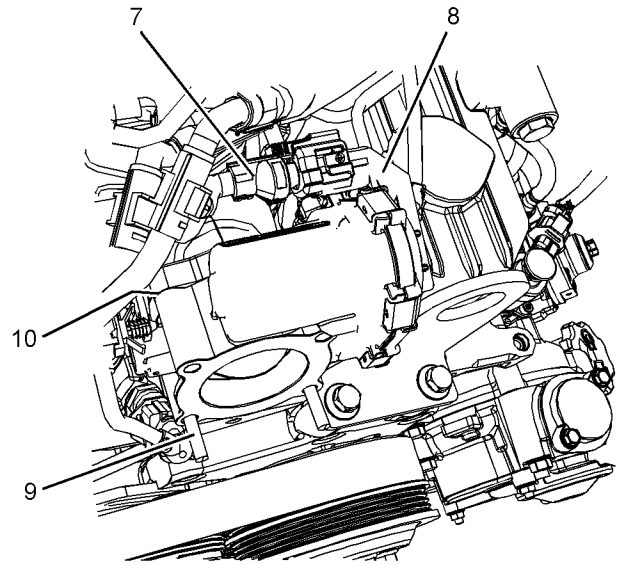


Illustration 47

g02906317

1. Loosen the hose clamp and disconnect the hose assembly from elbow (1).
2. Slide the locking tab into the unlocked position and disconnect harness assembly (7) from throttle valve (8).
3. Loosen hose clamp (2) and disconnect hose assembly (4) from elbow (1).
4. Remove bolts (5) and remove nuts (3) from the elbow.
5. Remove the air inlet elbow from studs (9).
6. Remove gasket (6) (not shown).
7. Remove throttle valve (8) from studs (9).
8. Remove gasket (6) (not shown).
9. If necessary, remove studs (9). Refer to Disassembly and Assembly, "Inlet Manifold - Remove and Install" for the correct procedure.

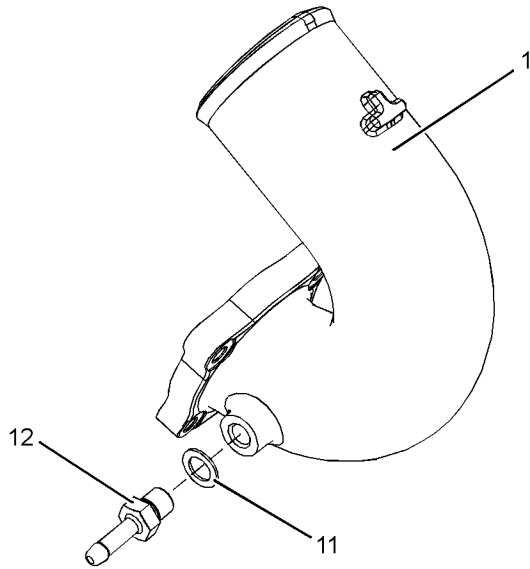


Illustration 48

g02906404

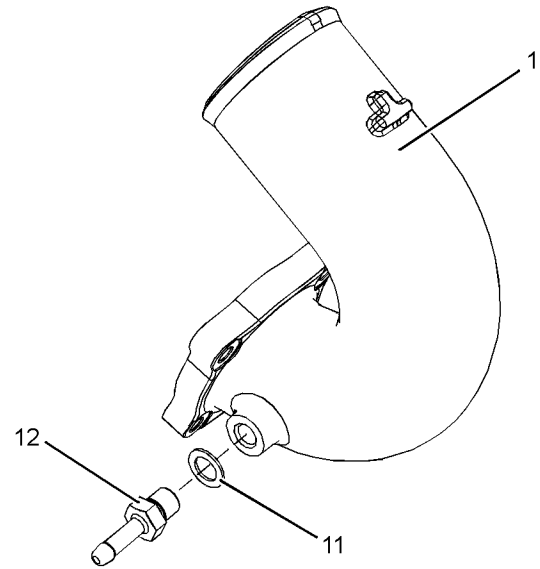


Illustration 49

g02906404

10. If necessary, remove adaptor (12) and sealing washer (11) from elbow (1).

### Installation Procedure

Table 8

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Technologic 15	1

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.

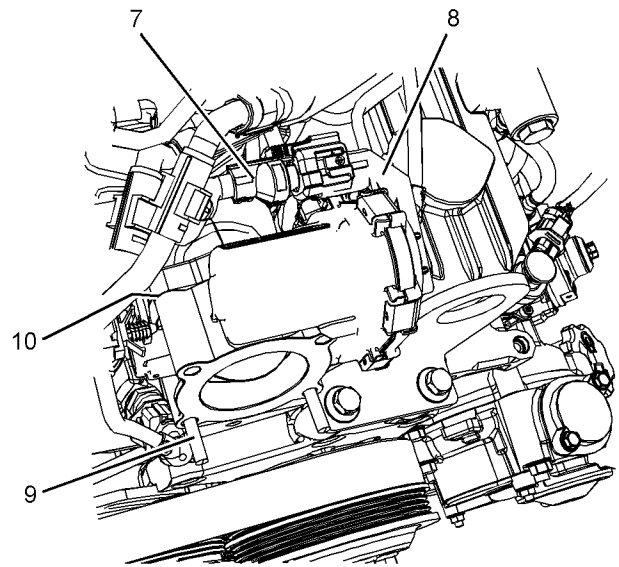


Illustration 50

g02906317

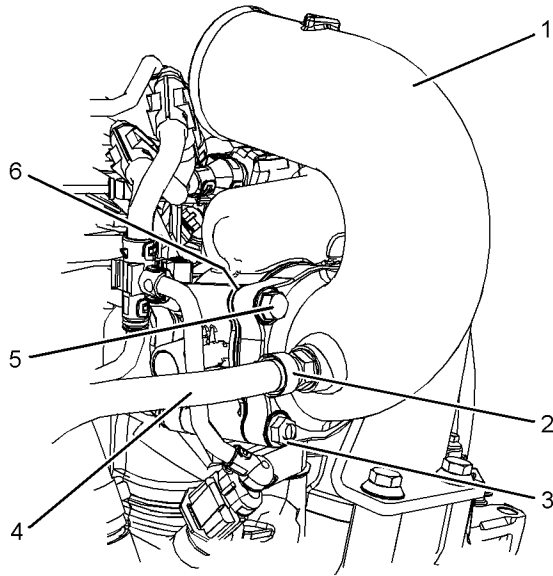


Illustration 51

g02906277

2. If necessary, install studs (9). Refer to Disassembly and Assembly, "Inlet Manifold - Remove and Install" for the correct procedure.
3. If necessary, install new sealing washer (11) to adaptor (12) and apply Tooling (A) to the threads of adaptor (12). Tighten the adaptor to a torque of 20 N·m (177 lb in).
4. Install gasket (10) to studs (9).
5. Install throttle valve (8) to studs (9).
6. Install gasket (6) to studs (9).
7. Install elbow (1) to studs (9).
8. Install bolts (5) finger tight.
9. Install nuts (3) finger tight.
10. Tighten bolts (5) and nuts (3) to a torque of 10 N·m (89 lb in).
11. Position hose clamp (2) onto hose assembly (4). Install hose assembly (4) to adaptor (12) and tighten hose clamp (2) securely.
12. Install harness assembly (7) to throttle valve (8). Slide the locking tab into the locked position.

13. Install the clamp to the air inlet hose and connect the air inlet hose to elbow (1).

i05268292

## Throttle Valve (Intake Air) - Remove and Install (Side Facing Inlet Elbow)

### Removal Procedure

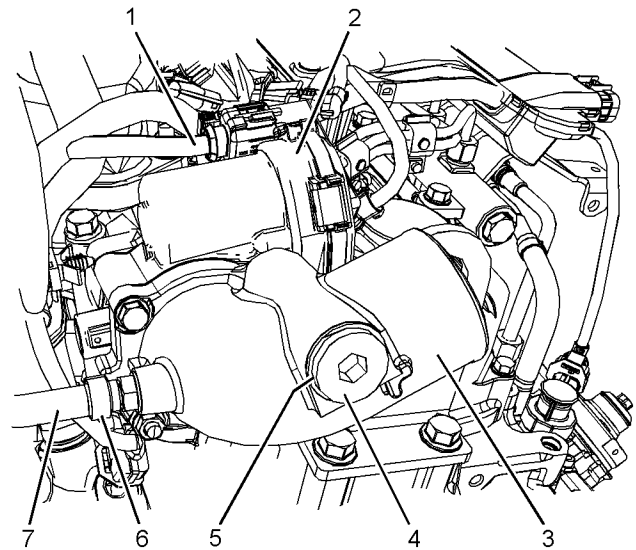


Illustration 52

g02909057

1. Loosen the hose clamp and disconnect the hose assembly from elbow (3).
2. Slide the locking tab into the unlocked position and disconnect harness assembly (1) from throttle valve (2).
3. Loosen hose clamp (6) and disconnect hose assembly (7) from elbow (3).
4. Remove plug (4) from elbow (3). Remove sealing washer (5) (not shown) from the plug.



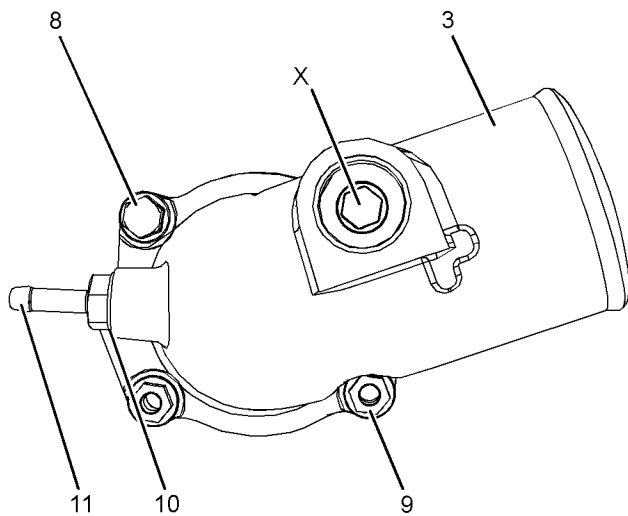


Illustration 53

g02909137

10. If necessary, remove adaptor (11) and sealing washer (10) from elbow (3).

11. If necessary, remove studs (13). Refer to Disassembly and Assembly, "Inlet Manifold - Remove and Install" for the correct procedure.

## Installation Procedure

Table 9

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Technologic 15	1

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.

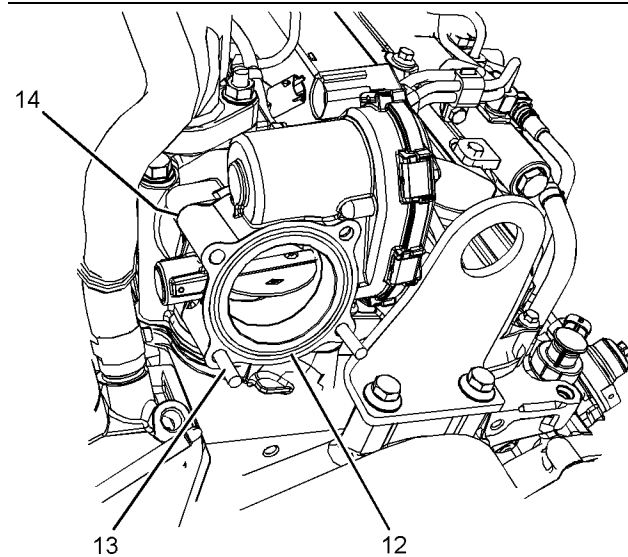


Illustration 54

g02909198

5. Remove nuts (9) from studs (13).

6. Remove bolts (8).

**Note:** Bolt (8) in Position (X) must be removed with air inlet elbow (3) in order to prevent the bolt from falling into the induction system.

7. Remove gasket (12).

8. Remove throttle valve (2) from studs (13).

9. Remove gasket (14) (not shown).

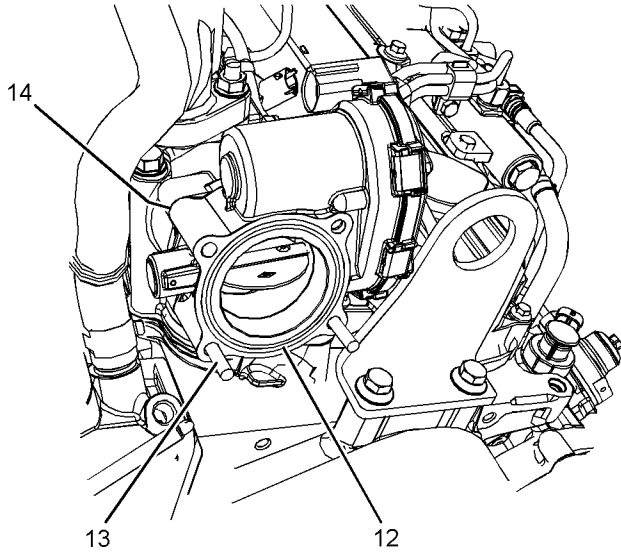


Illustration 55

g02909198

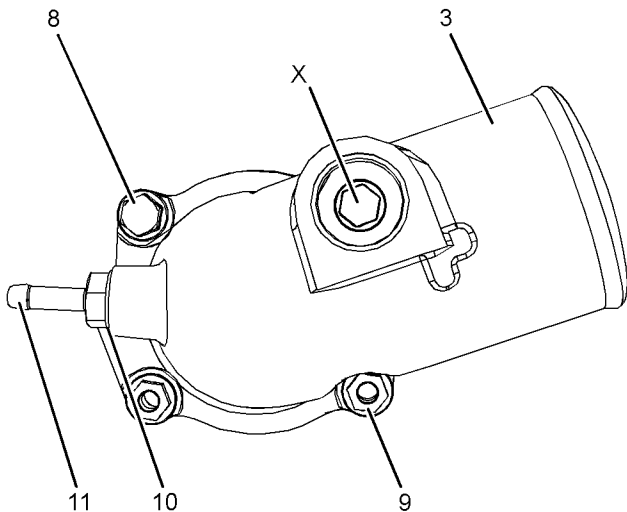


Illustration 56

g02909137

2. If necessary, install studs (13). Refer to Disassembly and Assembly, "Inlet Manifold - Remove and Install" for the correct procedure.
3. Install gasket (14) (not shown) onto studs (13).
4. If necessary, follow Step 4.a through Step 4.b in order to install adaptor (11).
  - a. Install new sealing washer (10) to adaptor (11).
  - b. Apply Tooling (A) to adaptor (11). Install adaptor assembly (11) to air inlet elbow (3). Tighten the adaptor to a torque of 20 N·m (177 lb in).

5. Install throttle valve (2) onto studs (13).
6. Install gasket (12) onto studs (13).

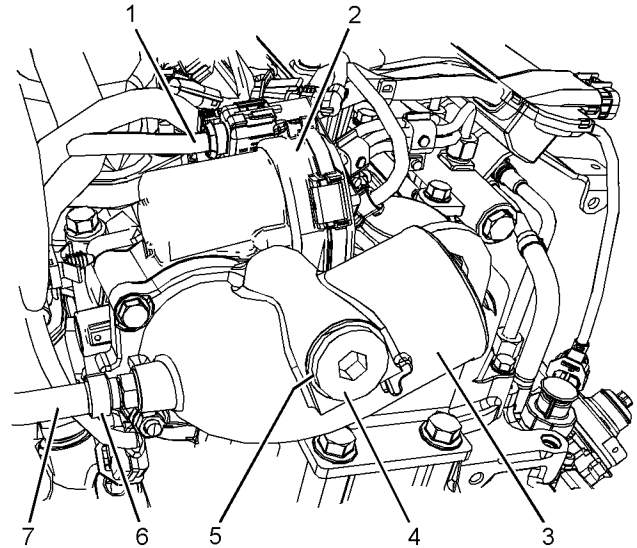


Illustration 57

g02909057

7. Install bolt (8) in Position (X) to elbow (3). Install elbow (3) onto studs (13) and tighten bolt (8) in Position (X) finger tight. Install remaining bolt (8).
8. Install nuts (9) to studs (13).
9. Tighten bolts (8) and nuts (9) to a torque of 10 N·m (89 lb in).
10. Install new sealing washer (5) (not shown) to plug (4).
11. Apply Tooling (A) to plug (4) and install the plug to air inlet elbow (3). Tighten the plug to a torque of 50 N·m (37 lb ft).
12. Install the clamp to the air inlet hose and connect the air inlet hose to air inlet elbow (3).
13. Connect harness assembly (1) onto throttle valve (2). Slide the locking tab into the locked position.

i05268296

## Fuel Injection Pump - Remove

### Removal Procedure

Table 10

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

**Start By:**

- a. Remove the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove" for the correct procedure.

**⚠ WARNING**

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

**NOTICE**

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.
3. Disconnect harness assembly (1) from the solenoid on fuel injection pump (6).

**Note:** The harness assemblies should be positioned away from fuel injection pump in order to avoid an obstruction to the fuel injection pump.

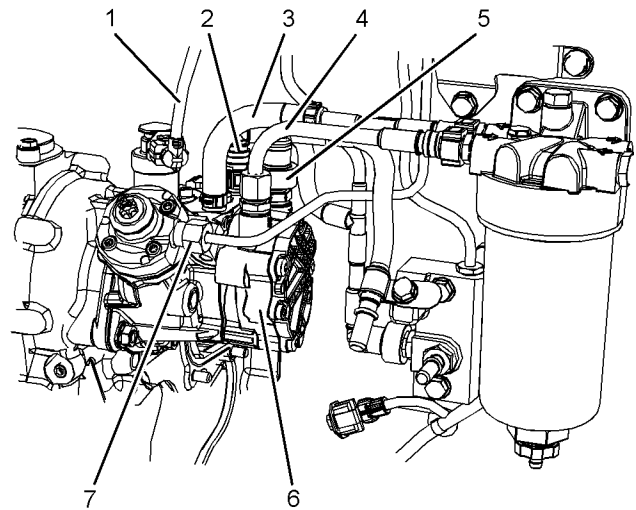


Illustration 58

g02709437

4. Place a suitable container below the fuel injection pump in order to catch any fuel that might be spilled.
  5. Clean the fuel injection pump and the area around the fuel injection pump. Ensure that the area is free from contamination before beginning disassembly.
  6. Remove fuel injection line (7) that connects fuel injection pump (6) to the fuel manifold. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove" for the correct procedure.
- Note: Discard the fuel injection line.**
7. Use Tooling (A) in order to cap the open port in the fuel injection pump immediately.
  8. Use Tooling (A) in order to cap the open port in the fuel manifold immediately.
  9. Make temporary identification marks on all plastic tube assemblies for installation purposes.
  10. Disconnect plastic tube assembly (2), plastic tube assembly (3), plastic tube assembly (4) plastic tube assembly (5) from fuel injection pump (6).
  11. Use Tooling (A) in order to cap the open ports in the fuel injection pump immediately.
  12. Use Tooling (A) in order to plug the plastic tube assemblies immediately.

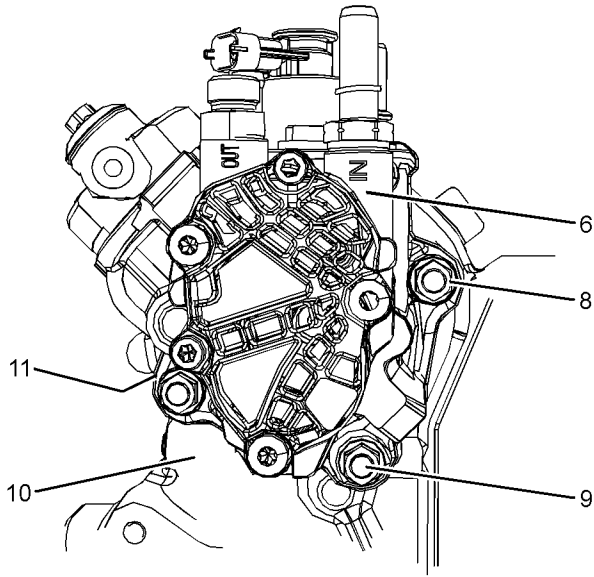


Illustration 59

g02709476

Fuel injection pump viewed from the rear

**13.** Remove nuts (8) from fuel injection pump (6).

**Note:** The fuel injection pump should be supported by hand as the nuts are removed.

**14.** Carefully remove the fuel injection pump from front housing (10).

**15.** Remove O-ring (11) (not shown) from the fuel injection pump.

**16.** If necessary, remove studs (9) from front housing (10).

i05500629

## Fuel Injection Pump - Install

### Installation Procedure

#### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

#### NOTICE

Ensure that the wiring harness assembly is correctly routed and the cable straps are not over tightened. Over tightening of the cable straps will damage the wiring harness convoluting.

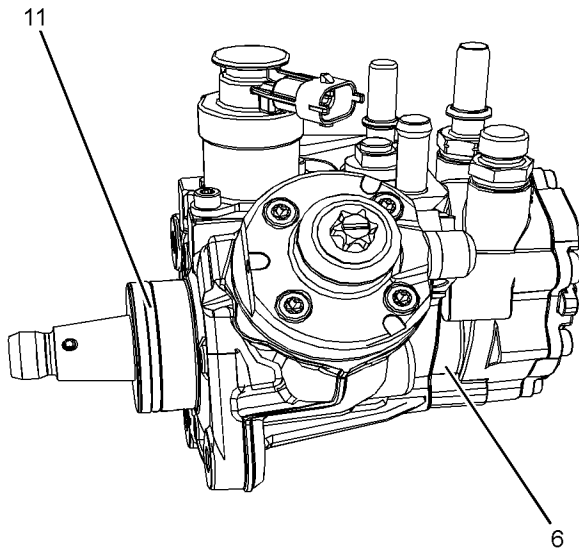


Illustration 60

g02937680

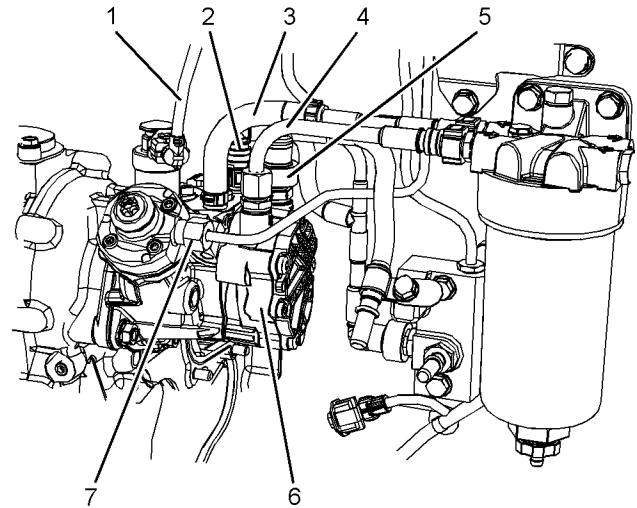


Illustration 62

g02709437

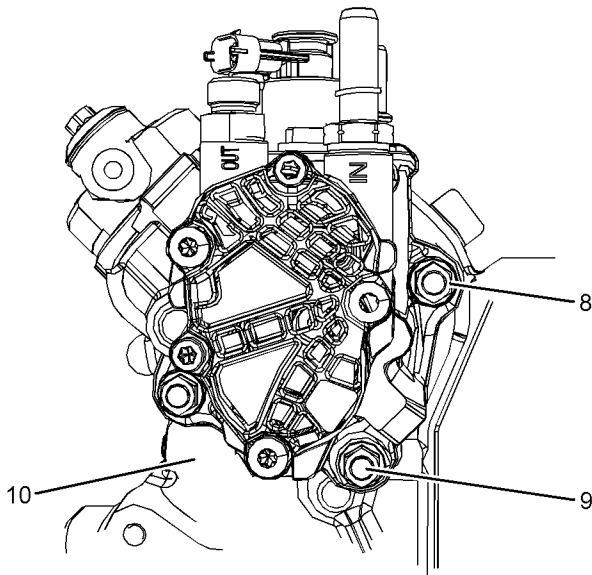


Illustration 61

g02937736

1. If necessary, install studs (9) into front cover (10). Tighten the studs to a torque of 18 N·m (159 lb in).
2. Install new O-ring seal (11) onto fuel injection pump (6).
3. Carefully install fuel injection pump (6) into front housing (10). Ensure that the bore in front housing (10) is not damaged as the fuel injection pump is installed.
4. Install nuts (8) onto studs (9). Tighten the nuts to a torque of 25 N·m (221 lb in).

5. Remove the appropriate caps in order to install a new fuel injection line (7). Install new fuel injection line (7) to the fuel injection pump and to the fuel manifold. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for the correct procedure.
6. Remove the appropriate plugs and caps and connect plastic tube assembly (2), plastic tube assembly (3), plastic tube assembly (4) plastic tube assembly (5) to fuel injection pump (6).
7. Connect harness assembly (1) to the solenoid on fuel injection pump (6).
8. Install the fuel injection pump gear. Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Install" for the correct procedure.
9. Replace the filters for primary fuel system. Refer to Operation and Maintenance Manual, "Fuel System Primary (Water Separator) Element - Replace" for the correct procedure.
10. Replace the filters for secondary fuel system. Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for the correct procedure.
11. Turn the fuel supply to the ON position.
12. Turn the battery disconnect switch to the ON position.

13. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.

i05268312

## Fuel Injection Pump Gear - Remove

### Removal Procedure

Table 11

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400086	Timing Pin (Crankshaft)	1
B	T400152	Timing Pin (Camshaft)	1
C	-	Snap-on PBS650 Small Pry Bar	1

#### Start By:

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

#### WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

#### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

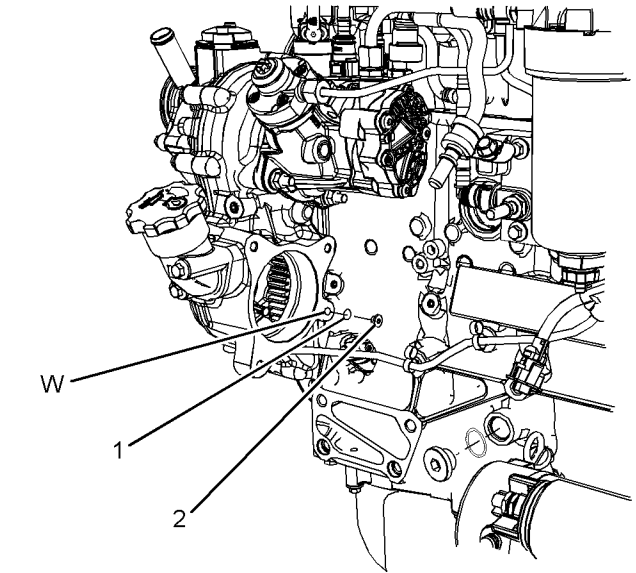


Illustration 63

g02937156

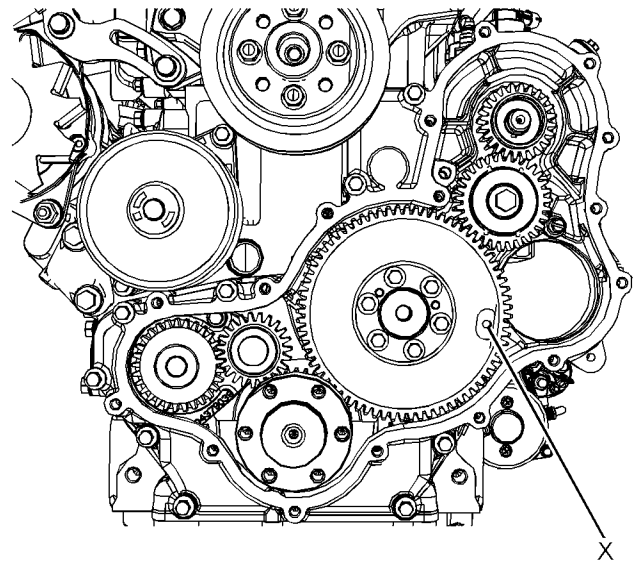


Illustration 64

g02937157

Camshaft timing ring removed for clarity.

3. Follow Step 3.a through Step 3.e in order to install the camshaft timing tool.
  - a. If equipped, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install" for the correct procedure.
  - b. Remove plug (2) in Position (W) from the front housing.
  - c. Remove O-ring seal (1) from plug (2).

- d. Rotate the engine until Hole (X) in the camshaft gear is aligned with Position (W) in the front housing.
- e. Install Tooling (B) through Position (W) and into Hole (X) in the camshaft gear.

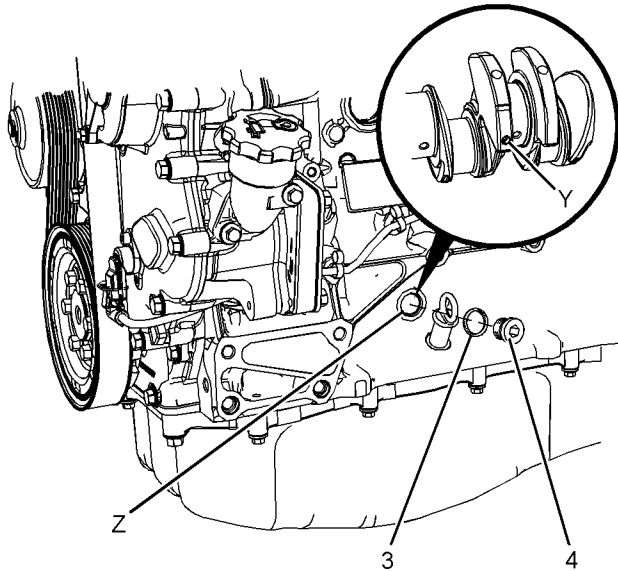


Illustration 65

g02934298

- 4. Follow Step 4.a through Step 4.c in order to install the crankshaft positioning tool.
  - a. Remove plug (4) from Position (X) in the cylinder block.
  - b. Remove O-ring seal (3) from plug (4).
  - c. Install Tooling (A) into the cylinder block in Position (Z).

**Note:** Tooling (A) must be located in Hole (Y) in the crankshaft.

**Note:** Ensure that Tooling (A) is located in the correct drilling in the crankshaft as shown in Illustration 65 .

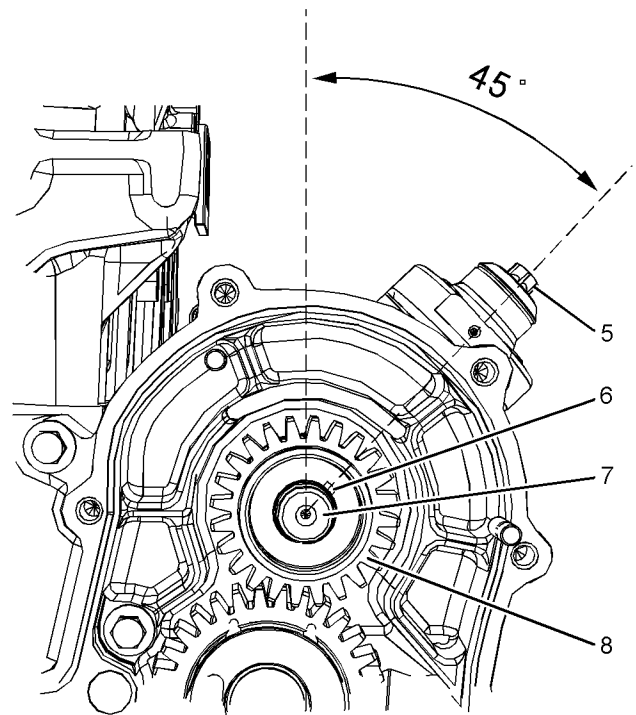


Illustration 66

g02937163

- 5. Before removing fuel injection pump gear, (8) ensure that alignment pin (6) is 45 degrees from vertical and parallel to the center of Torx head plug (5), refer to Illustration 66 .
- 6. Use Tooling (C) in order to remove the fuel injection pump gear from the fuel injection pump shaft (7).
- 7. If necessary, remove locating pin (6) from fuel injection pump shaft (7).

i05268316

## Fuel Injection Pump Gear - Install

### Installation Procedure

Table 12

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400086	Timing Pin (Crankshaft)	1
B	T400152	Timing Pin (Camshaft)	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged.
2. If Tooling (A) and Tooling (B) are not installed, install Tooling (A) and install Tooling (B). Refer to Disassembly and Assembly, "Fuel Injection Pump Gear - Remove" for the correct procedure.

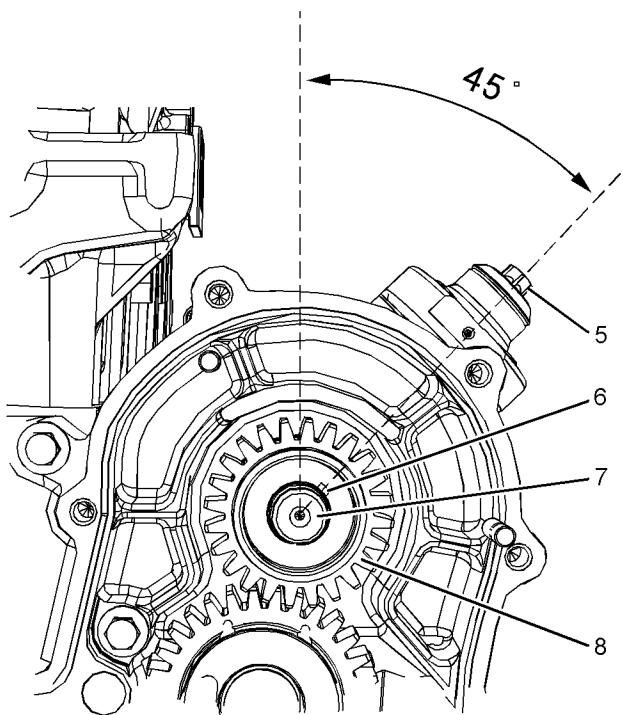


Illustration 67

g02937163

3. If necessary, install locating pin (6) into fuel injection pump shaft (7).
4. Ensure that locating pin (6) is 45 degrees from vertical and parallel to the center of Torx head plug (5), refer to Illustration 67 .
5. Position gear (8) onto fuel injection pump shaft (7).
6. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install" for the correct procedure.
7. Install the crankcase breather. Refer to Disassembly and Assembly, "Crankcase Breather - Install" for the correct procedure.

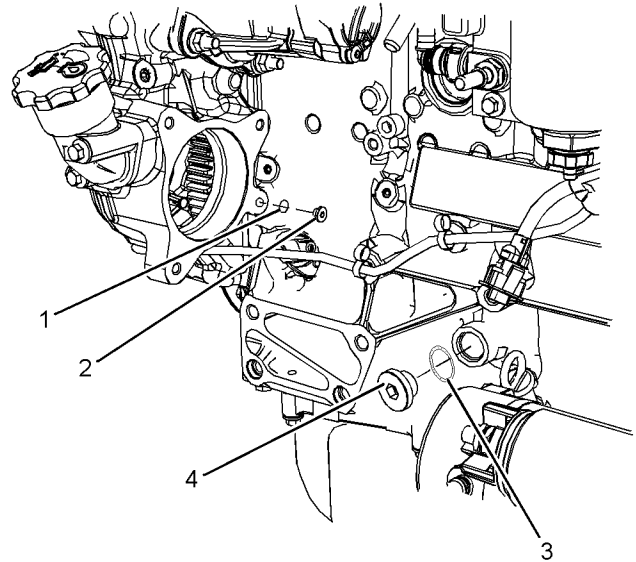


Illustration 68

g02937277

8. Remove Tooling (B) from the front housing.
9. Install new O-ring seal (1) to plug (2).
10. Install plug (2). Tighten the plug to a torque of 25 N·m (221 lb in).
11. Install new O-ring seal (3) to plug (4).
12. Install plug (4). Tighten the plug to a torque of 30 N·m (266 lb in).
13. If equipped, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install" for the correct procedure.

i05270670

## Electronic Unit Injector - Remove

### Removal Procedure

Table 13

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1



**Start By:**

- a. Remove the fuel injection lines. Refer to Disassembly and Assembly, "Fuel Injection Lines - Remove" for the correct procedure.

**⚠ WARNING**

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

**NOTICE**

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorised personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

**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.

Dispose of all fluids according to local regulations and mandates.

**Note:** Place identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. Plugging all hose assemblies and tube assemblies will prevent fluid loss. Plugging all hose assemblies and tube assemblies will to keep contaminants from entering the system.

**Note:** Plug or cap all open ports with new plugs or caps.

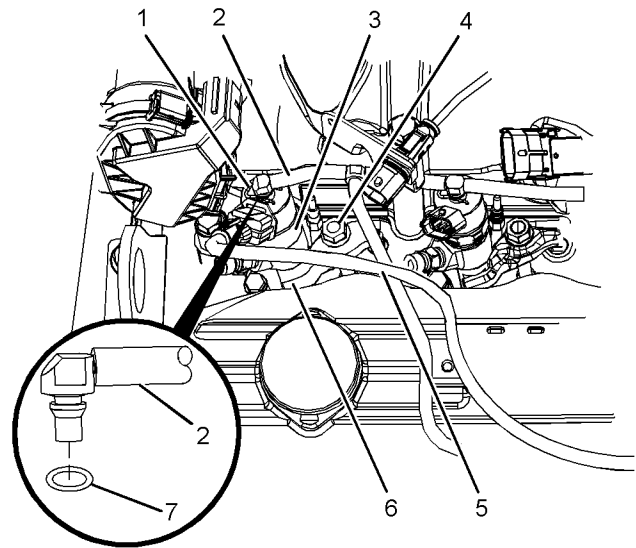


Illustration 69

g02701543

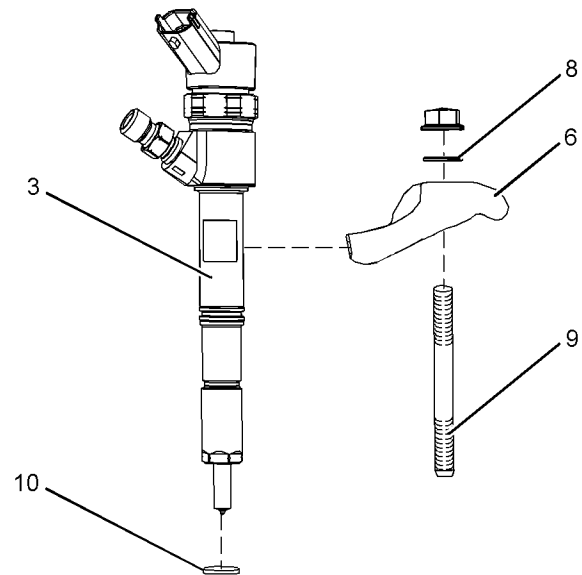


Illustration 70

g02701718

1. Disconnect wiring harness assembly (5) from electronic unit injector (3).

**Note:** Make a temporary mark on the wiring harness assembly in order to ensure that the wiring harness assembly is connected to the correct electronic unit injector during assembly.

2. Remove clip (1) from electronic unit injector (3).
3. Disconnect hose assembly (2) from electronic unit injector (3). Remove O-ring seal (7) from the hose assembly.

4. Use Tooling (A) in order to cap electronic unit injector (3) immediately. Use Tooling (A) in order to plug hose assembly (2) immediately.

5. Remove nut (4) and washer (8) from clamp (6).

**Note:** Note the orientation of the washer.

6. Make a temporary mark on the electronic unit injector in order to ensure that the electronic unit injector is reinstalled in the original location.

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

**Note: Always handle electronic unit injectors with care.**

8. Remove clamp (6) from electronic unit injector (3).

9. If electronic unit injector (3) is to be reused, Follow Step 10 through Step 11 in order to remove sealing washer (10).

10. Use a suitable tool in order to remove sealing washer (10) from electronic unit injector (3). If sealing washer (10) is not present on the electronic unit injector, ensure that the sealing washer is removed from the cylinder head.

**Note: Ensure that the nozzle for the electronic unit injector is not damaged in any way during removal of the sealing washer.**

11. Install Tooling (A) to the nozzle for electronic unit injector (3) immediately.

12. If necessary, repeat Step 1 through Step 10 in order to remove the remaining electronic unit injectors.

In some applications removal of the clean emissions bracket and exhaust gas recirculation valve will be necessary in order to remove number four electronic unit injector. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" and Disassembly and Assembly, "Exhaust Gas Recirculation Valve - Remove and Install" for the correct procedures.

13. If necessary, remove studs (9) from the cylinder head.

i05270671

## Electronic Unit Injector - Install Installation Procedure

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorised personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

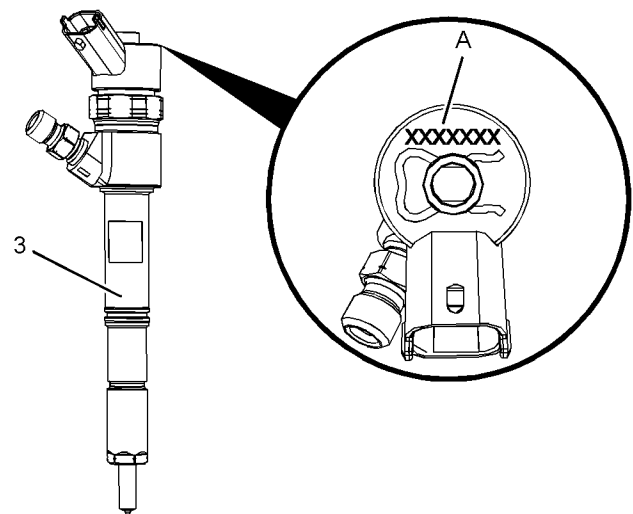


Illustration 71

g02704596

Injector code

1. If the original electronic unit injector (3) is installed, ensure that the electronic unit injector is installed into the original location.

2. If a replacement electronic unit injector is installed, the correct seven digit injector code that is located in Position (A) must be programmed into the electronic control module. Refer to Troubleshooting, "Injector Code - Calibrate" for more information.

**Note:** Record the seven digit injector code in Position (A) before the electronic unit injector is installed.

3. Ensure that the fuel inlet port of the electronic unit injector is capped. Ensure that the electronic unit injector is clean.

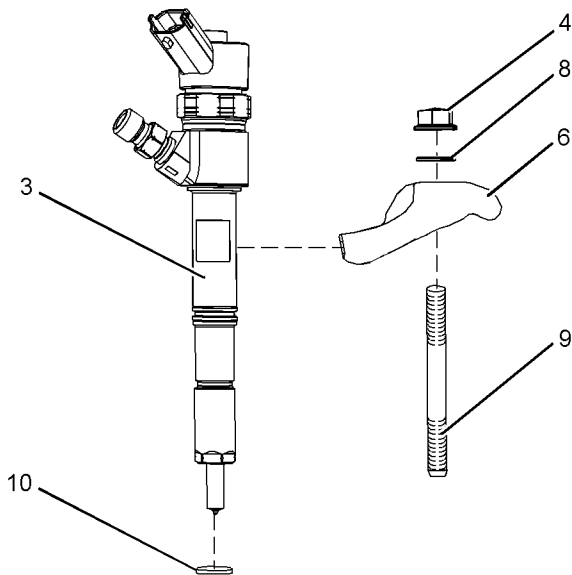


Illustration 72

g02851878

4. If necessary, install studs (9) to the cylinder head. Tighten the studs to a torque of 20 N·m (177 lb in).
5. If the original electronic unit injector (3) is to be reused, remove the protective cap from the nozzle and install a new sealing washer (10).

**Note:** Ensure that the nozzle for the electronic unit injector is not damaged during installation of the new sealing washer.

6. Remove the plug from the electronic unit injector port in the cylinder head.
7. Ensure that the seat for the electronic unit injector in the cylinder head is clean and free from damage. Ensure that the sealing washer has been removed from the cylinder head.
8. Position clamp (6) onto electronic unit injector (3). Align the assembly of electronic unit injector (3) to the bore for the electronic unit injector in the cylinder head.

**Note:** Ensure that the clamp is correctly positioned onto the electronic unit injector.

9. Push only on injector clamp (6) in order to install electronic unit injector (3). Do not apply pressure on any other part of the electronic unit injector. Ensure that the electronic unit injector is pushed firmly against the seat in the cylinder head.
10. Install washer (8) and nut (4) onto stud (9). Tighten the nut finger tight.

**Note:** Ensure that the washer is correctly orientated.

11. Remove the plugs from the new fuel injection line. Install the fuel injection line nuts hand tight. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for the correct installation procedure.

**Note:** Ensure that the ends of the fuel injection line are seated into the electronic unit injector and the fuel manifold.

**Note: Do not torque the fuel injection line nuts before the final torque has been applied to the electronic unit injector clamp nuts (4).**

12. When nuts (4) are installed, the nuts must be tightened in two stages. Follow Step 12.a through 12.b for the correct torque sequence.
  - a. Tighten nuts (4) to an initial torque of 15 N·m (133 lb in).
  - b. Tighten nuts (4) to a final torque of 25 N·m (221 lb in).
13. If necessary, repeat Step 1 through Step 12.b in order to install the remaining electronic unit injectors.
14. Tighten the fuel injection line nuts to a torque of 25 N·m (221 lb in). Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for further information.

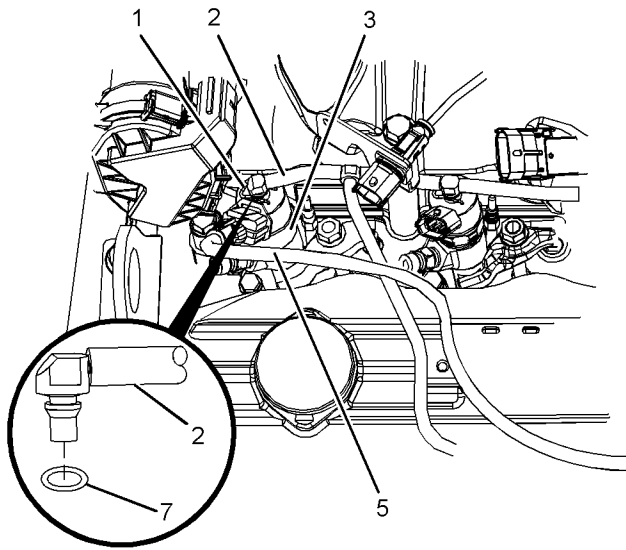


Illustration 73

g02706897

15. Install a new O-ring seal (7) to the connection on hose assembly (2).
16. Install hose assembly (2) to electronic unit injector (3).
17. Install clip (1) to electronic unit injector (3).
18. If necessary, repeat Step 15 through Step 17 in order to connect the remaining hose assemblies (2).
19. Connect wiring harness assemblies (5) to the electronic unit injectors. Slide the locking tab into the locked position
20. If necessary install the exhaust gas recirculation valve. Refer to Disassembly and Assembly, "Exhaust Gas Recirculation Valve - Remove and Install" for the correct procedure.
21. If necessary install the diesel particulate filter supporting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.
22. Install the wiring harness assembly. Refer to Disassembly and Assembly, "Fuel Injection Lines - Install" for the correct procedure.
23. Replace the primary fuel filter. Refer to Operation and Maintenance Manual, "Fuel System Primary (Water Separator) Element - Replace" for the correct procedure.
24. Replace the secondary fuel filter. Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for the correct procedure.

25. Turn the fuel supply to the ON position.
26. Turn the battery disconnect switch to the ON position.
27. Remove the air from the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.

i05270673

## Turbocharger - Remove (Top Mounted Turbochargers)

### Removal Procedure

#### Start By:

- a. Remove the flexible exhaust pipe from the turbocharger. Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.

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#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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#### 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.

Dispose of all fluids according to local regulations and mandates.

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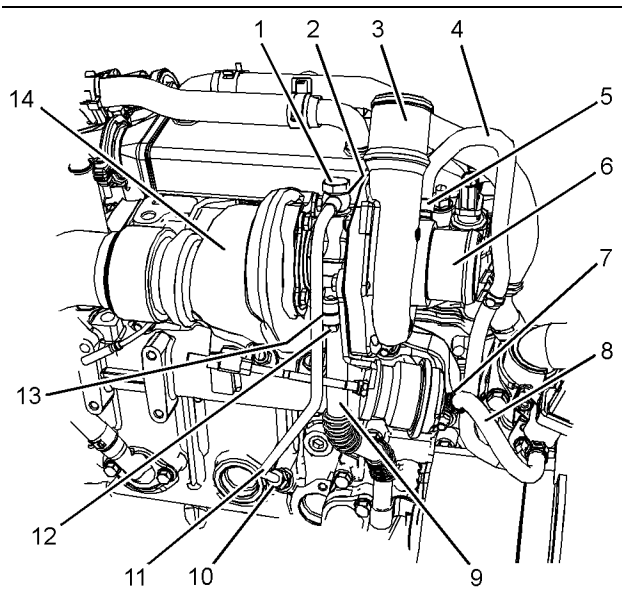


Illustration 74

g02719477

5. Remove hose clamp (7) from hose assembly (8). Disconnect hose assembly (8) from the wastegate actuator.
6. Remove bolts (12) from tube assembly (9).
7. Remove gasket (13) (not shown).
8. If necessary, follow Step 8.a through Step 8.d in order to remove tube assembly (9) from the cylinder block.
  - a. Remove bolts (16) and position tube assembly (18) away from the oil cooler.
  - b. Remove O-ring seal (15) (not shown) from tube assembly (18).
  - c. Remove bolt (17) and remove tube assembly (9) from the cylinder block.
  - d. Remove O-ring seal (19) (not shown) from tube assembly (9).

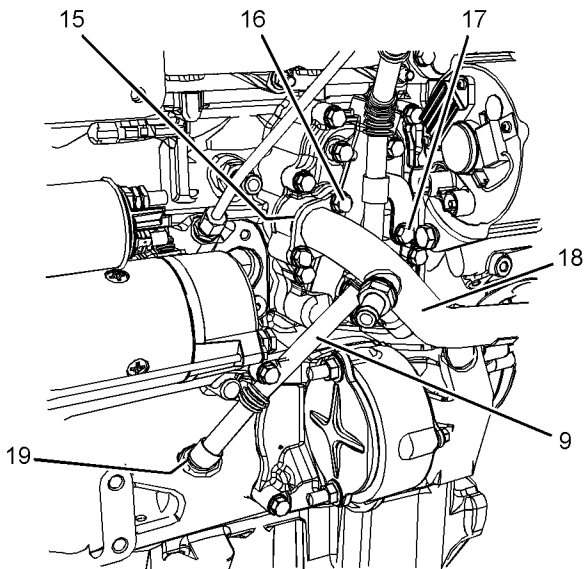


Illustration 75

g02868099

1. Loosen hose clamps and disconnect the hose assemblies from turbocharger inlet (6) and from turbocharger outlet (3).
2. Remove banjo bolt (1) from tube assembly (11). Remove sealing washers (2) (not shown).
3. Loosen nut (10) and remove tube assembly (11) from turbocharger (14) and the cylinder block.
4. Remove hose clamp (5) from hose assembly (4). Disconnect hose assembly (4).

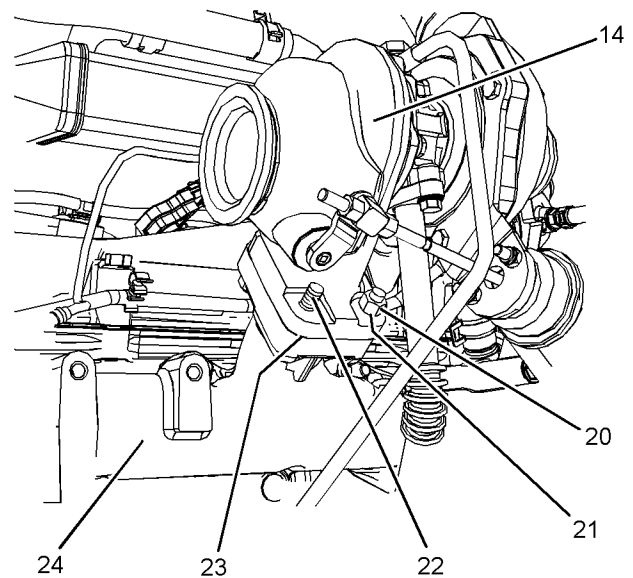


Illustration 76

g02719524

9. Remove nuts (20) and washers (21) (not shown). Remove turbocharger (14) from exhaust manifold (24).
- Note:** Do not use the actuator rod to lift the turbocharger.
10. Remove gasket (23) (not shown).
  11. If necessary, remove the studs (22) from turbocharger (14) and exhaust manifold (24).

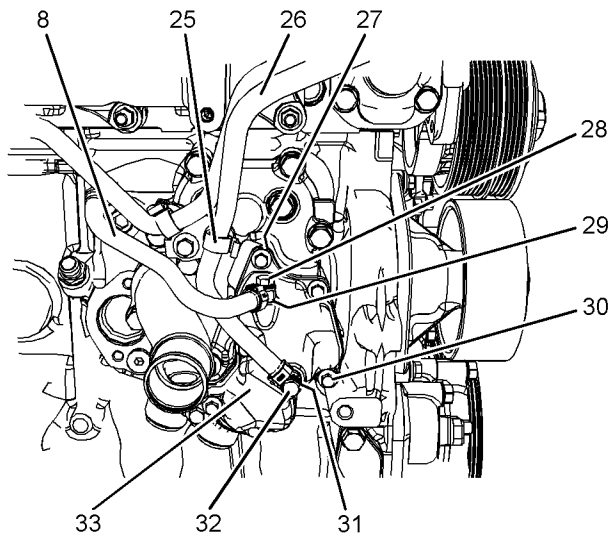


Illustration 77

g02868256

**12.** If necessary, follow Step 12.a through Step 12.f in order to remove boost pressure chamber cover (33).

- a. Remove the alternator and mounting bracket. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.
- b. Remove banjo bolt (28) and remove sealing washers (29) (not shown) from hose assembly (8).
- c. Remove banjo bolt (32) and remove sealing washers (31) (not shown) from hose assembly (26).
- d. Release the tube assembly (26) from clip (25) and position the hose assembly away from boost pressure chamber cover (33).
- e. Remove bolts (30) and remove boost pressure chamber cover (33) from the oil cooler.

- f. Remove gasket (27) (not shown).

i05270674

## Turbocharger - Remove (Side Mounted Turbochargers)

### Removal Procedure

#### Start By:

- a. Remove the flexible exhaust pipe from the turbocharger. Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.

---

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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#### 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.

Dispose of all fluids according to local regulations and mandates.

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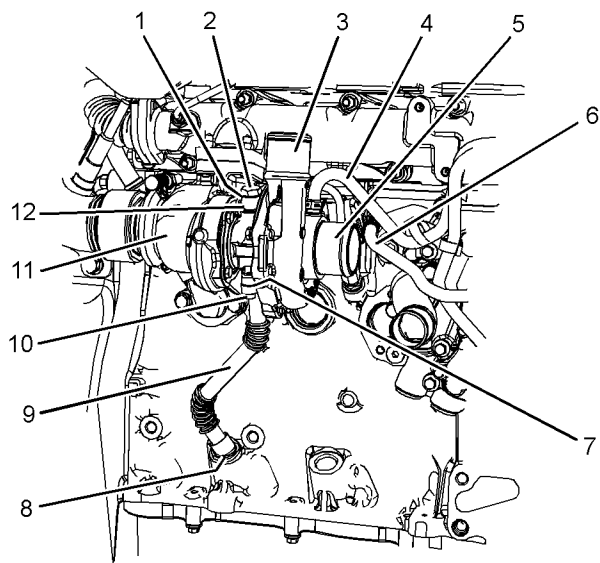


Illustration 78

g02859585

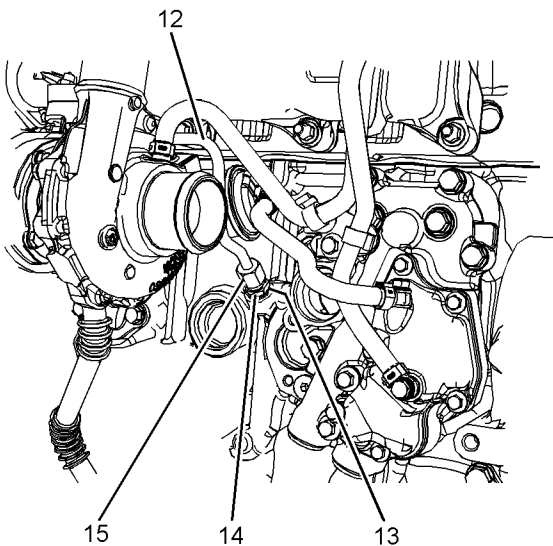


Illustration 79

g02859796

1. Loosen hose clamps and disconnect the hose assemblies from turbocharger inlet (5) and from turbocharger outlet (3).
2. Remove banjo bolt (2) from tube assembly (12). Remove sealing washers (1) (not shown).
3. Loosen nut (15) and remove tube assembly (12) from turbocharger (11) and the cylinder block.
4. If necessary, remove connection (14) from the cylinder block. Remove sealing washer (13) (not shown).

5. Loosen the hose clamp on hose assembly (4). Disconnect hose assembly (4) from the turbocharger.
6. Loosen the hose clamp on hose assembly (6). Disconnect hose assembly (6) from the wastegate actuator.
7. Remove bolts (10) from tube assembly (9).
8. Remove gasket (7) (not shown).
9. If necessary, remove tube assembly (9) from the cylinder block. Remove O-ring seals (8) (not shown).

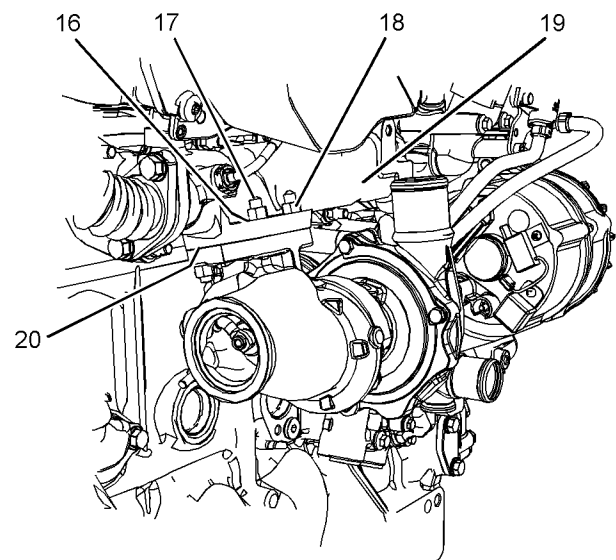


Illustration 80

g02861996

10. Remove nuts (18) and washers (16) (not shown). Remove turbocharger from the exhaust manifold (19).

**Note:** Do not use the actuator rod to lift the turbocharger.

11. Remove gasket (20) (not shown).
12. If necessary, remove the studs (17) from the turbocharger and exhaust manifold.

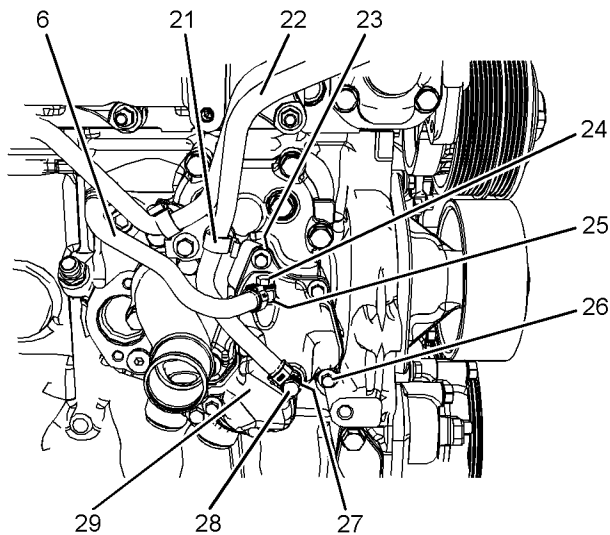


Illustration 81

g02862040

**13.** If necessary, follow Step 13.a through Step 13.f in order to remove boost pressure chamber cover (29).

- a. Remove the alternator and mounting bracket. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.
- b. Remove banjo bolt (24) and remove sealing washers (25) (not shown) from hose assembly (6).
- c. Remove banjo bolt (28) and remove sealing washers (27) (not shown) from hose assembly (22).
- d. Release the tube assembly (22) from clip (21) and position the hose assembly away from boost pressure chamber cover (29).
- e. Remove bolts (26) and remove boost pressure chamber cover (29) from the oil cooler.

f. Remove gasket (23) (not shown).

i05270677

## Turbocharger - Install (Top Mounted Turbochargers)

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the turbocharger is clean and free from damage. Inspect the turbocharger for wear. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect" for more information. If the turbocharger is worn, the complete turbocharger must be replaced.

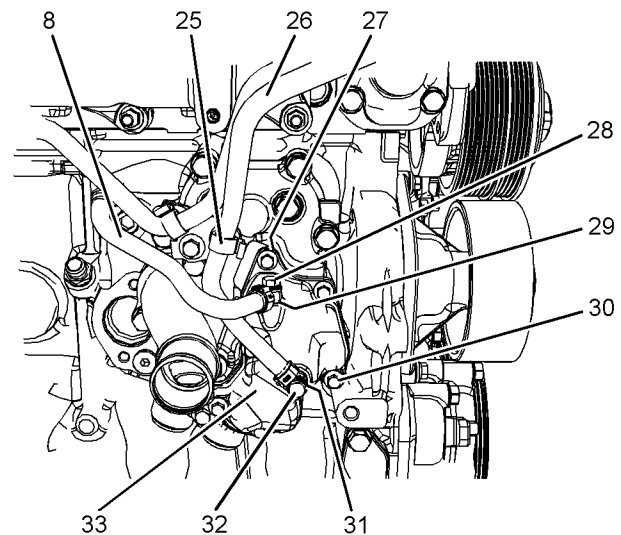


Illustration 82

g02868256

**2.** If necessary, follow Step 2.a through Step 2.f in order to remove boost pressure chamber cover (33).

- a. Position gasket (27) (not shown) onto boost pressure chamber cover (33).
- b. Position boost pressure chamber cover onto the engine oil cooler and install bolts (30). Tighten the bolts to a torque of 10 N·m (89 lb in)



- c. Install a new sealing washer (31) to banjo bolt (32). Install the banjo bolt assembly to hose assembly (26) and install the remaining sealing washer (31). Install hose assembly (26) to boost pressure chamber cover (33) finger tight.
- d. Install tube assembly (26) into clip (25).
- e. Install a new sealing washer (29) to banjo bolt (28). Install the banjo bolt assembly to hose assembly (8) and install the remaining sealing washer (28). Install hose assembly (8) to boost pressure chamber cover (33) finger tight.
- f. Install the alternator and mounting bracket. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.

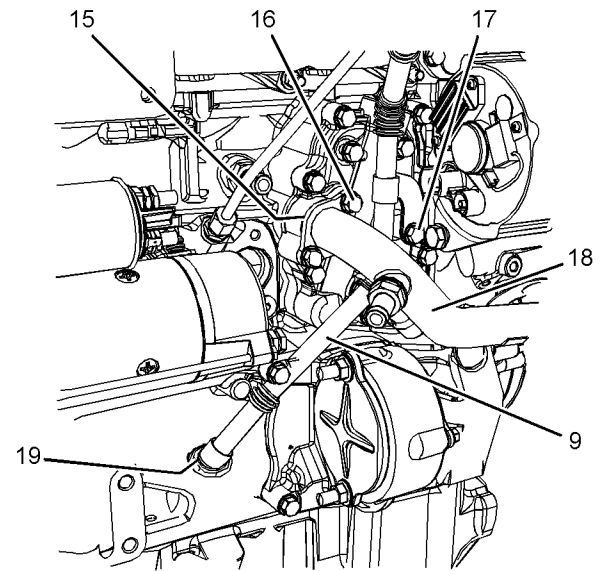


Illustration 83

g02868099

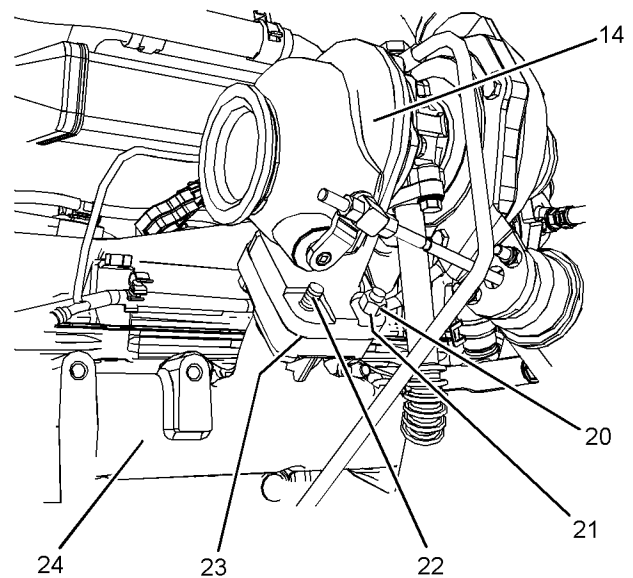


Illustration 84

g02719524

3. Test the turbocharger actuator for correct operation. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect" for more information. If the actuator is damaged or the actuator does not operate within the specified limits, the complete turbocharger must be replaced.
4. If necessary, follow Step 4 through Step 5 in order to install tube assembly (9).
  - a. Install new O-ring seal (19) (not shown) to tube assembly (9).

## Disassembly and Assembly Section

- b. Install tube assembly (9) to the cylinder block.
  - c. Install bolt (17) to tube assembly (9). Tighten the bolt to a torque of 25 N·m (221 lb in).
  - d. Install O-ring seal (15) (not shown) to tube assembly (18).
  - e. Install tube assembly (18) to the oil cooler assembly. Install bolts (16) to tube assembly (18). Tighten the bolts to a torque of 25 N·m (221 lb in).
5. Clean the gasket surface of exhaust manifold (24). If necessary, install studs (22) to exhaust manifold (24) and turbocharger (14). Tighten the studs to a torque of 15 N·m (133 lb in).
  6. Install a new gasket (23) (not shown) to the exhaust manifold.
  7. Position turbocharger (14) onto exhaust manifold (24) and install washers (21) and new nuts (20). Tighten the nuts to a torque of 28 N·m (248 lb in).

**Note:** Do not use the actuator rod to lift the turbocharger.

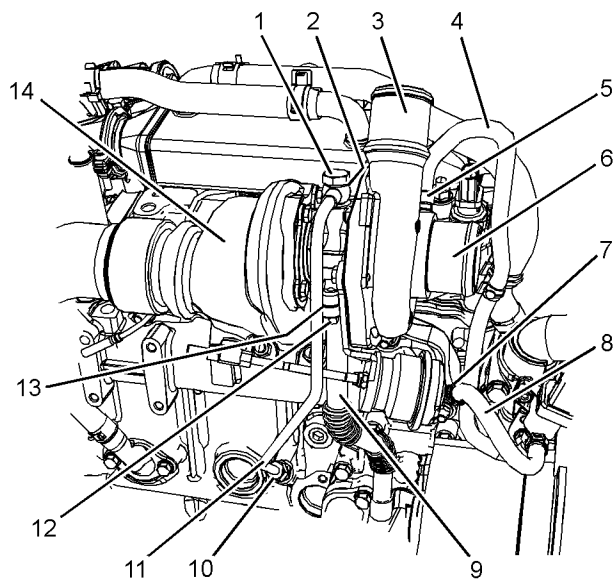


Illustration 85

g02847785

8. Position a new gasket (13) (not shown) onto tube assembly (9).
9. Position tube assembly (9) onto the turbocharger.
10. Install bolts (12) finger tight.
11. Tighten bolts (12) to a torque of 10 N·m (89 lb in).

12. Lubricate the bearings of the turbocharger with clean engine oil through the oil inlet port. Rotate the shaft of the turbocharger in order to distribute the lubricant.
13. Position a new sealing washer (2) (not shown) onto banjo bolt (1). Install banjo bolt (1) onto tube assembly (11) and install remaining new sealing washer (2) to banjo bolt (1).
14. Position tube assembly (11) onto the cylinder block. Loosely install nut (10).
15. Position tube assembly (11) onto the turbocharger. Loosely install banjo bolt (1).
16. Tighten banjo bolt (1) to a torque of 35 N·m (26 lb ft).

**Note:** Ensure that the tube assembly does not come into contact with any other engine component.

17. Tighten nut (10) to a torque of 25 N·m (221 lb in).
18. Connect hose assembly (8) to the wastegate actuator. Install hose clamp (7) to hose assembly (8). Tighten the hose clamp securely.

**Note:** Ensure that hose clamp is correctly positioned on the hose assembly.

19. Connect hose assembly (4) to the turbocharger. Install hose clamp (5) to hose assembly (4). Tighten the hose clamp securely.

**Note:** Ensure that hose clamp is correctly positioned on the hose assembly.

20. Connect the hose assemblies to turbocharger inlet (6) and for turbocharger outlet (3). Securely tighten the hose clamps.

**End By:**

- a. Install the flexible exhaust pipe to the turbocharger. Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.

i05270679

## Turbocharger - Install

### (Side Mounted Turbochargers)

### Installation Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the turbocharger is clean and free from damage. Inspect the turbocharger for wear. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect" for more information. If the turbocharger is worn, the complete turbocharger must be replaced.
2. Test the turbocharger actuator for correct operation. Refer to Systems Operation, Testing and Adjusting, "Turbocharger - Inspect" for more information. If the actuator is damaged or the actuator does not operate within the specified limits, the complete turbocharger must be replaced.

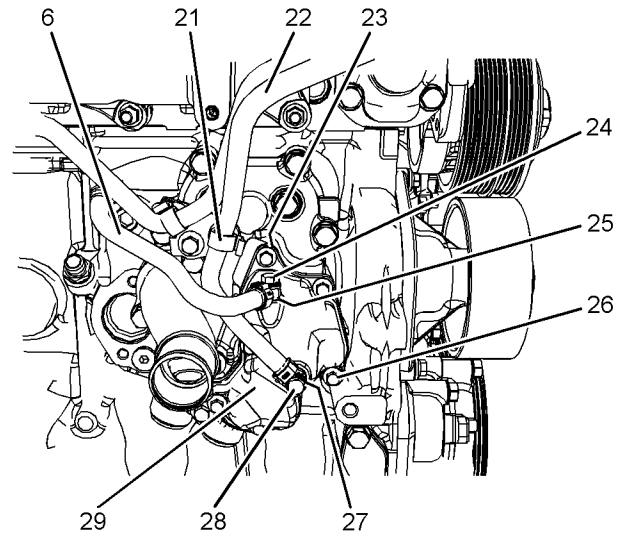


Illustration 86

g02862040

3. If necessary, follow Step 3.a through Step 3.f in order to install boost pressure chamber cover (29).
  - a. Position gasket (23) (not shown) onto boost pressure chamber cover (29).
  - b. Position boost pressure chamber cover onto the engine oil cooler and install bolts (26). Tighten the bolts to a torque of 10 N·m (89 lb in).
  - c. Install a new sealing washer (27) to banjo bolt (28). Install the banjo bolt assembly to hose assembly (22) and install the remaining sealing washer (28). Install hose assembly (22) to boost pressure chamber cover (29) finger tight.
  - d. Install tube assembly (22) into clip (21).
  - e. Install a new sealing washer (25) to banjo bolt (24). Install the banjo bolt assembly to hose assembly (6) and install the remaining sealing washer (24). Install hose assembly (6) to boost pressure chamber cover (29) finger tight.
  - f. Install the alternator and mounting bracket. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.

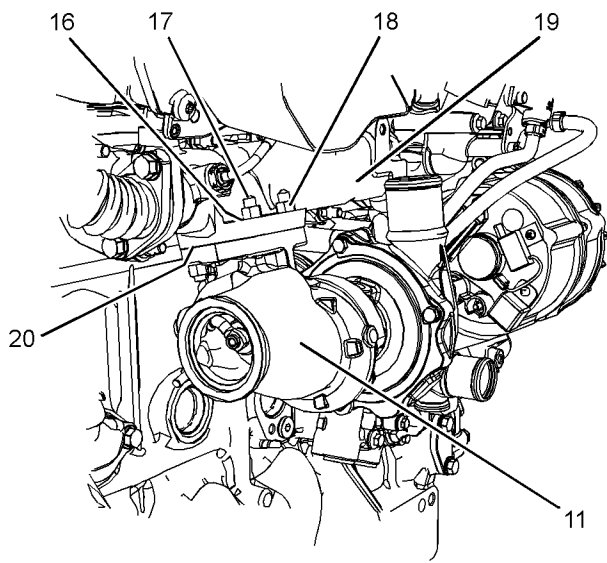


Illustration 87

g02862480

4. Clean the gasket surfaces of exhaust manifold (19). If necessary, install studs (17) to exhaust manifold (19) and turbocharger (11). Tighten the studs to a torque of 15 N·m (133 lb in).
5. Position a new gasket (20) (not shown) onto turbocharger (11).
6. Position turbocharger (11) onto exhaust manifold (19) and install washers (16) and new nuts (15). Tighten the nuts to a torque of 28 N·m (248 lb in).

**Note:** Do not use the actuator rod to lift the turbocharger.

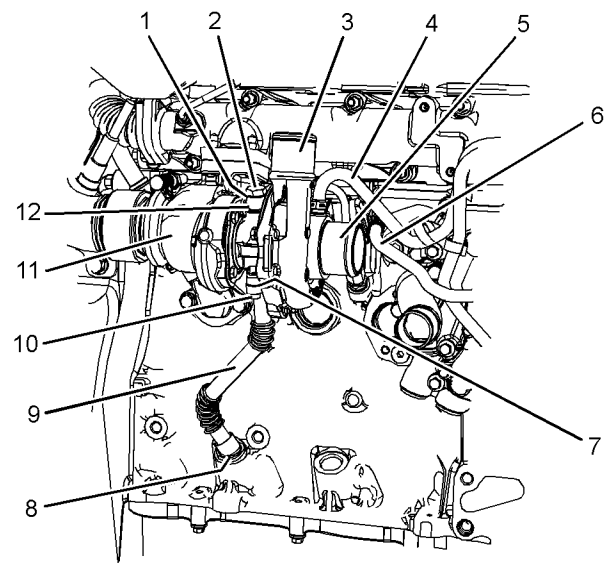


Illustration 88

g02859585

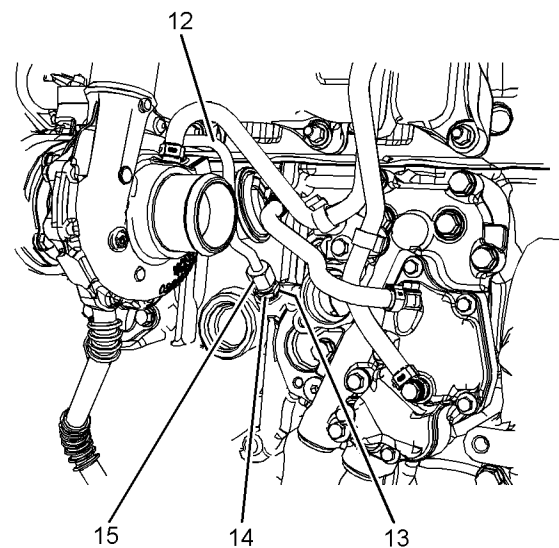


Illustration 89

g02859796

7. If necessary install new O-ring seals (8) onto tube assembly (9). Install tube assembly (9) into the cylinder block.
8. Position a new gasket (7) (not shown) onto tube assembly (9).
9. Position tube assembly (9) onto the turbocharger. Install bolts (10) to tube assembly (9). Tighten the bolts to a torque of 10 N·m (89 lb in).

10. Lubricate the bearings of the turbocharger with clean engine oil through the oil inlet port. Rotate the shaft of the turbocharger in order to distribute the lubricant.
11. If necessary, install a new sealing washer (13) onto connection (14). Install connection assembly (14) to the cylinder block. Tighten the connection assembly to a torque of 22 N·m (195 lb in).
12. Position tube assembly (12) onto connection assembly (14). Loosely install nut (15).
13. Position a new sealing washer (1) (not shown) onto banjo bolt (2). Install banjo bolt (2) onto tube assembly (12) and install remaining new sealing washer (12) and install remaining new sealing washer (1) to banjo bolt (2). Tighten the banjo bolt to torque of 35 N·m (26 lb ft).
14. Tighten nut (15) to torque of 25 N·m (221 lb in).
15. Connect hose assembly (6) to the wastegate actuator. Tighten the hose clamp securely.
16. Connect hose assembly (4) to the turbocharger. Tighten the hose clamp securely.
19. Connect the hose assemblies to the turbocharger inlet and the turbocharger outlet. Tighten the hose clamps securely.

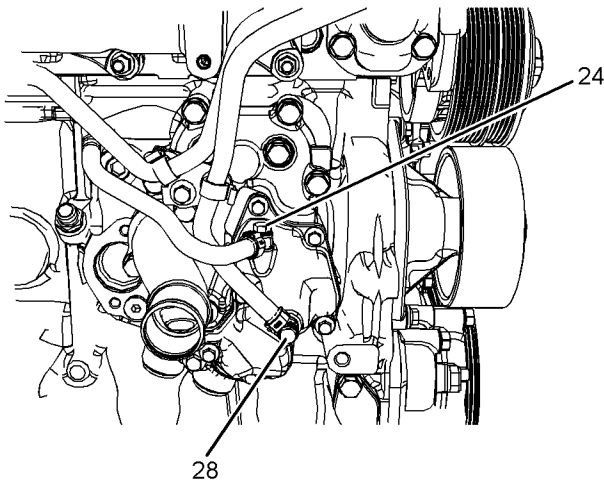


Illustration 90

g02862956

17. Tighten banjo bolt (28) to a torque of 12 N·m (106 lb in).

**Note:** Ensure that the hose assembly does not come into contact with any other engine components.

18. Tighten banjo bolt (24) to a torque of 12 N·m (106 lb in).

**Note:** Ensure that the hose assembly does not come into contact with any other engine components.

20. Install the flexible exhaust pipe to the turbocharger. Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.

i05270685

## Wastegate Solenoid - Remove and Install

### Removal Procedure

#### Start By:

- a. Turn the battery disconnect switch to the OFF position.

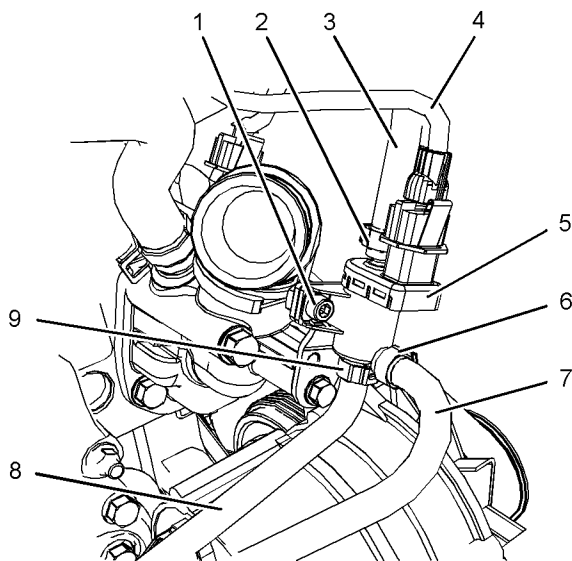


Illustration 91

g02720973

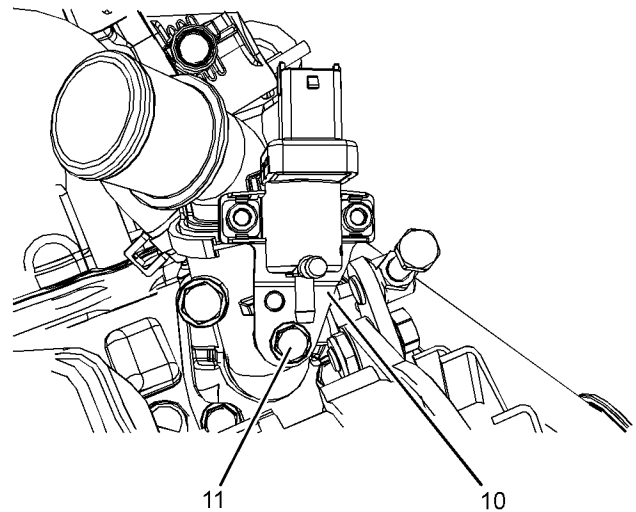


Illustration 92

g02720986

1. Disconnect harness assembly (4) from wastegate solenoid (5).
2. Place temporary marks on all hose assemblies in order to identify the position on the wastegate regulator (5).
3. Remove hose clamp (2). Disconnect hose assembly (3) from wastegate solenoid (5).
4. Remove hose clamp (6). Disconnect hose assembly (7) from wastegate solenoid (5).
5. Remove hose clamp (9). Disconnect hose assembly (8) from wastegate solenoid (5).
6. Remove Allen head bolts (1) and remove the wastegate solenoid from bracket (10).
7. If necessary, remove bolt (11) and remove bracket (10) from the water temperature regulator housing.

### Installation Procedure

1. Ensure that all components of wastegate regulator are clean and free from wear and damage. If necessary, replace the wastegate regulator as an assembly if any of the components are worn or damaged.

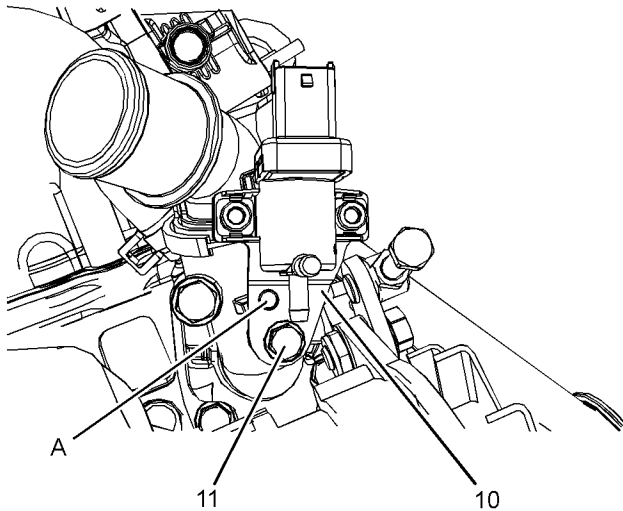


Illustration 93

g02721016

5. Position hose (8) onto the wastegate solenoid. Tighten hose clamp (9) securely.
6. Position hose (7) onto the wastegate solenoid. Tighten hose clamp (6) securely.
7. Position hose (3) onto the wastegate solenoid. Tighten hose clamp (2) securely.
8. Ensure that the hoses do not come into contact with any other engine components.
9. Connect harness assembly (4) to the wastegate solenoid.

**End By:**

- a. Turn the battery disconnect switch to the ON position.

i05291333

## Exhaust Gas Recirculation Valve - Remove and Install

### Removal Procedure

**Start By:**

- a. 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" for the correct procedure.

### **⚠ WARNING**

Sulfuric Acid Burn Hazard may cause serious personal injury or death.

The exhaust gas cooler may contain a small amount of sulfuric acid. The use of fuel with sulfur levels greater than 15 ppm may increase the amount of sulfuric acid formed. The sulfuric acid may spill from the cooler during service of the engine. The sulfuric acid will burn the eyes, skin and clothing on contact. Always wear the appropriate personal protective equipment (PPE) that is noted on a material safety data sheet (MSDS) for sulfuric acid. Always follow the directions for first aid that are noted on a material safety data sheet (MSDS) for sulfuric acid.

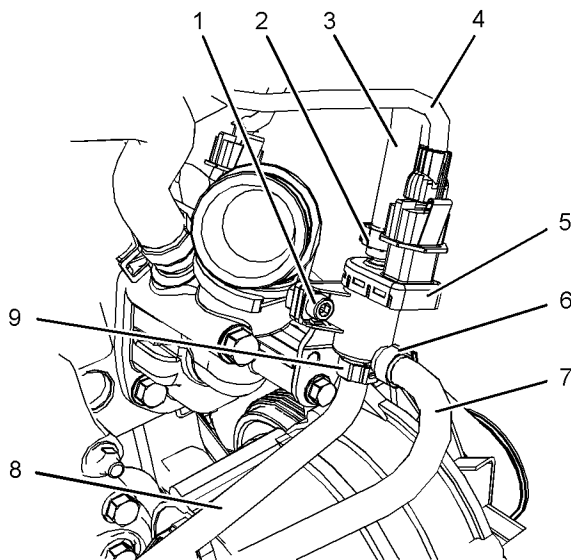


Illustration 94

g02720973

2. If necessary, position bracket (10) onto the water temperature regulator housing. Ensure that the bracket is correctly located onto the spigot in Position (A).
3. Install bolt (11) and tighten the bolt to a torque of 10 N·m (89 lb in).
4. Position wastegate solenoid (5) onto bracket (10). Install Allen head bolts (1) to wastegate solenoid (5). Tighten Allen head bolts (1) to a torque of 10 N·m (89 lb in).

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

## Disassembly and Assembly Section

**Note:** Plug or cap all open ports with new plugs or caps.

1. If necessary, remove the diesel particulate mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.

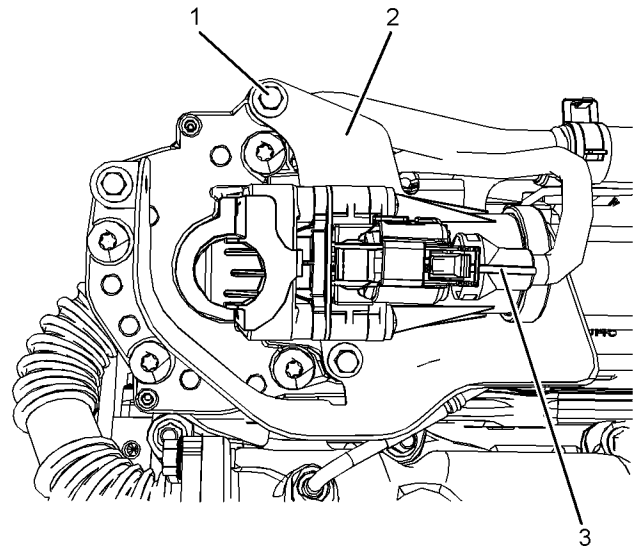


Illustration 95

g02912798

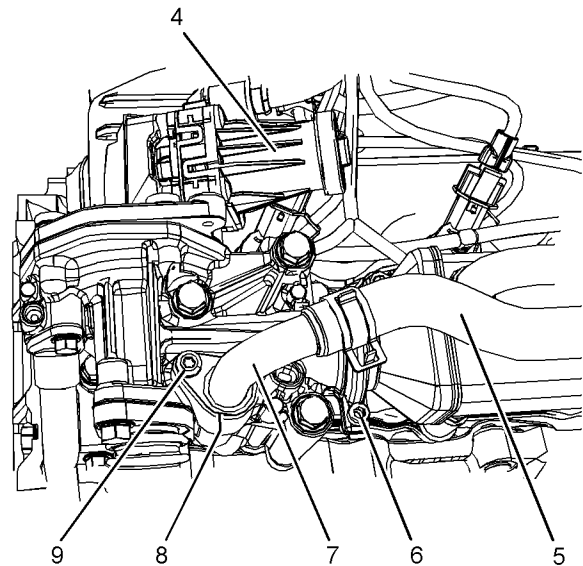


Illustration 96

g02898616



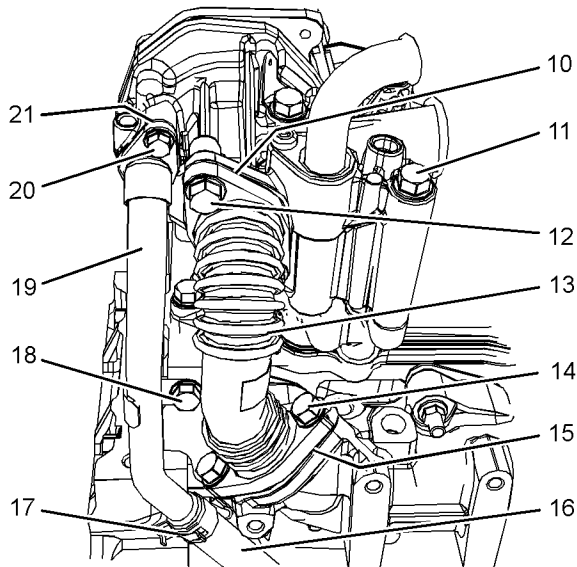


Illustration 97

g02898617

2. If necessary, remove bolts (1) and heat shield (2) from exhaust gas recirculation (EGR) valve (4).
  3. Slide the locking tab into the unlocked position and disconnect harness assembly (3) from EGR valve (4).
  4. Loosen clamp (6) and position the clamp away from EGR valve (4).
  5. Disconnect hose assembly (5) from EGR valve (4).
  6. Remove bolt (18) from the bracket for tube assembly (19).
  7. Remove bolt (20) and tube assembly (19) from EGR valve (4).
  8. Remove O-ring seal (21) (not shown).
  9. If necessary, slide hose clamp (17) along hose (16). Disconnect tube (19) from hose (16).
  10. Apply releasing fluid prior to and during the removal of bolts (12) and bolts (14).
  11. Remove bolts (12) and remove bolts (14). Remove flexible tube assembly (13) from the exhaust manifold.
  12. Remove bolts (11) from EGR valve (4).
- Note:** Note the position of different length bolts.
13. Remove from EGR valve (4) from the induction manifold.
  14. If necessary, remove bolt (9) and remove tube assembly (7) from EGR valve (4). Remove O-ring seal (8) (not shown).

## Installation Procedure

### **WARNING**

Sulfuric Acid Burn Hazard may cause serious personal injury or death.

The exhaust gas cooler may contain a small amount of sulfuric acid. The use of fuel with sulfur levels greater than 15 ppm may increase the amount of sulfuric acid formed. The sulfuric acid may spill from the cooler during service of the engine. The sulfuric acid will burn the eyes, skin and clothing on contact. Always wear the appropriate personal protective equipment (PPE) that is noted on a material safety data sheet (MSDS) for sulfuric acid. Always follow the directions for first aid that are noted on a material safety data sheet (MSDS) for sulfuric acid.

### NOTICE

Ensure that wiring harness are correctly routed and the cable straps are not over tightened. Over tightening of the cable straps will damage the wiring harness convoluting.

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.

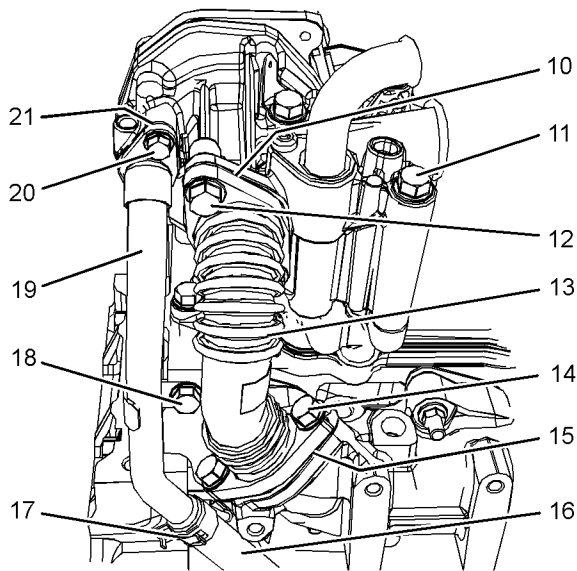


Illustration 98

g02898617

**Note:** Ensure that the bolts are installed into the correct position.

8. If necessary, install tube (19) to hose (16). Slide hose clamp (17) into position and tighten securely.
9. Install new O-ring seals (21) (not shown) to tube assembly (19).
10. Install tube assembly (19) to EGR valve (4).
11. Install bolt (18) and bolt (20) finger tight. Tighten the bolt
12. Tighten bolt (20) to a torque of 10 N·m (89 lb in).
13. Tighten bolt (18) to a torque of 25 N·m (221 lb in)
14. Position new gasket (15) onto flexible tube assembly (13).
15. Position flexible tube assembly (13) onto the exhaust manifold. Install bolts (14) finger tight.

**Note:** Ensure that the flexible tube assembly can move freely.

16. Position gasket (10) (not shown) between flexible tube assembly (13) and EGR valve (4). Install bolts (12) finger tight.

**Note:** Ensure that the flexible tube assembly can move freely and the gasket is correctly positioned.

17. Tighten bolts (12) to a torque of 25 N·m (221 lb in).
18. Tighten bolts (14) to a torque of 25 N·m (221 lb in).
19. Install hose assembly (5) onto pipe (7). Position hose clamp and tighten the clamp securely.

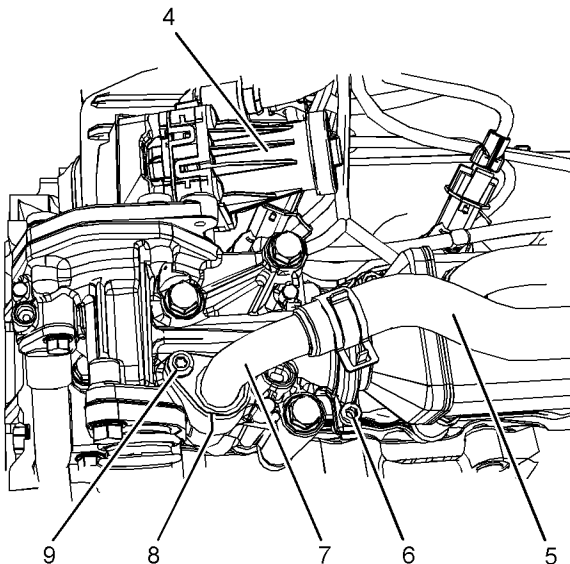


Illustration 99

g02898616

2. If necessary, install new O-ring seal (8) (not shown) to Exhaust Gas Recirculation (EGR) valve (4). Install tube assembly (7) to EGR valve (4).
3. Install new clamp (6) to EGR valve (4).
4. Position a new clamp (6) onto EGR valve (4).
5. Install bolts (11) to EGR valve (4) finger tight.
6. Position clamp (6). Tighten the clamp to a torque of 10 N·m (89 lb in).
7. Tighten bolts (11) to a torque of 25 N·m (221 lb in).

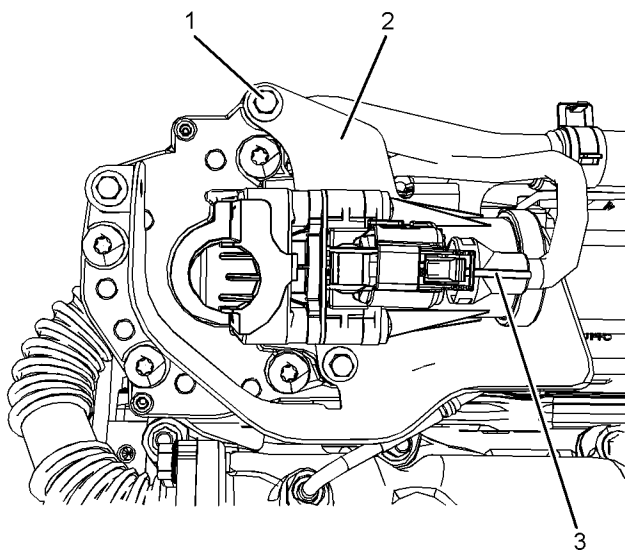


Illustration 100

g02912798

20. If necessary, position heat shield (2) onto EGR valve (4) and install bolts (1). Tighten the bolts to a torque of 10 N·m (89 lb in).
21. Connect harness assembly (3) to EGR valve (3) and slide the locking tab into the locked position.
22. If necessary, install the diesel particulate mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.

**End By:**

- a. Fill the cooling system. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.
- b. When the EGR valve is cleaned or a new replacement is installed, it will be necessary to use the Electronic Service Tool (EST) in order to perform the "EGR Valve Learn Reset" procedure.

i05270693

## Flexible Exhaust Pipe - Remove and Install

### Removal Procedure for the Flexible Exhaust Pipe as an Assembly



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

**NOTICE**

The bellows must be supported at all times when the bellows are not installed in the application. Failure to support the bellows adequately could result in the failure of the bellows. Do not use power tools in order to disassemble or assemble any part of the flexible exhaust system.

The alignment of the bellows is important. Incorrect alignment may lead to premature failure of the bellows. Misalignment can be identified by visually inspecting the uniformity of the spacing between the convolutions on the bellows.

Inspect the bellows for damage prior to installation. If there is any damage to the convolutions, discard the bellows. If there is any difficulty in installation after the repair, discard the bellows.

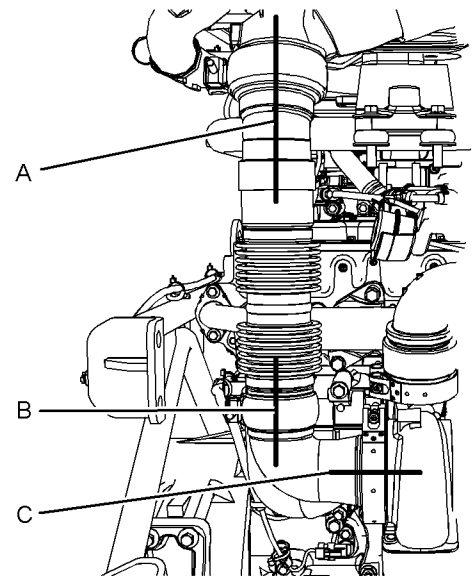


Illustration 101

g02354623

**Typical example**

1. The lateral alignment of the bellows is critical. All the components must be assembled in the same alignment as prior to disassembly. The components that require correct lateral alignment are shown at Positions (A, B, and C).



## Assembly Procedure for the Flexible Exhaust Pipe Assembly

Table 14

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Drill Bit 3 mm (0.118 inch) Ø	1
B	-	Drill Bit 6.5 mm (0.256 inch) Ø	1

1. Ensure that all components of the flexible exhaust pipe assembly are clean and free from wear and damage. If necessary, replace any components of the flexible exhaust pipe assembly that are worn or damaged. Refer to Disassembly and Assembly, "Inspection of Parts" for more information.

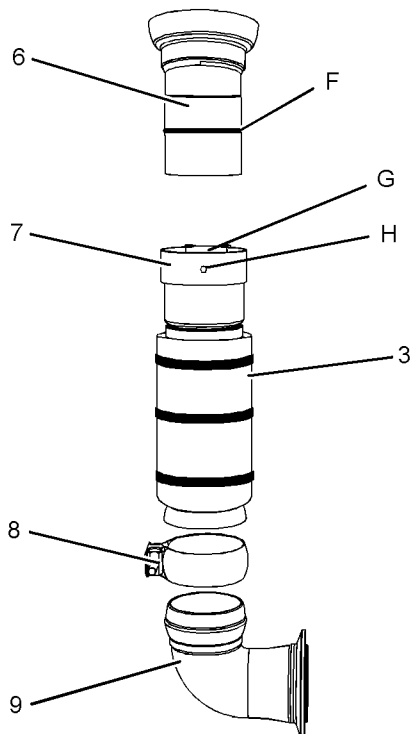


Illustration 104

g02469603

Typical example

2. If the flexible exhaust pipe assembly was previously disassembled. Follow Step 2.a through Step 2.i in order to assemble the flexible exhaust pipe assembly.

### NOTICE

Use the correct personal protective equipment when removing the clamp.

a. If original bellows are to be reinstalled, place the internal area in Position (G) of the bellows on a suitable support. Use Tooling (A) in order to drill a pilot hole through the spot weld in Position (H) on clamp (7).

**Note: Do not center punch the spot weld on clamp (7).**

b. Use Tooling (B) in order to drill out the spot weld in Position (H) on clamp (7). Remove clamp (7) from the bellows.

c. Remove all burrs from the internal and external areas of bellows (3). **Ensure that debris does not enter the bellows.**

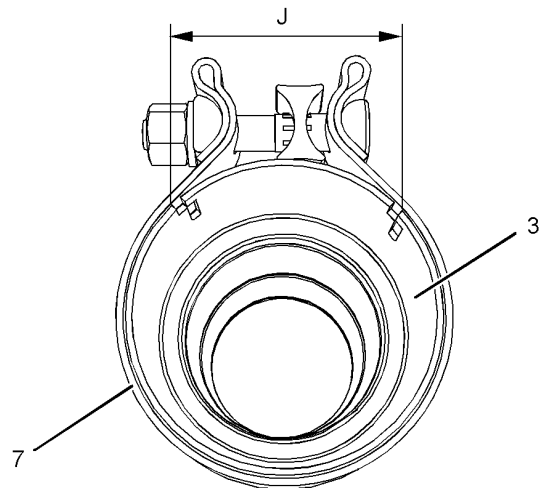


Illustration 105

g02354619

Typical example

d. Position a new clamp (7) onto bellows (3). Hand tighten clamp (7). Ensure that the center of the clamp is central to Slots (J) on the bellows. The clamp must be flush with the end of bellows (3).

**Note:** Ensure that the bellows are not subjected to any undue stress.

e. If new bellows (3) are installed, clamp (7) will be pre-installed to the bellows.

**Note:** Ensure that the bellows are not subjected to any undue stress.

f. Position a new ball clamp (8) onto elbow (9).

g. Position bellows (3) onto elbow (9). Align the bellows and the elbow with temporary marks.

h. Tighten ball clamp (8) hand tight.

**Note:** Ensure that the bellows are not subjected to any undue stress.

- i. Install tube assembly (6), align the tube assembly with the temporary marks on the bellows. Tighten clamp (7) hand tight.

## Installation Procedure for the Flexible Exhaust Pipe as an Assembly

### NOTICE

Inspect the bellows for damage prior to installation. If there is any damage to the convolutions, discard the bellows. If there is any difficulty in installation after the repair, discard the bellows.

1. Check the flexible exhaust pipe assembly for damage. Refer to Disassembly and Assembly, "Inspection of Parts" for more information.

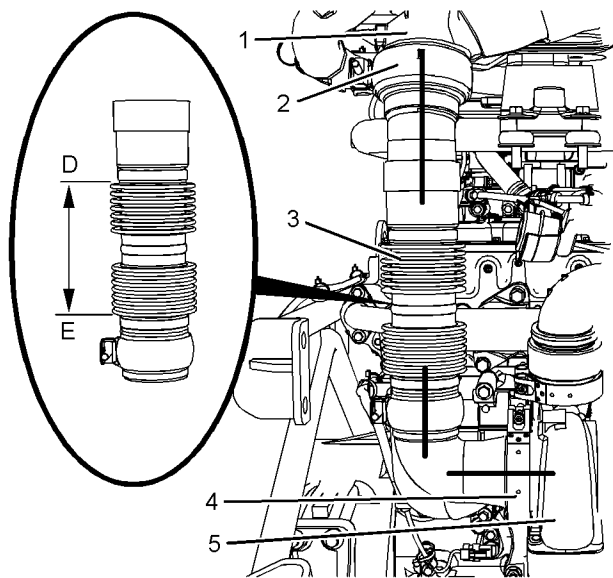


Illustration 106

g02354616

Typical example

2. Position a new ball clamp (2) onto the flexible exhaust pipe assembly.
3. Install V-band clamp (4) onto turbocharger (5).
4. Install assembly of the flexible exhaust pipe onto CEM (1) and turbocharger (5).

**Note:** Ensure that the assembly of the flexible exhaust pipe is supported at all times.

5. Tighten V-band clamp (4) hand tight.
6. Tighten ball clamp (2) hand tight.

### NOTICE

Failure to reinstall the bellows into the original position will result in a failure of the bellows and possible emissions failure.

7. Align the assembly of the flexible exhaust pipe with the temporary marks. Ensure that bellows (3) are not subjected to any undue stress.

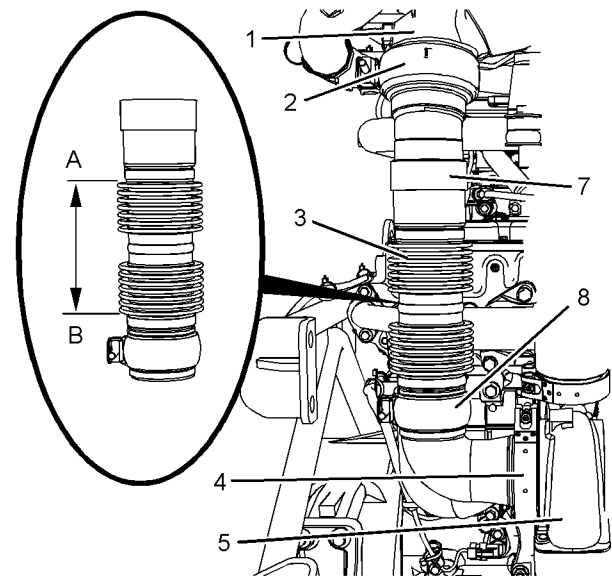


Illustration 107

g02250353

Typical example

8. If a new bellows assembly has been installed, ensure that all components of the flexible exhaust pipe are not subjected to any undue stress and are correctly aligned.
9. Tighten ball clamp (2) to a torque of 35 N·m (26 lb ft).
10. Tighten clamp (7) to a torque of 55 N·m (40 lb ft).
11. Tighten ball clamp (8) to a torque of 35 N·m (26 lb ft).
12. Tighten V-band clamp (4) to a torque of 25 N·m (221 lb in).

13. Cut cable straps from the suitable material that was encasing bellows (3) between Position (A) and Position (B). Remove the suitable material from bellows (3).

i05270715

## Exhaust Manifold - Remove and Install

### Removal Procedure

#### Start By:

- a. Remove the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Remove" for the correct procedure.

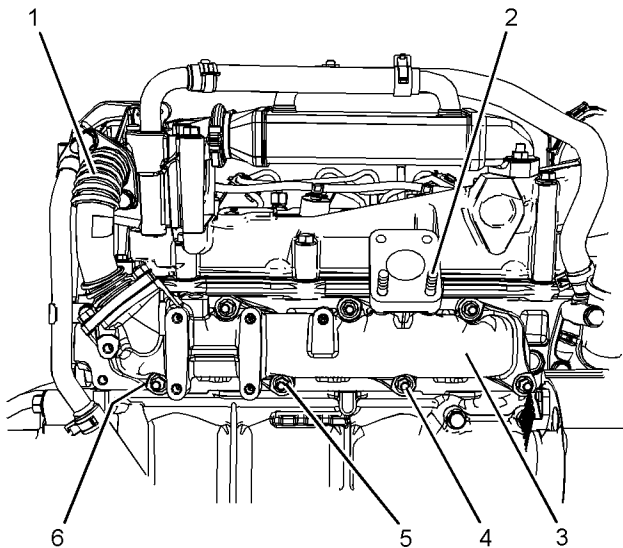


Illustration 108

g02725206

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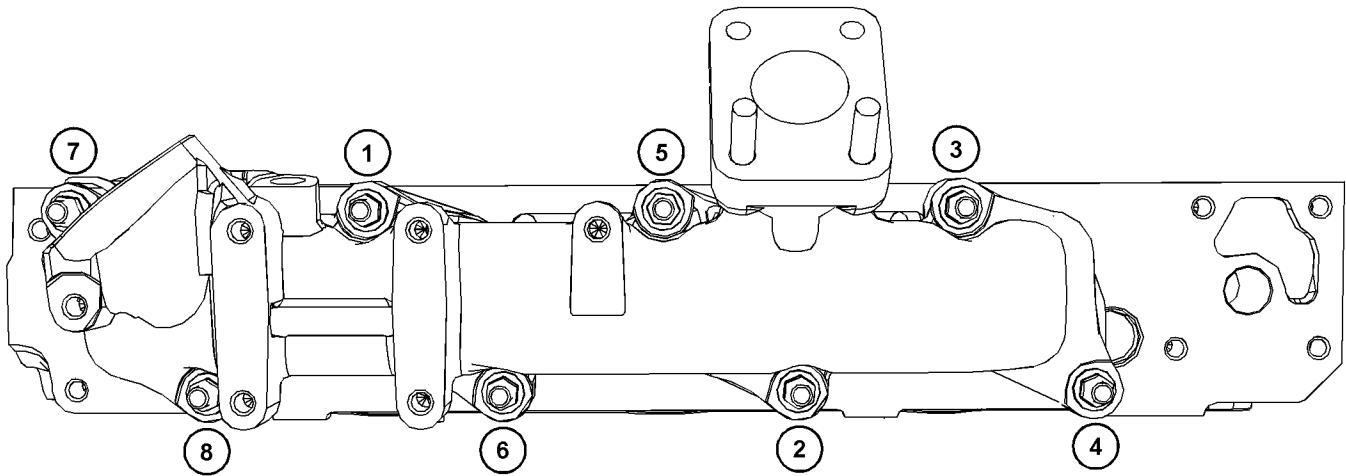


Illustration 109

g02725251

**Tighten sequence of exhaust manifold**

1. Remove tube assembly (1). Refer to Disassembly and Assembly, "Air Control Valve - Remove and Install" for the correct procedure.
  2. Loosen nuts (5) in reverse numerical order. Refer to Illustration 109 .
- Note:** Loosening the bolts in reverse numerical order will help prevent distortion of the exhaust manifold.
3. Remove nuts (5) and remove exhaust manifold (3) from the cylinder head.
  4. Remove exhaust manifold gasket (6) (not shown).
  5. If necessary, remove studs (2) from the exhaust manifold.
  6. If necessary, remove studs (4) from the cylinder head.



## Installation Procedure

1. Ensure that the exhaust manifold is clean and free from damage. If necessary, replace the exhaust manifold. Clean the gasket surface of the cylinder head.

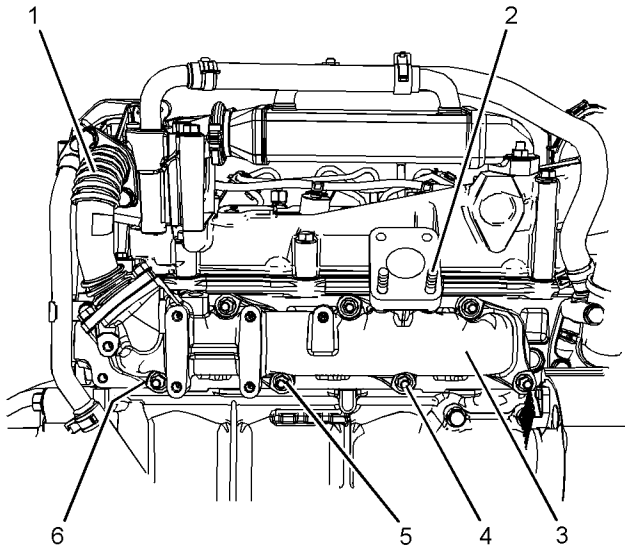


Illustration 110

g02725206

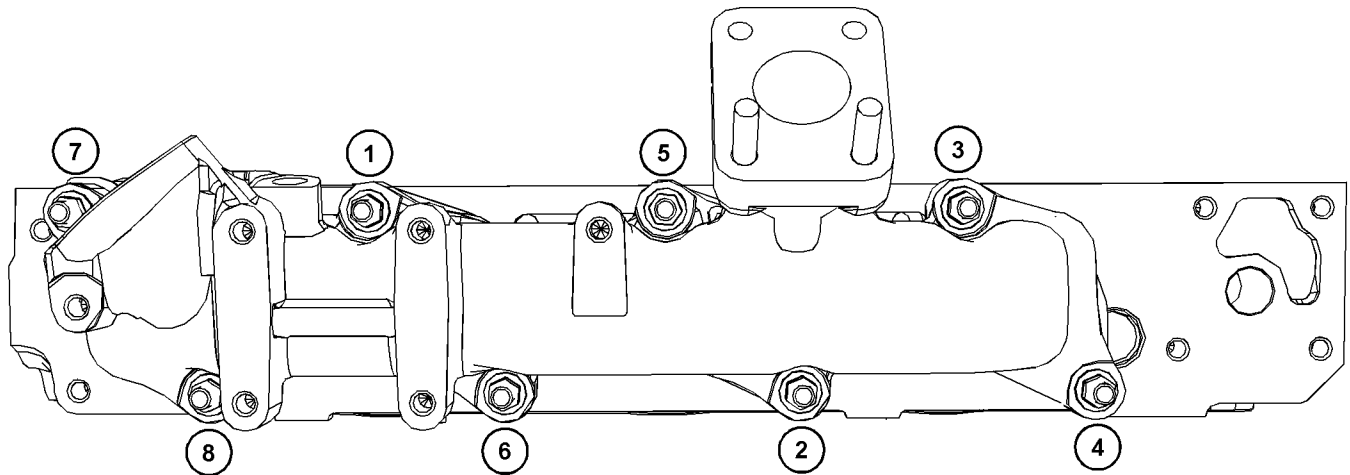


Illustration 111

g02725251

2. If necessary, install studs (2) to exhaust manifold (3). Tighten the stud to a torque of 18 N·m (159 lb in).
3. Position a new exhaust manifold gasket (6) (not shown) onto studs (4).

**Note:** Ensure that the exhaust manifold gasket is correctly oriented.

4. Position exhaust manifold (3) onto studs (4).
5. Install nuts (5) to studs (4) finger tight. Tighten the nuts in the sequence that is shown in Illustration 111 in two stages.

Tighten the nuts to an initial torque of 10 N·m (89 lb in).

Tighten the nuts to a final torque of 27 N·m (239 lb in).

6. Install tube assembly (1). Refer to Disassembly and Assembly, "Air Control Valve - Remove and Install" for the correct procedure.

**End By:**

- a. Install the turbocharger to the exhaust manifold. Refer to Disassembly and Assembly, "Turbocharger - Install" for the correct procedure.

i05270721

## Diesel Particulate Filter - Remove

(Through Flow Diesel Particulate Filter)

S/N: JR11-Up

S/N: JS11-Up

S/N: JT11-Up

### Removal Procedure

Table 15

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bellows Protector	1

**⚠ 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.

**⚠ WARNING**

The muffler, catalytic converter/muffler, and diesel particulate filter will become extremely hot during engine operation. A hot muffler, catalytic converter/muffler and diesel particulate filter can cause serious burns. Allow adequate cooling time before working on or near the muffler, catalytic converter/muffler and diesel particulate filter.

**NOTICE**

Do not strike any part of the assembly of the Diesel Particulate Filter (DPF). Do not allow any object to contact the internal element of the DPF. If the internal element of the DPF becomes damaged, the assembly must be replaced.

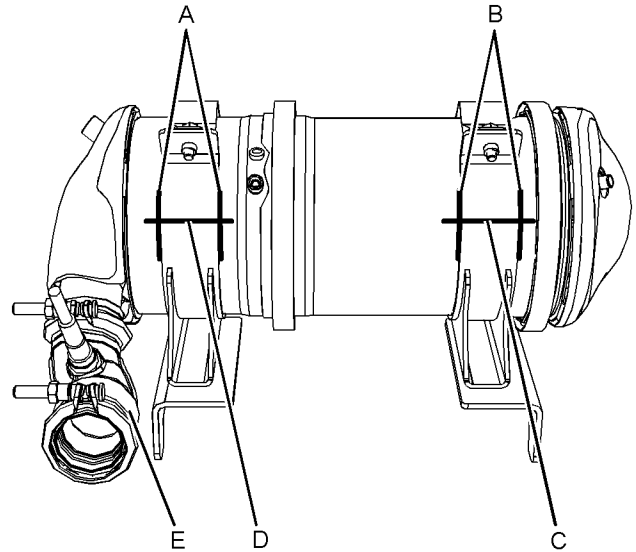


Illustration 112

g03020017

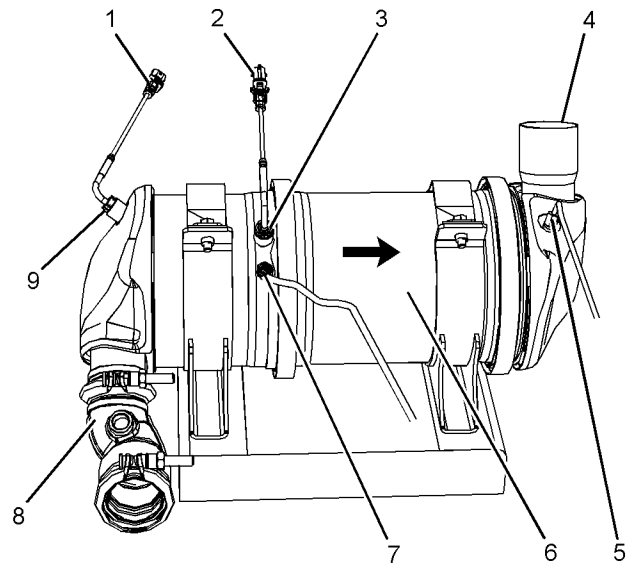


Illustration 113

g03013138

Typical example

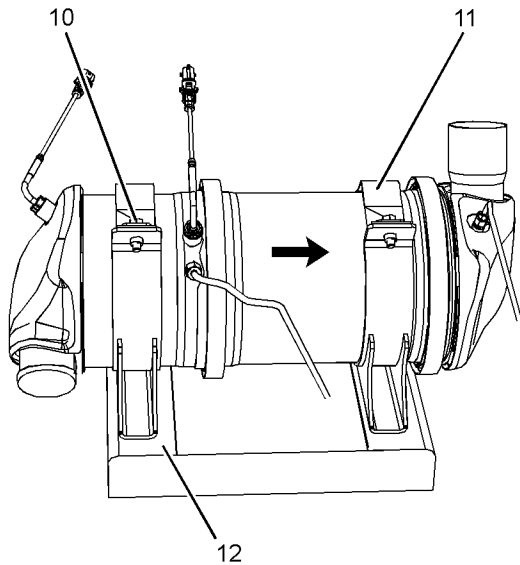


Illustration 114

g03013381

## Typical example

1. If necessary, remove the Original Equipment Manufacturer's (OEM) exhaust tube assembly from outlet (4). Refer to the OEM for the correct procedure.
  2. Make temporary alignment marks on DPF (6) and clamps (11) in Positions (A), (B), (C) and (D) in order to ensure that the DPF is installed in the original position.
  3. If the DPF is installed onto the flywheel housing, install Tooling (A) in Position (E) in order to maintain correct alignment of flexible exhaust pipe assembly (8).
  4. Disconnect the flexible exhaust pipe assembly (8). Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.
  5. Make a temporary mark on Diesel Particulate Filter (DPF) (6) in order to show the direction of the flow for the exhaust gases.
  6. Disconnect the wiring harness from connection (1) for temperature sensor (9).
- Note:** Make temporary identification marks on all connections for assembly purposes.
7. Disconnect the wiring harness from connection (2) for temperature sensor (3)

**Note:** Make temporary identification marks on all connections for assembly purposes.

8. Disconnect pressure sensor tube assembly (5) from the DPF.

**Note:** Make temporary identification marks on the tube assembly for assembly purposes.

9. Disconnect pressure sensor tube assembly (7) from the DPF.

**Note:** Make temporary identification marks on the tube assembly for assembly purposes.

10. Remove bolts (10) from clamps (11). Remove the clamps from the DPF in order to allow removal of the DPF.

11. Attach a suitable lifting device to the DPF. The weight of the DPF is approximately 15 kg (33 lb).

12. Use the suitable lifting device in order to remove the DPF from bracket (12).

13. If necessary, remove temperature sensor (3) and temperature sensor (9). Refer to Disassembly and Assembly, "Temperature Sensor (DPF) - Remove and Install" for the correct procedure.

i05315169

## Diesel Particulate Filter - Remove

### (Wall Flow Diesel Particulate Filter)

### Removal Procedure

Table 16

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bellows Protector	1

### 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.**

## ⚠ WARNING

The muffler, catalytic converter/muffler, and diesel particulate filter will become extremely hot during engine operation. A hot muffler, catalytic converter/muffler and diesel particulate filter can cause serious burns. Allow adequate cooling time before working on or near the muffler, catalytic converter/muffler and diesel particulate filter.

## NOTICE

Do not strike any part of the assembly of the Diesel Particulate Filter (DPF). Do not allow any object to contact the internal element of the DPF. If the internal element of the DPF becomes damaged, the assembly must be replaced.

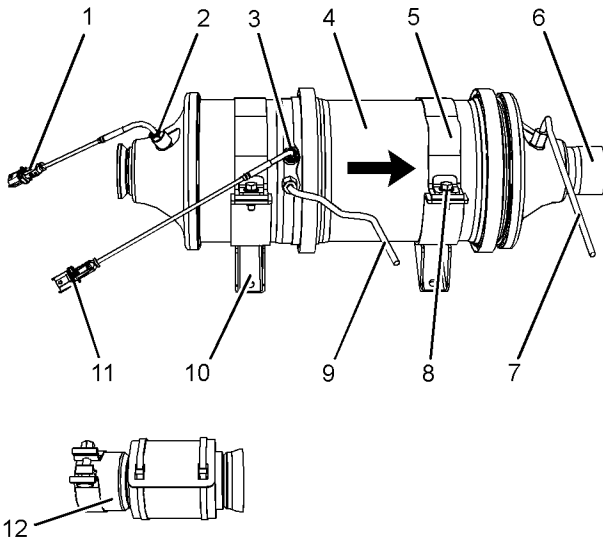


Illustration 115

g03370358

Flexible exhaust pipe assembly with bellows protector Tooling (A) in position.

Typical example

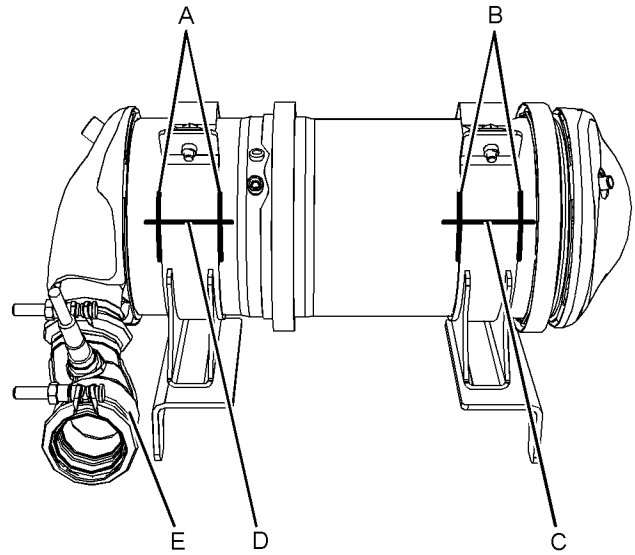


Illustration 116

g03370799

Typical example

1. If necessary, remove the Original Equipment Manufacturer's (OEM) exhaust tube assembly from outlet (6). Refer to the OEM for the correct procedure.
  2. Make temporary alignment marks on DPF (4) and clamps (5) in Positions (A), (B), (C) and (D) in order to ensure that the DPF is installed in the original position.
  3. If the DPF is installed onto the flywheel housing, install Tooling (A) in Position (E) in order to maintain correct alignment of flexible exhaust pipe assembly (12).
  4. Disconnect the flexible exhaust pipe assembly (12). Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.
- Note:** Do not remove the bellows protector prior to installing the flexible exhaust pipe assembly.
5. Make a temporary mark on Diesel Particulate Filter (DPF) (4) in order to show the direction of the flow for the exhaust gases.
  6. Disconnect the wiring harness from connection (1) for temperature sensor (2).

**Note:** Make temporary identification marks on all connections for assembly purposes.

7. Disconnect the wiring harness from connection (11) for temperature sensor (3)

**Note:** Make temporary identification marks on all connections for assembly purposes.

8. Disconnect pressure sensor tube assembly (7) from the DPF.

**Note:** Make temporary identification marks on the tube assembly for assembly purposes.

9. Disconnect pressure sensor tube assembly (9) from the DPF.

**Note:** Make temporary identification marks on the tube assembly for assembly purposes.

10. Remove bolts (8) from clamps (5). Remove the clamps from the DPF in order to allow removal of the DPF.
11. Attach a suitable lifting device to the DPF. The weight of the DPF is approximately 15 kg (33 lb).
12. Use the suitable lifting device in order to remove the DPF from brackets (10).
13. If necessary, remove temperature sensor (2) and temperature sensor (3). Refer to Disassembly and Assembly, "Temperature Sensor (DPF) - Remove and Install" for the correct procedure.

i05270723

## Diesel Particulate Filter - Install

### (Through Flow Diesel Particulate Filter)

**S/N:** JR11-Up

**S/N:** JS11-Up

**S/N:** JT11-Up

### Installation Procedure

Table 17

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bellows Protector	1

### 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.**

#### NOTICE

Do not strike any part of the assembly of the Diesel Particulate Filter (DPF). Do not allow any object to contact the internal element of the DPF. If the internal element of the DPF becomes damaged, the assembly must be replaced.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.
2. If the flexible exhaust pipe was removed as an assembly, refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct installation procedure.

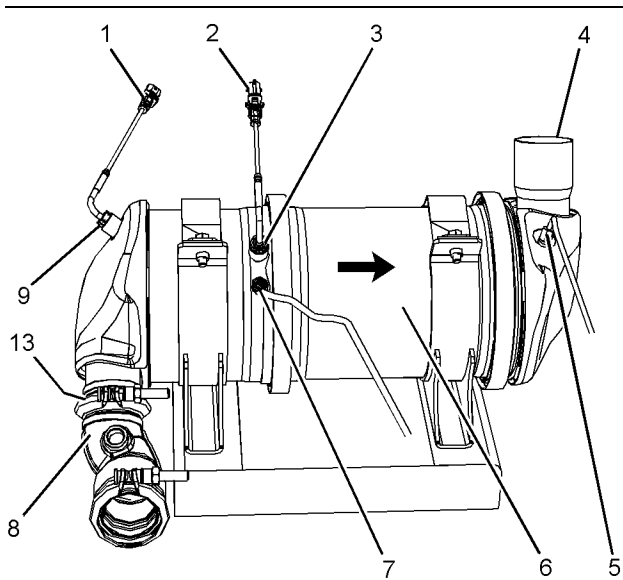


Illustration 117

g03017439

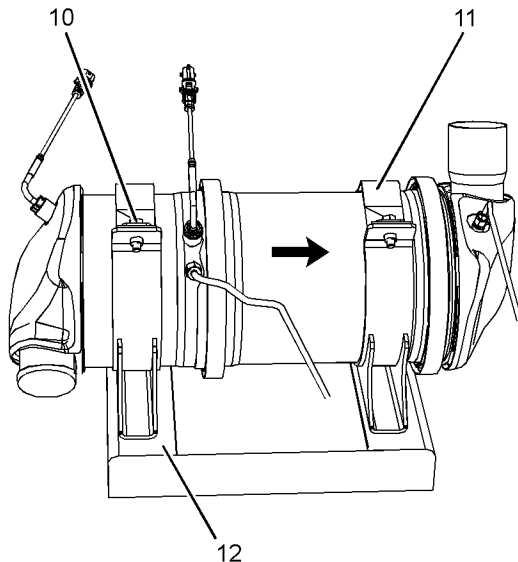


Illustration 118

g03017436

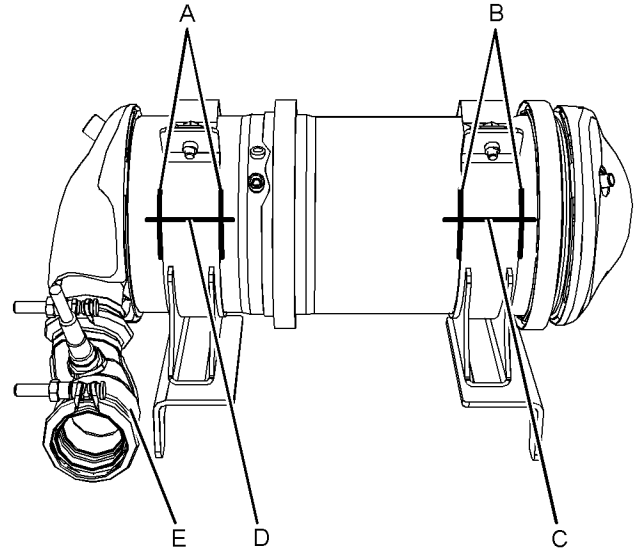


Illustration 119

g03022697

3. If necessary, install the temperature sensors (3) and temperature sensor (9) into the DPF. Refer to Disassembly and Assembly, "Temperature Sensor (DPF) - Remove and Install" for the correct procedure.
  4. Position a new V-band clamp onto flexible exhaust pipe (8).
  5. Attach a suitable lifting device to the assembly of the Diesel Particulate Filter (DPF) (6). The weight of the DPF is approximately 15 kg (33 lb).
  6. Use the suitable lifting device in order to install the DPF to mounting bracket (12). Ensure that the flexible exhaust pipe is correctly seated onto the turbocharger and DPF with the alignment pin (13) (not shown) fully engaged.
- Note:** Ensure that the exhaust gases flow in the direction of temporary mark.
7. Remove the suitable lifting device from the assembly of the DPF.
  8. Position clamps (11) onto DPF (6). Loosely install bolts (10).
  9. Loosely install the Original Equipment Manufacturer's (OEM) exhaust pipe assembly to outlet section (4) of the DPF.
  10. Align the temporary alignment marks on DPF (6) and clamps (11) in Positions (A), (B), (C) and (D).

**Note:** Ensure that the flexible exhaust pipe bellows are not subjected to any undue stress.

**11.** If a new DPF is being installed, the DPF must be aligned using flexible exhaust pipe (8) as the reference point.

**Note:** Ensure that the flexible exhaust pipe bellows are not subjected to any undue stress.

**12.** Position the V-band clamp onto the DPF. Tighten the flexible exhaust pipe clamp. Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.

**13.** Tighten the OEM exhaust pipe assembly to the outlet section of the DPF. Refer to the OEM for the correct procedure.

**14.** Ensure that the DPF is installed in the original position and all of the temporary alignment marks are aligned.

**Note:** Ensure that the flexible exhaust pipe bellows are not subjected to any undue stress.

**15.** Tighten bolts (10) evenly in three stages.

Tighten bolts (10) to an initial torque of 8 N·m (71 lb in)

Tighten bolts (10) to a secondary torque of 16 N·m (141.6 lb in)

Tighten bolts (10) to a final torque of 25 N·m (221 lb in).

**16.** If necessary, remove Tooling (A) from flexible exhaust pipe (8).

**17.** Connect the wiring harness assembly to connection (1) on temperature sensor (9).

**18.** Connect the wiring harness assembly to connection (2) on temperature sensor (3).

**19.** Connect the pressure sensor tube assembly (5) to the DPF. Tighten the connection to a torque of 25 N·m (221 lb in).

**20.** Connect the pressure sensor tube assembly (7) to the DPF. Tighten the connection to a torque of 30 N·m (265 lb in).

#### End By:

**a.** If the DPF has had an ash service, it will be necessary to use the electronic service tool in order to perform the "DPF Ash Cleaning" procedure.

**b.** If the DPF required replacing and a new DPF has been installed, it will be necessary to use the electronic service tool in order to perform the "DPF Replacement Reset" procedure.

i05315171

## Diesel Particulate Filter - Install (Wall Flow Diesel Particulate Filter )

### Installation Procedure

Table 18

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bellows Protector	1

#### 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.**

#### NOTICE

Do not strike any part of the assembly of the Diesel Particulate Filter (DPF). Do not allow any object to contact the internal element of the DPF. If the internal element of the DPF becomes damaged, the assembly must be replaced.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged. Refer to Disassembly and Assembly, "Inspection of Parts" for the correct procedures.
2. If the flexible exhaust pipe was removed as an assembly, refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct installation procedure.

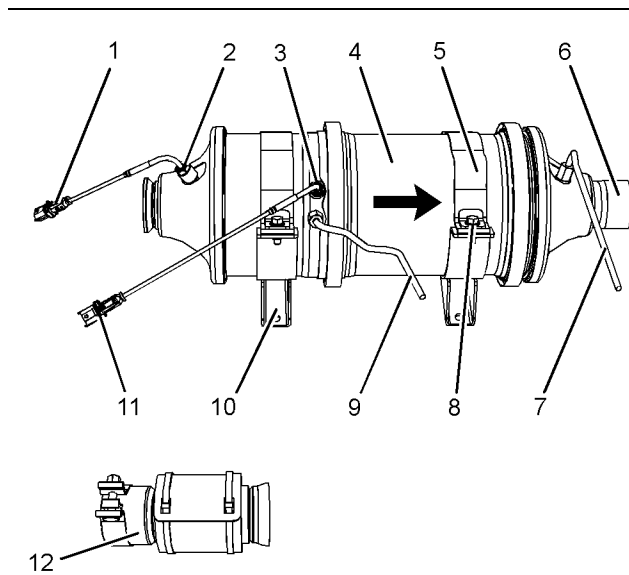


Illustration 120

g03372061

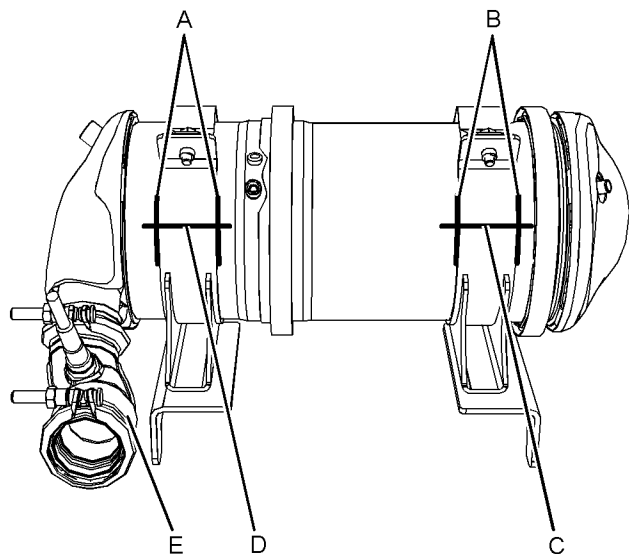


Illustration 121

g03372062

3. If necessary, install the temperature sensors (3) and temperature sensor (9) into the DPF. Refer to Disassembly and Assembly, "Temperature Sensor (DPF) - Remove and Install" for the correct procedure.
4. Position a new V-band clamp onto flexible exhaust pipe (12).
5. Attach a suitable lifting device to the assembly of the Diesel Particulate Filter (DPF) (4). The weight of the DPF is approximately 15 kg (33 lb).

6. Use the suitable lifting device in order to install the DPF to mounting bracket (10). Ensure that the flexible exhaust pipe is correctly seated onto the turbocharger and DPF with the alignment pin (not shown) fully engaged.

**Note:** Ensure that the exhaust gases flow in the direction of temporary mark.

7. Remove the suitable lifting device from the assembly of the DPF.
8. Position clamps (5) onto DPF (4). Loosely install bolts (8).
9. Loosely install the Original Equipment Manufacturer's (OEM) exhaust pipe assembly to outlet section (6) of the DPF.
10. Align the temporary alignment marks on DPF (4) and clamps (5) in Positions (A), (B), (C) and (D).

**Note:** Ensure that the flexible exhaust pipe bellows are not subjected to any undue stress.

11. If a new DPF is being installed, the DPF must be aligned using flexible exhaust pipe (12) as the reference point.

**Note:** Ensure that the flexible exhaust pipe bellows are not subjected to any undue stress.

12. Position the V-band clamp onto the DPF. Tighten the flexible exhaust pipe clamp. Refer to Disassembly and Assembly, "Flexible Exhaust Pipe - Remove and Install" for the correct procedure.

13. Tighten the OEM exhaust pipe assembly to the outlet section of the DPF. Refer to the OEM for the correct procedure.

14. Ensure that the DPF is installed in the original position and all of the temporary alignment marks are aligned.

**Note:** Ensure that the flexible exhaust pipe bellows are not subjected to any undue stress.

15. Tighten bolts (8) evenly in three stages.

Tighten bolts (8) to an initial torque of 8 N·m (71 lb in)

Tighten bolts (8) to a secondary torque of 16 N·m (141.6 lb in)

Tighten bolts (8) to a final torque of 25 N·m (221 lb in).

16. If necessary, remove Tooling (A) from flexible exhaust pipe (12).



**Note:** Do not start the engine with the bellows protector in place.

17. Connect the wiring harness assembly to connection (1) on temperature sensor (2).
18. Connect the wiring harness assembly to connection (11) on temperature sensor (3).
19. Connect the pressure sensor tube assembly (9) to the DPF. Tighten the connection to a torque of 30 N·m (265 lb in).
20. Connect the pressure sensor tube assembly (7) to the DPF. Tighten the connection to a torque of 30 N·m (265 lb in).

**End By:**

- a. If the DPF has had an ash service, it will be necessary to use the electronic service tool in order to perform the “DPF Ash Cleaning” procedure.
- b. If the DPF required replacing and a new DPF has been installed, it will be necessary to use the electronic service tool in order to perform the “DPF Replacement Reset” procedure.

i05270725

## Support and Mounting (CEM) - Remove and Install (Option 3)

### CEM Assembly Removal Procedure

**Start By:**

- a. Remove the DPF. Refer to Disassembly and Assembly, “Diesel Particulate Filter - Remove” for the correct procedure.

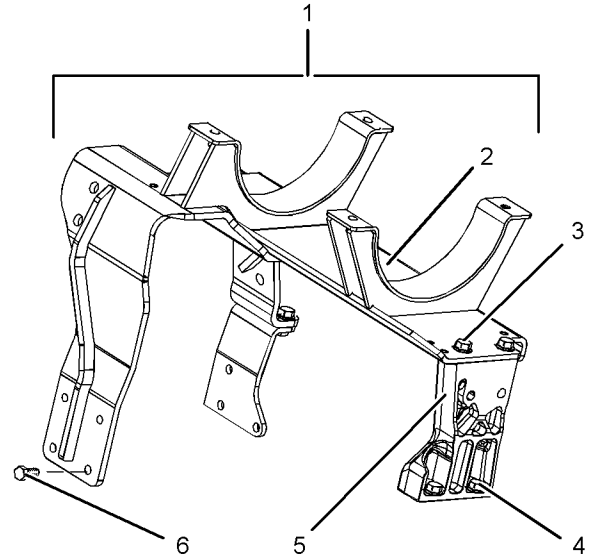


Illustration 122

g03019496

Make temporary marks on all components on support assemblies (1) and all bolts, in order to aide alignment during installation.

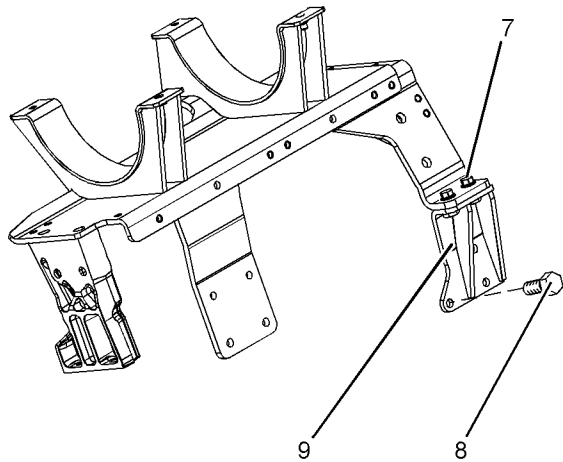


Illustration 123

g03020379

1. Remove bolts (3) from bracket (2).
2. Remove bolts (7) from bracket (2).
3. Remove bolts (6) from bracket (2) and remove bracket (2) from the engine. The weight of bracket (2) is approximately 10 kg (22 lb).
4. If necessary, remove bolts (4) from bracket (5). remove bracket (5) from the engine.
5. Remove bolts (8) from bracket (9) and remove bracket (9) from the engine.

## CEM Assembly Installation Procedure

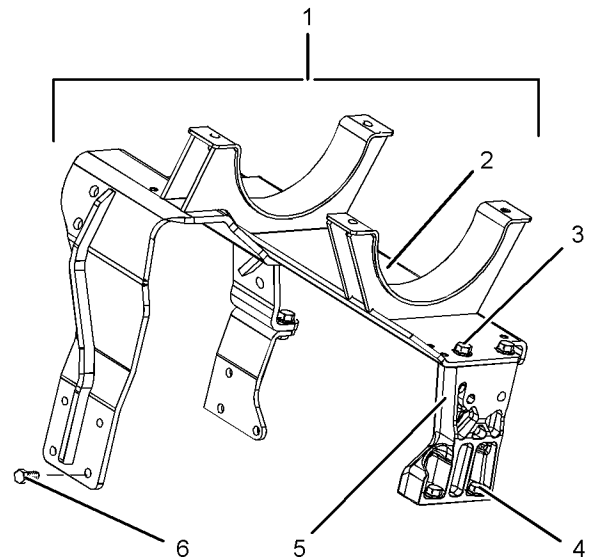


Illustration 124

g03019496

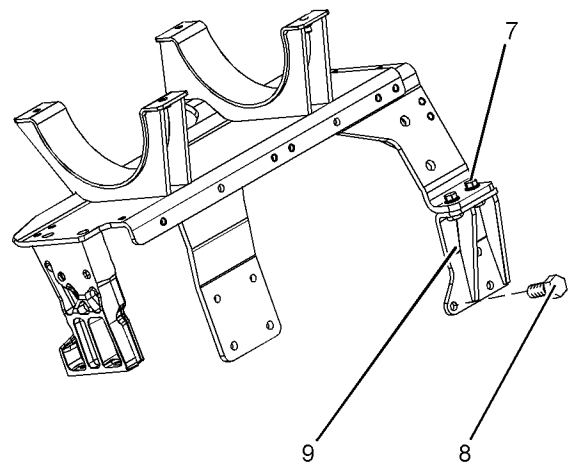


Illustration 125

g03020379

1. If necessary, using temporary marks position bracket (5) onto the engine install bolts (4). Tighten bolts (4) hand tight.
2. If necessary, using temporary marks position bracket (9) onto the engine. Tighten bolts (8) hand tight.
3. Position bracket (2) and loosely install bolts (3), loosely install bolts (6), and loosely install bolts (7).

4. Using temporary marks align assembly (1) and tighten the bolts.
5. If necessary, tighten bolts (4) to a torque of 25 N·m (221 lb in).
6. If necessary, tighten bolts (8) to a torque of 25 N·m (221 lb in).
7. Tighten bolts (6) to a torque of 25 N·m (221 lb in).
8. Tighten bolts (7) to a torque of 25 N·m (221 lb in).
9. Tighten bolts (3) to a torque of 45 N·m (33 lb ft).

**End By:**

- a. Install the DPF. Refer to Disassembly and Assembly, “Diesel Particulate Filter - Install ” for the correct procedure.

i05270728

## Support and Mounting (CEM) - Remove and Install (Option 2)

### CEM Assembly Removal Procedure

**Start By:**

- a. Remove the DPF. Refer to Disassembly and Assembly, “Diesel Particulate Filter - Remove ” for the correct procedure.

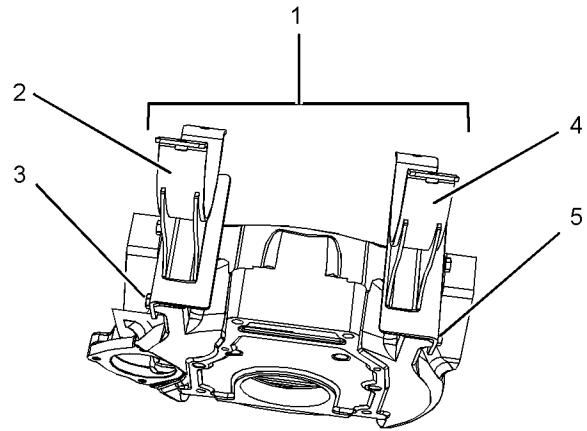


Illustration 126

g03017437

Make temporary marks on all components on both support assemblies (1) and all bolts, in order to aide alignment during installation.

1. Remove bolts (3) from bracket (2) and remove bracket (2) from the engine.
2. Remove bolts (5) from bracket (4) and remove bracket (4) from the engine.

## CEM Assembly installation Procedure

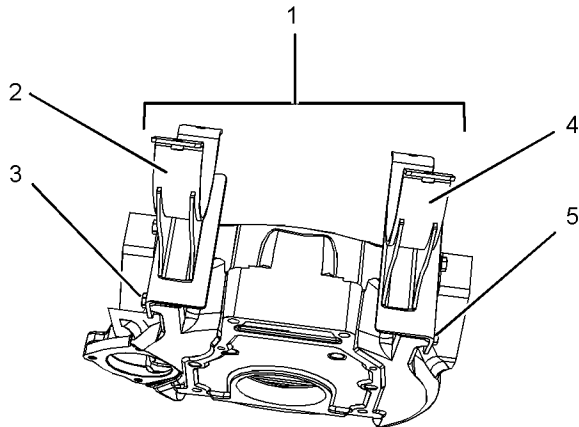


Illustration 127

g03017437

1. Position bracket (2) and loosely install bolts (3). Position bracket (4) and loosely install bolts (5).
2. Using temporary marks, align bracket (2) and tighten bolts (3) to a torque of 25 N·m (221 lb in)
3. Using temporary marks, align bracket (4) and tighten bolts (5) to a torque of 25 N·m (221 lb in)

### End By:

- a. Install the DPF. Refer to Disassembly and Assembly, “Diesel Particulate Filter - Install ” for the correct procedure.

i05270751

## Support and Mounting (CEM) - Remove and Install (Option 1)

### CEM Assembly Removal Procedure

#### Start By:

- a. Remove the DPF. Refer to Disassembly and Assembly, “Diesel Particulate Filter - Remove ” for the correct procedure.

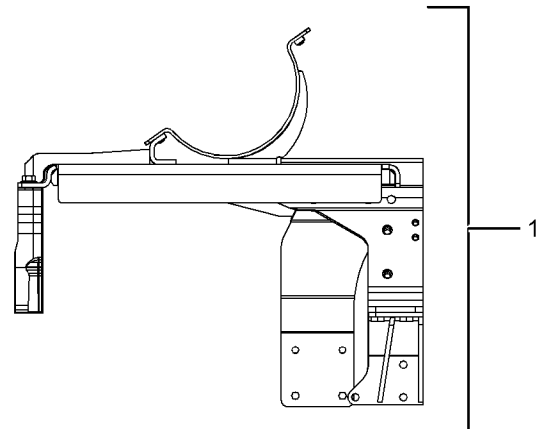


Illustration 128

g03013176

#### Typical example

Make temporary marks on all components on the support assembly (1) and all bolts, in order to aide alignment during installation.

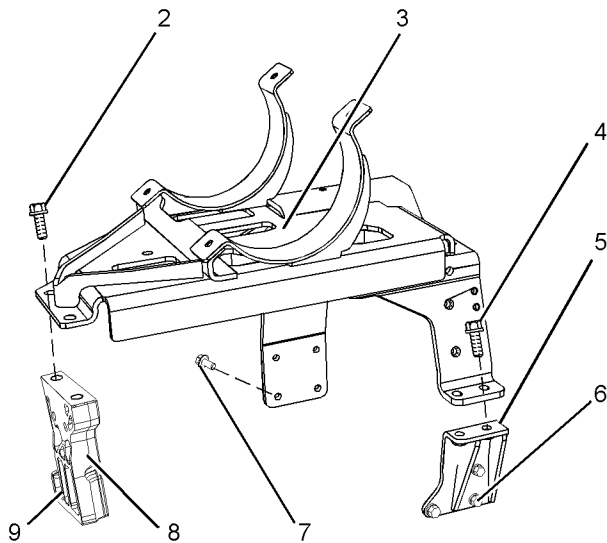


Illustration 129

g03015096

## Typical example

1. Remove bolts (2) from bracket (3).
2. Remove bolts (4) from bracket (3).
3. Remove bolts (7) from bracket (3) and remove bracket (3) from the engine. The weight of bracket (3) is approximately 10 kg (22 lb).
4. If necessary, remove bolts (9) (not shown) and remove bracket (8) from the engine.
5. If necessary, remove bolts (6) and remove bracket (5) from the engine.

## CEM Assembly Installation Procedure

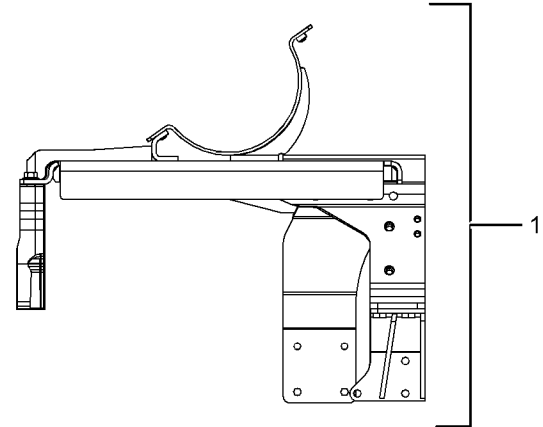


Illustration 130

g03013176

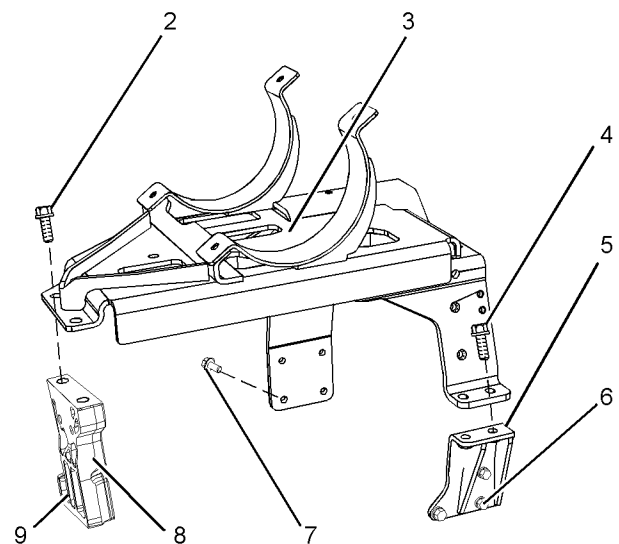


Illustration 131

g03015096

1. If necessary, using temporary marks position bracket (8) and install bolts (9) (not shown). Tighten bolts (9) hand tight.
2. If necessary, using temporary marks position bracket (5) and install bolts (6). Tighten bolts (6) hand tight.
3. Position bracket (3) and loosely install bolts (4) loosely install bolts (2), and loosely install bolts (7).

4. Using temporary marks, align support assembly (1) and tighten bolts.
5. Tighten bolts (9) to a torque of 25 N·m (221 lb in)
6. Tighten bolts (6) to a torque of 25 N·m (221 lb in)
7. Tighten bolts (2) to a torque of 45 N·m (33 lb ft)
8. Tighten bolts (4) to a torque of 25 N·m (221 lb in)
9. Tighten bolts (7) to a torque of 25 N·m (221 lb in)

**End By:**

- a. Install the DPF. Refer to Disassembly and Assembly, "Diesel Particulate Filter - Install" for the correct procedure.

i05270754

## Inlet Manifold - Remove and Install

### Removal Procedure

**Start By:**

- a. Remove the exhaust gas recirculation valve. Refer to Disassembly and Assembly, "Exhaust Gas Recirculation Valve - Remove and Install" for the correct procedure.
- b. Remove the exhaust cooler. Refer to Disassembly and Assembly, "Exhaust Cooler (NRS) - Remove and Install" for the correct procedure.
- c. Remove the exhaust back pressure sensor bracket and tube assembly. Refer to Disassembly and Assembly, "Pressure Sensor (Exhaust Back Pressure) - Remove and Install" for the correct procedure.
- d. Remove the throttle valve. Refer to Disassembly and Assembly, "Throttle Valve (Intake Air) - Remove and Install" for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Plug the apertures in the cylinder head in order to prevent the entry of loose parts into the engine.

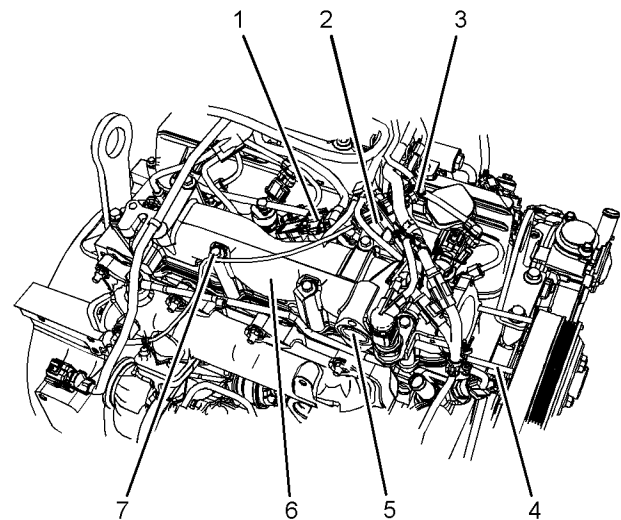


Illustration 132

g02729114

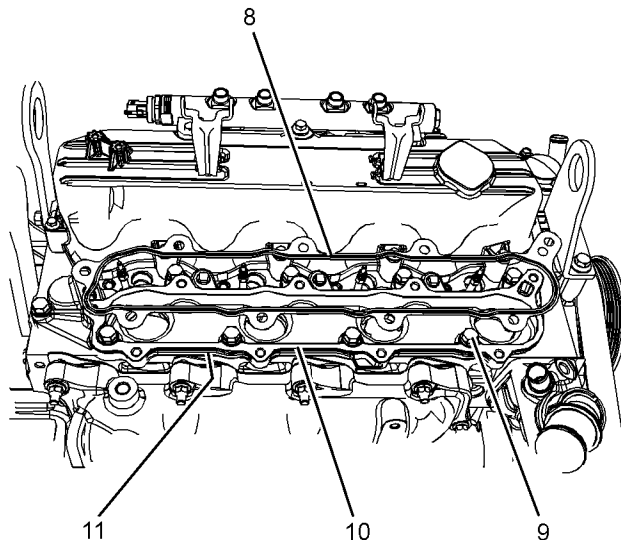


Illustration 133

g02919516

1. Slide the locking tab into the unlocked position and disconnect harness assembly (1) from the inlet manifold temperature and pressure sensor.
2. Position exhaust gas temperature connection (3) away from bracket (2).
3. Remove bolts (7) from inlet manifold (6).
4. Remove the inlet manifold from adaptor plate (10).
5. Remove gasket (8).
6. If necessary, remove studs (4) from inlet manifold (5).

7. If necessary, remove diffuser (5) from inlet manifold (6).
8. If necessary, follow Step 8.a through Step 8.d in order to remove adaptor plate (10).
  - a. Remove the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" for the correct procedure.
  - b. Remove bolts (9) from adaptor plate (10).
  - c. Remove adaptor plate (10) from the cylinder head.
  - d. Remove O-ring seals (11) (not shown).

## Installation Procedure

Table 19

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M8 x 1.25mm by 90mm	2

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

### NOTICE

Remove the plugs that were installed during the disassembly procedure prior to installing components. Care must be taken to ensure that loose parts and debris do not enter the engine.

1. Clean all gasket surfaces.

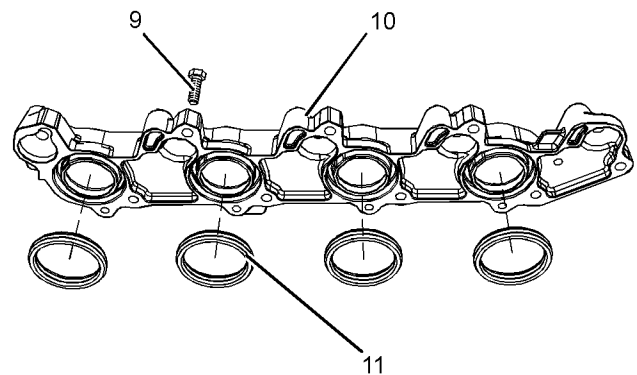


Illustration 134

g02921858

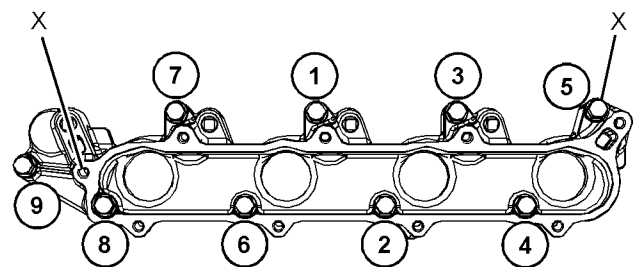


Illustration 135

g02922116

2. If necessary, follow Step 2.a through Step 2.d in order to install adaptor plate (10).
  - a. Install new O-ring seals (11) into adaptor plate (10).
  - b. Position adaptor plate assembly (10) onto the cylinder head.
  - c. Install bolts (9) finger tight. Tighten the bolts evenly in the sequence that is shown in Illustration 135 to a torque of 25 N·m (221 lb in).
  - d. Install the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Install" for the correct procedure.

## Disassembly and Assembly Section

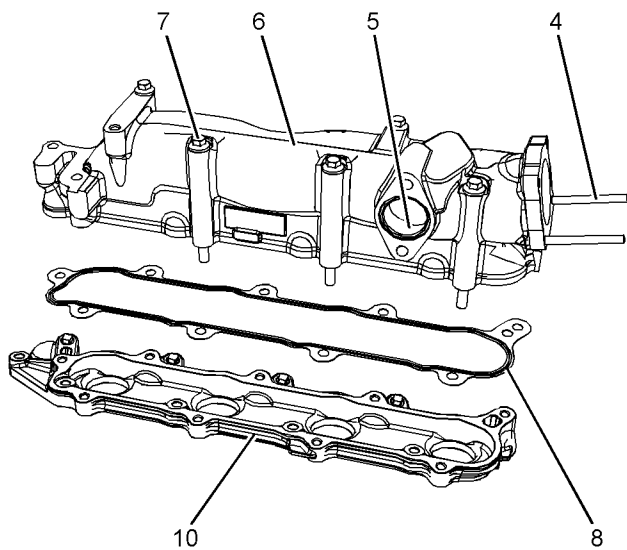


Illustration 136

g02922816

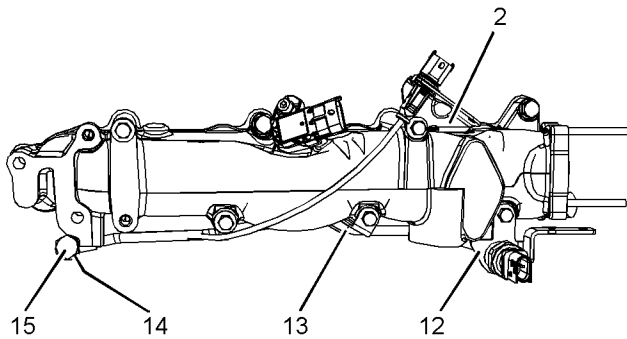


Illustration 137

g02922879

3. If necessary, install studs (4) into inlet manifold (6). Tighten the studs to a torque of 5 N·m (44 lb in).
4. If necessary, install diffuser (5) into inlet manifold (6).
5. Install Tooling (A) in Positions (X) in adaptor plate assembly (10). Refer to Illustration 135 .
6. Position new gasket (8) onto Tooling (A).
7. Install inlet manifold (6) onto Tooling (A).
8. Position bracket (2) onto inlet manifold (6) and install bolt (7) finger tight.
9. Position tube and bracket assembly (13) onto inlet manifold (6) and install bolt (7) finger tight.

10. Install sealing washers (14) (not shown) and banjo bolt (15) to tube and bracket assembly (13). Refer to Disassembly and Assembly, "Pressure Sensor (Exhaust Back Pressure) - Remove and Install" for the correct procedure.

11. Position bracket (12) onto inlet manifold (6) and install bolt (7) finger tight. Connect tube and bracket assembly (13) onto bracket (12). Refer to Disassembly and Assembly, "Pressure Sensor (Exhaust Back Pressure) - Remove and Install" for the correct procedure.

12. Remove Tooling (A).

13. Install remaining bolts (7) in available positions.

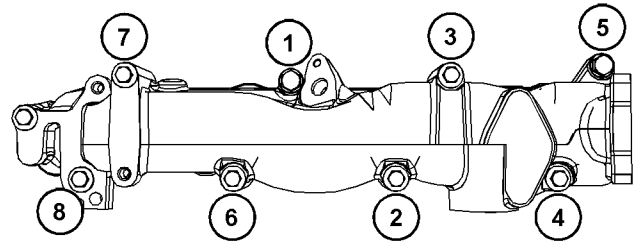


Illustration 138

g02924860

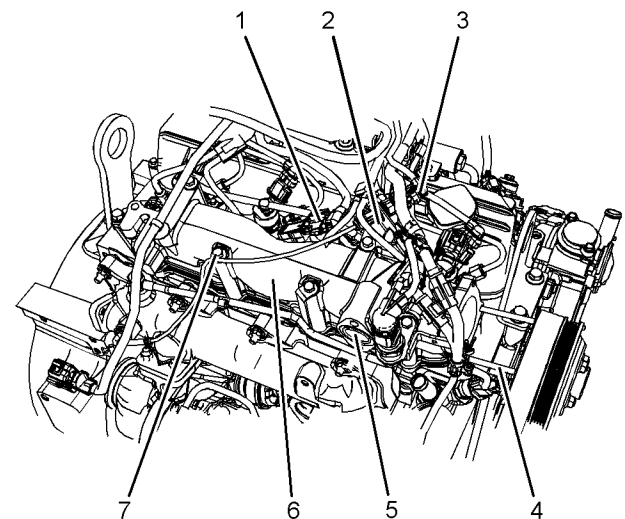


Illustration 139

g02924916

14. Tighten bolts (7) in the sequence that is shown in Illustration 138 to a torque of 27 N·m (239 lb in).



15. Install exhaust gas temperature connection (3) into bracket (2).
16. Connect harness assembly (1) to the inlet manifold temperature and pressure sensor and slide the locking tab into the locked position.

**End By:**

- a. **Install the throttle valve. Refer to Disassembly and Assembly, “Throttle Valve (Intake Air) - Remove and Install” for the correct procedure.**
- b. **Install the remaining components for the exhaust back pressure sensor. Refer to Disassembly and Assembly, “Pressure Sensor (Exhaust Back Pressure) - Remove and Install” for the correct procedure.**
- c. **Install the exhaust cooler. Refer to Disassembly and Assembly, “Exhaust Cooler (NRS) - Remove and Install” for the correct procedure.**
- d. **Install the exhaust gas recirculation valve. Refer to Disassembly and Assembly, “Exhaust Gas Recirculation Valve - Remove and Install” for the correct procedure.**

i05270759

## Inlet and Exhaust Valve Springs - Remove and Install

### Removal Procedure

Table 20

Required Tools			
Tool	Part Number	Part Description	Qty
A <sup>(1)</sup>	T400156	Housing	1
	T400157	Engine Turning Tool	1
B	T400158	Valve Spring Compressor	1
	-	Stud M6 by 25mm	1

<sup>(1)</sup> This Tool is used in the aperture for the electric starting motor.

**Start By:**

- a. **Remove the rocker shaft assembly. Refer to Disassembly and Assembly, “Rocker Shaft and Pushrod - Remove”.**

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** The following procedure should be adopted in order to remove the valve springs when the cylinder head is installed to the engine. Refer to Disassembly and Assembly, “Inlet and Exhaust Valves - Remove and Install” for the procedure to remove the valve springs from a cylinder head that has been removed from the engine.

**Note:** Ensure that the appropriate piston is at the top center position before the valve spring is removed. Failure to ensure that the piston is at the top center position may allow the valve to drop into the cylinder bore.

**NOTICE**

Plug the apertures for the push rods in the cylinder head in order to prevent the entry of loose parts into the engine.

 **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.

**NOTICE**

Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

1. Follow Steps 1.a through 1.d in order to position the appropriate piston at top center.
  - a. Install Tooling (B) in position on the cylinder head in order to compress a valve spring for the appropriate piston.
  - b. Use Tooling (B) in order to compress valve spring (3) and open the valve slightly.

**Note:** Do not compress the spring so that valve spring retainer (2) touches the valve stem seal.

- c. Use Tooling (A) in order to rotate the crankshaft carefully, until the piston touches the valve.

**Note:** Do not use excessive force to turn the crankshaft. The use of force can result in bent valve stems.

## Disassembly and Assembly Section

- d. Continue to rotate the crankshaft and gradually release the pressure on Tooling (B) until the piston is at the top center position. The valve is now held in a position that allows the valve spring to be safely removed.

**NOTICE**

Do not turn the crankshaft while the valve springs are removed.

**Note:** Valve springs must be replaced in pairs for the inlet valve or the exhaust valve of each cylinder. If all valve springs require replacement, the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders, 1 with 4 and 2 with 3. Ensure that all of the valve springs are installed before changing from one pair of cylinders to another pair of cylinders.

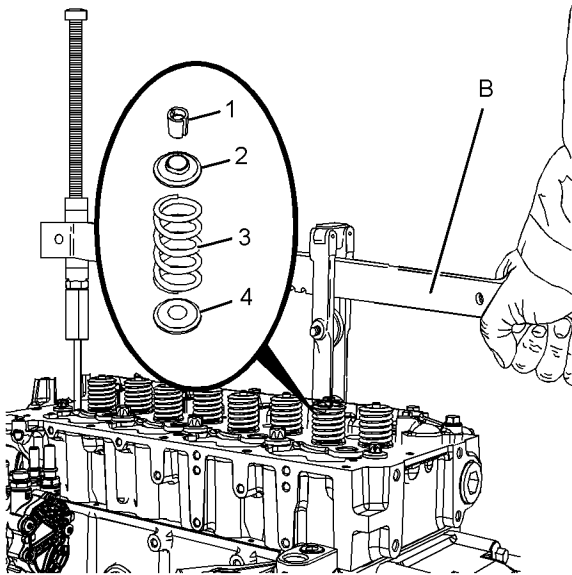


Illustration 140

g03001601

Typical example

2. Apply sufficient pressure to Tooling (B) in order to allow removal of valve keepers (1). Remove valve keepers (1).

**Note:** Do not compress the spring so that valve spring retainer (2) touches the valve stem seal.

3. Slowly release the pressure on Tooling (B).
4. Remove valve spring retainer (2) and remove valve spring (3).
5. If necessary, remove the valve stem seal in order to remove valve spring seat (4).

6. Repeat Steps 2 through 5 in order to remove the remaining valve spring from the appropriate cylinder.

7. Remove Tooling (B).

**Installation Procedure**

Table 21

Required Tools			
Tool	Part Number	Part Description	Qty
A <sup>(1)</sup>	T400156	Housing	1
	T400157	Engine Turning Tool	1
B	T400158	Valve Spring Compressor	1
	-	Stud M6 by 25mm	1
C	T400154	Valve Stem Seal Installer	1

<sup>(1)</sup> This Tool is used in the aperture for the electric starting motor.

**Note:** Either Tooling (A) can be used. Use the Tooling that is most suitable.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Do not turn the crankshaft while the valve springs are removed.

1. Inspect the valve springs for the correct length. Refer to Specifications, "Cylinder Head Valves " for more information.

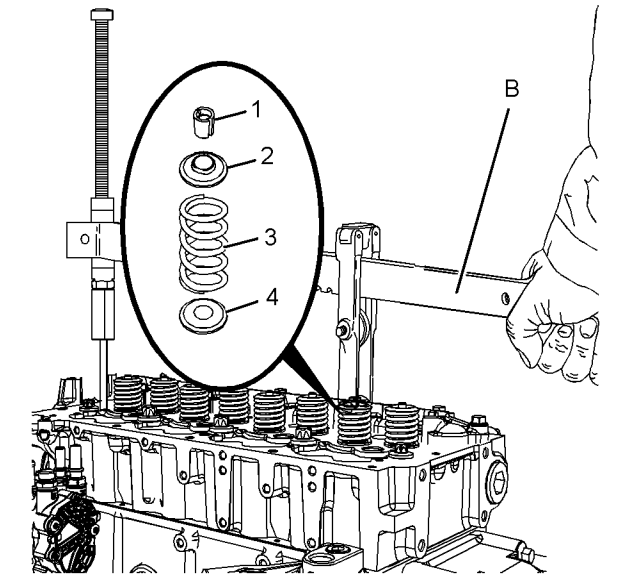


Illustration 141 g03001601

Typical example

2. If necessary, valve spring seat (4) onto cylinder head.
3. If necessary, use Tooling (C) in order to install a new valve stem seal onto the valve guide.

**Note:** The outer face of the valve guide must be clean and dry before installing the valve stem seal.

4. Install valve spring (3) onto the cylinder head. Position valve spring retainer (2) onto valve spring (3).

**⚠ 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.**

5. Install Tooling (B) in the appropriate position on the cylinder head in order to compress the valve spring.

**NOTICE**

Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

6. Apply sufficient pressure to Tooling (B) in order to install valve keepers (1). Install valve spring keepers (1).

**Note:** Do not compress the spring so that valve spring retainer (2) touches the valve stem seal.

7. Carefully release the pressure on Tooling (B).

**Note:** Ensure that the valve keepers are correctly seated.

8. Repeat Steps 3 to 7 for the remaining valves.

**⚠ 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.

9. Remove Tooling (B).

**End By:**

- a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, “Rocker Shaft and Pushrod - Install”.

i05270766

## Inlet and Exhaust Valves - Remove and Install

### Removal Procedure

Table 22

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400158	Valve Spring Compressor	1
	-	Stud M6 by 25mm	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.

1. Clean the bottom face of the cylinder head. Check the depth of the valves below the face of the cylinder head before the valve springs are removed. Refer to Specifications, “Cylinder Head Valves” for the correct dimensions.

## Disassembly and Assembly Section

- Place a temporary identification mark on the heads of the valves in order to identify the correct position. Inlet valves have a recess in the center of the head.

**Note:** Do not stamp the heads of the valve. Stamping or punching the heads of the valves could cause the valves to fracture.

- Use a suitable lifting device to position the cylinder head with the valve springs upward. The weight of the cylinder head is approximately 56 kg (125 lb).

**Note:** Ensure that the cylinder head is kept on a clean, soft surface in order to prevent damage to the machined face.

**⚠ 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.

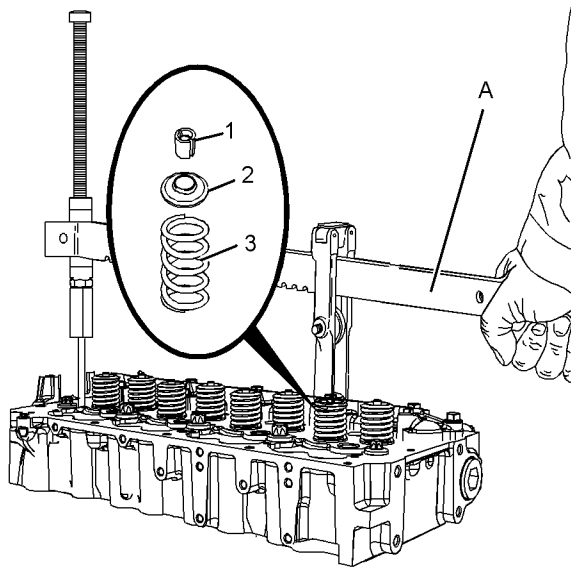


Illustration 142

g03003297

Typical example

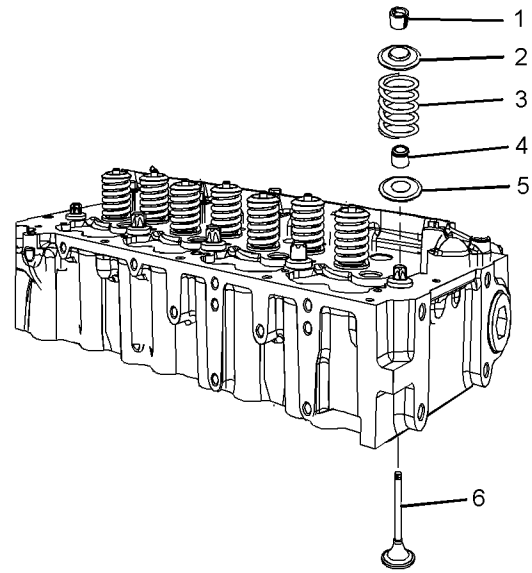


Illustration 143

g03003337

Typical example

- Install Tooling (A) in position on the cylinder head in order to compress the appropriate valve spring.

**NOTICE**

Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

- Apply sufficient pressure to Tooling (A) in order to remove valve keepers (1).

**Note:** Do not compress the spring so that valve spring retainer (2) touches valve stem seal (4).

- Slowly release the pressure on Tooling (A).
- Remove valve spring retainer (2). Remove valve spring (3).
- Repeat Steps 4 to 7 for the remaining valves.
- Remove Tooling (A).
- Remove valve stem seals (4) and valve spring seats (4).
- Use a suitable lifting device to carefully turn over the cylinder head.
- Remove valves (6).

## Installation Procedure

Table 23

Required Tools			
Tool	Part Number	Part Description	Qty

(continued)

(Table 23, contd)

A	T400158	Valve Spring Compressor	1
	-	Stud M6 by 25mm	1
B	T400154	Valve Stem Seal Installer	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean all components of the cylinder head assembly. Ensure that all ports, all coolant passages, and all lubrication passages in the cylinder head are free from debris. Follow Steps 1.a through 1.e in order to inspect the components of the cylinder head assembly. Replace any components that are worn or damaged.
  - a. Inspect the cylinder head for wear and for damage. Refer to Systems Operation, Testing and Adjusting, "Cylinder Head Inspect".
  - b. Inspect the valve seats for wear and for damage. Refer to Specifications, "Cylinder Head Valves" for further information.
  - c. Inspect the valve guides for wear and for damage. Refer to Specifications, "Cylinder Head Valves" and Systems Operation, Testing and Adjusting, "Valve Guide - Inspect" for further information.
  - d. Inspect the valves for wear and for damage. Refer to Specifications, "Cylinder Head Valves".
  - e. Inspect the valve springs for the correct length. Refer to Specifications, "Cylinder Head Valves".

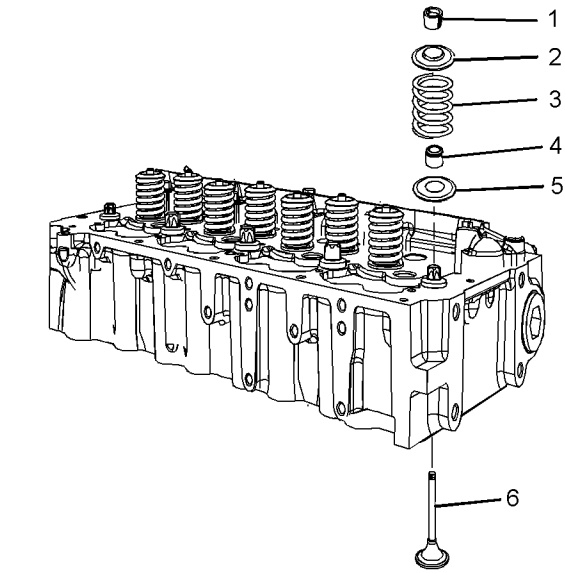


Illustration 144

g03003337

2. Lubricate the stems of valves (6) with clean engine oil. Install valves (6) in the appropriate positions in the cylinder head. Check the depth of the valves below the face of the cylinder head. Refer to Systems Operation, Testing and Adjusting, "Valve Depth - Inspect" for more information.
3. Use a suitable lifting device to carefully turn over the cylinder head. The weight of the cylinder head is approximately 56 kg (125 lb).
 

**Note:** Ensure that all of the valves remain in place.
4. Install valve spring seats (5).
5. Use Tooling (B) in order to install new valve stem seals (4) onto each of the valve guides.
 

**Note:** The outer face of the valve guides must be clean and dry before installing the valve stem seals.
6. Install valve spring (3) onto the cylinder head. Position valve spring retainer (2) onto valve spring (3).

**⚠ 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.

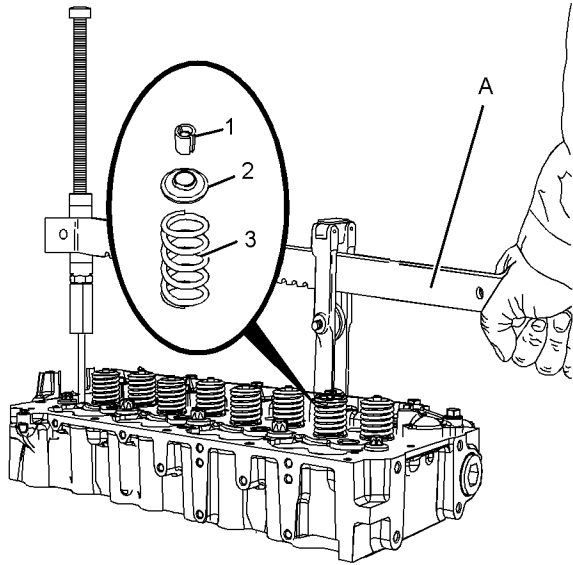


Illustration 145

g03003297

Typical example

7. Install Tooling (A) in the appropriate position on the cylinder head in order to compress valve spring (3).

**NOTICE**

Ensure that the valve spring is compressed squarely or damage to the valve stem may occur.

8. Apply sufficient pressure to Tooling (A) in order to install valve keepers (1).

**Note:** Do not compress the spring so that valve spring retainer (2) touches valve stem seal (4).

 **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.

9. Carefully release the pressure on Tooling (A).
10. Repeat Steps 6 to 9 for the remaining valves.
11. Remove Tooling (A) from the cylinder head.

**End By:**

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

i05270769

## Inlet and Exhaust Valve Guides - Remove and Install

### Removal Procedure

Table 24

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400159	Valve Guide Driver	1

**Start By:**

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

**NOTICE**

Removal and installation of the valve guide and valve seat must be carried out by personnel with the correct training. Also special machinery is required. For more information, refer to your authorized Perkins dealer.

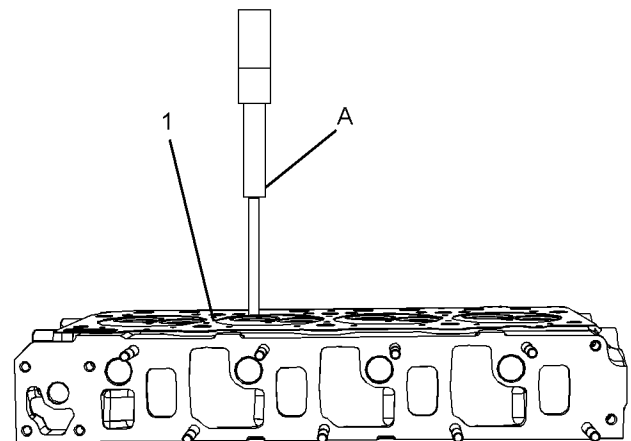


Illustration 146

g03003636

1. Use Tooling (A) in order to remove valve guides (2) from cylinder head (1).
2. Repeat the Step 1 for the remaining valve guides.

## Installation Procedure

Table 25

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400159	Valve Guide Driver	1
	T400153	Stop Collar	1
B	T400155	Valve Guide Reamer	1

### NOTICE

Removal and installation of the valve guide and valve seat must be carried out by personnel with the correct training. Also special machinery is required. For more information, refer to your authorized Perkins dealer.

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the parent bores in the cylinder head for the valve guides.

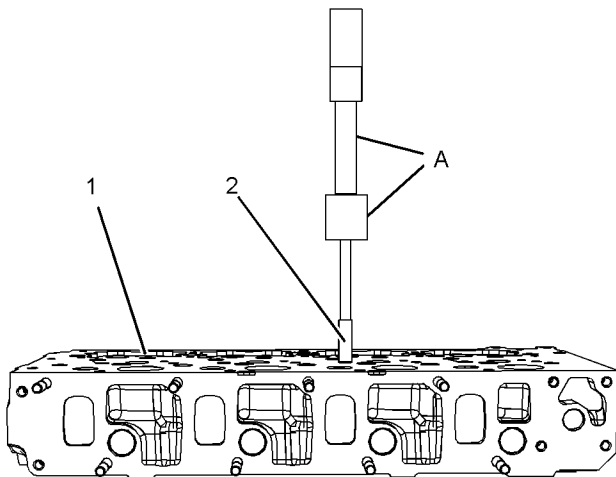


Illustration 147

g03003639

2. Lubricate a new valve guide (2) and place the valve guide in position. Carefully tap the valve guide in order to start the installation. Use Tooling (A) to install the valve guide into the cylinder head.
3. Repeat Step 2 for the remaining valve guides.

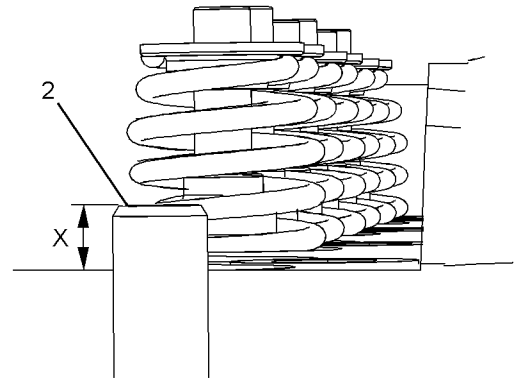


Illustration 148

g03005596

4. Check protrusion (X) of valve guides (2). The valve guides should protrude  $8.5 \pm 0.15$  mm ( $0.33465 \pm 0.00591$  inch) above the valve spring recess. Refer to Specifications, "Cylinder Head Valves" for more information.
5. After installation of valve guides (2), the valve guides must be reamed to the finished diameter. Follow Steps 5.a through 5.c in order to ream the valve guides.
  - a. Lubricate the bores of valve guides (2) with clean engine oil.
  - b. Use Tooling (B) in order to ream the valve guides. Ensure that even pressure is applied to Tooling (B).
  - c. Ensure that the cylinder head is clean and free from machining debris.
6. Check the finished diameter of valve guides (2). Refer to Specifications, "Cylinder Head - Valves" for more information.
7. Check the depths of the valves below the face of the cylinder head. Refer to System Operation, Testing and Adjusting, "Valve Depth - Inspect" for more information.

**End By:**

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

i05270770

## Engine Oil Filter Base - Remove and Install

### Removal Procedure

Table 26

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400083	Filter Cartridge Tool	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**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.

Dispose of all fluids according to local regulations and mandates.

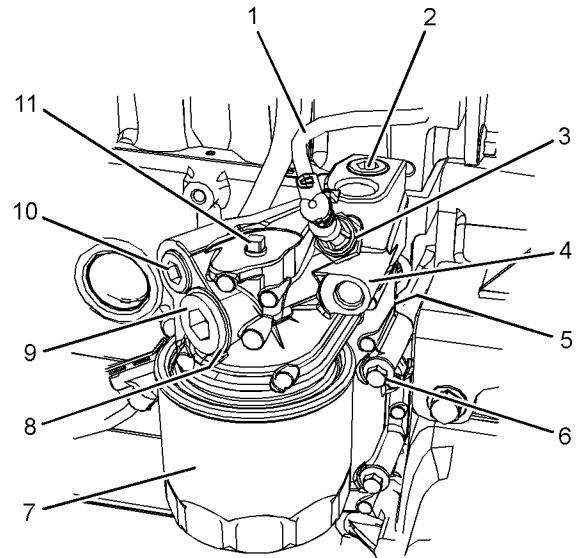


Illustration 149

g02675998

**Typical example**

1. Disconnect wiring harness assembly (1) from engine oil pressure switch (3).
  2. Place a suitable container below engine oil filter (7) in order to catch any oil that might be spilled.
  3. Use Tooling (A) in order to remove engine oil filter (7). Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.
  4. Remove bolts (6) from oil filter base (1).
- Note:** Note the position of the different length bolts for installation purposes.
5. Remove engine oil filter base (4) from the cylinder block.
  6. Remove gasket (5) (not shown).
  7. If necessary, remove plug (2) from engine oil filter base (4).
  8. If necessary, remove plug (11) from engine oil filter base (4).
  9. If necessary, remove plug (10) from engine oil filter base (4).
  10. If necessary, remove plug (9) from engine oil filter base (1). Remove O-ring seal (8) (not shown) from plug (9).
  11. If necessary, remove the engine oil pressure switch. Refer to Disassembly and Assembly, "Engine Oil Pressure Switch - Remove and Install".



## Installation Procedure

Table 27

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400083	Filter Cartridge Tool	1

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

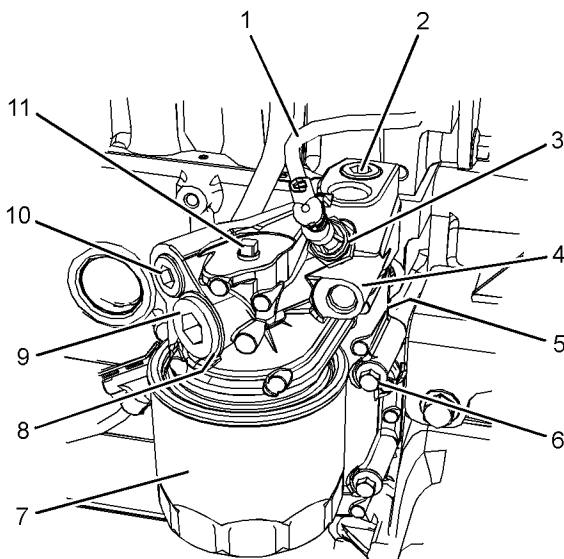


Illustration 150

g02675998

Typical example

1. Clean the gasket surface of the engine oil filter base (4). Clean the gasket surface of the cylinder block.
2. If necessary, install new O-ring seal (8) (not shown) to plug (9). Install plug (9) to engine oil filter base (1). Tighten the plug to a torque of 30 N·m (266 lb in).
3. If necessary, install new plug (10) to engine oil filter base (4). Tighten the plug to a torque of 30 N·m (266 lb in).
4. If necessary, install new plug (11) to engine oil filter base (4). Tighten the plug to a torque of 10 N·m (89 lb in).
5. If necessary, install new plug (2) to engine oil filter base (4). Tighten the plug to a torque of 30 N·m (266 lb in).

6. Position new gasket (5) (not shown) onto engine oil filter base (4). Install bolts (6) to engine oil filter base (4).

**Note:** Ensure that the different length bolts are installed in the correct position.

7. Install the assembly of the engine oil filter base to the cylinder block. Tighten bolts (6) to a torque of 25 N·m (221 lb in).
8. If necessary, install the engine oil pressure switch. Refer to Disassembly and Assembly, "Engine Oil Pressure Switch - Remove and Install" for the correct procedure.
9. Connect wiring harness assembly (1) to engine oil pressure switch (3).
10. Use Tooling (A) in order to install new engine oil filter (7). Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.
11. Check the level of the engine oil. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check" for the correct procedure.

i05270773

## Engine Oil Cooler - Remove

### Removal Procedure

#### Start By:

- a. Remove the alternator and mounting bracket. Refer to Disassembly and Assembly, "Alternator - Remove" for the correct procedure.

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

### 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.

Dispose of all fluids according to local regulations and mandates.

## Disassembly and Assembly Section

1. Drain the coolant from the cooling system into a suitable container. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.
2. If the engine oil has become contaminated with coolant, the engine oil and filter must be replaced. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

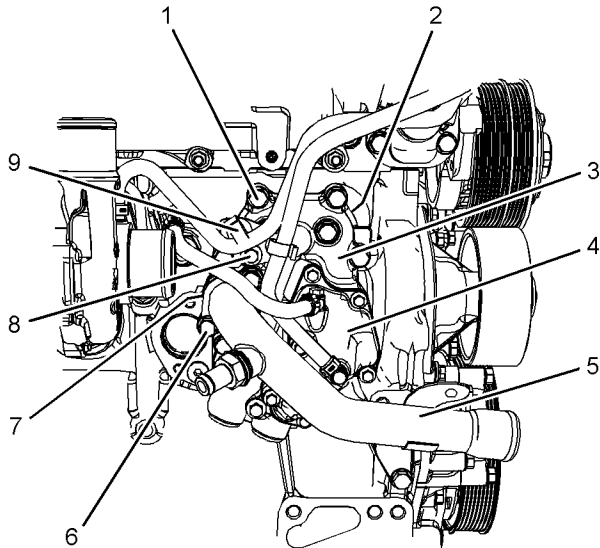


Illustration 151

g02706998

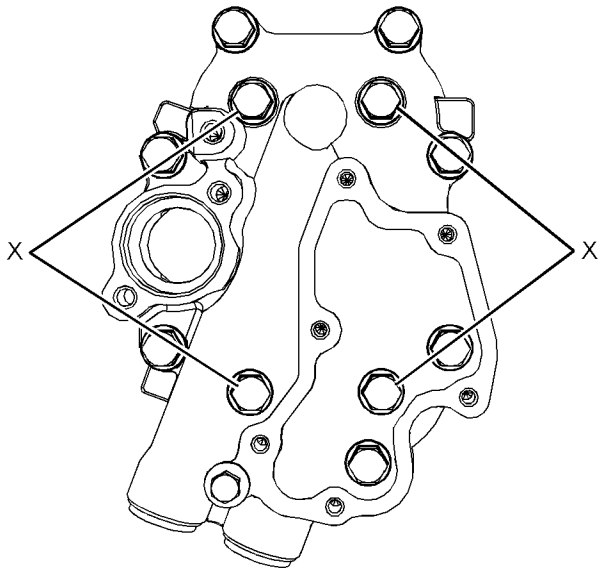


Illustration 152

g02871078

3. Disconnect the coolant hoses from tube assembly (5).

4. Remove bolts (6) from tube assembly (5). Remove tube assembly (5) from engine oil cooler assembly (3).
5. Remove O-ring seal (7) (not shown) from tube assembly (5).
6. Remove bolt (8) and bracket (9) from the engine oil cooler assembly.
7. Remove boost pressure chamber cover (4). Refer to Disassembly and Assembly, "Turbocharger - Remove" for the correct procedure.
8. Remove bolts (1) from the engine oil cooler. Do not remove the bolts in Position (X). Remove the engine oil cooler assembly from the cylinder block.

**Note:** The bolts are different lengths. Note the position of the different lengths bolts.

9. Remove gasket (2) (not shown).

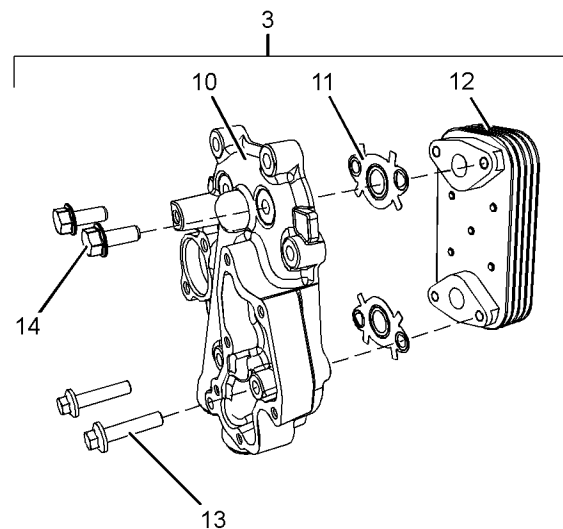


Illustration 153

g02707318

10. If necessary, follow Step 10.a through Step 10.c in order to disassemble the engine oil cooler.
  - a. Remove bolts (13) and bolts (14) from the engine oil cooler assembly (3).
  - b. Remove cooler matrix (12) from housing (10).

c. Remove gaskets (11).

i05270774

## Engine Oil Cooler - Install

### Installation Procedure

1. Ensure that all components are free from wear and damaged. If necessary, replace any components that are worn or damaged.

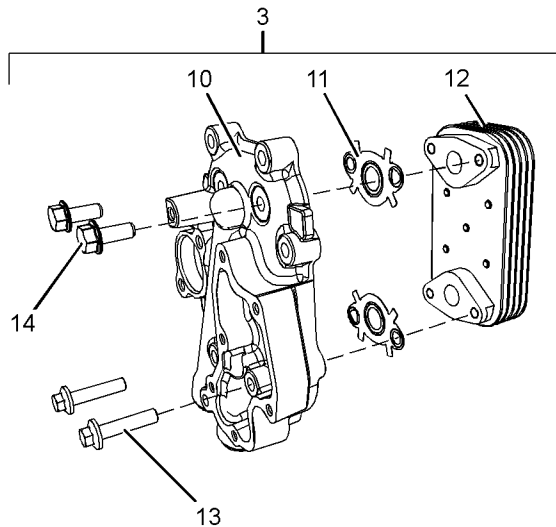


Illustration 154

g02707318

2. If necessary, follow Step 2.a through Step 2.d in order to assembly the engine oil cooler.

- a. Ensure that engine oil cooler matrix (12) is clean, free from damage and restriction. Replace engine oil cooler matrix (12) if damaged or restricted.
- b. Ensure that housing (10) is clean and free from damage. Replace housing (10) if damaged.
- c. Position new gaskets (11) onto engine oil cooler matrix (12). Install engine oil cooler matrix (12) to housing (10).
- d. Install bolts (13) and bolts (14) to the assembly of oil cooler (3). Tighten bolts (13) and bolts (14) to a torque of 25 N·m (221 lb in).

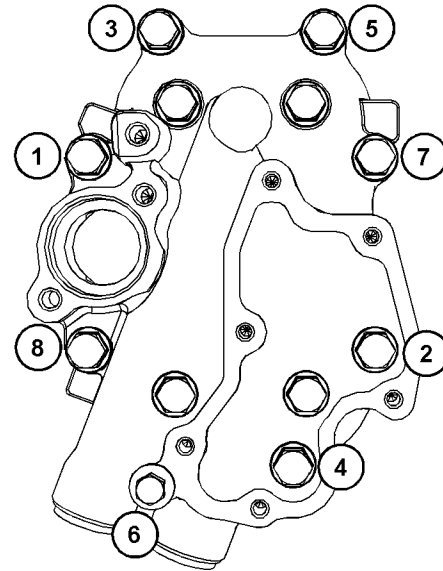


Illustration 155

g02871598

Tightening sequence for the engine oil cooler.

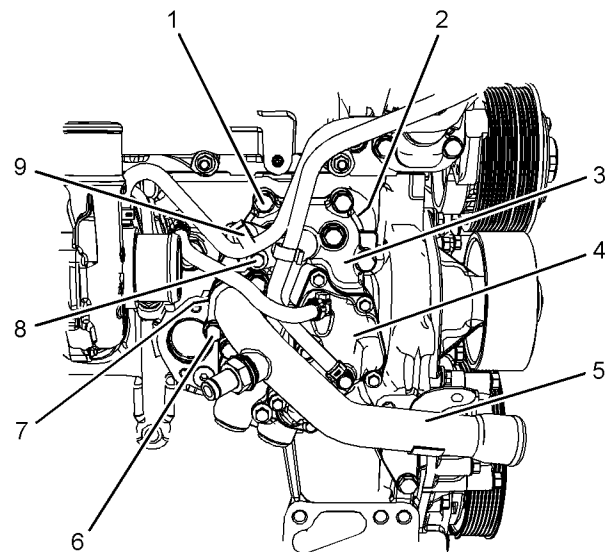


Illustration 156

g02706998

3. Clean the gasket surfaces of the cylinder block.
4. Position a new gasket (4) onto the engine oil cooler.
5. Install assembly of engine oil cooler (5) to the cylinder block. Install bolts (1) to the assembly of oil cooler (3).

**Note:** Ensure that the bolts of different lengths are installed in the correct position.

6. Tighten bolts (3) to a torque of 25 N·m (221 lb in) in sequence that is shown in Illustration 155 .
7. Position bracket (9) onto engine oil cooler (3). Install bolt (8) to bracket (9). Tighten the bolt to a torque of 15 N·m (133 lb in).
8. Install boost pressure chamber cover (4). Refer to Disassembly and Assembly, "Turbocharger - Install" for the correct procedure.
9. If necessary, install the turbo charger oil drain tube assembly. Refer to Disassembly and Assembly, "Turbocharger - Install" for the correct procedure.
10. Install a new O-ring seal (7) (not shown) to tube assembly (5).
11. Install tube assembly (5) to engine oil cooler (3).
12. Install bolts (6) to tube assembly (5). Tighten the bolts to a torque of 25 N·m (221 lb in).
13. Connect the coolant hoses to tube assembly (5).
14. Install the Alternator. Refer to Disassembly and Assembly, "Alternator - Install" for the correct procedure.
15. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.
16. If the engine oil was drained during the engine oil cooler removal procedure, refill the lubrication system. Refer to Operation and Maintenance Manual, "Engine Oil and Filter - Change" for the correct procedure.

17. Check the level of the engine lubricating oil. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check" for the correct procedure.

i05270776

## Engine Oil Relief Valve - Remove and Install

### Removal Procedure

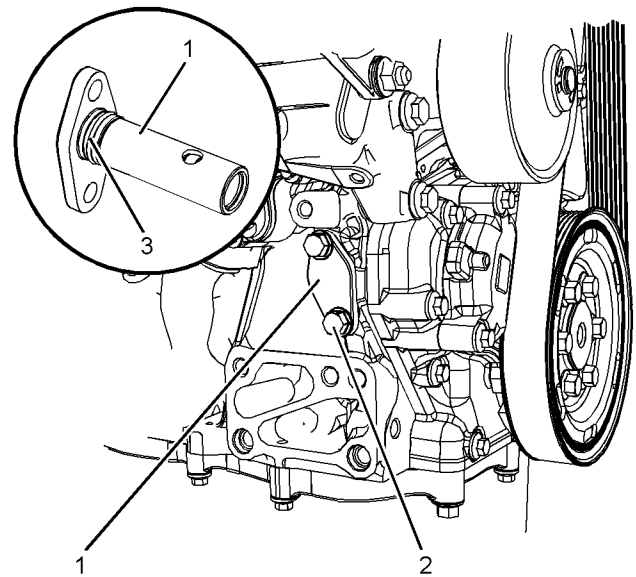


Illustration 157

g02953956

1. Remove bolts (2) from engine oil relief valve (1).
2. Remove engine oil relief valve (1) from the cylinder block.
3. Remove O-ring seal (3) from engine oil relief valve (1).

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.

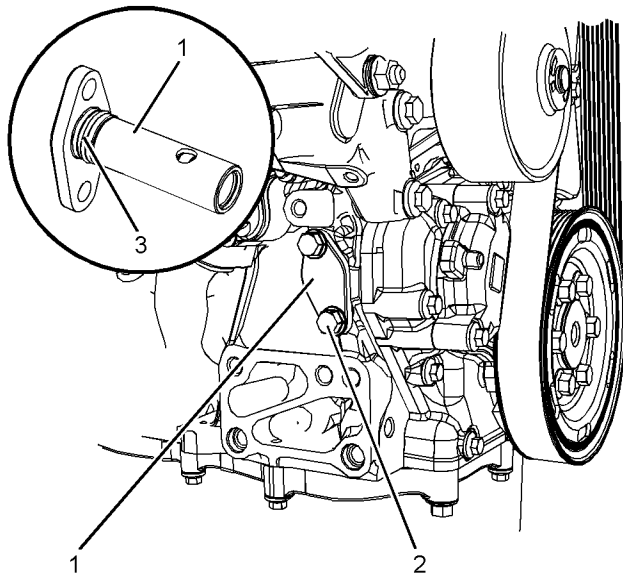


Illustration 158

g02953956

2. Install new O-ring seal (3) to engine oil relief valve (1).
3. Install engine oil relief valve (1) to the cylinder block.
4. Install bolts (2) to engine oil relief valve (1). Tighten the bolts to a torque of 10 N·m (89 lb in)

i05270779

## Engine Oil Pump - Remove

### Removal Procedure

**Start By:**

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

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**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.

Dispose of all fluids according to local regulations and mandates.

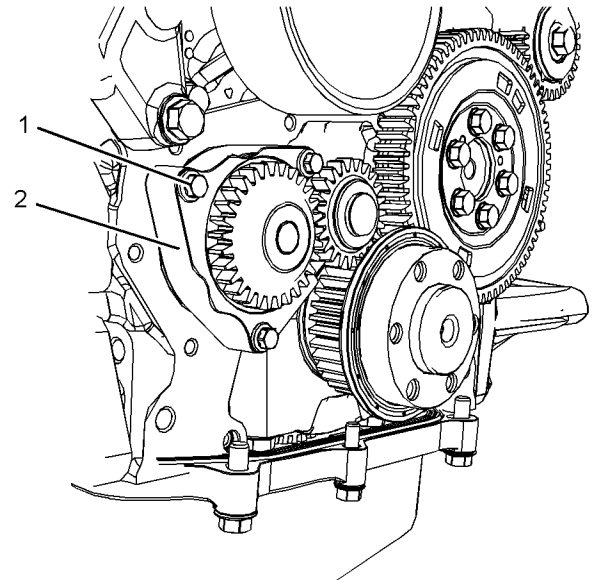


Illustration 159

g02986438

1. Remove bolts (2) from engine oil pump (3).
2. Remove engine oil pump (3) from the cylinder block.

i05270780

## Engine Oil Pump - Install

### Installation Procedure

Table 28

Required Tools			
Tool	Part Number	Part Description	Qty
A	21825617	Dial Indicator	1
	-	Magnetic Base and Stand	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that bushing is free from wear or damage. Refer to Specifications, "Engine Oil Pump" for more information. If necessary, replace the bushing.

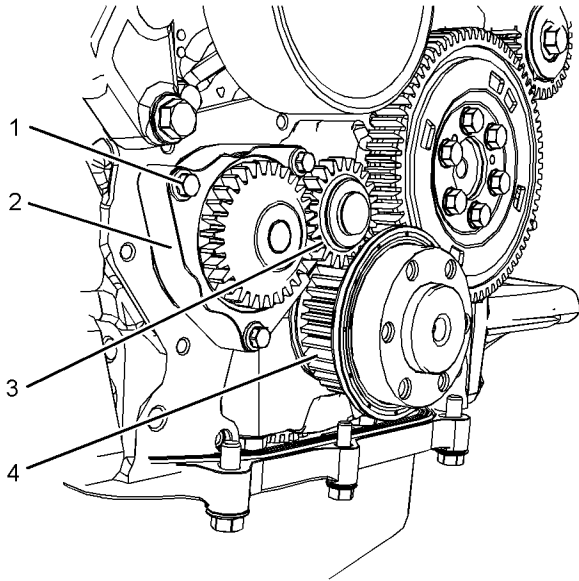


Illustration 160

g02986456

2. Ensure that engine oil pump (2) is clean and free from wear or damage. Refer to Specifications, "Engine Oil Pump" for more information. If necessary, replace the engine oil pump.
3. Lubricate the rotors of the engine oil pump (2) with clean engine oil.
4. Align engine oil pump gear (3) with crankshaft gear (4). Install the engine oil pump to the cylinder block.
5. Install bolts (1). Tighten the bolts to a torque of 11 N·m (97 lb in).
6. Use Tooling (A) to check the backlash between oil pump gear (3) and crankshaft gear (4). Ensure that the backlash is within specified values. Refer to Specifications, "Gear Group (Front)" for further information.

**End By:**

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

i05270783

**Water Pump - Remove****Removal Procedure****Start By:**

- a. Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**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.

Dispose of all fluids according to local regulations and mandates.

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" for the correct procedure.

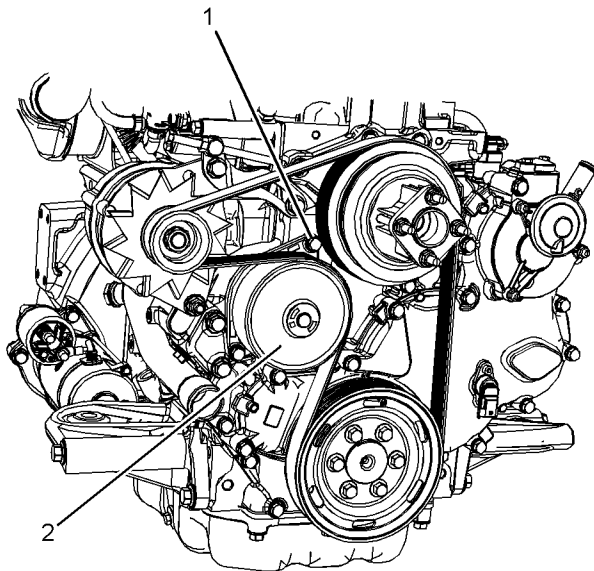


Illustration 161

g02663376

4. Remove seal (3).

i05270787

## Water Pump - Install

### Installation Procedure

---

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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1. Ensure that the water pump is clean and free from wear and damage. If necessary, replace the water pump. Clean the seal surface of the water pump.

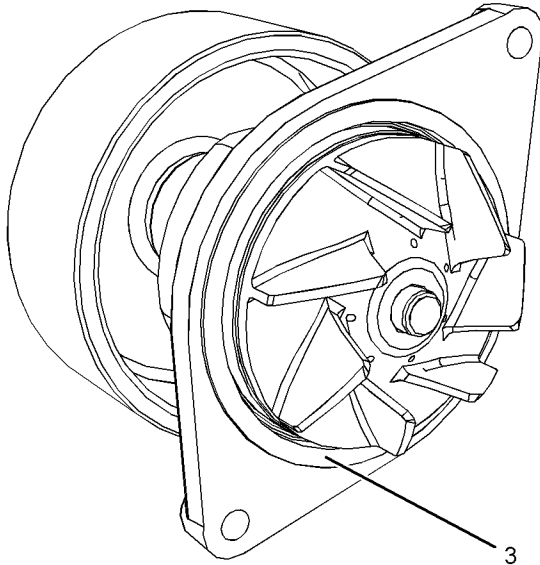


Illustration 162

g02663417

2. Remove bolts (1) from water pump (2).
3. Remove water pump (2) from the cylinder block.

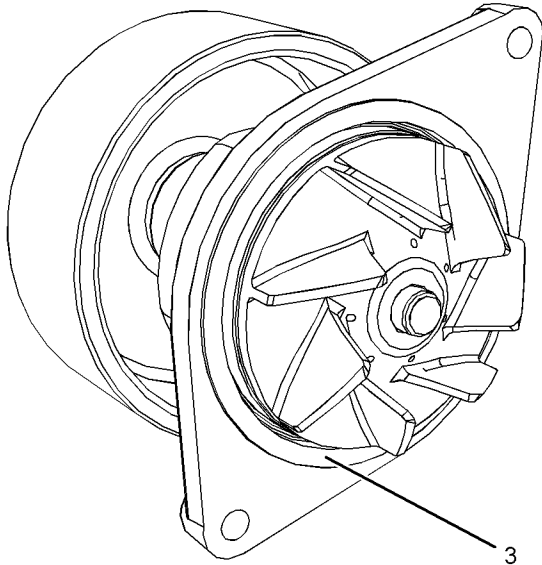


Illustration 163

g02663458

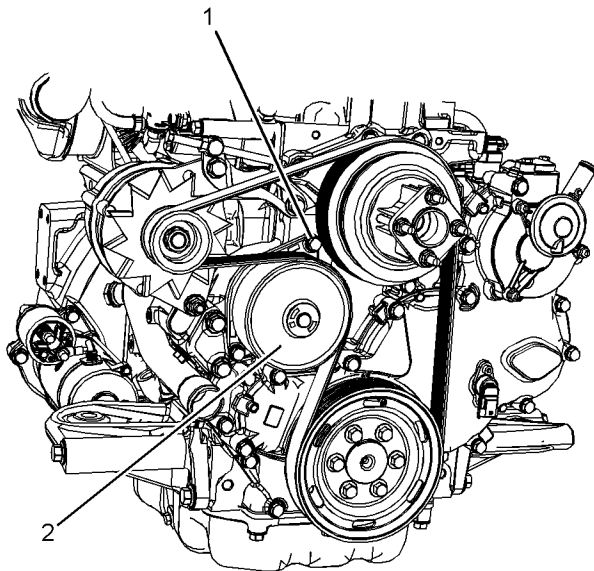


Illustration 164

g02663598

2. Clean the seal surface on the cylinder block.
3. Install a new seal (3) to the water pump (2).
4. Install the water pump (2) to the cylinder block.

**Note:** Ensure that the water pump is correctly orientated.

5. Install bolts (1) to the water pump. Tighten the bolts to a torque of 25 N·m (221 lb in).

6. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct procedure.

**End By:**

- a. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

i05270793

## Water Temperature Regulator - Remove and Install

### Removal Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**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.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system to a level below the water temperature regulator, into a suitable container for storage or for disposal. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.
2. Remove the wastegate regulator valve. Refer to Disassembly and Assembly, "Wastegate Solenoid - Remove and Install" for the correct procedure.



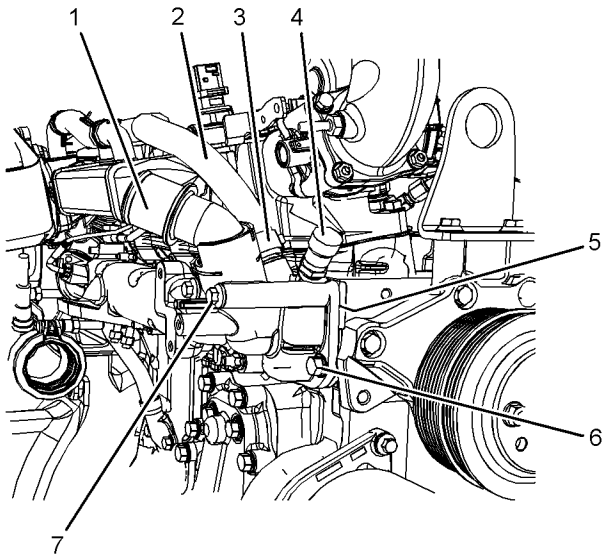


Illustration 165

g02829476

## Typical example

3. Loosen the hose clamps from the upper radiator hose and disconnect the upper radiator hose from water temperature regulator housing (1).
4. Loosen clamp (3) and disconnect exhaust gas recirculation (EGR) cooler hose (2) from water temperature regulator housing (1). Position the EGR cooler hose away from the water temperature regulator housing.
5. Slide the locking tab into the unlocked position and disconnect the wiring harness from coolant temperature sensor (4).
6. Remove bolts (6) and remove bolts (7) from water temperature regulator housing (1).
7. Remove water temperature regulator housing (1) from the cylinder head.
8. Remove gasket (5) (not shown).
9. If necessary, remove the coolant temperature sensor. Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install" for the correct procedure.

## Installation Procedure

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free of wear and damage. If necessary, replace any components that are worn or damaged.
2. Check the water temperature regulator for correct operation. Refer to System Operation, Testing, and Adjusting, "Water Temperature Regulator - Test" for the procedure to test the water temperature regulator. If the water temperature regulator is not operating correctly, the complete assembly must be replaced.
3. If necessary, install the coolant temperature sensor. Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install" for the correct procedure.

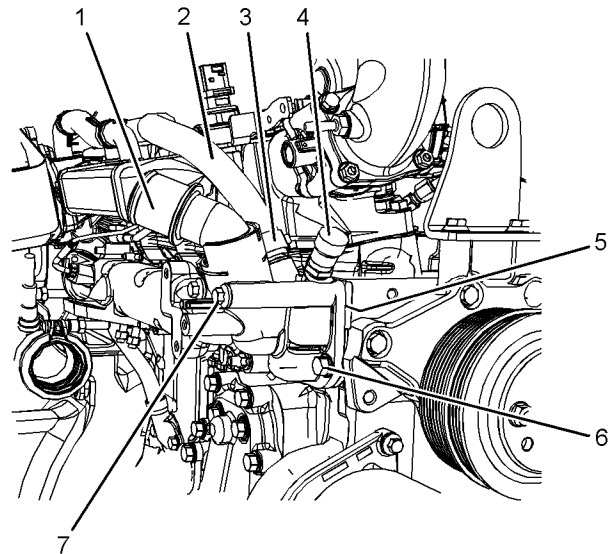


Illustration 166

g02829476

## Typical example

4. Position gasket (5) (not shown) onto water temperature regulator housing (1).
- Note:** Ensure that the gasket is correctly orientated.
5. Install bolts (7) to water temperature regulator housing (1).
  6. Position water temperature regulator housing (1) onto the cylinder head.
  7. Install bolts (6) to the water temperature regulator housing finger tight.
  8. Tighten the bolts (6) and bolts (7) to a torque of 25 N·m (221 lb in).
  9. Connect hose (2) to the water temperature regulator housing and tighten clamp (3) securely.

10. Connect the upper radiator hose to water temperature regulator housing (1) and tighten the hose clamps securely.
11. Connect the wiring harness to coolant temperature sensor (4). Slide the locking tab into the locked position.
12. Install the wastegate solenoid. Refer to Disassembly and Assembly, "Wastegate Solenoid - Remove and Install" for the correct procedure.
13. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Check" and Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedures.

i05270798

## Engine Lifting Bracket - Remove

### Removal Procedure

Follow the removal procedure for the configuration of engine lifting brackets that are installed.

#### Option 1

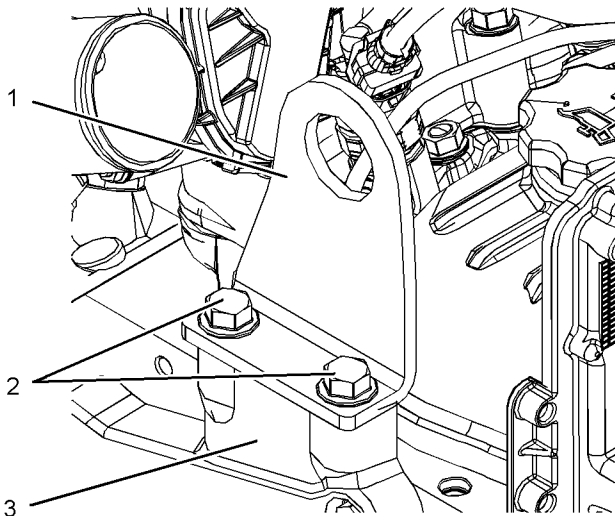


Illustration 167

g03001156

View of the engine lifting bracket on the front of the engine

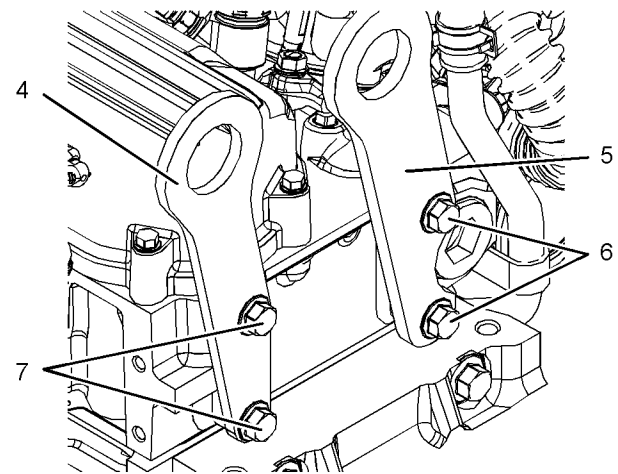


Illustration 168

g03001176

View of the engine lifting brackets on the rear of the engine

1. Remove bolts (2) from lifting bracket (1).
2. Remove lifting bracket (1) from fan drive assembly (3).
3. Remove bolts (7) from lifting bracket (4).
4. Remove lifting bracket (4) from the cylinder head.
5. Remove bolts (6) from lifting bracket (5).
6. Remove lifting bracket (5) from the cylinder head.

## Option 2

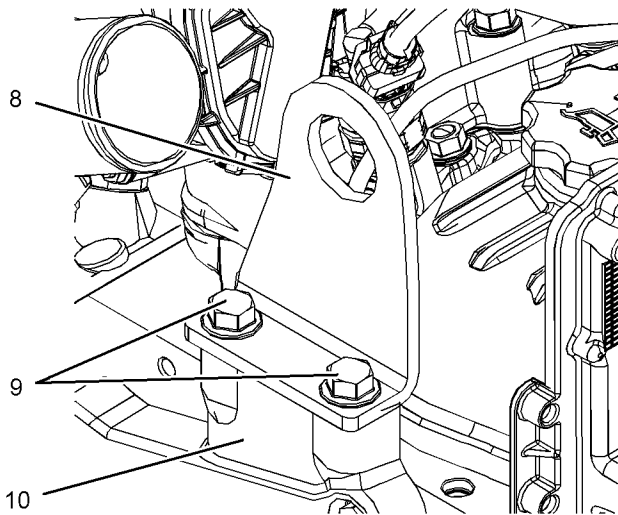


Illustration 169

g03001576

View of the engine lifting bracket on the front of the engine

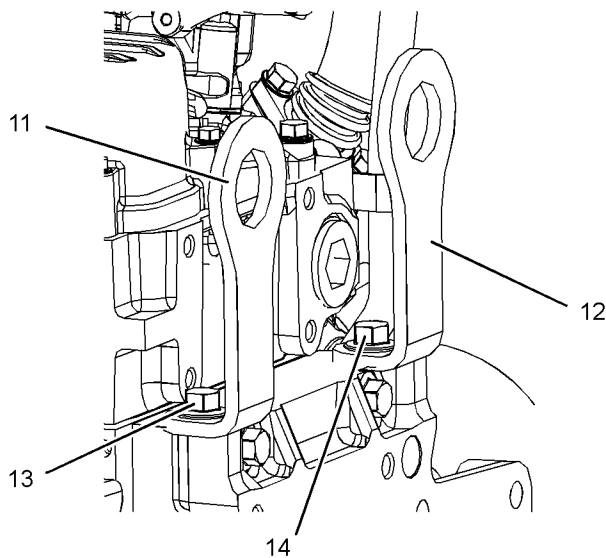


Illustration 170

g03001603

View of the engine lifting brackets on the rear of the engine

1. Remove bolts (9) from lifting bracket (8).
2. Remove lifting bracket (8) from fan drive assembly (10).
3. Remove bolt (13) from lifting bracket (11).
4. Remove lifting bracket (11) from the flywheel housing.

5. Remove bolt (14) from lifting bracket (12).

6. Remove lifting bracket (12) from the flywheel housing.

i05270802

## Engine Lifting Bracket - Install

### Installation Procedure

Follow the installation procedure for the configuration of engine lifting brackets that are installed.

### Option 1

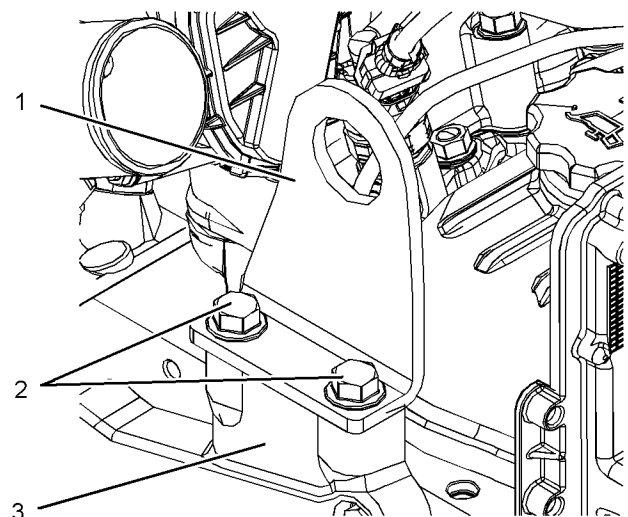


Illustration 171

g03001156

View of the engine lifting bracket on the front of the engine

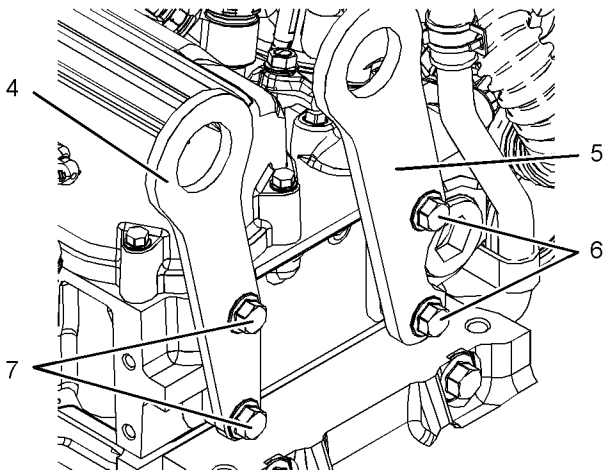


Illustration 172

g03001176

View of the engine lifting brackets on the rear of the engine

1. Position lifting bracket (1) onto fan drive (3). Refer to Illustration 171 .
2. Install bolts (2) finger tight to lifting bracket (1). Tighten the bolts to a torque of 45 N·m (33 lb ft).
3. Position lifting bracket (4) onto the cylinder head. Refer to Illustration 172 .
4. Install bolts (7) finger tight to lifting bracket (4). Tighten the bolts to a torque of 65 N·m (48 lb ft).
5. Position lifting bracket (5) onto the cylinder head. Refer to Illustration 172 .
6. Install bolts (6) finger tight to lifting bracket (5). Tighten the bolts to a torque of 65 N·m (48 lb ft).

## Option 2

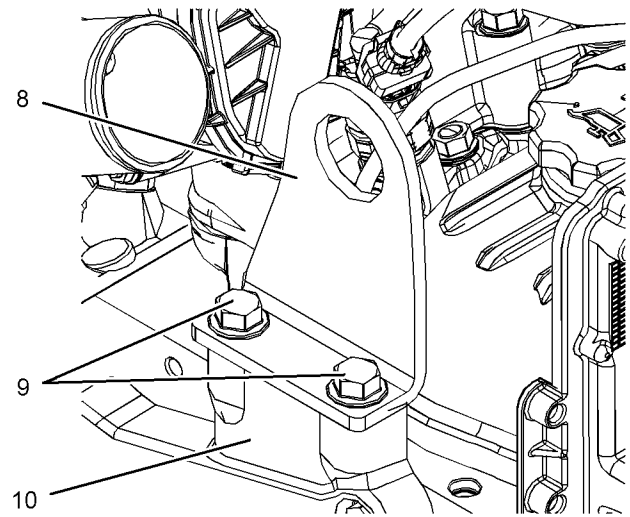


Illustration 173

g03001576

View of the engine lifting bracket on the front of the engine

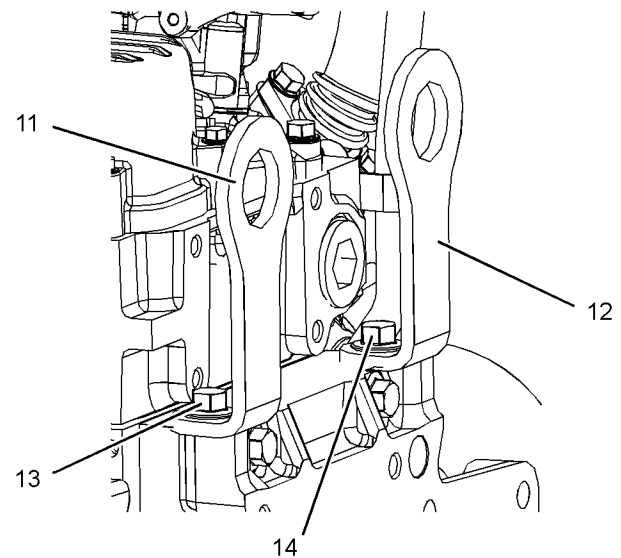


Illustration 174

g03001603

View of the engine lifting brackets on the rear of the engine

1. Position lifting bracket (8) onto fan drive (10). Refer to Illustration 173 .
2. Install bolts (9) finger tight to lifting bracket (8). Tighten the bolts to a torque of 45 N·m (33 lb ft).
3. Position lifting bracket (11) onto the flywheel housing. Refer to Illustration 174 .

4. Install bolt (13) finger tight to lifting bracket (11).  
Tighten the bolt to a torque of 110 N·m (81 lb ft).
5. Position lifting bracket (12) onto the flywheel housing. Refer to Illustration 174 .
6. Install bolt (14) finger tight to lifting bracket (12).  
Tighten the bolts to a torque of 110 N·m (81 lb ft).

i05270805

## Flywheel - Remove

### Removal Procedure

Table 29

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M12 x 1.25mm by 100mm	2

#### Start By:

- a. Remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install" for the correct procedure.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

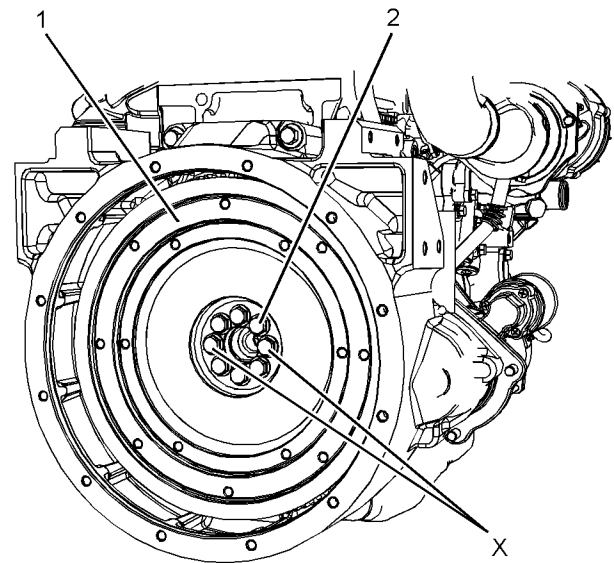


Illustration 175

g02657336

1. Remove bolts from Position (X) from flywheel (1).  
**Discard the bolts.**
2. Install Tooling (A) in Position (X) to flywheel (1).
3. Install a suitable lifting device onto flywheel (1).  
Support the weight of the flywheel. The flywheel can weigh 75 kg (165 lb).
4. Remove remaining bolts (2). **Discard the bolts.**
5. Use the suitable lifting device to remove the flywheel from the engine.

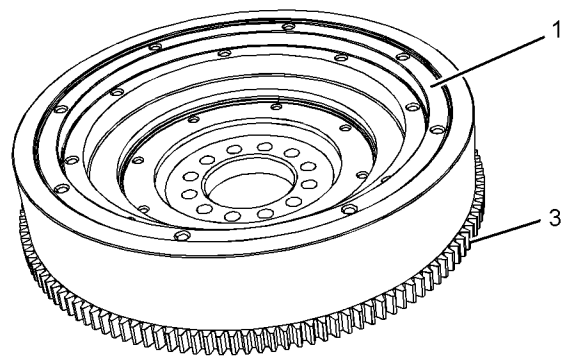


Illustration 176

g02657439

6. Inspect flywheel (1) and ring gear (3) for wear and damage. Replace any worn or damaged components.
7. To remove flywheel ring gear (3), follow Step 7.a through Step 7.b.

- a. Place the flywheel assembly on a suitable support.
- b. Use a hammer and a punch in order to remove ring gear (3) from flywheel (1).

**Note:** Identify the orientation of the teeth on the flywheel ring gear.

i05270806

## Flywheel - Install

### Installation Procedure

Table 30

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M12 x 1.25 by 100mm	2
B	27610289	Angle Gauge	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.

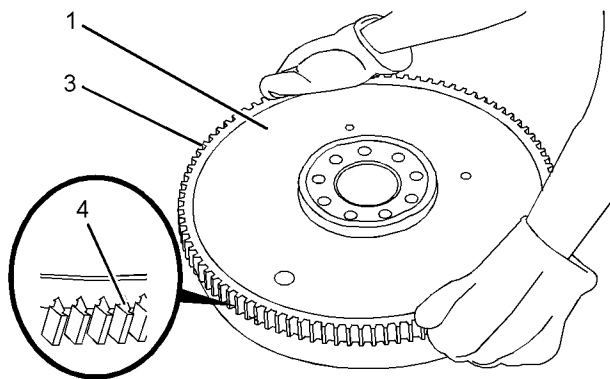


Illustration 177

g02659159

Typical example

#### WARNING

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

1. If the flywheel ring gear was removed, follow Step 1.a through Step 1.c in order to install a new ring gear (3) to flywheel (1).

- a. Identify the orientation of teeth (4) on new ring gear (3).

**Note:** The chamfered side of ring gear teeth (4) must face toward the starting motor when the flywheel is installed. The chamfered side of ring gear teeth ensures the correct engagement of the starting motor.

- b. Heat flywheel ring gear (3) in an oven to a maximum temperature of 250 °C (482 °F) prior to installation.

**Note:** Do not use a torch to heat the ring gear.

- c. Ensure that the orientation of ring gear (3) is correct and quickly install the ring gear onto flywheel (1).

2. Inspect the crankshaft rear seal for leaks. If there are any oil leaks, replace the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove and Install".

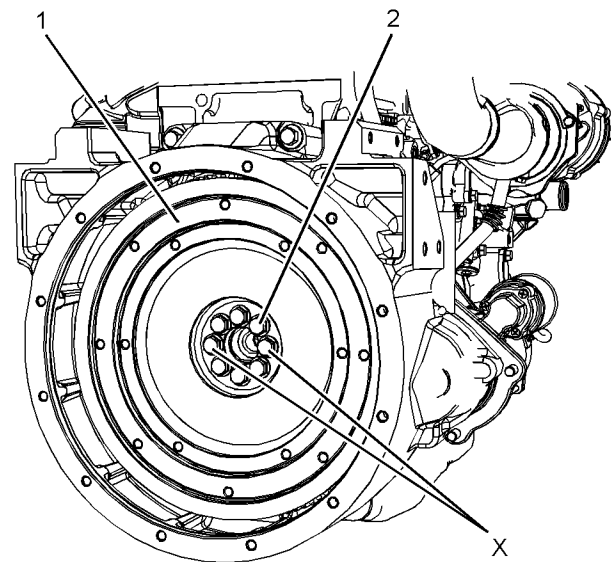


Illustration 178

g02659160

Typical example

3. Install a suitable lifting device to flywheel (1). The flywheel can weigh 75 kg (165 lb).
4. Install Tooling (A) in Position (X) on the crankshaft.
5. Use the suitable lifting device to position flywheel (1) onto Tooling (A).
6. Install new bolts (2) hand tight to flywheel (1).

7. Remove Tooling (A) and install remaining new bolts (2) hand tight to flywheel (1).
8. Remove the lifting device from flywheel (1).
9. Use a suitable tool to prevent the flywheel from rotating. Tighten bolts (2) to a torque of 30 N·m (266 lb in). Use Tooling (B) to rotate bolts (2) through an additional 90 degrees in a clockwise direction in order to achieve the required final torque.
10. Check the run out of the flywheel. Refer to System Operation, Testing and Adjusting, "Flywheel" for further information.

**End By:**

- a. Install the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install" for the correct procedure.

i05270810

## Crankshaft Rear Seal - Remove and Install

### Removal Procedure

Table 31

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Drill Bit (3 mm)	1
B	27610311	Slide Hammer Puller	1
C	-	Telescopic Magnet	1

**Start By:**

- a. Remove the flywheel. Refer to Disassembly and Assembly, "Flywheel - Remove" for the correct procedure.

**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.

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.

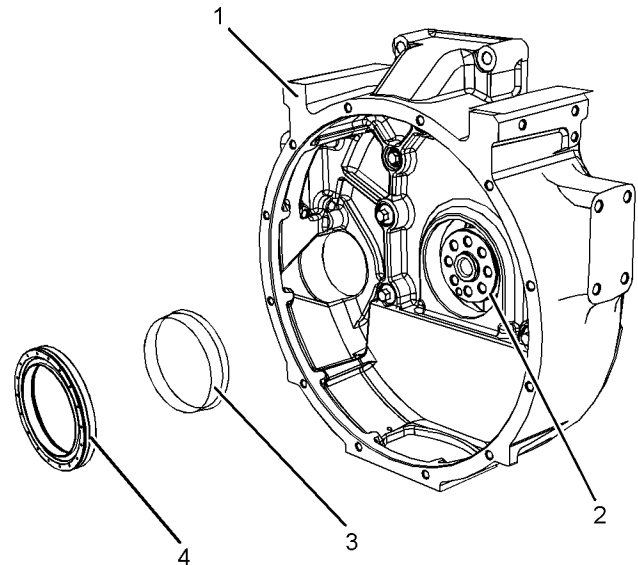


Illustration 179

g02873976

## Typical example

1. Apply clean grease to Tooling (A) in order to prevent any swarf that is generated from entering the engine. Use Tooling (A) to drill three evenly spaced holes in crankshaft rear seal (4).
2. Use Tooling (B) with care in order to remove crankshaft rear seal (4) from flywheel housing (1). Alternate the position of Tooling (B) from one hole to another. Alternating the position of Tooling (B) will allow the crankshaft rear seal to be easily removed from the flywheel housing.
3. Apply clean grease to Tooling (A) in order to prevent any swarf that is generated from entering the engine. Use Tooling (A) to drill two evenly spaced holes in crankshaft wear sleeve (3).
4. Use Tooling (B) with care in order to remove crankshaft wear sleeve (3) from crankshaft (2). Alternate the position of Tooling (B) from one hole to the other. Alternating the position of Tooling (B) will allow the crankshaft wear sleeve to be easily removed from the crankshaft.
5. Use Tooling (C) to collect any swarf that is on the flywheel housing or crankshaft assembly.

## Installation Procedure

Table 32

Required Tools			
Tool	Part Number	Part Description	Qty
D	T400089	Crankshaft Rear Seal Installer	1

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the flange of the crankshaft and the inside of the flywheel housing are clean and free from oil and damage.

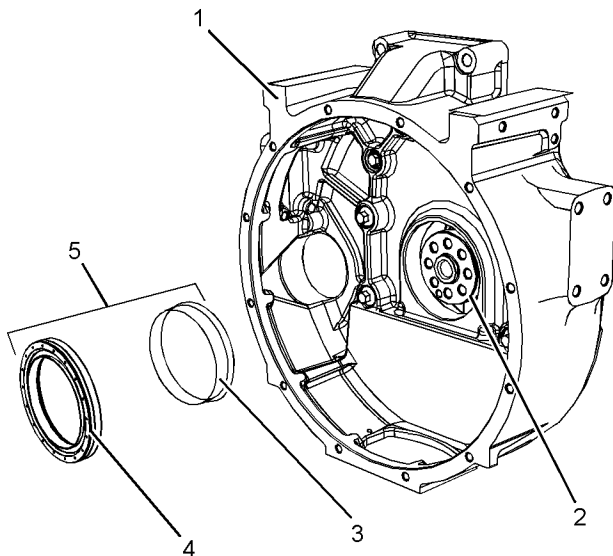


Illustration 180

g02876556

Typical example

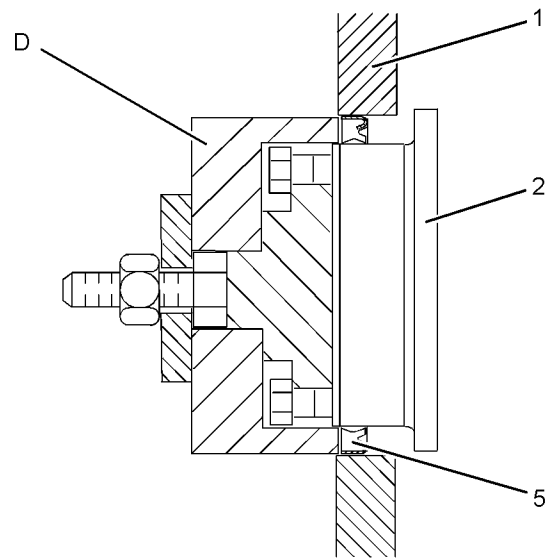


Illustration 181

g02876596

Sectional view of the crankshaft rear seal, the crankshaft, and the installation tool

2. Crankshaft rear seal (4) and crankshaft wear sleeve (3) are supplied as a crankshaft rear seal assembly (5) and should not be separated for installation.

**Note:** Do not remove the crankshaft rear seal from the crankshaft wear sleeve.

3. Use Tooling (D) and follow Step 3.a through Step 3.f in order to install crankshaft rear seal assembly (5).

- a. Position the adaptor of Tooling (D) onto the palm of the crankshaft and secure with bolts.
- b. Position the new crankshaft rear seal assembly (5) over the adaptor onto the rear of the crankshaft.
- c. Align the seal installer of Tooling (D) with the crankshaft.

**Note:** Check that the installer of Tooling (D) is parallel to the adaptor.

- d. Install the nut and washer to the locator.
- e. Tighten the nut until the installer bottoms out on the adaptor in order to install crankshaft rear seal assembly (5) into flywheel housing (1) and onto crankshaft (2).
- f. Remove Tooling (D).



**End By:**

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

i05270813

## Flywheel Housing - Remove and Install

(Stressed Cylinder Block)

**Removal Procedure**

Table 33

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M8 by 100 mm	2

**Start By:**

- a. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Remove and Install" for the correct procedure.
- b. Remove the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install" for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

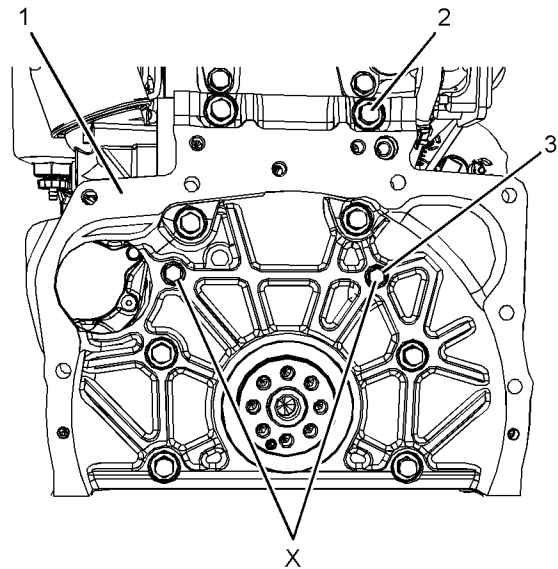


Illustration 182

g02879298

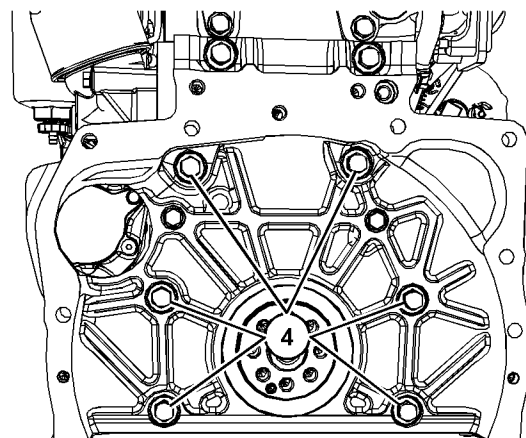


Illustration 183

g02879337

1. Remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install" for the correct procedure.
2. Remove bolts (3) from Position (X) from flywheel housing (1).
3. Install Tooling (A) into Position (X) on flywheel housing (1).

4. Install a suitable lifting device to the flywheel housing in order to support the flywheel housing. The weight of the flywheel housing is approximately 40 kg (88 lb).
5. Remove bolts (2) from flywheel housing (1).
6. Remove bolts (4) from flywheel housing (1).
7. Use the suitable lifting device in order to remove flywheel housing (1) from the cylinder block.

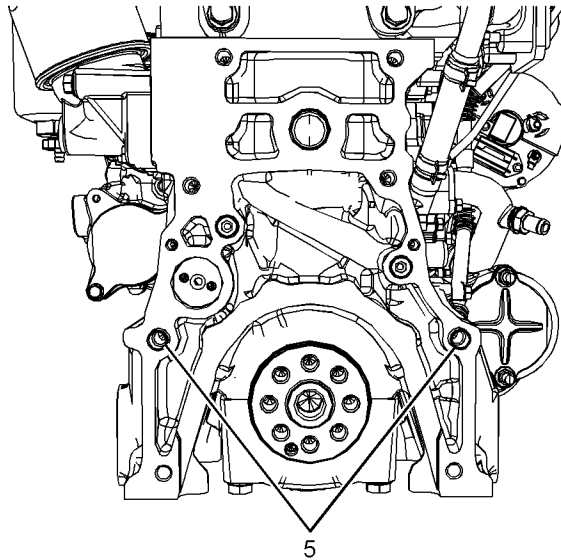


Illustration 184

g02879456

8. If necessary, remove dowels (5).

### Installation Procedure

Table 34

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M8 by 100 mm	2
B	-	Loctite 5970	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the flywheel housing is clean and free from damage. If necessary, replace the flywheel housing.

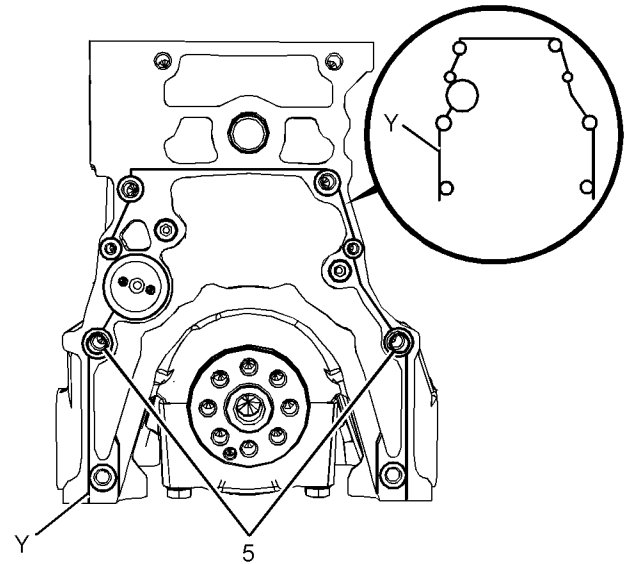


Illustration 185

g02881996

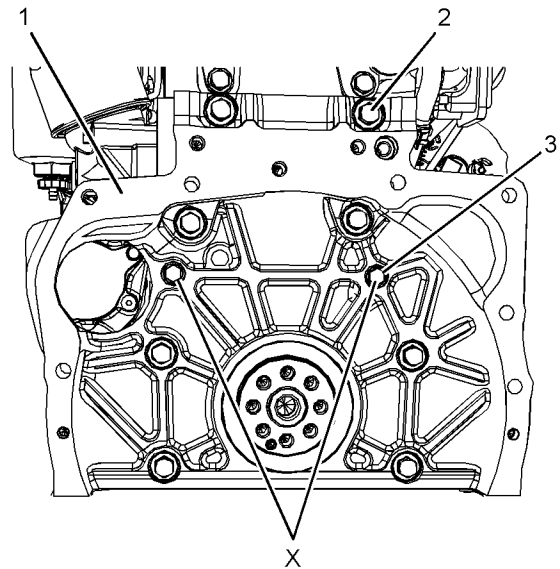


Illustration 186

g02879298

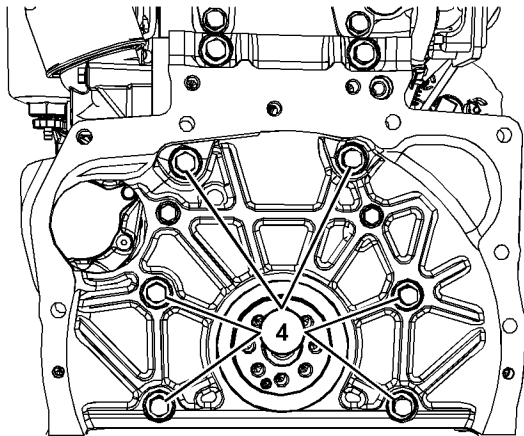


Illustration 187

g02879337

2. Clean the rear face of the cylinder block.
3. If necessary, install dowels (5) to the cylinder block.
4. Apply a 3mm bead of Tooling (B) in Position (Y) to the cylinder block as shown in Illustration 185 .
5. Install Tooling (A) into the cylinder block in Positions (X).
6. Install a suitable lifting device onto the flywheel housing. The weight of the flywheel housing is approximately 40 kg (88 lb).
7. Use the suitable lifting device to align flywheel housing (1) with Tooling (A). Install the flywheel housing to the cylinder block.
8. Install bolts (4) and bolts (2) finger tight.
9. Remove Tooling (A). Install bolts (3) finger tight.
10. Tighten bolts (4) and bolts (2) to a torque of 110 N·m (81 lb ft).
11. Tighten bolts (3) to a torque of 35 N·m (26 lb ft).
12. Check the alignment of flywheel housing (1) with the crankshaft. Refer to System Operation, Testing and Adjusting, “Flywheel Housing - Inspect” for more information.
13. Install the electric starting motor. Refer to Disassembly and Assembly, “Electric Starting Motor - Remove and Install” for the correct procedure.

**End By:**

- a. Install the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for the correct procedure.
- b. Install the crankshaft rear seal. Refer to Disassembly and Assembly, “Crankshaft Rear Seal - Remove and Install” for the correct procedure.

i05270819

## Flywheel Housing - Remove and Install

### (Non-Stressed Cylinder Block)

**Removal Procedure**

Table 35

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M8 by 100 mm	2

**Start By:**

- a. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, “Crankshaft Rear Seal - Remove and Install” for the correct procedure.
- b. Remove the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

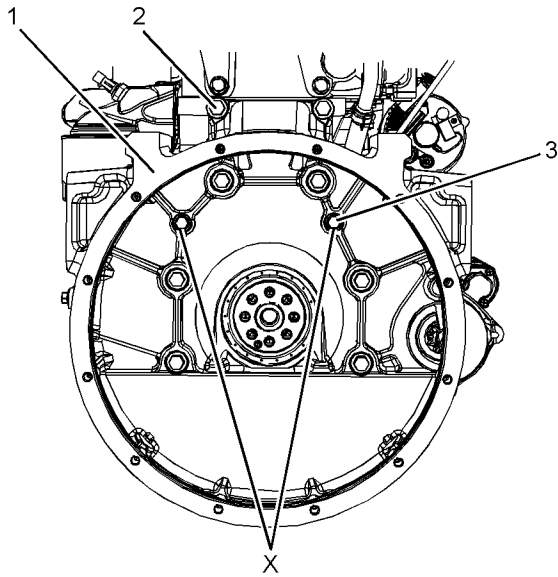


Illustration 188

g02659276

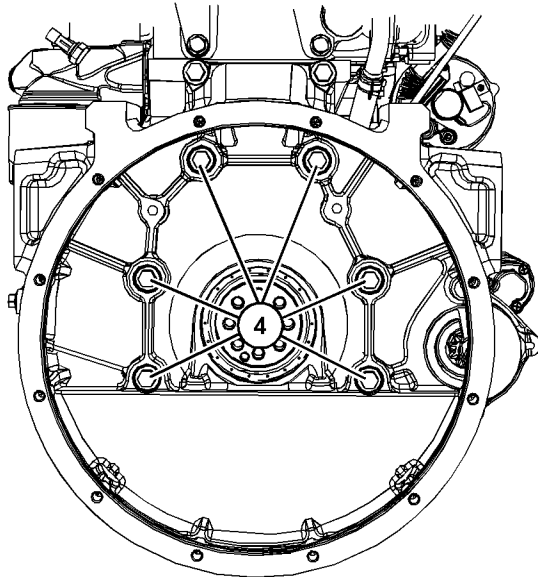


Illustration 189

g02659298

1. Remove the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install" for the correct procedure.
2. If necessary install the diesel particulate filter supporting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.
3. Remove bolts (3) from Position (X) from flywheel housing (1).

4. Install Tooling (A) into Position (X) on flywheel housing (1).
5. Install a suitable lifting device to the flywheel housing in order to support the flywheel housing. The weight of the flywheel housing is approximately 40 kg (88 lb).
6. Remove bolts (2) from flywheel housing (1).
7. Remove bolts (4) from flywheel housing (1).
8. Use the suitable lifting device in order to remove flywheel housing (1) from the cylinder block.

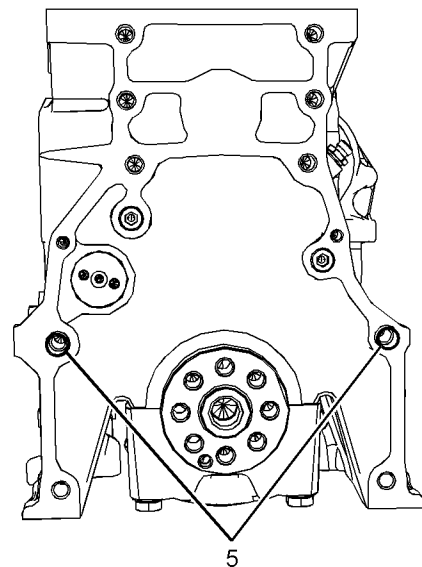


Illustration 190

g02882157

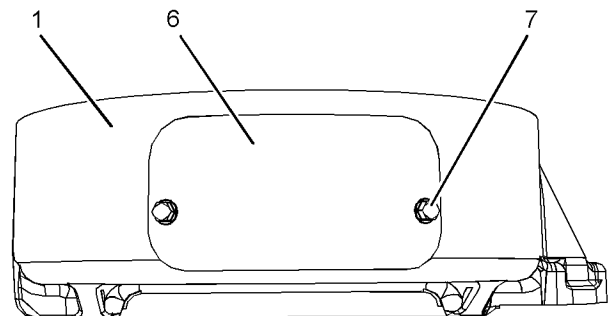


Illustration 191

g02661536

9. If necessary, remove dowels (5).
10. If necessary, remove bolts (7) and inspection cover (6) from flywheel housing (1).

## Installation Procedure

Table 36

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M8 by 100 mm	2
B	-	Loctite 5970	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the flywheel housing is clean and free from damage. If necessary, replace the flywheel housing.

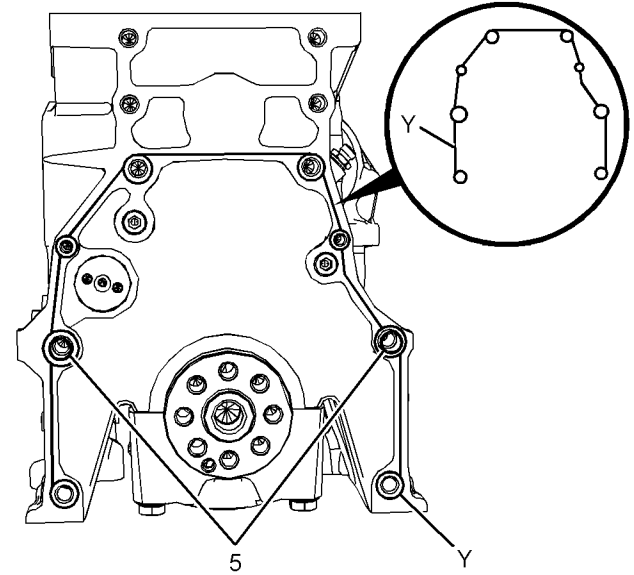


Illustration 192

g02882197

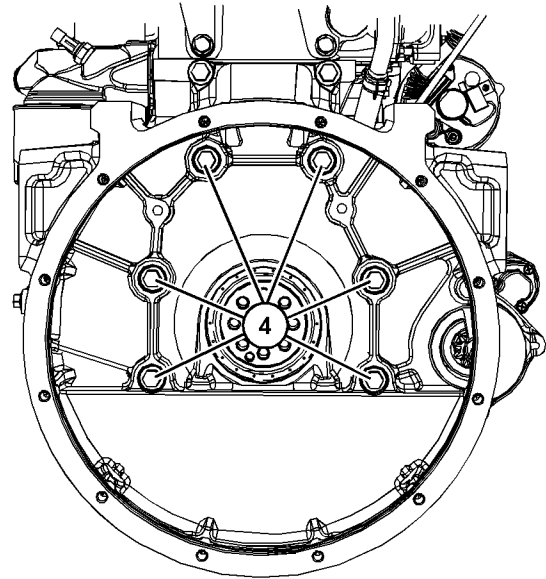


Illustration 193

g02659298

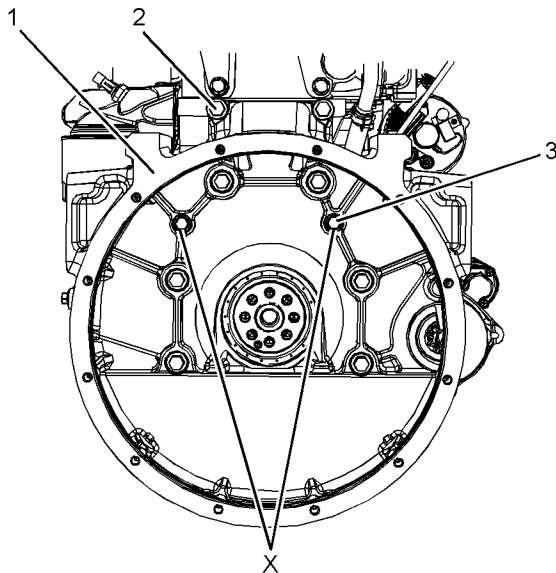


Illustration 194

g02659276

2. Clean the rear face of the cylinder block. If necessary, install dowels (5) to the cylinder block.
3. If necessary, install dowels (5) to the cylinder block.
4. Apply a 3mm bead of Tooling (B) in Position (Y) to the cylinder block as shown in Illustration 192 .
5. Install Tooling (A) into the cylinder block in Positions (X).
6. Install a suitable lifting device onto the flywheel housing. The weight of the flywheel housing is approximately 40 kg (88 lb).
7. Use the suitable lifting device to align flywheel housing (1) with Tooling (A). Install the flywheel housing to the cylinder block.
8. Install bolts (4) and bolts (2) finger tight.
9. Remove Tooling (A). Install bolts (3) finger tight.
10. Tighten bolts (4) and bolts (2) to a torque of 110 N·m (81 lb ft).
11. Tighten bolts (3) to a torque of 35 N·m (26 lb ft).
12. Check the alignment of flywheel housing (1) with the crankshaft. Refer to System Operation, Testing and Adjusting, “Flywheel Housing - Inspect” for more information.

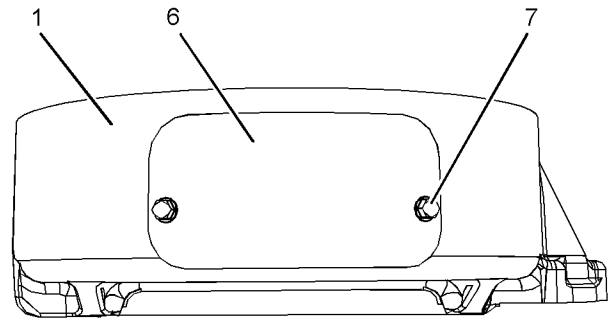


Illustration 195

g02661536

13. If necessary, install inspection cover (6) and bolts (7) to flywheel housing (1). Tighten the bolts to a torque of 25 N·m (221 lb in).
  14. Install the electric starting motor. Refer to Disassembly and Assembly, “Electric Starting Motor - Remove and Install” for the correct procedure.
- End By:**
- a. Install the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for the correct procedure.
  - b. Install the crankshaft rear seal. Refer to Disassembly and Assembly, “Crankshaft Rear Seal - Remove and Install” for the correct procedure.

i05270821

## Power Take-Off Drive - Remove and Install

### Removal Procedure

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#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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**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.

Dispose of all fluids according to local regulations and mandates.

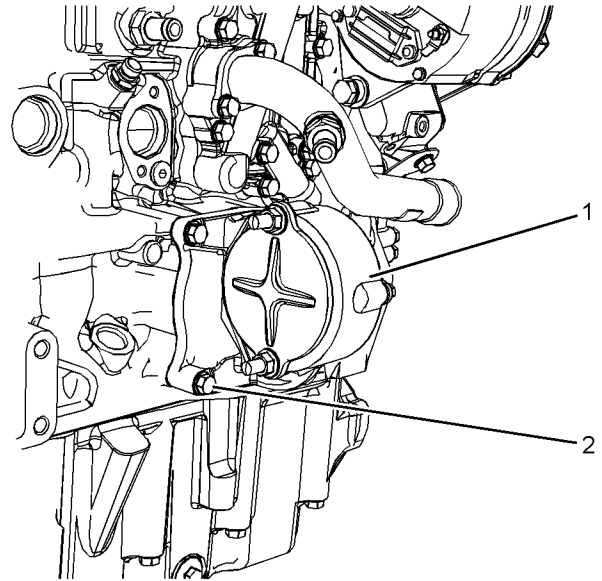


Illustration 196

g02901518

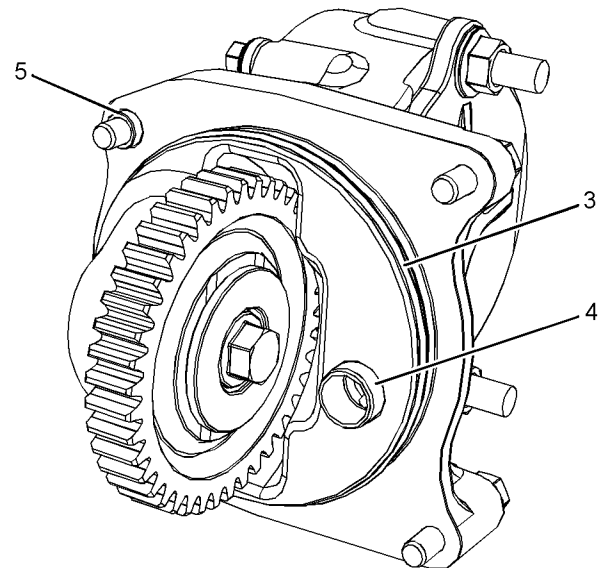


Illustration 197

g02901685

1. If necessary, remove the Original Equipment Manufacturer's (OEM) driven equipment from power take-off drive (1). Refer to the OEM for the correct procedure.
  2. Remove bolts (2) from power take-off drive (1).
- Note:** Note the positions of the different length bolts.
3. Remove the power take-off drive (1) from the cylinder block.
  4. Remove O-ring seal (3) from power take-off drive (1).

5. Note the position of dowel (4) and dowel (5) in the power take-off drive. Do not remove the dowels unless the dowels are damaged.

## Installation Procedure

Table 37

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Delphi Lockheed Compound Rubber Grease	1

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.

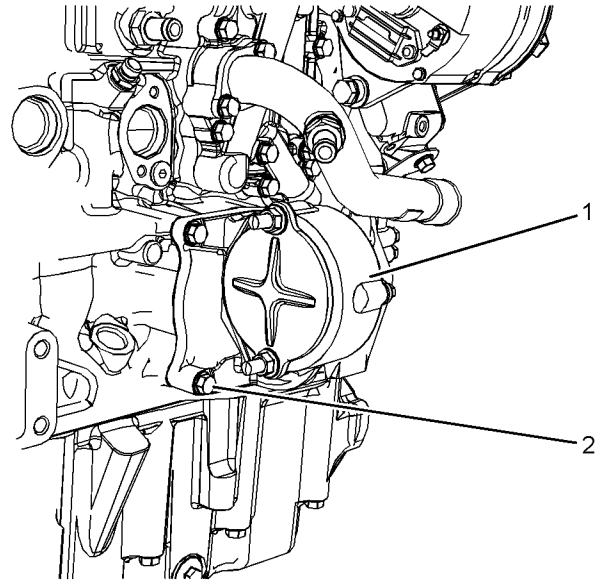


Illustration 198

g02901518

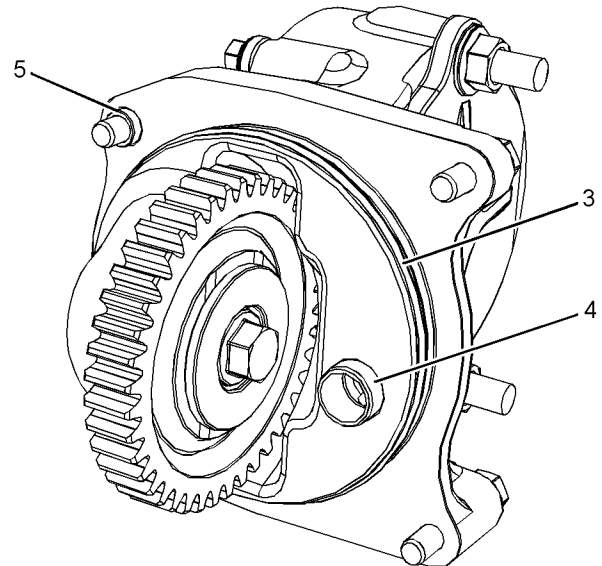


Illustration 199

g02901685

2. If necessary, install dowel (4) and dowel (5) into power take-off drive (1).
3. Install a new O-ring seal (3) onto power take-off drive (1).
4. Apply Tooling (A) onto O-ring seal (3).
5. Position power take-off drive (1) onto the cylinder block.

**Note:** Ensure that the drive gear for the power take-off drive is correctly engaged with the gear on the crankshaft.



6. Equally tighten bolts (2) in order to pull power take-off drive (1) into the cylinder block
7. Tighten bolts (2) to a torque of 25 N·m (221 lb in)
8. Ensure that there is tactile backlash between the idler gear and the accessory drive gear.
9. If necessary, install the OEM driven equipment to power take-off drive (1). Refer to the OEM for the correct procedure.

i05270822

## Crankshaft Pulley - Remove and Install

### Removal Procedure

#### Start By:

- a. Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

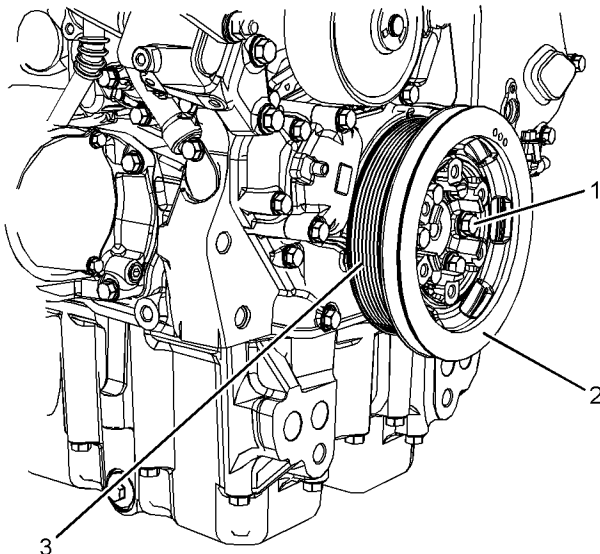


Illustration 200

g02926996

1. Use a suitable method in order to prevent the crankshaft from rotating.
2. Remove bolts (1) from crankshaft pulley (2).
3. If equipped, remove crankshaft V-pulley (2).

4. Remove crankshaft multi V-pulley (3).

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are free from wear and damage.

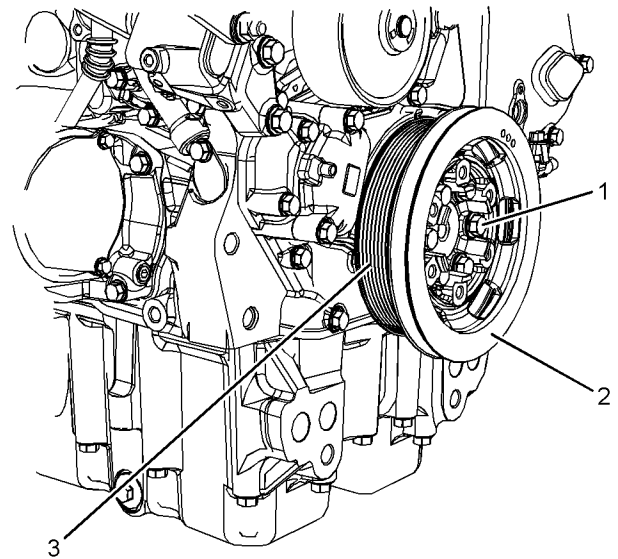


Illustration 201

g02926996

2. Install crankshaft multi V-pulley (3) onto the crankshaft.
3. If equipped, install crankshaft V-pulley (2).
4. Install bolts (1) to the crankshaft pulley. Tighten the bolts to a torque of 45 N·m (33 lb ft)

**Note:** Use a suitable method in order to prevent the crankshaft from rotating when torquing the bolts.

**End By:**

- a. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

i06096313

## Crankshaft Front Seal - Remove and Install

### Removal Procedure

Table 38

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Drill Bit (3 mm)	1
B	27610311	Slide Hammer Puller	1
C	-	Telescopic Magnet	1

**Start By:**

- a. Remove the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install" for the correct procedure.

**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.

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.

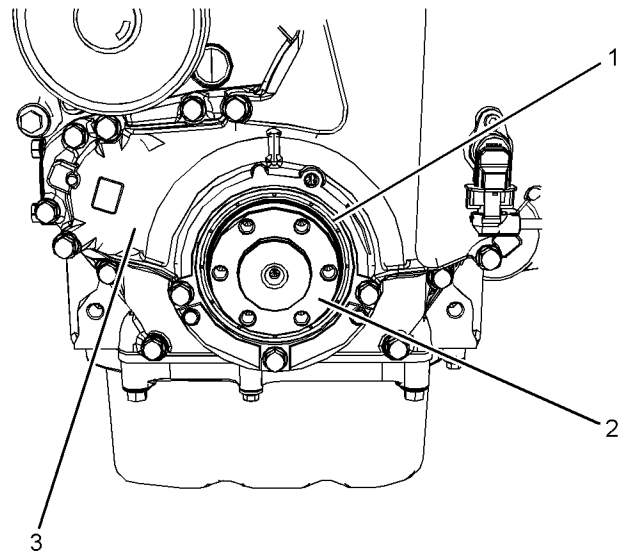


Illustration 202

g02927001

1. Apply clean grease to Tooling (A) in order to prevent any swarf that is generated from entering the engine. Use Tooling (A) to drill three evenly spaced holes in crankshaft front seal (1).
2. Use Tooling (B) with care in order to remove crankshaft front seal (1) from front cover (3) and crankshaft pulley adaptor (2). Alternate the position of Tooling (B) from one hole to another. Alternating the position of Tooling (B) will allow the crankshaft front seal to be easily removed from the crankshaft.
3. Use Tooling (C) to collect any swarf that has entered the engine.

### Installation Procedure

Table 39

Required Tools			
Tool	Part Number	Part Description	Qty
D <sup>(1)</sup>	T400450	Crankshaft Front Seal Installer	1
D <sup>(2)</sup>	T400090	Crankshaft Front Seal Installer	

<sup>(1)</sup> Used for Procedure 1

<sup>(2)</sup> Used for Procedure 2

**Note:** The tool used is determined by which crankshaft front seal is installed.

## Procedure 1

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the crankshaft pulley adaptor and the front cover are clean and free from oil and damage.

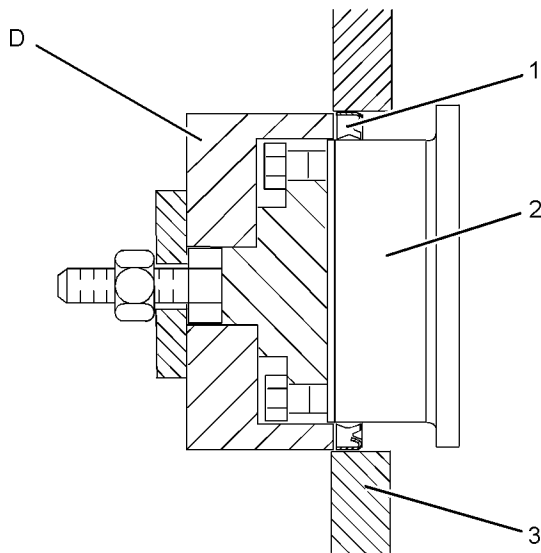


Illustration 203

g02927218

Sectional view of the crankshaft front seal, the crankshaft pulley adaptor, and the installation tool

2. Use Tooling (D) and follow Step 2.a through Step 2.f in order to install crankshaft front seal (1).
  - a. Position the adaptor of Tooling (D) onto the crankshaft pulley adaptor and secure with bolts.
  - b. Position the new crankshaft front seal (1) over the adaptor onto the front of the crankshaft.
  - c. Align the seal installer of Tooling (D) with the crankshaft.

**Note:** Check that the installer of Tooling (D) is parallel to the adaptor.

  - d. Install the nut and washer to the locator.
  - e. Tighten the nut until the installer bottoms out on the adaptor in order to install crankshaft front seal (1) into front cover (3) and onto crankshaft pulley adaptor (2).
  - f. Remove Tooling (D).

### End By:

- a. Install the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install" for the correct procedure.

## Procedure 2

1. Ensure that the crankshaft pulley adaptor and the front cover are clean and free from oil and damage.

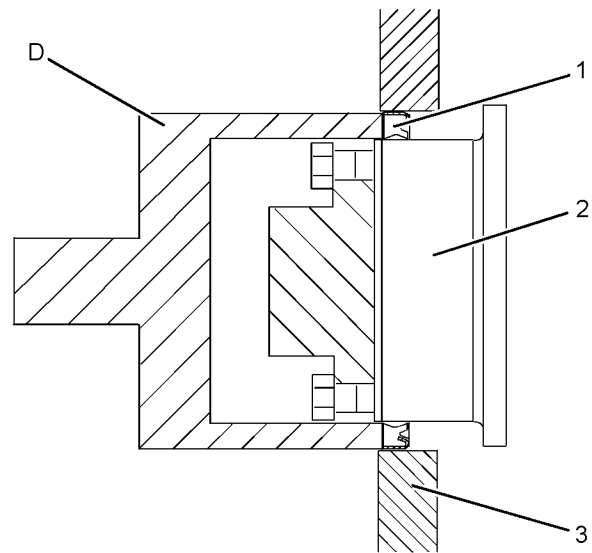


Illustration 204

g03805916

Sectional view of the crankshaft front seal, the crankshaft pulley adaptor, and the installation tool

2. Use Tooling (D) and follow Step 2.a through Step 2.e in order to install crankshaft front seal (1).
  - a. Position the new crankshaft front seal (1) over the nose of the crankshaft into the recess in the front cover.
  - b. Position Tooling (D) onto the new crankshaft front seal.
  - c. Align Tooling (D) with the crankshaft.
  - d. Use a suitable tool to drive (D) and the new crankshaft front seal (1) into position.
  - e. Remove Tooling (D).

**End By:**

- a. Install the crankshaft pulley. Refer to Disassembly and Assembly, “Crankshaft Pulley - Remove and Install” for the correct procedure.

i05270827

## Front Cover - Remove and Install

### Removal Procedure

**Start By:**

- a. If the engine is equipped with a fan, remove the fan. Refer to Disassembly and Assembly, “Fan - Remove and Install” for the correct procedure.
- b. Remove the camshaft position sensor. Refer to Disassembly and Assembly, “Camshaft Position Sensor - Remove and Install” for the correct procedure.
- c. Remove the crankshaft pulley. Refer to Disassembly and Assembly, “Crankshaft Pulley - Remove and Install” for the correct procedure.

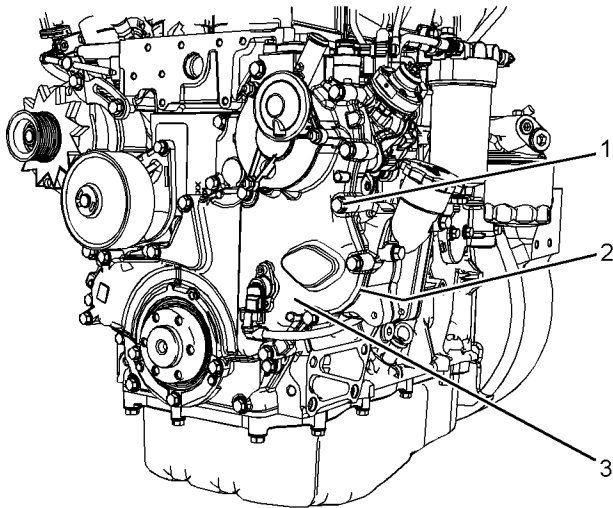


Illustration 205

g02727693

1. Remove bolts (1) from front cover (3).
2. Remove front cover (3) from the front housing.
3. Remove gasket (2) (not shown) from the front cover.

4. Remove the crankshaft front seal using a suitable tool. Ensure that the front cover (3) is not damaged during the removal of the crankshaft front seal.

### Installation Procedure

Table 40

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Guide Stud M8 by 70 mm	2
B	T400090	Front Cover Alignment Tool (Crankshaft)	1
C	T400087	Front Cover Alignment Tool (Crankcase Breather)	1

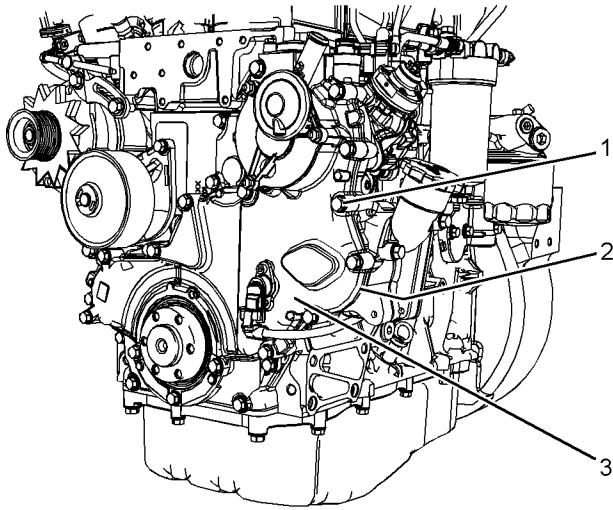


Illustration 206

g02727693

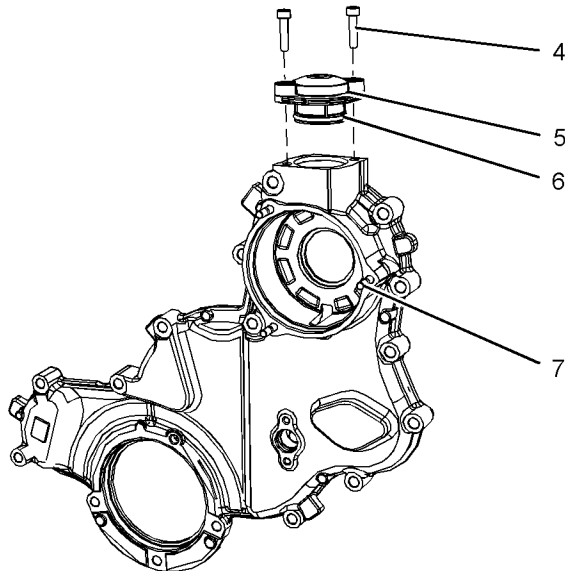


Illustration 207

g02727966

1. Thoroughly clean the gasket surface of the front housing.
2. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.
3. Position a new gasket (2) (not shown) onto the front cover.
4. Install Tooling (A) into Holes (X) in the front housing.
5. Use Tooling (A) in order to position the front cover assembly onto the front housing.

6. Install bolts (1) finger tight.
7. Use Tooling (B) and Tooling (C) in order to align the front cover.
8. Remove Tooling (A) and install remaining bolts (1).

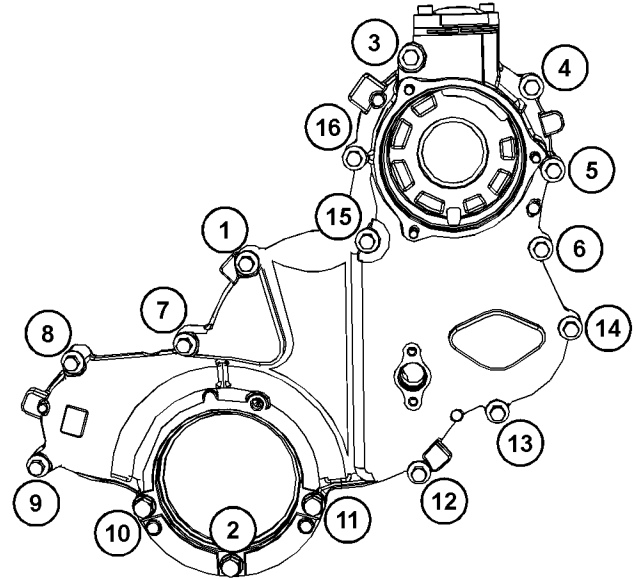


Illustration 208

g02727967

9. Tighten bolts (1) to a torque of 25 N·m (221 lb in).
10. Remove Tooling (B) and Tooling (C) from the front cover.
11. Install the crankshaft front seal to the front cover. Refer to Disassembly and Assembly, "Crankshaft Front Seal - Remove and Install" for the correct procedure.

**End By:**

- a. Install the crankshaft pulley. Refer to Disassembly and Assembly, "Crankshaft Pulley - Remove and Install" for the correct procedure.
- b. If the engine was equipped with a fan, install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install" for the correct procedure.
- c. Install the camshaft position sensor. Refer to Disassembly and Assembly, "Camshaft Position Sensor - Remove and Install" for the correct procedure.

i05270830

**Idler Gear - Remove****Removal Procedure**

Table 41

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400086	Timing Pin (Crankshaft)	1
B	T400152	Timing Pin (Camshaft)	1

**Start By:**

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

**Note:** Care must be taken in order to ensure that the fuel injection pump timing is not lost during the removal of the idler gear.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shorten component life.

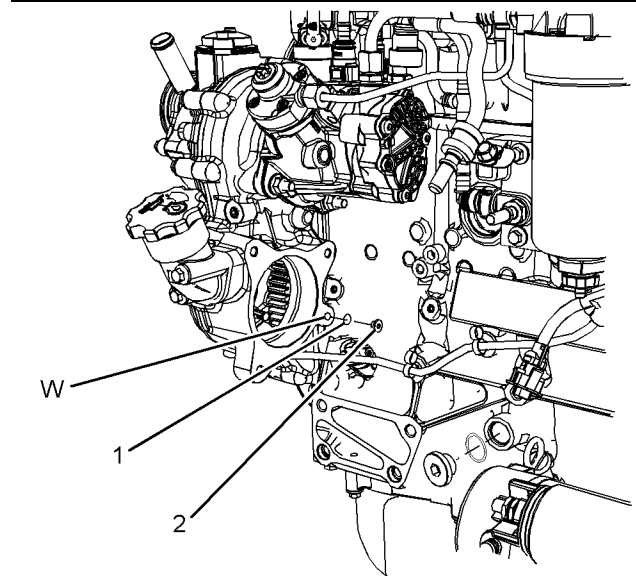


Illustration 209

g02937156

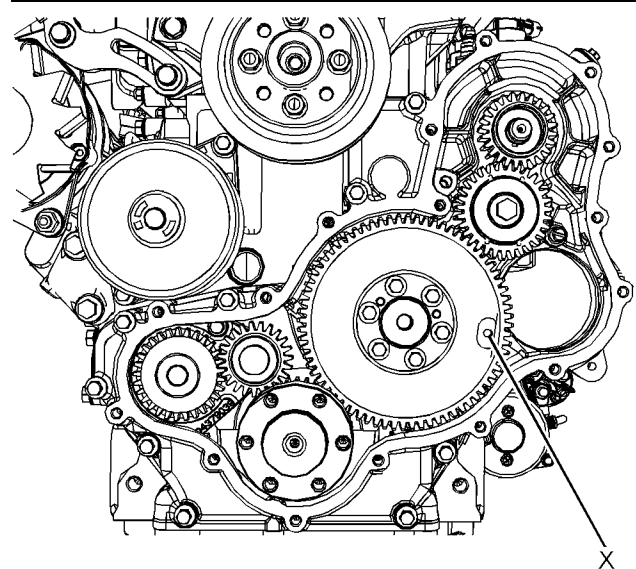


Illustration 210

g02937157

Camshaft timing ring removed for clarity.

1. Follow Step 1.a through Step 1.e in order to install the camshaft timing tool.
  - a. If equipped, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install" for the correct procedure.
  - b. Remove plug (2) in Position (W) from the front housing.
  - c. Remove O-ring seal (1) from plug (2).

- d. Rotate the engine until Hole (X) in the camshaft gear is aligned with Position (W) in the front housing.
- e. Install Tooling (B) through Position (W) and into Hole (X) in the camshaft gear.

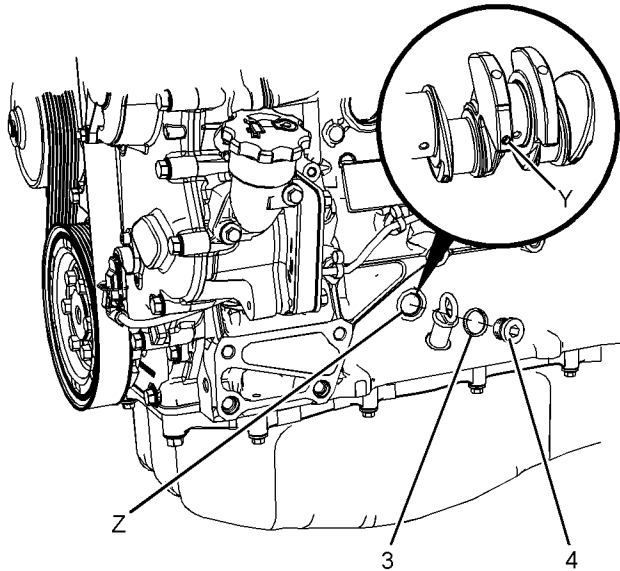


Illustration 211

g02934298

2. Follow Step 2.a through Step 2.c in order to install the crankshaft positioning tool.

- a. Remove plug (4) from Position (X) in the cylinder block.
- b. Remove O-ring seal (3) from plug (4).
- c. Install Tooling (A) into the cylinder block in Position (Z).

**Note:** Tooling (A) must be located in Hole (Y) in the crankshaft.

**Note:** Ensure that Tooling (A) is located in the correct drilling in the crankshaft as shown in Illustration 211 .

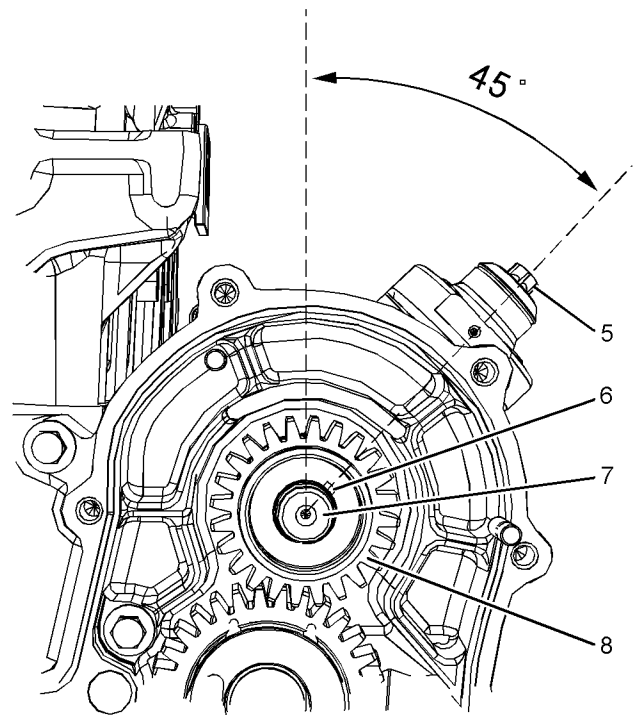


Illustration 212

g02937163

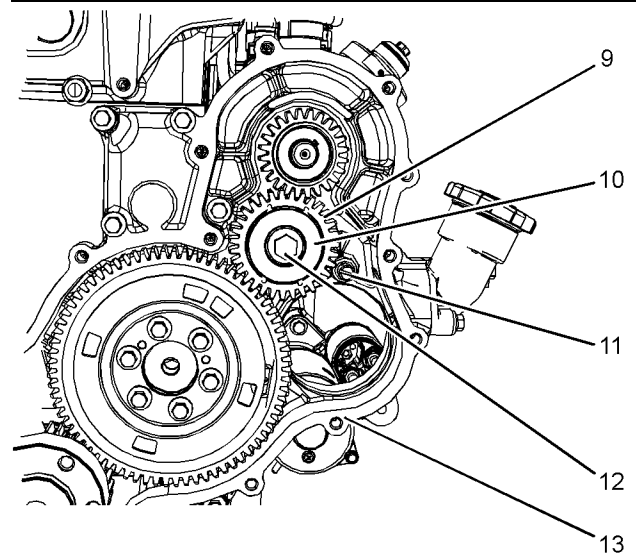


Illustration 213

g02939977

3. Before removing the idler gear ensure that alignment pin (6) on the fuel injection pump gear is 45 degrees from vertical and parallel to the center of Torx head plug (5), refer to Illustration 212 .
4. Make temporary identification marks on idler hub (10) for installation purposes.

5. Remove bolt (12) from idler hub (10).
6. Remove the idler hub (10) and gear (9) from front housing (13).
7. Remove idler hub (10) from gear (9).
8. If necessary, remove lubricating jet (11) from front housing (13).

i05270835

## Idler Gear - Install

### Installation Procedure

Table 42

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400086	Timing Pin (Crankshaft)	1
B	T400152	Timing Pin (Camshaft)	1
C	-	Loctite 506	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear or damage. If necessary, replace any components that are worn or damaged.
2. If Tooling (A) and Tooling (B) are not installed, install Tooling (A) and install Tooling (B). Refer to Disassembly and Assembly, "Idler Gear - Remove" for the correct procedure.

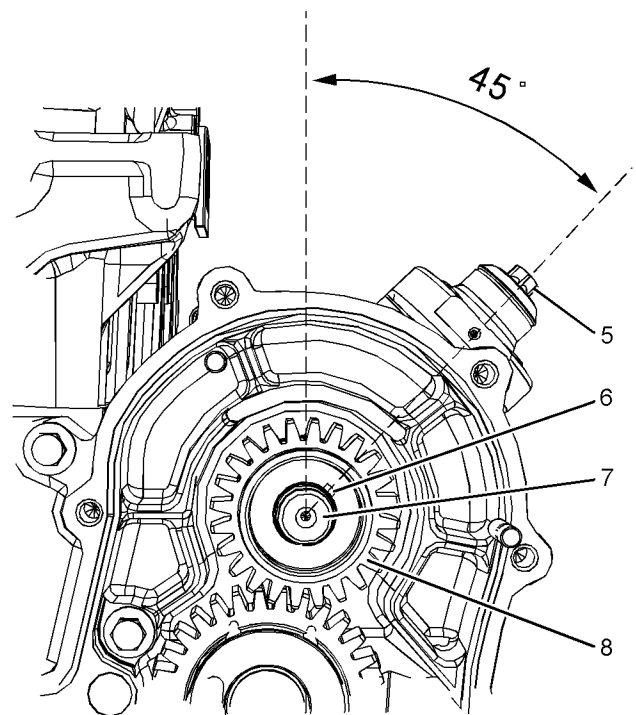


Illustration 214

g02937163

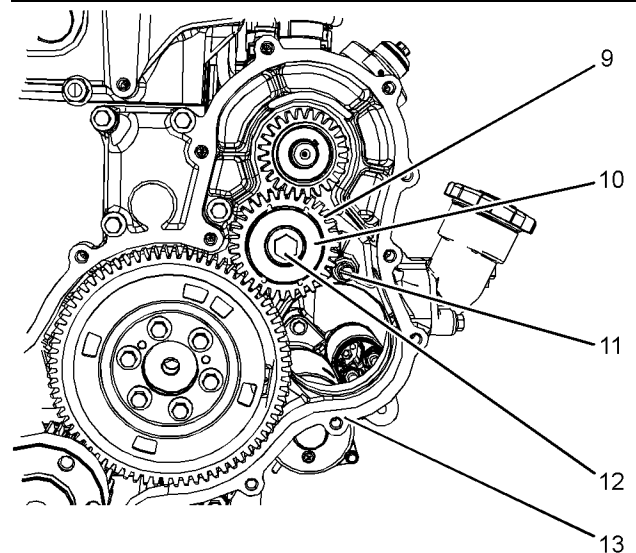


Illustration 215

g02939977

3. If necessary, Apply Tooling (C) to lubricating jet (11) and install the lubricating jet into front housing (13). Tighten the lubricating jet to a torque of 18 N·m (159 lb in).



4. Ensure that locating pin (6) is 45 degrees from vertical and parallel to the center of Torx head plug (5), refer to Illustration 214 .
5. Position gear (9) into the front housing. Ensure that the teeth on all gears mesh correctly.
6. Install idler hub (10) to gear (9). Ensure that the temporary marks are aligned and the idler hub (10) is correctly installed into the front housing.
7. Install bolt (12) to idler hub (10). Tighten the bolt to a torque of 50 N·m (37 lb ft)
8. Install the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install" for the correct procedure.

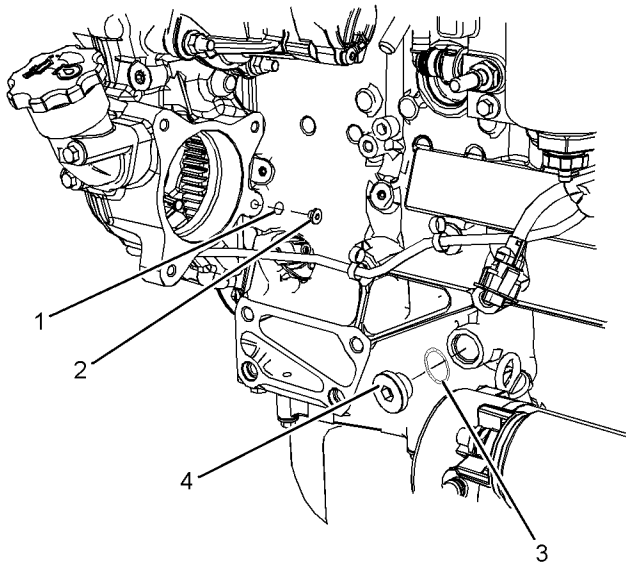


Illustration 216

g02937277

9. Remove Tooling (B) from the front housing.
10. Install new O-ring seal (1) to plug (2).
11. Install plug (2). Tighten the plug to a torque of 25 N·m (221 lb in).
12. Remove Tooling (A) from the cylinder block.
13. Install new O-ring seal (3) to plug (4).
14. Install plug (4). Tighten the plug to a torque of 30 N·m (266 lb in).

15. If equipped, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install" for the correct procedure.

i05270836

## Housing (Front) - Remove

### Removal Procedure

#### Start By:

- a. Remove the engine oil pan . Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install" for the correct procedure.
- b. Remove the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install" for the correct procedure.
- c. Remove the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Remove" for the correct procedure.

---

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shorten component life.

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#### 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.

Dispose of all fluids according to local regulations and mandates.

---

1. If necessary, remove the fan drive. Refer to Disassembly and Assembly, "Fan Drive - Remove and Install" for the correct procedure.

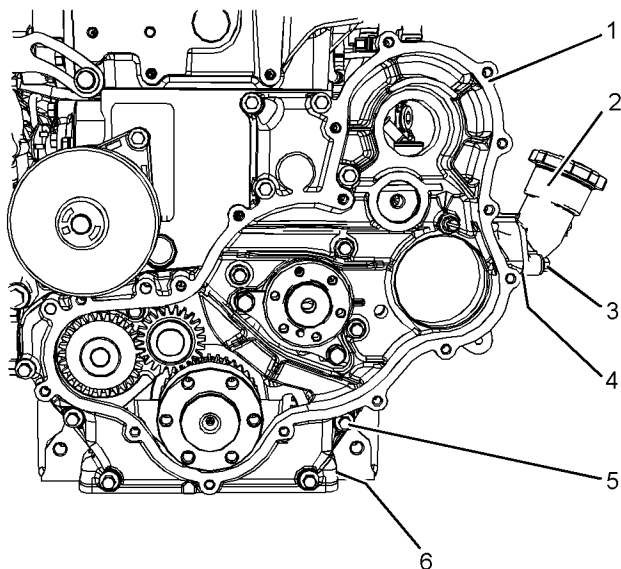


Illustration 217

g02729108

2. Remove bolts (5) from front housing (1).

**Note:** Note the positions of the different length bolts for installation purposes.

3. Remove front housing (1) from the cylinder block and dowels (6) (not shown).

4. Dowels (6) (not shown) should only be removed if damaged.

5. If necessary, follow Step 5.a through Step 5.c in order to remove engine oil filler (2).

a. Remove bolts (3) from engine oil filler (2).

b. Remove engine oil filler (2) from front housing (1).

c. Remove O-ring seal (4) (not shown).

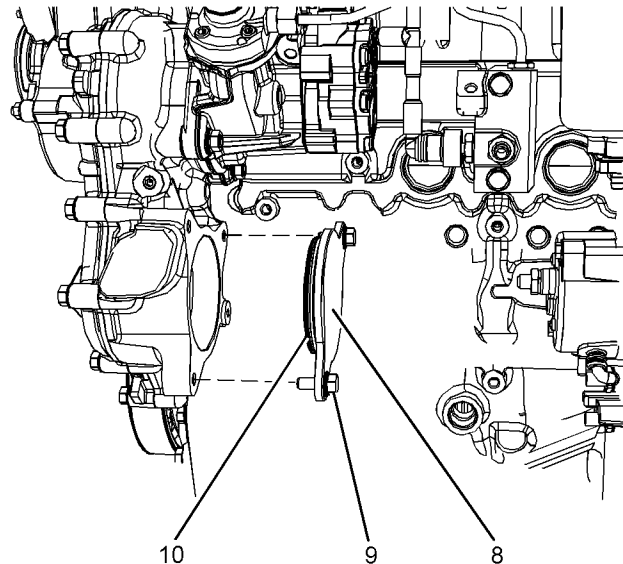


Illustration 218

g03025257

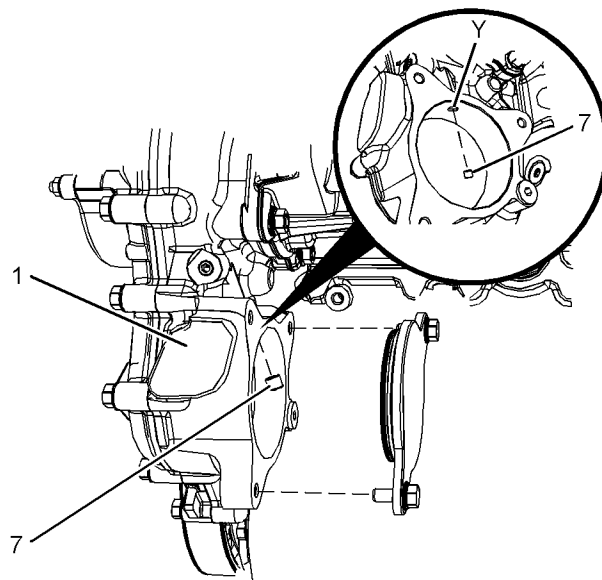


Illustration 219

g03025256

6. If necessary, follow Step 6.a through Step 6.c in order to remove cover plate (8) from the front housing.

a. Remove bolts (9) from cover plate (8).

b. Remove cover plate (8) from front housing (1).

c. Remove O-ring seal (10) from the cover plate.

7. If necessary, remove plug (7) in Position (Y) from the front housing.

i05270839

## Housing (Front) - Install

### Installation Procedure

Table 43

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Loctite 5970 Silicone Sealant	1
B	-	Guide Bolt M8 x 1.25 by 35 mm	2
C	-	Loctite 506	1
D	-	Delphi Lockheed Com- pound Rubber Grease	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shorten component life.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.

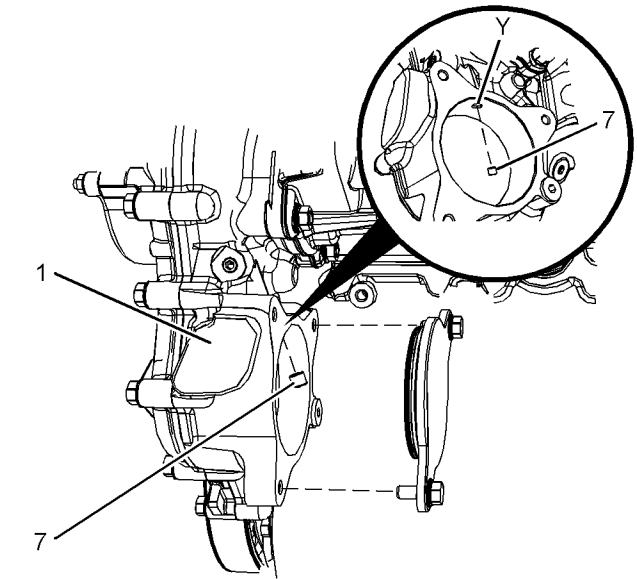


Illustration 220

g03022878

2. If a new front housing is being installed, it will be necessary to remove plug (7) in Position (Y) for engines that are equipped with any accessory drive in order to maintain the lubrication of the accessory drive.
3. If the accessory drive was removed but will not be installed, the oil gallery in Position (Y) must be plugged. Follow Step 3.a through Step 3.c in order to maintain engine oil circulation.
  - a. Apply Tooling (C) to plug (7).
  - b. Install plug (7) into front housing (1).
  - c. Tighten plug (7) to a torque of 15 N·m (133 lb in).

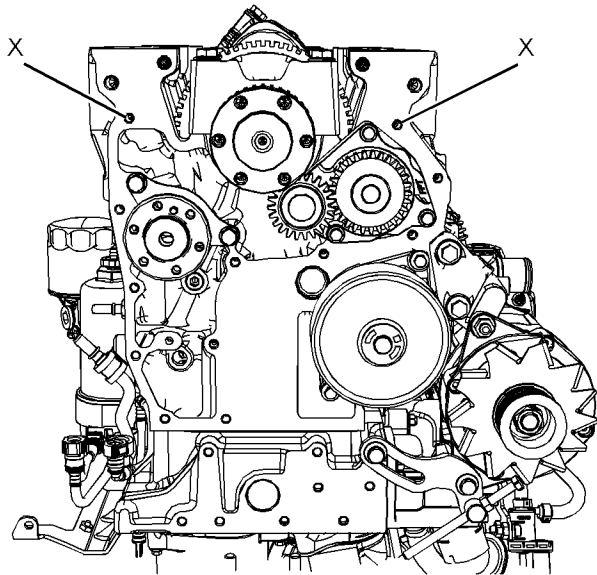


Illustration 221

g02951196

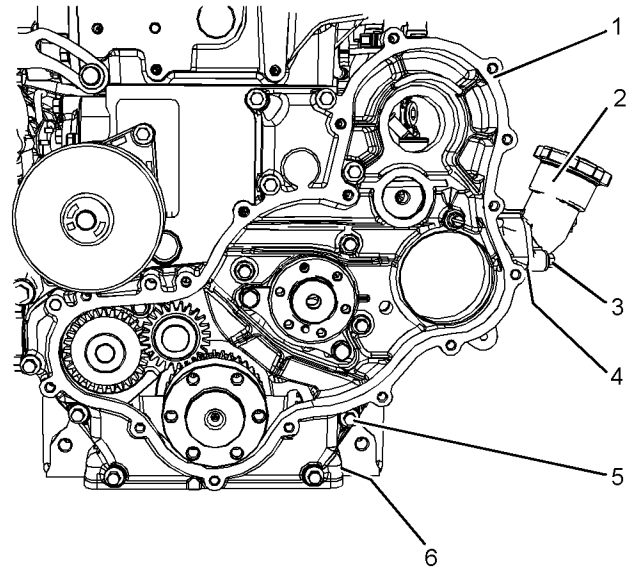


Illustration 223

g02729108

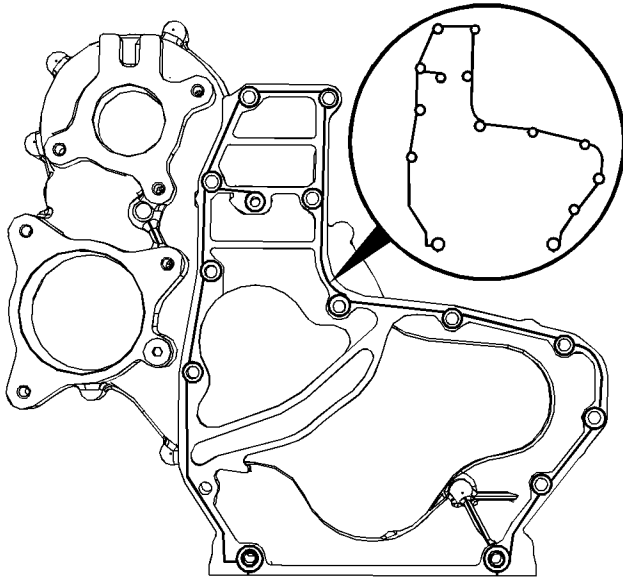


Illustration 222

g02729111

Front housing sealant path.

4. Thoroughly clean the gasket surface of the front housing (1) and the cylinder block.
5. If necessary, install dowels (6) (not shown) to the cylinder block.
6. Install Tooling (B) into the cylinder block in Positions (X).
7. Apply a 3mm bead of Tooling (A) to front housing (1) as shown in Illustration 222 .
8. Install front housing (1) onto Tooling (B) and dowels (6) (not shown).
9. Apply Tooling (C) onto the threads of bolts (5).
10. Install bolts (5) into front housing (1) in available location finger tight.
11. Remove Tooling (B) from the cylinder block.

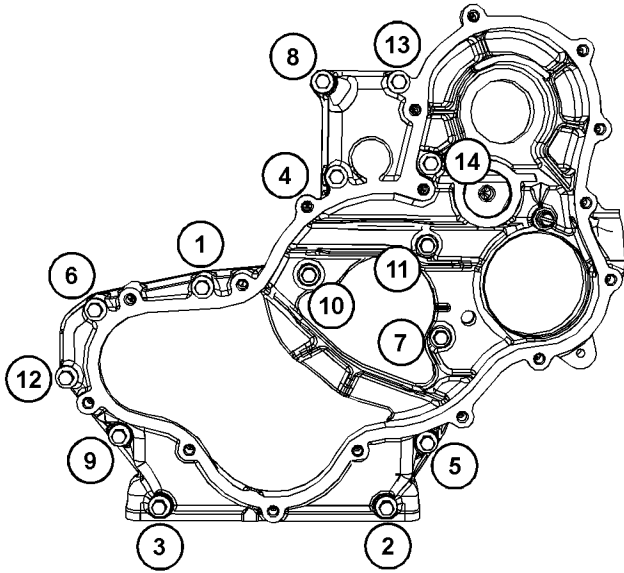


Illustration 224

g02951436

12. Install remaining bolts (5). Tighten the bolts in the sequence that is shown in Illustration 224 to a torque of 25 N·m (221 lb in).
13. Install the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Install" for the correct procedure.
14. Install the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install" for the correct procedure.
15. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove" for the correct procedure.
16. If necessary, install the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install" for the correct procedure.

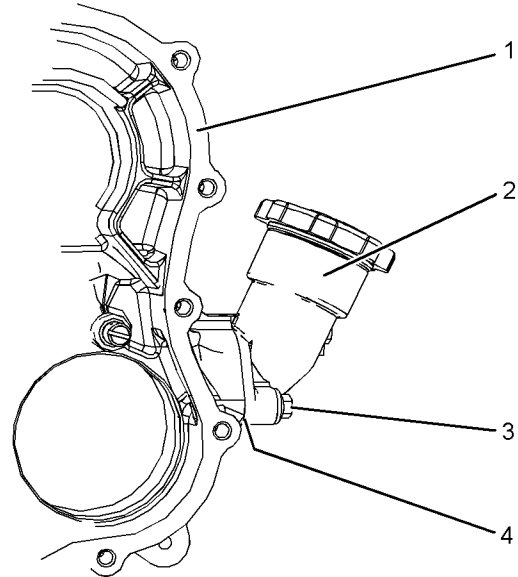


Illustration 225

g02951696

17. If necessary, follow Step 17.a through Step 17.c in order to install engine oil filler (2).
  - a. Install new O-ring seal (4) (not shown) onto engine oil filler (2).
  - b. Install engine oil filler (2) into front housing (1).
  - c. Install bolts (3) into engine oil filler (2). Tighten the bolts to a torque of 25 N·m (221 lb in).

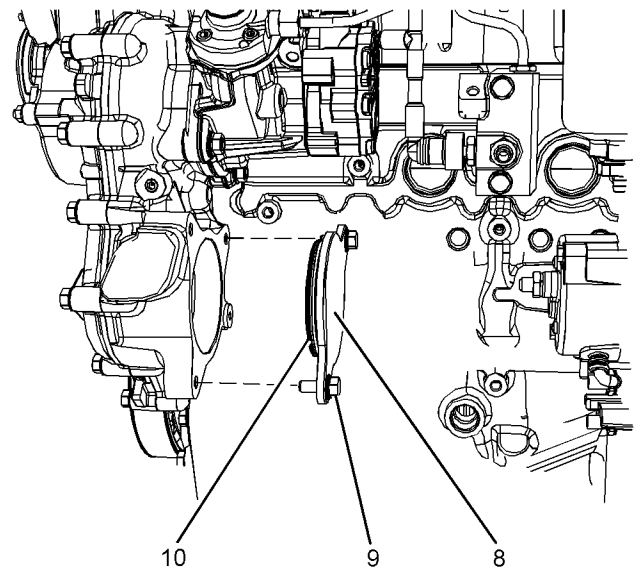


Illustration 226

g03025197

18. If necessary, install cover plate (8) to the front housing. Follow Step 18.a through Step 18.c in order to install the cover plate.

- a. Install new O-ring seal (10) to cover plate (8).  
Apply Tooling (D) to O-ring seal (10).
  - b. Install cover plate (8) to the front housing.
  - c. Install bolts (9) to the cover plate and tighten the bolts to a torque of 25 N·m (221 lb in).
19. If necessary, install the fan drive. Refer to Disassembly and Assembly, "Fan Drive - Remove and Install" for the correct procedure.

**End By:**

- a. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Fill" for the correct procedure.

i05270844

## Accessory Drive - Remove and Install

### Removal Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**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.

Dispose of all fluids according to local regulations and mandates.

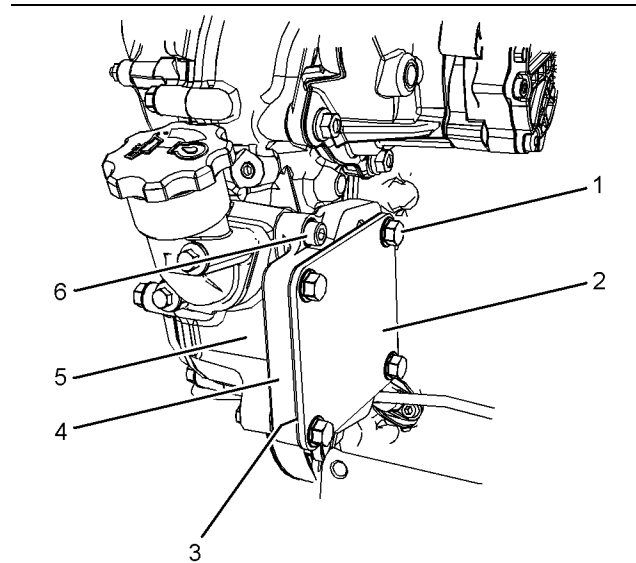


Illustration 227

g02898881

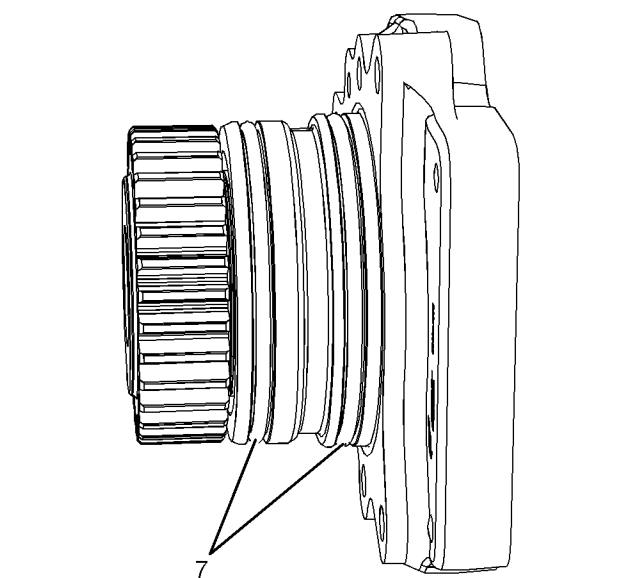


Illustration 228

g02898938

1. If necessary, remove the Original Equipment Manufacturer's (OEM) driven equipment from accessory drive (4). Refer to the OEM for the correct procedure.
2. If the OEM driven equipment was not installed onto accessory drive (4). Remove cover plate (2) and remove gasket (3) (not shown).
3. Remove Allen head bolts (6) from accessory drive (4). Remove the accessory drive housing from the front housing.
4. Remove O-ring seals (7) from the accessory drive.

## Installation Procedure

Table 44

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Delphi Lockheed Compound Rubber Grease	1

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Inspect the bore in the front housing for damage. If necessary, replace the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove" and Disassembly and Assembly, "Housing (Front) - Install" for the correct procedure.

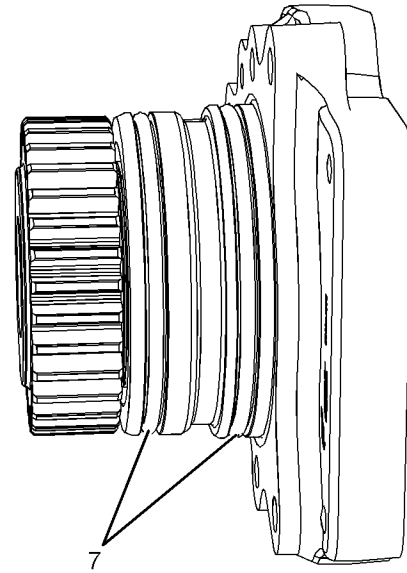


Illustration 229

g02898938

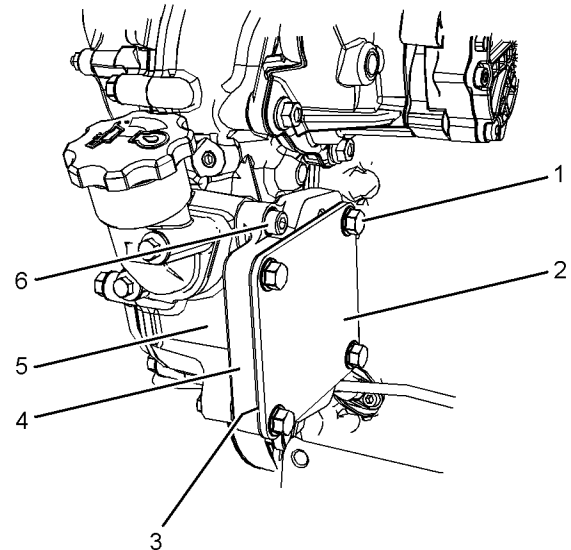


Illustration 230

g02898881

2. Install new O-ring seals (7) onto accessory drive (4).
3. Apply Tooling (A) onto O-ring seals (7).
4. Install accessory drive (4) to housing (5).
5. Install Allen head bolts (6) to accessory drive (4).
6. Equally tighten the Allen head bolts (6) in order to pull accessory drive (4) into housing (5).
7. Tighten Allen head bolts to a torque of 25 N·m (221 lb in).

8. Ensure that there is tactile backlash between the idler gear and the accessory drive gear.
9. If necessary, install the OEM driven equipment to accessory drive (4). Refer to the OEM for the correct procedure.
10. If the OEM driven equipment was not installed onto accessory drive (4), position new gasket (3) (not shown) and cover plate (2) onto accessory drive (4).
11. Install bolts (1) to cover plate (2). Tighten the bolts to a torque of 25 N·m (221 lb in).

i05270847

## Crankcase Breather - Remove

### Removal Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Table 45

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	1/2 Inch Drive x 19 mm Hex Drive	1

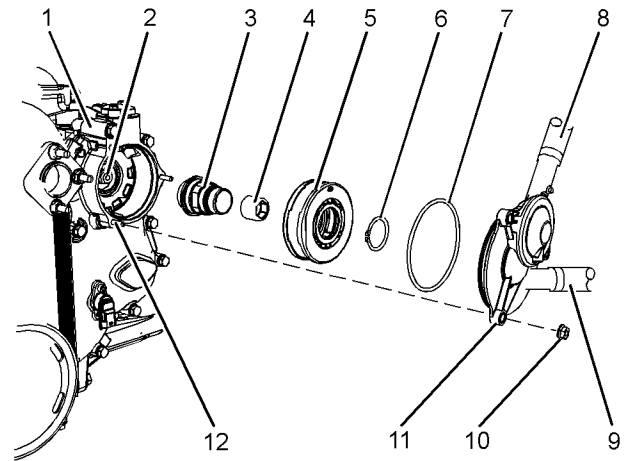


Illustration 231

g02689857

1. Disconnect hose (8) from crankcase breather cover (11).
2. If necessary, disconnect hose (9) from crankcase breather cover (11).
3. Remove nuts (10) from studs (12).
4. Remove crankcase breather cover (11) from front cover (1). Remove O-ring (7) from the crankcase breather cover.
5. Remove circlip (6) from spigot (3).
6. Remove breather element (5) from spigot (3).
7. If necessary, use Tooling (A) in order to remove threaded insert (4) and spigot (3) from fuel injection pump shaft (2).
8. If necessary, remove studs (12) from front cover (1).

i05270850

## Crankcase Breather - Install

### Installation Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.



Table 46

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	1/2 Inch Drive x 19 mm Hex Drive	1

1. Ensure that all components of the crankcase breather are clean and free from wear and damage. Replace any components that are worn or damaged.

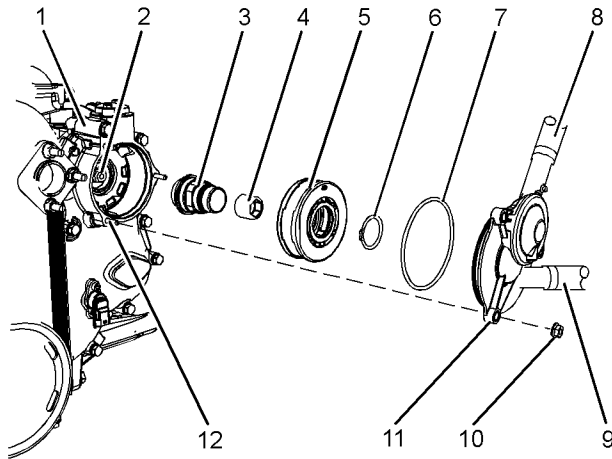


Illustration 232

g02665516

2. If necessary, install studs (12) to front cover (1). Tighten the studs to a torque of 8 N·m (71 lb in).
  3. If necessary, install spigot (3) and threaded insert (4). Press the spigot onto fuel injection pump shaft (2). Ensure that the spigot is correctly positioned onto fuel injection pump shaft (2). Install threaded insert (4). Use a suitable tool in order to prevent the crankshaft from rotating. Use Tooling (A) in order to tighten threaded insert (4) to a torque of 85 N·m (63 lb ft).
  4. Install new breather element (4) to spigot (3). Install circlip (6) to spigot (3).
- Note:** Ensure that the circlip is correctly seated into the retaining groove in the spigot.
5. Install new O-ring (7) to crankcase breather cover (11).
  6. Position crankcase breather cover (11) onto front cover (1).

7. Install nuts (10) to studs (12). Tighten the nuts to a torque of 10 N·m (7 lb ft).
8. Ensure that hose (8) is clean and free from restriction.
9. Connect hose (8) to crankcase breather cover (11) and tighten the hose clip securely.
10. Ensure that hose (9) is clean and free from restriction.
11. Connect hose (9) to crankcase breather cover (11) and tighten the hose clip securely.

i05275350

## Valve Mechanism Cover - Remove and Install

### Removal Procedure

Table 47

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

#### Start By:

- a. Remove the fuel manifold. Refer to Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install" for the correct procedure.
- b. Remove the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" for the correct procedure.

#### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorised personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

## Disassembly and Assembly Section

**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.

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.

**Note:** Plug or cap all open ports and tube assemblies.

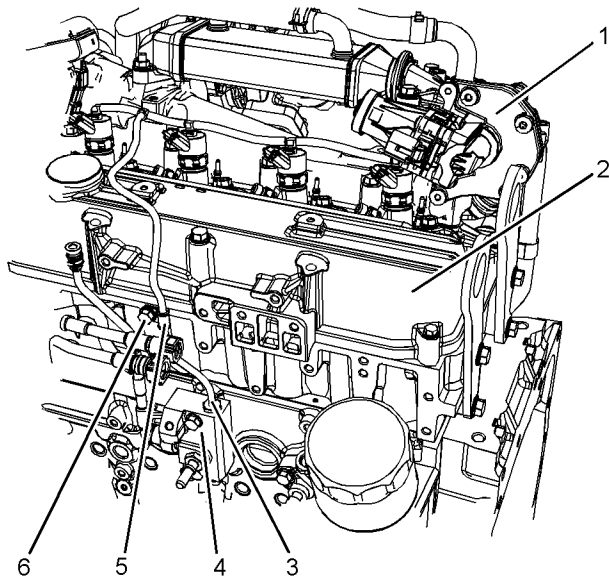


Illustration 233

g03010837

Typical example

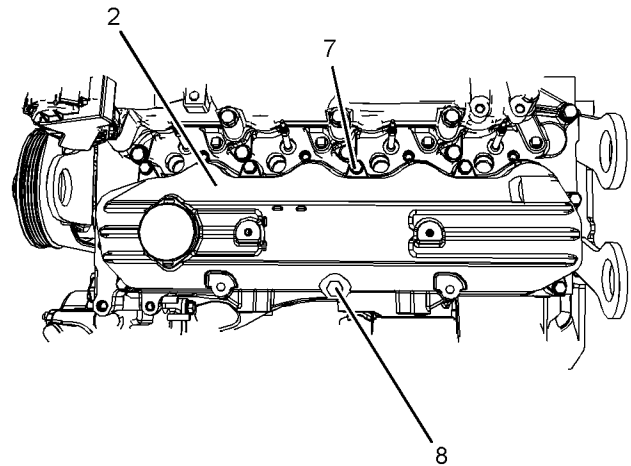


Illustration 234

g03010836

Typical example

1. If necessary, remove exhaust gas recirculation valve (1). Refer to Disassembly and Assembly, "Exhaust Gas Recirculation Valve - Remove and Install" for the correct procedure.
2. Disconnect the hose assembly (3) from fuel distribution block (4).
3. Use Tooling (A) in order to plug hose assembly (3).
4. Use Tooling (A) in order to cap fuel distribution block (4).
5. Remove bolt (6) from clip for hose assembly (3). Position the hose assembly away from the valve mechanism cover.
6. Remove bolts (7) and bolt (8) from valve mechanism cover (2).
7. Remove valve mechanism cover (2) from the cylinder head.

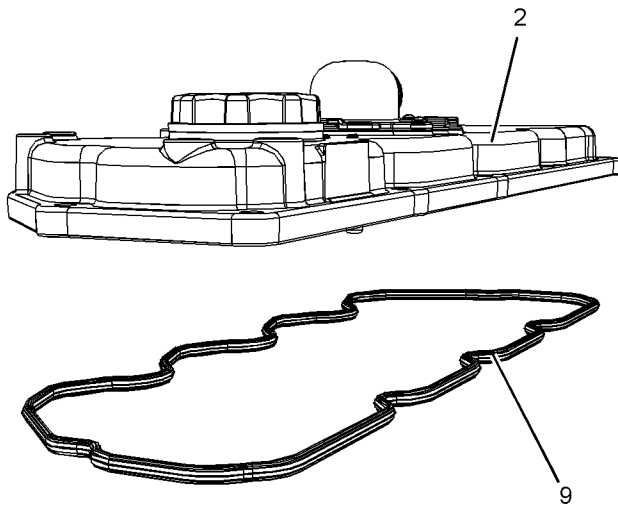


Illustration 235 g03010838  
Typical example

8. Remove gasket (9) from valve mechanism cover (2).

### Installation Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

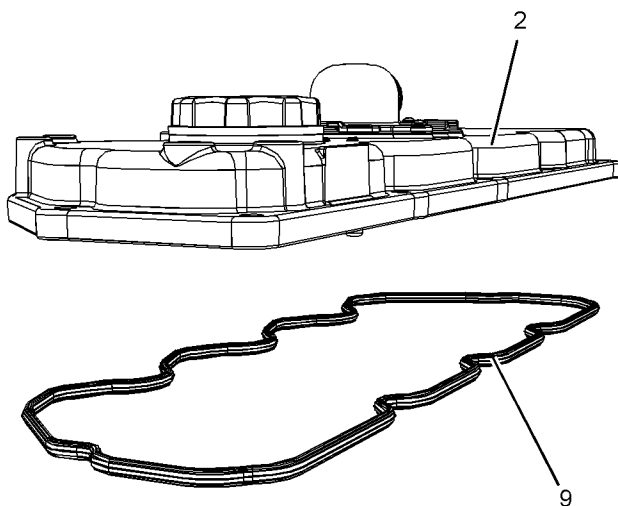


Illustration 236 g03010838  
Typical example

1. Thoroughly clean all gasket surfaces of valve mechanism cover (2). Clean the gasket surfaces of the cylinder head.
2. Install a new gasket (9) to valve mechanism cover (2).

**Note:** Ensure that the gasket is fully seated into the groove of the valve mechanism cover.

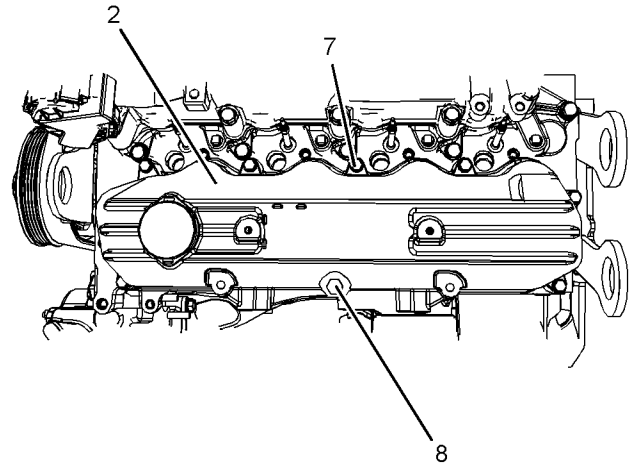


Illustration 237 g03010836  
Typical example

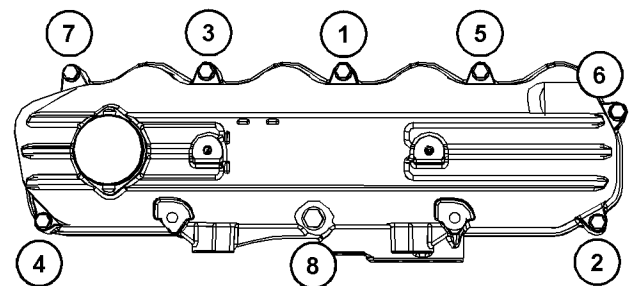


Illustration 238 g02671296

3. Position valve mechanism cover (2) onto the cylinder head.
4. Install bolts (7) and bolt (8) to the valve mechanism cover.
5. Tighten the bolts in the numerical sequence that is shown in Illustration 238 .

## Disassembly and Assembly Section

Tighten the bolts 1 through 7 to a torque of 10 N·m (89 lb in).

Tighten the bolt 8 to a torque of 27 N·m (239 lb in)

Repeat Step 5 in order to ensure the correct torque.

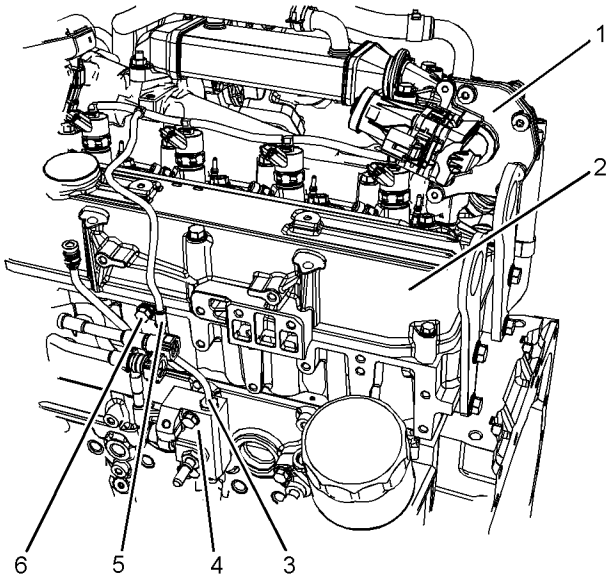


Illustration 239

g03010837

Typical example

6. Remove plug from hose assembly (3). Remove cap from fuel distribution block (4).
7. Connect hose assembly (3) to the fuel distribution block (4).
8. Position clip (5) for hose assembly (3) onto the cylinder block. Install bolt (6) to clip (5).
9. Tighten the bolt (6) to a torque of 25 N·m (221 lb in)
10. If necessary, install exhaust gas recirculation valve (1). Refer to Disassembly and Assembly, "Exhaust Gas Recirculation Valve - Remove and Install" for the correct procedure.

**End By:**

- a. Install the electronic unit injectors. Refer to Disassembly and Assembly, "Electronic Unit Injector - Remove" for the correct procedure.
- b. Install the fuel manifold. Refer to Disassembly and Assembly, "Fuel Manifold (Rail) - Remove and Install" for the correct procedure.

i05275356

## Rocker Shaft and Pushrod - Remove

### Removal Procedure

Table 48

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400086	Timing Pin (Crankshaft)	1

**Start By:**

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

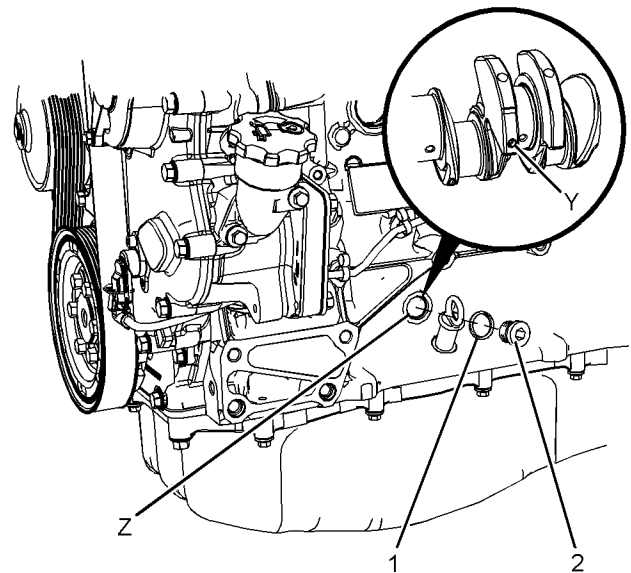


Illustration 240

g02942738

1. Follow Step 1.a through Step 1.c in order to install the crankshaft positioning tool.
  - a. Remove plug (4) from Position (X) in the cylinder block.

- b. Remove O-ring seal (3) from plug (4).
- c. Install Tooling (A) into the cylinder block in Position (Z).

**Note:** Tooling (A) must be located in Hole (Y) in the crankshaft.

**Note:** Ensure that Tooling (A) is located in the correct drilling in the crankshaft as shown in Illustration 240 .

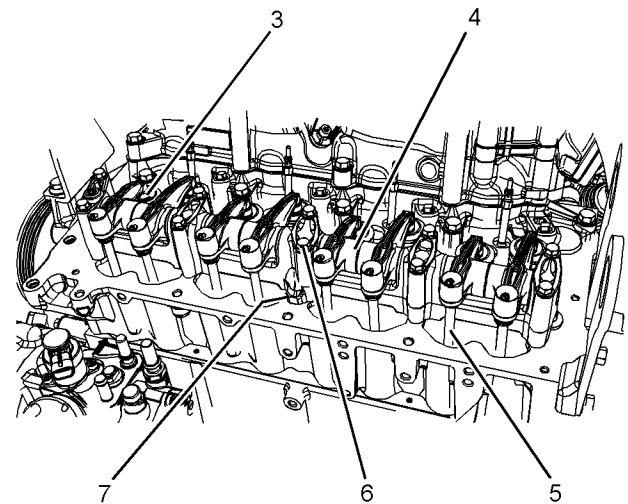


Illustration 241

g02942696

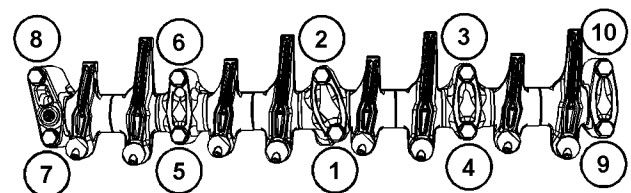


Illustration 242

g02942756

2. Remove bolts (6) from rocker shaft (4) in the reverse numerical sequence shown in Illustration 242 .
3. Remove rocker shaft (4) from the cylinder head.
4. Make temporary identification marks on push rods (5). Remove the push rods from the cylinder head.
5. Remove wear caps (3) from the valve stems. Identify the position of the wear caps in order for the wear caps to be installed in the original location.

6. If necessary, remove dowel (7) (not shown).

i05275370

## Rocker Shaft - Disassemble

### Disassembly Procedure

#### Start By:

- a. Remove the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove" for the correct procedure.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

### 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. Make an identification mark on each rocker arm assembly in order to show the location.

**Note:** The components must be reinstalled in the original location. Do not interchange components.

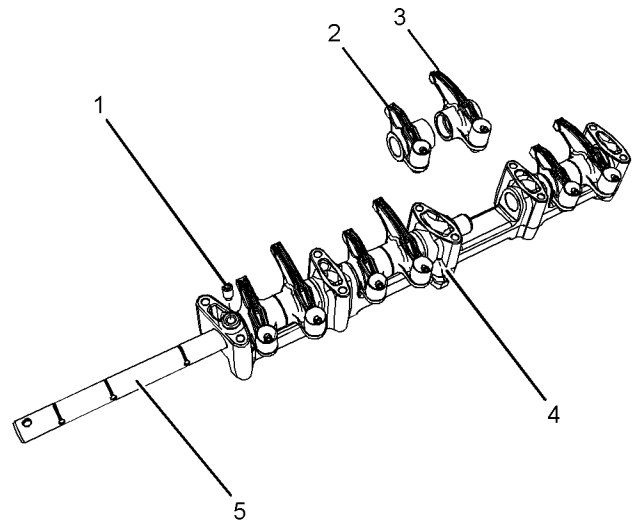


Illustration 243

g02942776

2. Remove grub screw (1) from rocker shaft housing (4).
3. Remove rocker shaft (5) from rocker shaft housing (4).
4. Remove rocker arm assembly (3) for the exhaust valve from rocker shaft (5). Remove rocker arm assembly (2) for the inlet valve from rocker shaft (5).

**Note:** The rocker arm assembly for the inlet valve is shorter than the rocker arm assembly for the exhaust valve.

i05275372

## Rocker Shaft - Assemble

### Assembly Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear and damage. Refer to Specifications, "Rocker Shaft" for more information. If necessary, replace any components that are worn or damaged.

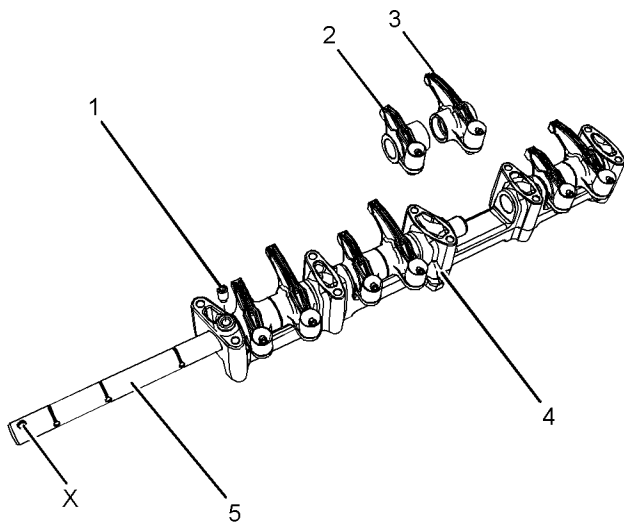


Illustration 244

g02942879

2. Lubricate the bore of rocker arm assemblies (2) for the inlet valve with clean engine oil.
3. Lubricate the bore of rocker arm assemblies (3) for the exhaust valve with clean engine oil.
4. Lubricate rocker shaft (5) with clean engine oil.
5. Install rocker shaft (5) into rocker shaft housing (4). Hole (X) must be in the upper most position in order for grub screw (1) to secure rocker shaft (5) in the correct position.
6. Install rocker arm assembly (2) for number 1 inlet valve to the rocker shaft. Install rocker arm assembly (3) for number 1 exhaust valve to rocker shaft (5).
7. Repeat Step 6 in order to assemble the remaining components to rocker shaft (5).
8. Install new grub screw (1) to rocker shaft housing (4). Tighten the grub screw to a torque of 15 N·m (133 lb in)

**Note:** Ensure that Hole (X) is in the upper most position.

### End By:

- a. Install the rocker shaft assembly. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install" for the correct procedure.

i05275374

## Rocker Shaft and Pushrod - Install

### Installation Procedure

Table 49

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400086	Timing Pin (Crankshaft)	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from damage. If necessary, replace any components that are worn or damaged.
2. If Tooling (A) is not installed, install Tooling (A). Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Remove" for the correct procedure.

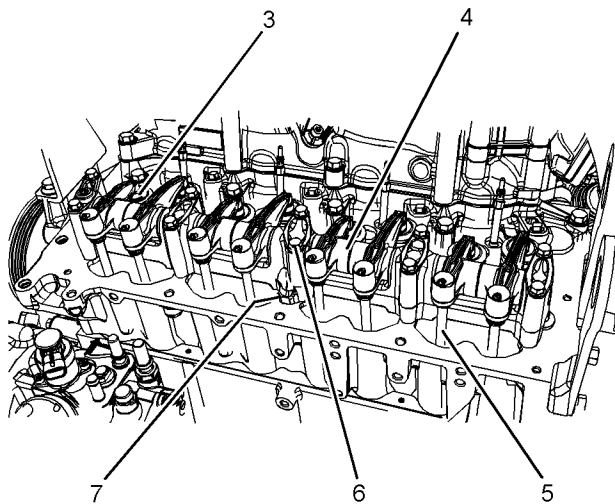


Illustration 245

g02942696



Illustration 246

g02942756

3. If necessary, install dowel (7) (not shown).
4. Apply clean engine oil to wear caps (3). Install the wear caps to the valve stems.

**Note:** If the wear caps were previously used, the wear caps must be installed in the original location.

5. Apply clean engine oil to both ends of push rods (5). Install the push rods into the cylinder head.

**Note:** If the push rods have previously been used, the push rods must be installed in the original location.

**Note:** Ensure that the push rods are seated in the cups of the lifters

6. Position rocker shaft assembly (4) onto the cylinder head.
7. Install bolts (6) to rocker shaft assembly (4). Tighten the bolts in the numerical sequence that is shown in Illustration 246 to a torque of 10 N·m (89 lb in).

**Note:** Ensure that the rocker arms are seated in the cups of the push rods.

**Note:** Ensure that the wear caps are not displaced from the valve stems when the rocker shaft assembly is installed.

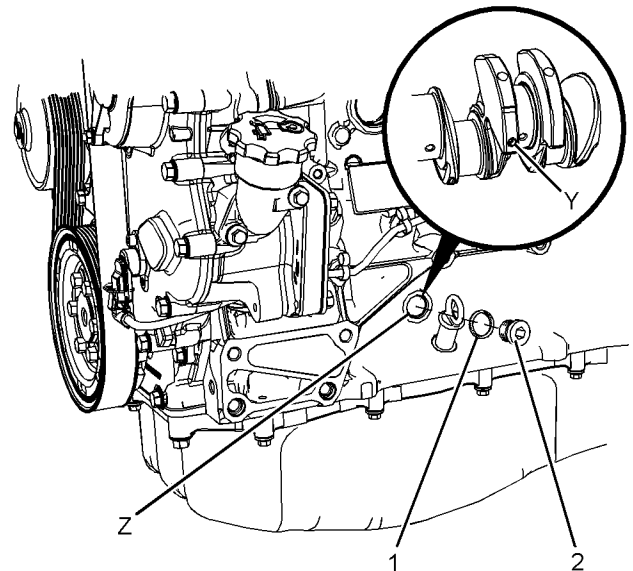


Illustration 247

g02942738

8. Remove Tooling (A) from the cylinder block.
9. Install new O-ring seal (1) onto plug (2).
10. Install plug (2) into Position (Z) in the cylinder block. Tighten the plug to a torque of 30 N·m (266 lb in).



**End By:**

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

i05275396

## Cylinder Head - Remove

### Removal Procedure

Table 50

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	E14 Torx 1/2 Inch Drive Socket	1
B	27610299	E18 Torx 1/2 Inch Drive Socket	1

**Start By:**

- a. **Remove the exhaust manifold. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install".**
- b. **Remove the injectors. Refer to Disassembly and Assembly, "Injector - Remove".**
- c. **Remove the rocker shaft assembly and the pushrods. Refer to Disassembly and Assembly Manual, "Rocker Shaft and Pushrod - Remove".**
- d. **Remove the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install".**

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**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.

Dispose of all fluids according to local regulations and mandates.

**Note:** Put identification marks on all hoses, on all hose assemblies, on wires and on all tube assemblies for installation purposes. Plug all hose assemblies and tube assemblies. Plugging all hose assemblies helps to prevent fluid loss and helps to keep contaminants from entering the system.

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" for the correct draining procedure.
2. Disconnect the upper radiator hose from the water temperature regulator housing.

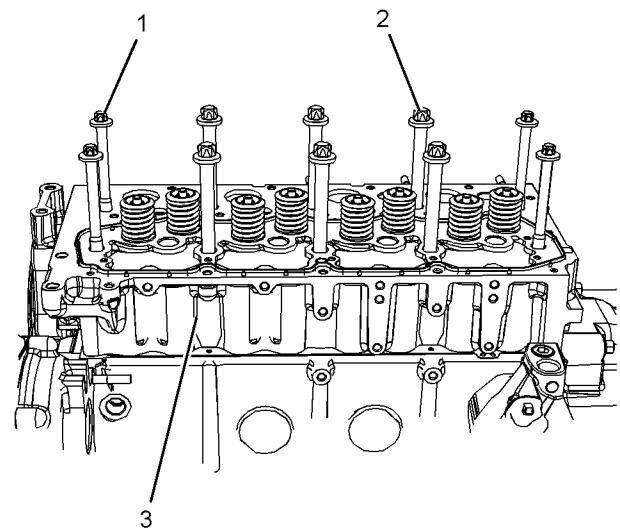


Illustration 248

g03005656

Typical example

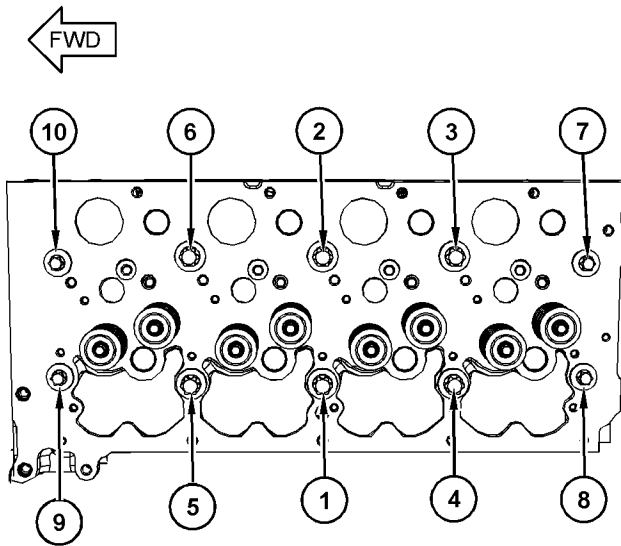


Illustration 249

g03005658

Sequence for tightening the bolts for the cylinder head

3. Use Tooling (A) and Tooling (B) in order to gradually loosen bolts (1) and bolts (2) in the reverse numerical order to the sequence that is shown in Illustration 249 .

**Note:** Follow the correct sequence in order to help prevent distortion of the cylinder head.

4. Remove bolts (1) and bolts (2) from cylinder head (3).

**Note:** The bolts are two different lengths. Note the positions of the different bolts.

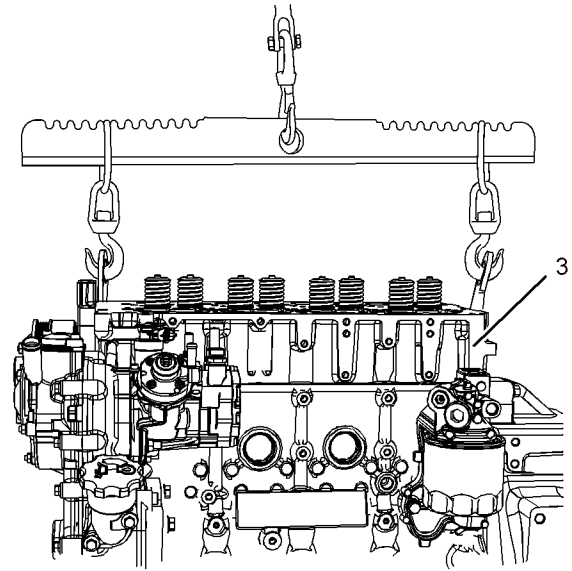


Illustration 250

g03005660

Typical example

5. Attach a suitable lifting device to cylinder head (3). Support the weight of the cylinder head. The weight of the cylinder head is approximately 30 kg (66 lb).

**Note:** Use a spreader bar during the lifting operation in order to distribute the weight of the cylinder head.

6. Use the lifting device to lift cylinder head (3) carefully off the cylinder block.

**Note:** Do not use a lever to separate the cylinder head from the cylinder block. Take care not to damage the machined surfaces of the cylinder head during the removal procedure.

#### NOTICE

Place the cylinder head on a surface that will not scratch the face of the cylinder head.

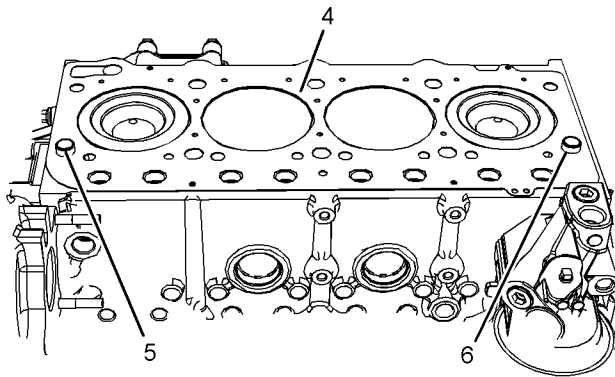


Illustration 251

g03005663

7. Remove cylinder head gasket (4).
8. Note the position of dowel (5) and dowel (6) in the cylinder block. Do not remove the dowels unless the dowels are damaged.
9. If necessary, remove the water temperature regulator from the cylinder head. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

i05275401

## Cylinder Head - Install

### Installation Procedure

Table 51

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	E14 Torx 1/2 Inch Drive Socket	1
B	27610299	E18 Torx 1/2 Inch Drive Socket	1
C	27610289	Angle Gauge	1
D	-	Guide Bolt (M12 by 115mm)	1
E	-	Straight Edge	1

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the gasket surfaces of the cylinder head and the cylinder block. Do not damage the gasket surfaces of the cylinder head or the cylinder block. Ensure that no debris enters the cylinder bores, the coolant passages, or the lubricant passages.
2. Inspect the gasket surface of the cylinder head for distortion. Refer to Specifications, "Cylinder Head" for more information.

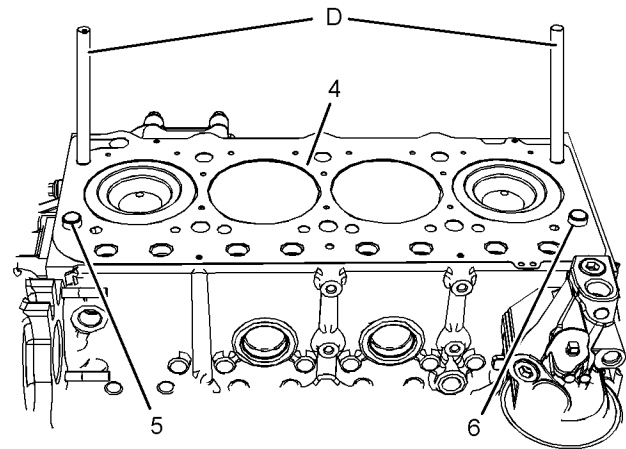


Illustration 252

g03005897

Typical example

3. Inspect dowel (5) and dowel (6) for damage. If necessary, replace the dowels in the cylinder block.
4. Install Tooling (D) to the cylinder block. Refer to Illustration 252 .
5. Align cylinder head gasket (4) with Tooling (D) and with dowel (5) and dowel (6). Install the cylinder head gasket onto the cylinder block.

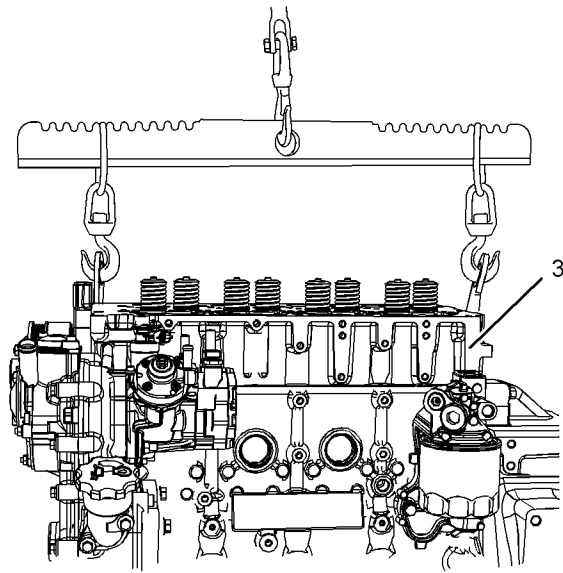


Illustration 253

g03005660

6. Use a suitable lifting device to lift the cylinder head. The weight of the cylinder head is approximately 30 kg (66 lb).

**Note:** Use a spreader bar during the lifting operation in order to distribute the weight of the cylinder head.

7. Use Tooling (D) to align cylinder head (3) with the cylinder block. Install the cylinder head to the cylinder block.

**Note:** Ensure that the cylinder head is correctly positioned onto dowels.

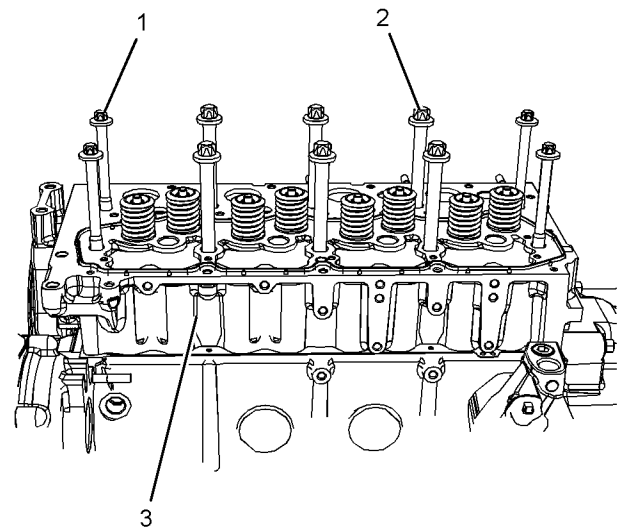


Illustration 254

g03005656

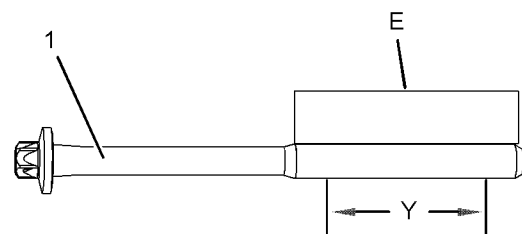
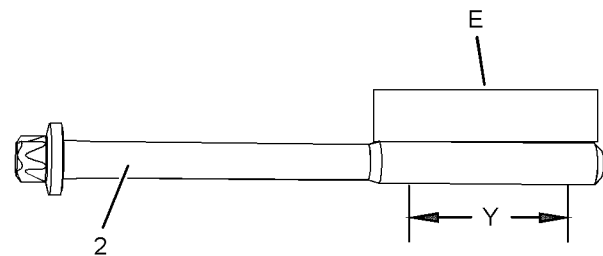


Illustration 255

g03005937

8. Clean Torx bolts (1) and Torx bolts (2). Follow Steps 8.a and 8.b for the procedure to inspect the Torx bolts.

a. Check the length of the Torx bolts (1) and Torx bolts (2).

b. Use Tooling (E) in order to check the threads of the Torx bolts. Refer to Illustration 255. Replace any Torx bolts that show visual reduction in the diameter of the thread over length (Y).

9. Lubricate the threads and the shoulder of Torx bolts (1) and Torx bolts (2) with clean engine oil.

- 10. Install Torx bolts (1) and Torx bolts (2) to cylinder head (3).
- 11. Remove Tooling (D).
- 12. Install remaining Torx bolts (1) to cylinder head (3).

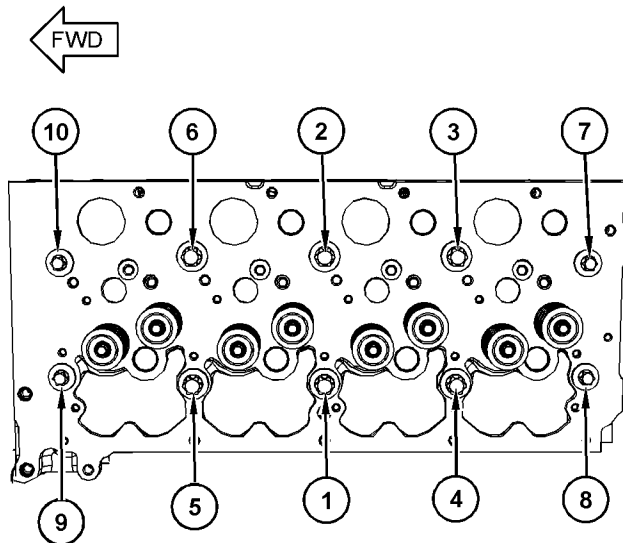


Illustration 256 g03005658  
Sequence for tightening the bolts for the cylinder head

- 13. Use Tooling (A) in order to tighten Torx bolts (2) to a torque of 130 N·m (96 lb ft) in the sequence that is shown in Illustration 256 .
- 14. Use Tooling (B) in order to tighten Torx bolt (1) to a torque of 65 N·m (48 lb ft) in the sequence that is shown in Illustration 256 .

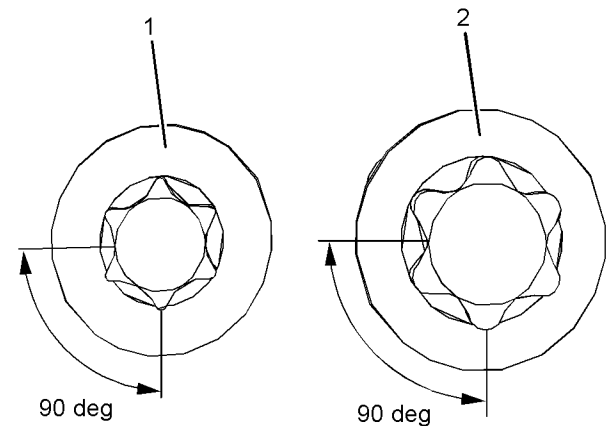


Illustration 257 g03005916

- 15. Use Tooling (A), Tooling (B), and Tooling (C) in order to turn Torx bolts (1) and Torx bolts (2) through an additional angle in the sequence that is shown in Illustration 256 .

Turn Torx bolts (2) through 90 degrees.

Turn Torx bolts (1) through 90 degrees.

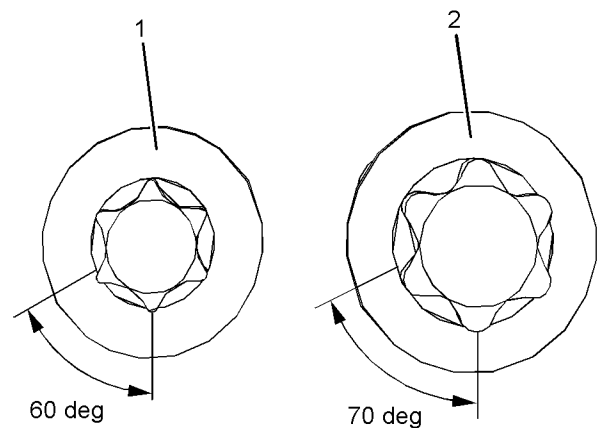


Illustration 258 g03017298

- 16. Use Tooling (A), Tooling (B), and Tooling (C) in order to turn Torx bolts (1) and Torx bolts (2) through an additional angle in the sequence that is shown in Illustration 256 .

Turn Torx bolts (2) through 70 degrees.

Turn Torx bolts (1) through 60 degrees.

17. Install the injectors. Refer to Disassembly and Assembly, "Injector - Install" for the correct procedure.
18. Install the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install" for the correct procedure.
19. Install the rocker shaft assembly and the pushrods. Refer to Disassembly and Assembly Manual, "Rocker Shaft and Pushrod - Remove" for the correct procedure.
20. Install the exhaust manifold. Refer to Disassembly and Assembly, "Exhaust Manifold - Remove and Install" for the correct procedure.
21. If necessary, install the water temperature regulator housing to the cylinder head. Refer to Disassembly and Assembly, "Water Temperature Regulator Housing - Remove and Install" for the correct procedure.
22. Connect the upper radiator hose to the water temperature regulator housing .
23. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedure.
24. If necessary, fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check".

i05275402

## Lifter Group - Remove and Install

### Removal Procedure

Table 52

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Telescoping Magnet	1

### Start By:

- a. Remove the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install" for the correct procedure.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

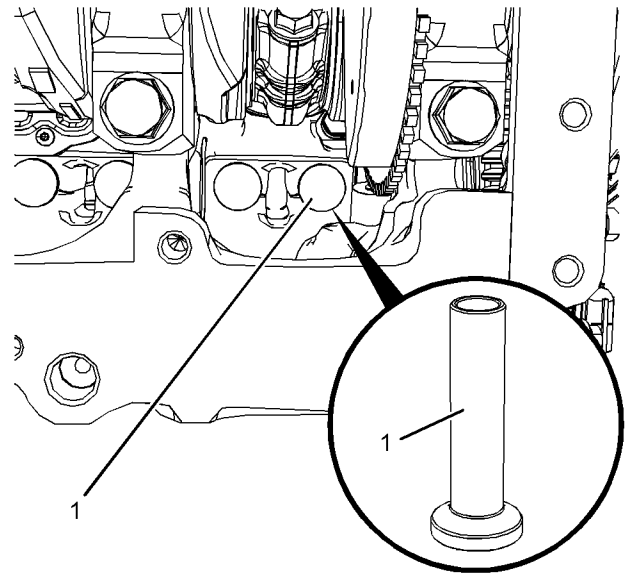


Illustration 259

g02729121

1. If the crankshaft is installed, rotate the crankshaft in order to gain access to the appropriate lifters.
2. Use Tooling (A) in order to remove lifters (1) from the cylinder block.

**Note:** Place a temporary identification mark on each lifter in order to identify the correct location.

### Installation Procedure

Table 53

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Telescoping Magnet	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Replace all lifters when a new camshaft is installed.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.
2. Clean the lifters. Follow Step 2.a through Step 2.c in order to inspect the lifters. Replace any worn lifters or damaged lifters.
  - a. Inspect the seat of the pushrod in the lifter for visual wear and damage.
  - b. Inspect the shank of the lifter for wear and damage. Refer to Specifications, "Lifter Group" for more information.
  - c. Inspect the face of the lifter that runs on the camshaft for visual wear and damage.

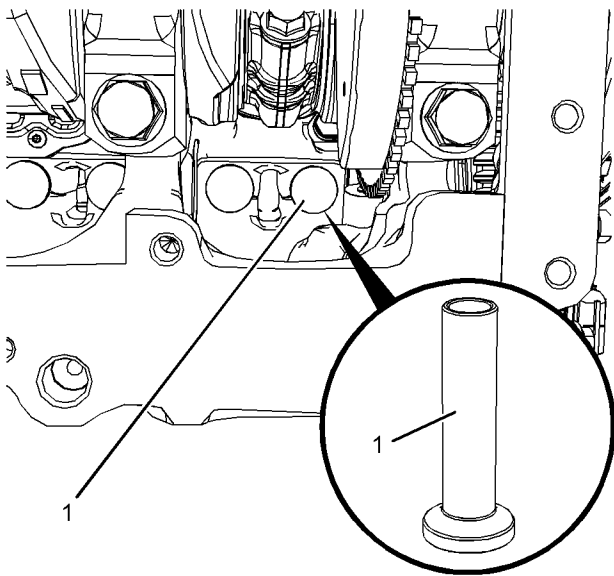


Illustration 260

g02729121

3. If the crankshaft is installed, rotate the crankshaft in order to allow access for the installation of appropriate lifters (1).
4. Lubricate lifters (1) with clean engine oil.
5. Use Tooling (A) to install lifters (1) to the cylinder block. Ensure that used lifters are installed in the original location.

**Note:** The lifters should be free to rotate.

**End By:**

- a. Install the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install" for the correct procedure.

i05293777

**Camshaft - Remove and Install****Removal Procedure****Start By:**

- a. Remove the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install" for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. The engine should be mounted on a suitable stand and placed in the inverted position.

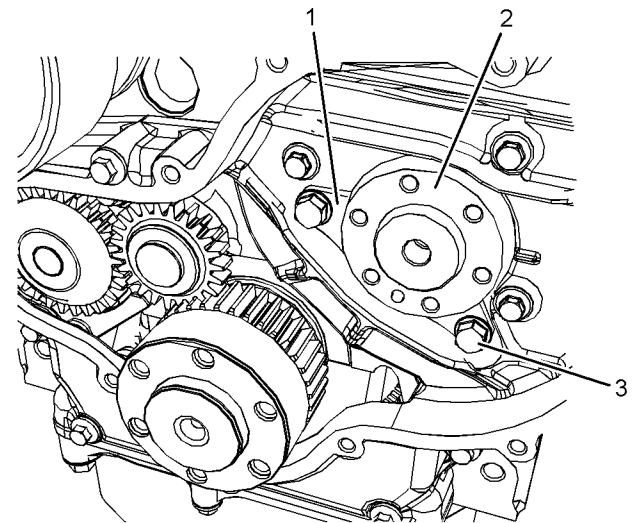


Illustration 261

g02946416

2. Remove bolts (3) from thrust plate (1).
3. Make a temporary mark in order to identify the orientation of thrust plate (1). Slide the camshaft towards the front of the engine in order to allow removal of the thrust plate. Remove the thrust plate.

**NOTICE**

Do not damage the lobes or the bearings when the camshaft is removed or installed.

- Carefully remove camshaft (3) from the cylinder block.

**Installation Procedure****NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

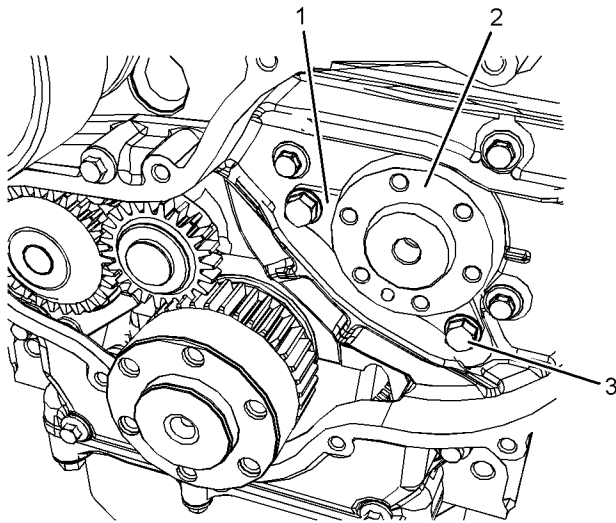


Illustration 262

g02946416

- Clean camshaft (2) and clean thrust plate (1). Inspect the camshaft and the thrust plate for wear and damage. Refer to Specifications, "Camshaft" for more information. If necessary, replace any components that are worn or damaged.
- Clean the camshaft bearing in the cylinder block. Inspect the camshaft bearing for wear and damage. Refer to Specifications, "Camshaft Bearings" for more information. If necessary, replace the camshaft bearing. Refer to Disassembly and Assembly, "Camshaft Bearing - Remove and Install".

**NOTICE**

Replace all lifters when a new camshaft is installed.

- Inspect the lifters for wear and for damage. Refer to Specifications, "Lifter Group" for more information. If necessary, replace any lifters that are worn or damaged. Refer to Disassembly and Assembly, "Lifter Group - Remove and Install" for the correct procedure.

- Lubricate the lobes and the bearing surfaces of the camshaft with clean engine oil.

**NOTICE**

Do not damage the lobes or the bearings when the camshaft is removed or installed.

- Carefully install camshaft (3) into the cylinder block. Leave the camshaft slightly protruding in order to allow installation of the thrust plate.

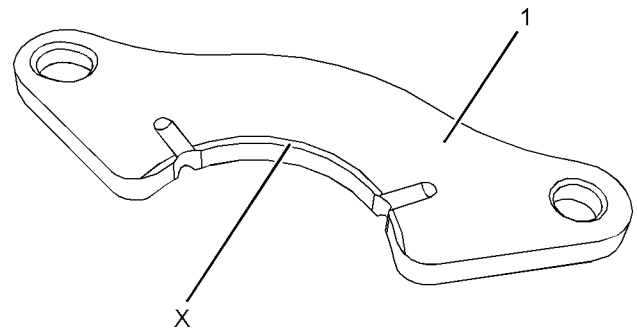


Illustration 263

g02948296

- Lubricate thrust plate (1) with clean engine oil. Position the thrust plate onto the camshaft with the chamfer in Position (X) facing towards the cylinder block. Slide the camshaft into the cylinder block.
- Install bolts (3) to thrust plate (1). Tighten the bolts to a torque of 25 N·m (221 lb in)



**End By:**

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

i05279011

## Camshaft Gear - Remove and Install

### Removal Procedure

Table 54

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400089	Timing Pin (Crankshaft)	1
B	T400152	Timing Pin (Camshaft)	1
C	-	Snap-on PBS650 Small Pry Bar	1

**Start By:**

- a. Remove the rocker shaft and pushrods. Refer to Disassembly and Assembly, “Rocker Shaft and Pushrod - Remove” for the correct procedure.

**NOTICE**

Keep all parts clean and free from contaminants.

Contaminants may cause rapid wear and shorten component life.

**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.

Dispose of all fluids according to local regulations and mandates.

1. Remove the idler gear. Refer to Disassembly and Assembly, “Idler Gear - Remove” for the correct procedure.
2. Ensure that Tooling (A) remains in position during the removal and installation procedures for the camshaft gear.
3. Remove Tooling (B).

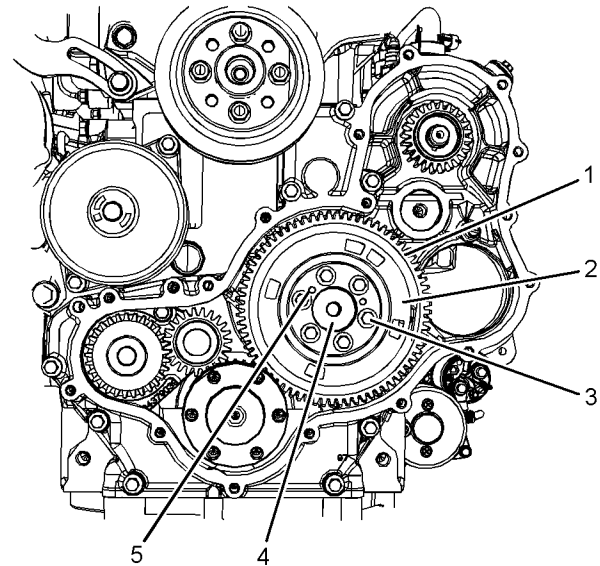


Illustration 264

g02945576

4. Remove bolts (3) from camshaft (4).
5. Remove camshaft timing ring (2) from dowels (5).
6. Use Tooling (C) in order to remove camshaft gear (1) from camshaft (4).

### Installation Procedure

Table 55

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400089	Timing Pin (Crankshaft)	1
B	T400152	Timing Pin (Camshaft)	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.
2. If Tooling (A) is not installed, install Tooling (A). Refer to Disassembly and Assembly, “Idler Gear - Remove” for the correct procedure.

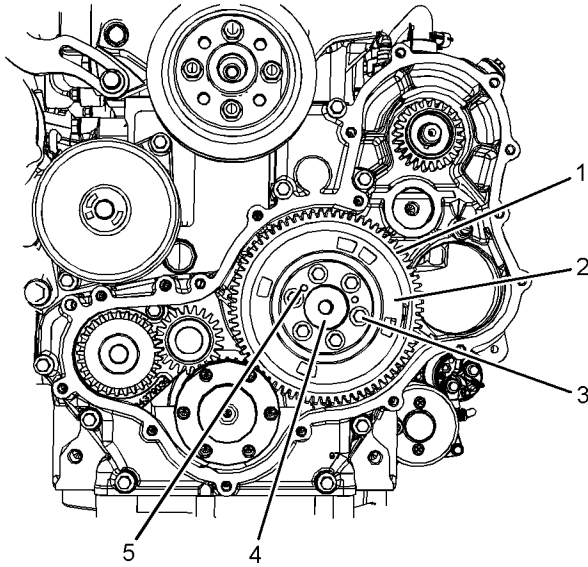


Illustration 265

g02945576

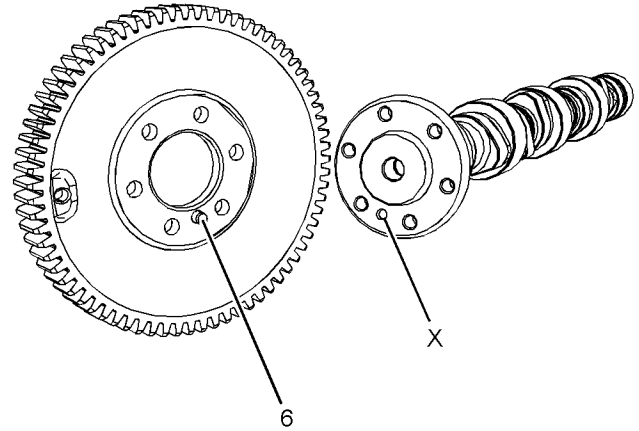


Illustration 267

g02945716

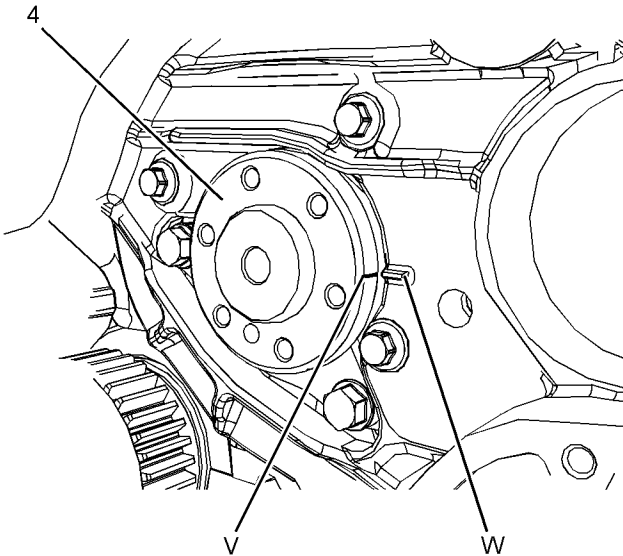


Illustration 266

g02945776

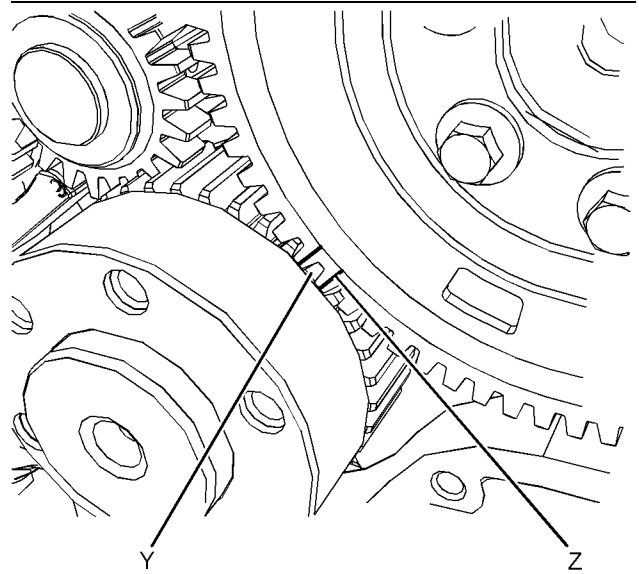


Illustration 268

g02945837

3. Lubricate the teeth of gear (1) with clean engine oil.
4. Align the timing mark on camshaft (4) in Position (V) with the timing mark on the front housing in Position (W).
5. Position camshaft gear (1) onto camshaft (4). Ensure that dowel (6) is installed into Hole (X) in the camshaft.
6. Ensure that the chamfered tooth on the crankshaft gear in Position (Y) is between the timing marks in Positions (Z) on the camshaft gear.

7. Install Tooling (B). Refer to Disassembly and Assembly, "Idler Gear - Remove" for the correct procedure.
8. Install camshaft timing ring (2) onto dowels (5).
9. Install bolts (3) into camshaft (4). Tighten the bolts to a torque of 25 N·m (221 lb in).

**End By:**

- a. Install the idler gear. Refer to Disassembly and Assembly, "Idler Gear - Install" for the correct procedure.
- b. Install the rocker shaft and pushrods. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install" for the correct procedure.

i05279035

## Camshaft Bearings - Remove and Install

### Removal Procedure

Table 56

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400085	Camshaft Bushing Punch Tool	1
B	T400084	Handle for Punch Tool	1

**Start By:**

- a. Remove the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install" for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

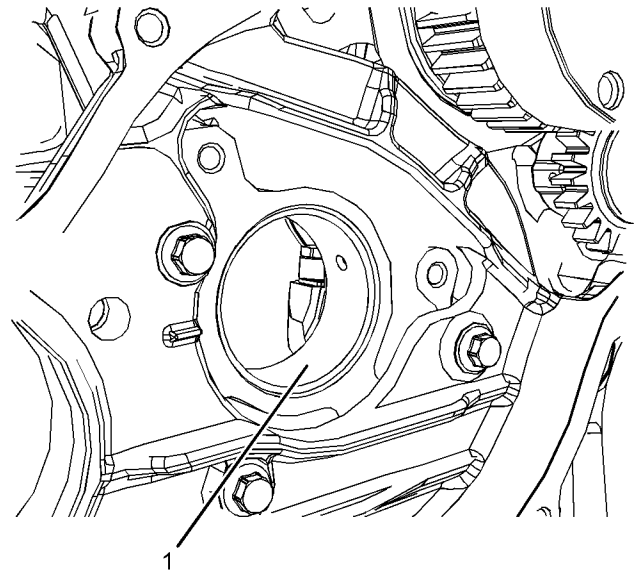


Illustration 269

g02729141

1. Inspect camshaft bearing (1). Refer to Specifications, "Camshaft Bearings" for more information.
2. If camshaft bearing (1) is worn or damaged, use Tooling (A) and Tooling (B) in order to remove the camshaft bearing from the cylinder block.

**Note:** Remove the camshaft bearing from the front of the cylinder block.

### Installation Procedure

Table 57

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400085	Camshaft Bushing Punch Tool	1
B	T400084	Handle for Punch Tool	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the bearing housing in the cylinder block. Ensure that the oil hole in the bearing housing is free from debris.

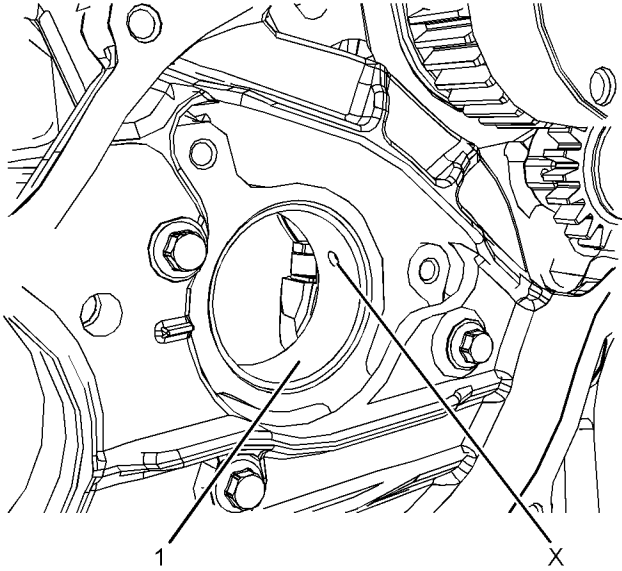


Illustration 270

g02948516

2. Lubricate the bearing housing in the cylinder block with clean engine oil.
3. Accurately align large oil Hole (X) in camshaft bearing (1) with the oil hole in the cylinder block.
4. Use Tooling (A) and Tooling (B) in order to install camshaft bearing (1) into the cylinder block.

**Note:** Ensure that the oil holes are correctly aligned. If the oil is not correctly aligned, the camshaft bearing should be removed.

#### End By:

- a. Install the camshaft. Refer to Disassembly and Assembly, "Camshaft - Remove and Install" for the correct procedure.

i05279037

## Engine Oil Pan - Remove and Install

### (Pressed Steel Oil Pan)

#### Removal Procedure

##### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

##### 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.

Dispose of all fluids according to local regulations and mandates.

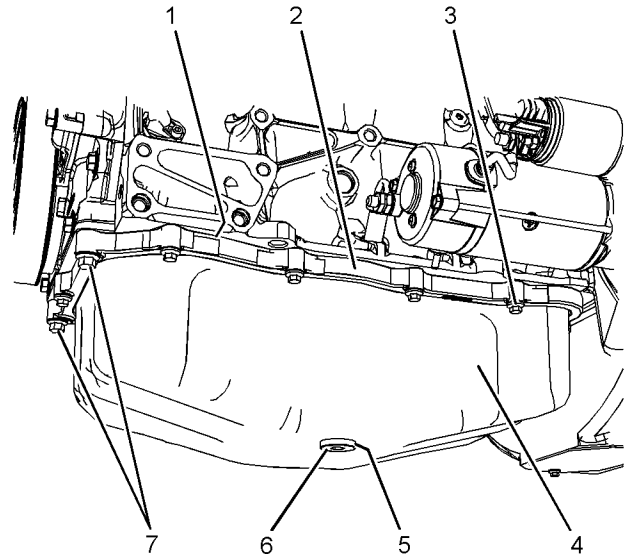


Illustration 271

g02823478

1. Remove oil drain plug (6). Drain the engine oil into a suitable container for storage or disposal.
2. Remove sealing washer (5) (not shown) from oil drain plug (5).
3. Remove two M10 bolts (7) and remove M8 bolts (3) from engine oil pan (4).

**Note:** Support the weight of the engine oil pan.

4. Remove spacer (2) from engine oil pan (4).
5. Remove engine oil pan (4) from the cylinder block.
6. Remove gasket (1) (not shown).

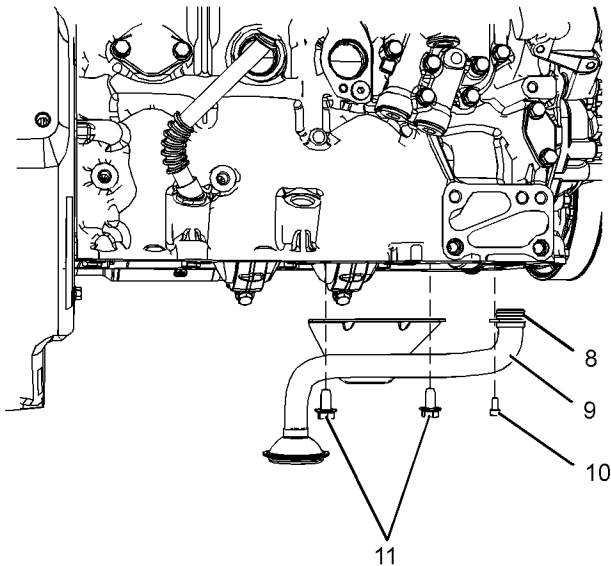


Illustration 272

g02823476

7. If necessary, follow Step 7.a through Step 7.d in order to remove oil suction pipe (9) from the cylinder block.

- a. Remove Allen head cap screw (10) from oil suction pipe (9).
- b. Remove bolts (11) from oil suction pipe (9).
- c. Remove oil suction pipe (9) from the cylinder block.
- d. Remove O-ring (8) from oil suction pipe (9).

### Installation Procedure

Table 58

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Technologic 15	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

- 1. Ensure that all components are clean and free from damage. If necessary, replace any components that are worn or damaged.

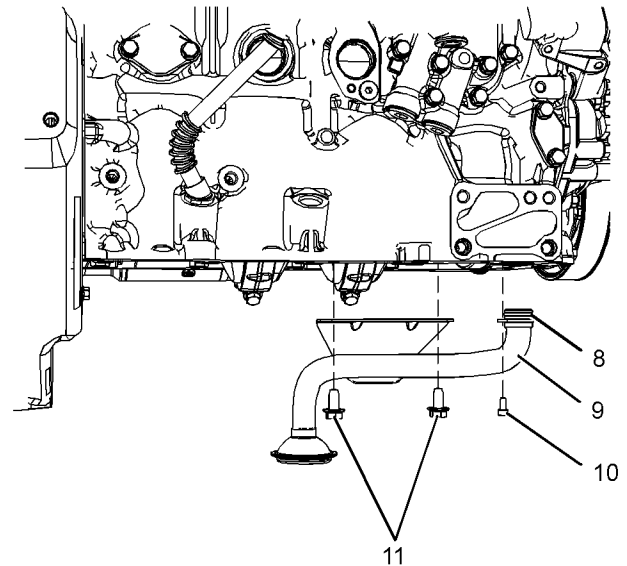


Illustration 273

g02823476

2. If necessary, follow Step 2.a through Step 2.f in order to install oil suction pipe (9).

- a. Install new O-ring seal (8) to oil suction pipe (9).
- b. Install oil suction pipe (9) to the cylinder block.
- c. Apply Tooling (A) onto the threads of Allen head cap screw (10). Install the Allen head cap screw to the oil suction pipe.
- d. Apply Tooling (A) onto the threads of bolts (11). Install bolts (11) to the oil suction pipe support.
- e. Tighten Allen head cap screw (10) to a torque of 10 N·m (89 lb in).
- f. When a M8 bolts are installed, tighten bolts (11) to a torque of 25 N·m (221 lb in).

When a M10 bolts are installed, tighten bolts (11) to a torque of 45 N·m (33 lb ft).

- 3. Clean the mating surface of the cylinder block.

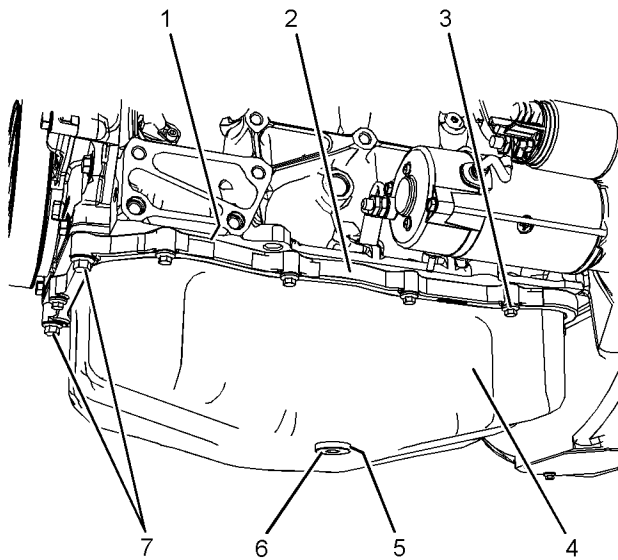


Illustration 274

g02823478

- Tighten bolts (7) to a torque of 45 N·m (33 lb ft).
9. Install a new sealing washer (5) to oil drain plug (6).
  10. Install oil drain plug (6) to the engine oil pan . Tighten the oil drain plug to a torque of 50 N·m (37 lb ft).
  11. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, “Engine Oil and Filter - Change” for the correct procedure.

i05279039

## Engine Oil Pan - Remove and Install

### (Cast Iron Engine Oil Pan)

#### Removal Procedure

##### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

##### 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.

Dispose of all fluids according to local regulations and mandates.

**Note:** Ensure that the engine lubricating oil is drained. Refer to Operation and Maintenance Manual, “Engine Oil and Filter - Change” for the correct procedure.

**Note:** In order to remove a cast iron oil pan, the engine must be removed from the machine. The engine should be mounted in a suitable stand and placed in the inverted position.

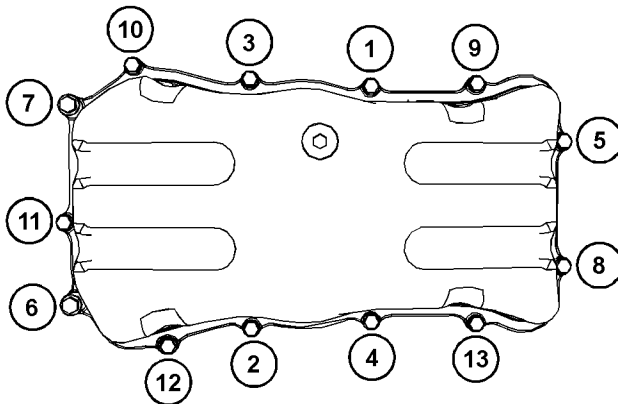


Illustration 275

g02826556

4. Position gasket (1) (not shown) onto engine oil pan (4).
5. Position spacer (2) onto the engine oil pan.
6. Position engine oil pan assembly (4) onto the cylinder block. Use a suitable tool to support the weight of the engine oil pan.
7. Install bolts (3) and install bolts (7) finger tight.
8. Tighten bolts (3) and bolts (7) in the sequence that is shown in Illustration 275 .

Tighten bolts (3) to a torque of 25 N·m (221 lb in).

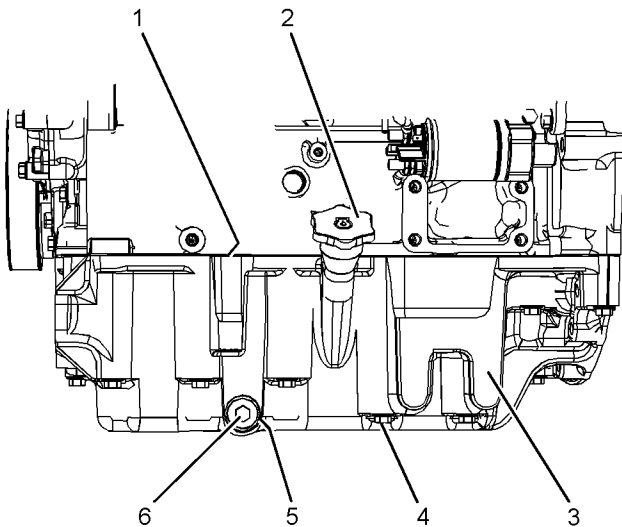


Illustration 276

g02835137

1. Mount the engine in a suitable stand and place in the inverted position.
2. If necessary, remove dipstick (2) from engine oil pan (3).
3. Remove sealing washer (5) (not shown) from oil drain plug (6).
4. Remove bolts (4) from engine oil pan (3).
5. Attach a suitable lifting device to engine oil pan (3). The engine oil pan can weigh 45 kg (99 lb).
6. Use the lifting device in order to remove engine oil pan (3) from the cylinder block.
7. Remove gasket (1) (not shown).

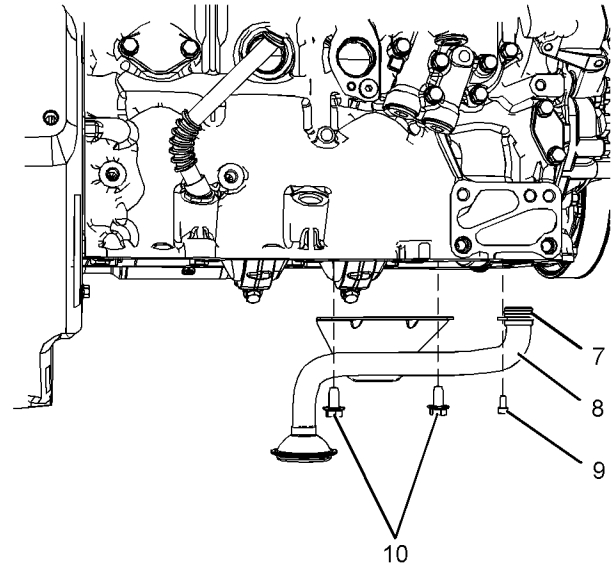


Illustration 277

g02835177

Typical example

8. If necessary, follow Step 8.a through Step 8.d in order to remove oil suction pipe (8) from the cylinder block.
  - a. Remove Allen head cap screw (9) from oil suction pipe (8).
  - b. Remove bolts (10) from the oil suction pipe.
  - c. Remove the oil suction pipe from the cylinder block.
  - d. Remove O-ring (7) from oil suction pipe (8).

**Installation Procedure**

Table 59

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Technologic 15	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.

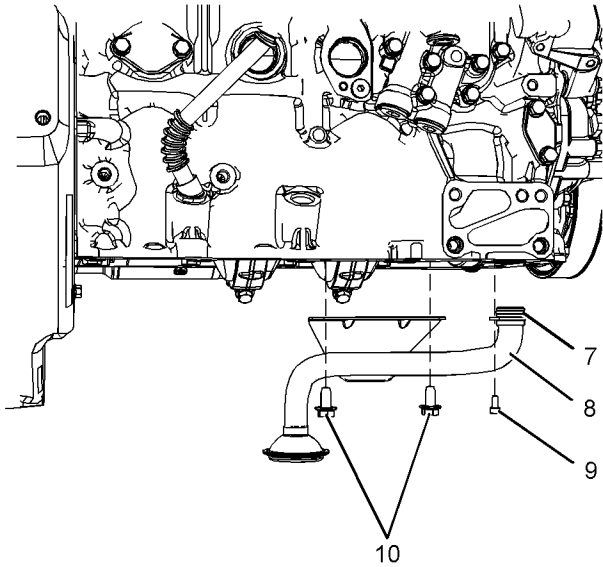


Illustration 278

g02835177

## Typical example

2. If necessary, follow Step 2.a through Step 2.f in order to install oil suction pipe (8).
  - a. Install new O-ring seal (7) to oil suction pipe (8).
  - b. Install the oil suction pipe to the cylinder block.
  - c. Apply Tooling (A) onto the threads of Allen head cap screw (9). Install the Allen head cap screw to the oil suction pipe.
  - d. Apply Tooling (A) onto the threads of bolts (10). Install bolts (10) to the oil suction pipe support.
  - e. Tighten Allen head cap screw (9) to a torque of 10 N·m (89 lb in).
  - f. When M8 bolts are installed, tighten bolts (10) to a torque of 25 N·m (221 lb in).  
When M10 bolts are installed, tighten bolts (10) to a torque of 45 N·m (33 lb ft).

3. Clean the mating surface of the cylinder block.

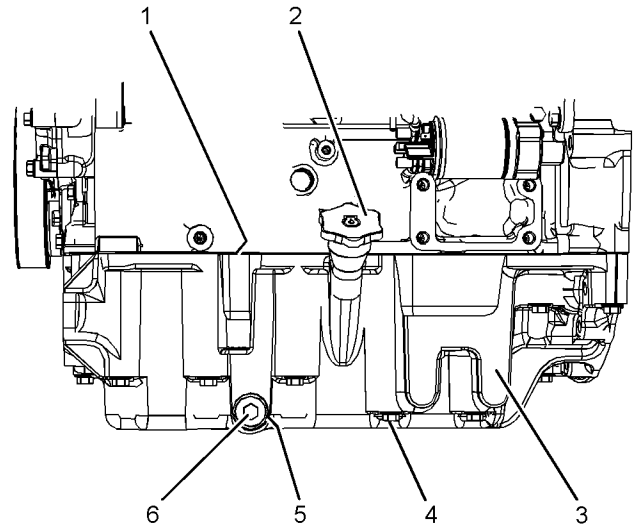


Illustration 279

g02835137



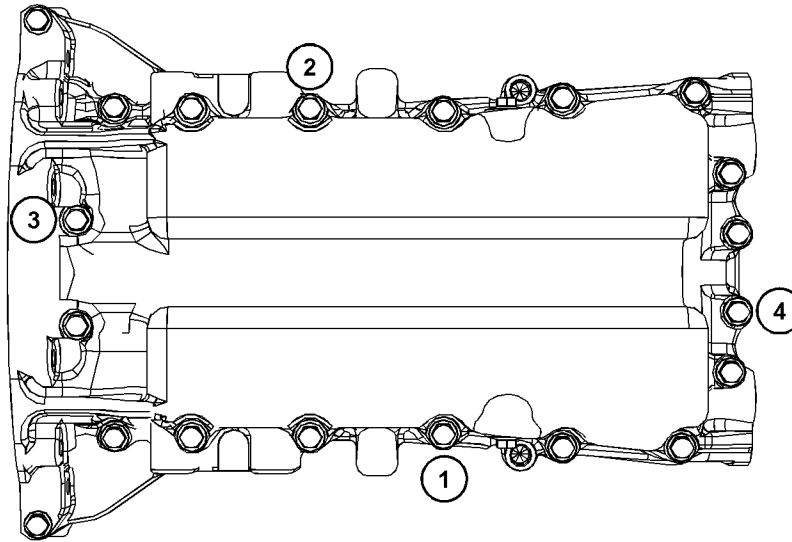


Illustration 280

g02835539

## Initial tightening sequence

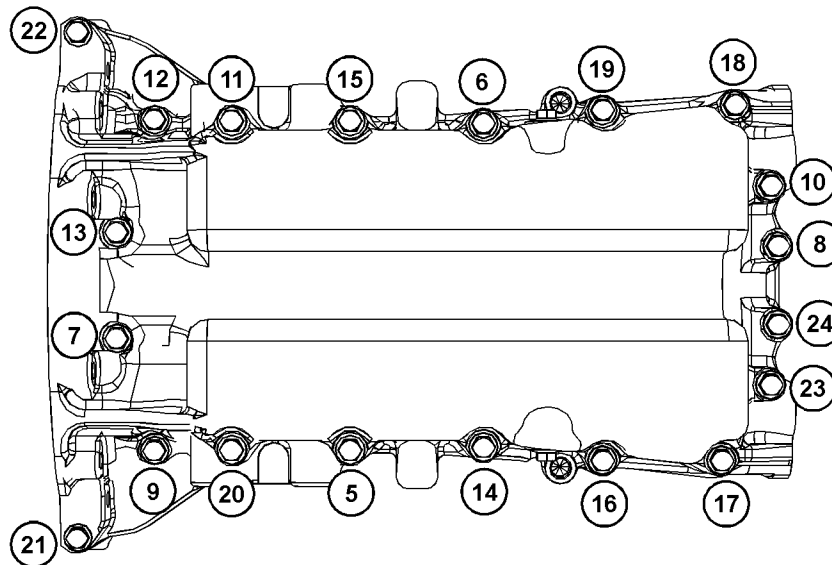


Illustration 281

g02835357

## Secondary tightening sequence

4. Position gasket (1) (not shown) onto engine oil pan (4).
5. Attach a suitable lifting device to engine oil pan (3). The engine oil pan can weigh 45 kg (99 lb).
6. Use the lifting device in order to position engine oil pan (3) onto the cylinder block.
7. Apply Tooling (A) to bolts (4). Install the bolts finger tight.
8. Align the rear face of the engine oil pan with the rear of the cylinder block.
9. Tighten bolts (4) in the initial sequence that is shown in Illustration 280 .  
Tighten bolts (7) to a torque of 45 N·m (33 lb ft).
10. Tighten bolts (4) in the final sequence that is shown in Illustration 281 .  
Tighten bolts (7) to a torque of 45 N·m (33 lb ft).

11. Ensure that the face of engine oil pan (3) and the cylinder block are still correctly aligned.
12. Install a new sealing washer (5) to oil drain plug (6).
13. Install oil drain plug (6) to the engine oil pan . Tighten the oil drain plug to a torque of 50 N·m (37 lb ft).
14. Remove the engine from the suitable stand.
15. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, “Engine Oil and Filter - Change” for the correct procedure.

i05279046

## Balancer - Remove

### Removal Procedure

Table 60

Required Tools			
Tool	Part Number	Part Name	Qty
A	T400086	Crankshaft Locking Pin	1
B	-	Balancer Timing Pin (Bolt M8 by 22mm)	1

#### Start By:

- a. Remove the engine oil pan. Refer to **Disassembly and Assembly, “Engine Oil Pan - Remove and Install”** for the correct procedure.

**Note:** In order to remove the balancer safely, the engine must be removed from the machine. The engine should be mounted in a suitable stand and placed in the inverted position.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

#### 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.

Dispose of all fluids according to local regulations and mandates.

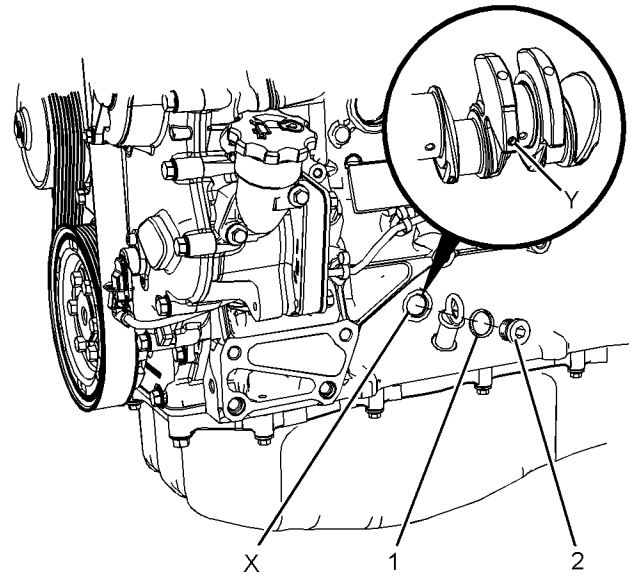


Illustration 282

g02887016

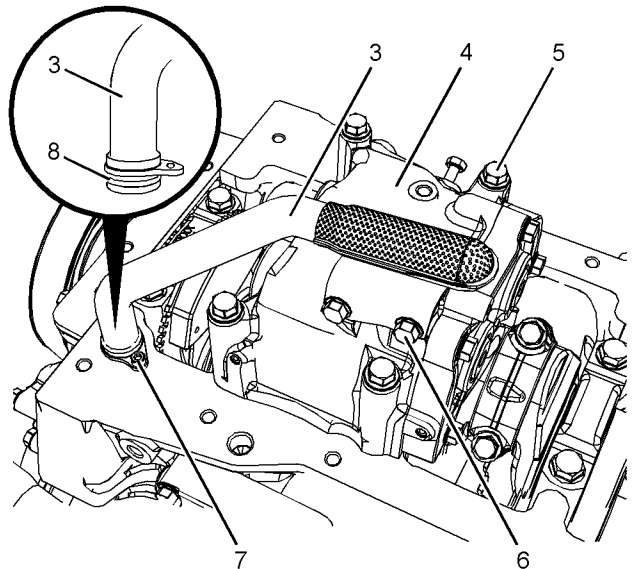


Illustration 283

g02709625

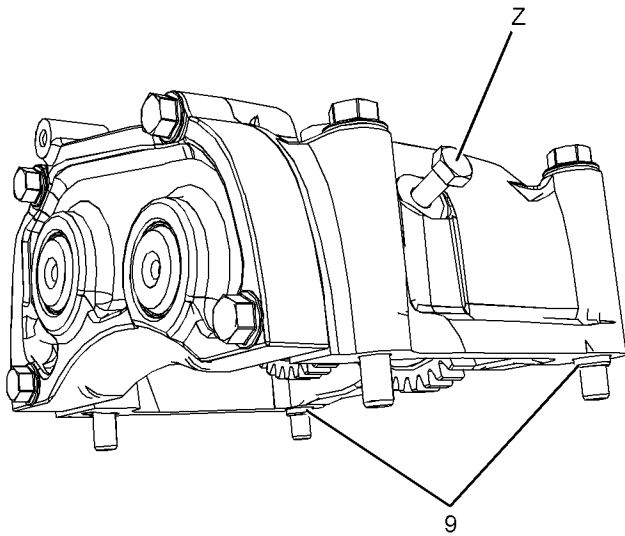


Illustration 284

g02893017

1. Remove plug (2) from Position (X) in the cylinder block. Remove O-ring seal (1) from the plug.
2. Install Tooling (A) into the cylinder block in Position (X).

**Note:** Tooling (A) must be located in Position (Y) in the crankshaft.

**Note:** Ensure that Tooling (A) is located in the correct drilling in the crankshaft as shown in Illustration 282 .

3. Remove bolts (6) from oil suction pipe (3).
4. Remove bolt (7) from oil suction pipe (3).
5. Remove oil suction pipe (3) from the cylinder block. Remove O-ring seal (8) from the oil suction pipe.

### **WARNING**

**Movement of the counterweight can cause personal injury.**

6. Install Tooling (B) in Position (Z) in order to prevent movement of the counterweights.

**Note:** If Tooling (B) cannot be installed to the balancer, the crankshaft is not in the correct position.

7. Remove bolts (5).
8. Attach a suitable lifting device to balancer (4). Support the weight of balancer, the weight is approximately 15 kg (33 lb).
9. Use the suitable lifting device in order to remove the balancer from the cylinder block.

10. Do not remove dowels (9) unless the dowels are damaged.

i05279048

## Balancer - Install

### Installation Procedure

Table 61

Required Tools			
Tool	Part Number	Part Name	Qty
A	T400086	Crankshaft Locking Pin	1
B	-	Balancer Timing Pin (Bolt M8 by 22mm)	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.
2. Check that the balancer drive gear is not worn or damaged. If necessary, replace the balancer drive gear.

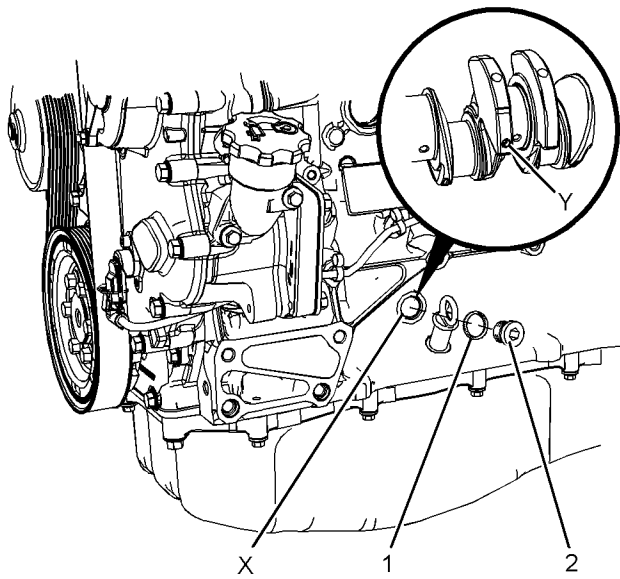


Illustration 285

g02887016

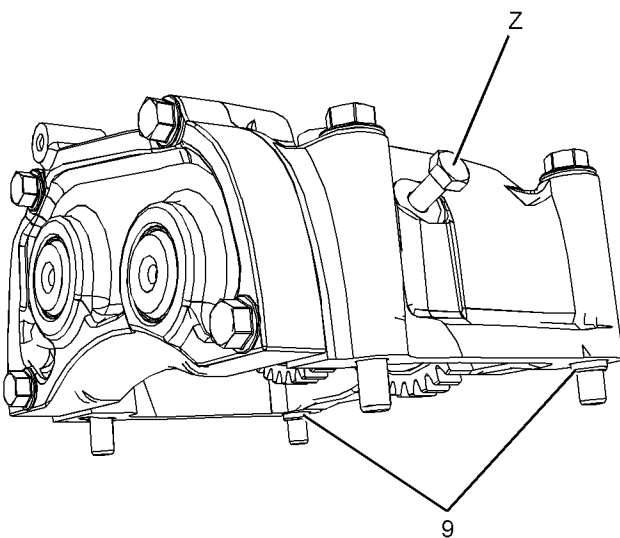


Illustration 286

g02893017

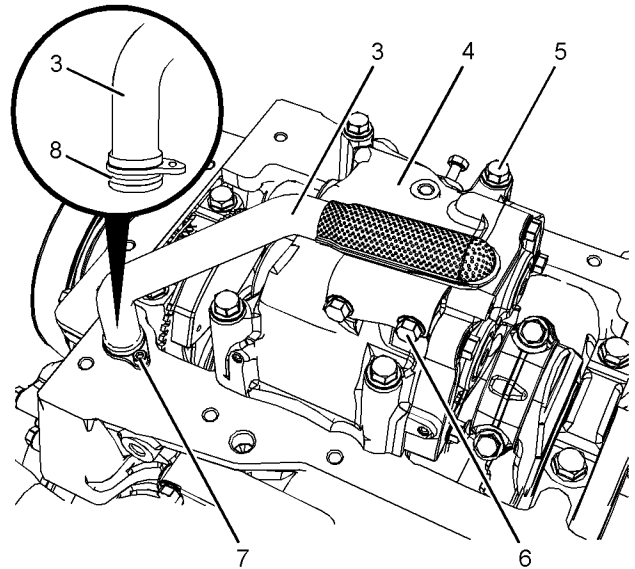


Illustration 287

g02709625

3. Install Tooling (A) into Position (X) in the cylinder block. Tooling (A) must be located in Position (Y) in the crankshaft.

**Note:** Ensure that Tooling (A) is located in the correct drilling in the crankshaft as shown in Illustration 285 .

**Note:** Failure to locate the crankshaft in the correct position will cause severe engine damage.

4. Ensure that Tooling (B) is installed to balancer (4).

**Note:** New balancers will be supplied with Tooling (B) in position.

5. If necessary, install dowels (9) to balancer (4).

6. Attach a suitable lifting device to the balancer. The weight is approximately 15 kg (33 lb).

7. Use the suitable lifting device in order to install the balancer to the cylinder block.

8. Install bolts (5) to the balancer. Tighten the bolts to a torque of 70 N·m (52 lb ft).

9. Remove the suitable lifting device from the balancer.

10. Install a new O-ring seal (8) onto suction pipe (3). Install the suction pipe assembly to the cylinder block.

11. Install bolt (7) finger tight.

12. Install bolts (6) finger tight.

13. Tighten bolt (7) to a torque of 10 N·m (89 lb in)

14. When M8 bolts are installed, tighten bolts (6) to a torque of 25 N·m (221 lb in).

When M10 bolts are installed, tighten bolts (6) to a torque of 45 N·m (33 lb ft).

15. Remove Tooling (B) from Position (Z) in the balancer.
16. Remove Tooling (A) from Position (X) in the cylinder block.
17. Install a new O-ring seal (1) to plug (2). Install plug (2) into Position (X) in the cylinder block. Tighten the plug to a torque of 50 N·m (37 lb ft).

**End By:**

- a. Install the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for the correct procedure.

i05279052

## Piston Cooling Jets - Remove and Install

### Removal Procedure

**Start By:**

- a. Remove the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for the correct procedure.
- b. Remove the crankshaft. Refer to Disassembly and Assembly, “Crankshaft - Remove” for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

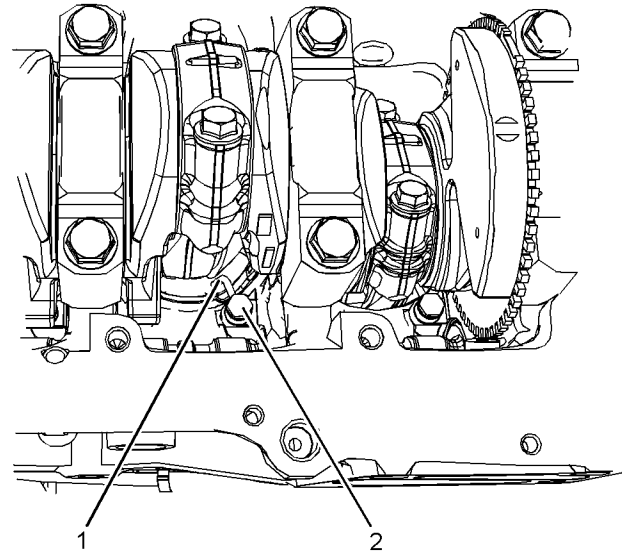


Illustration 288

g02895676

1. Remove banjo bolt (2) and piston cooling jet (1) from the cylinder block.
2. Repeat Step 1 in order to remove the remaining piston cooling jets.

### Installation Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

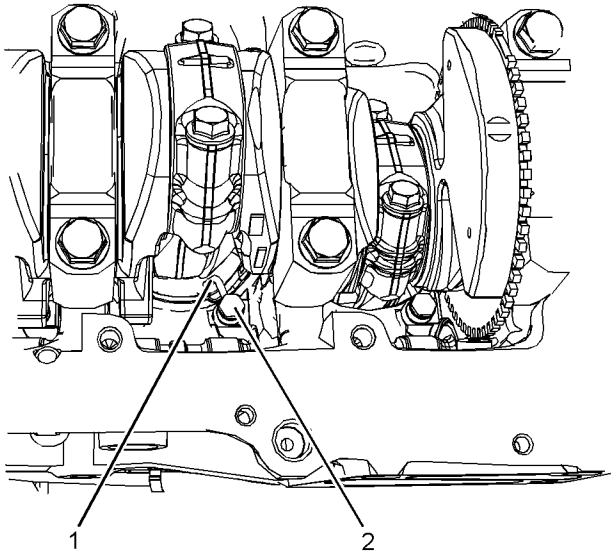


Illustration 289

g02895676

1. Clean the piston cooling jets and inspect the piston cooling jets for damage. Replace any damaged piston cooling jets. The procedure for checking that the alignment of the piston cooling jets is described in Specifications, "Piston Cooling Jet Alignment" for the correct information.
2. Install banjo bolt (2) to piston cooling jet (1). Install the piston cooling jet assembly into the recess in the cylinder block.
3. Tighten banjo bolt (2) to a torque of 18 N·m (159 lb in).
4. Repeat Step 2 through Step 3 for the remaining piston cooling jets.

**End By:**

- a. Install the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Install" for the correct procedure.
- b. Install the engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Install" for the correct procedure.

i05279061

## Pistons and Connecting Rods - Remove

### Removal Procedure

Table 62

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610274	Ridge Reamer	1

**Start By:**

- a. Remove the oil suction pipe. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install" for the correct procedure.
- b. If necessary, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove" for the correct procedure.
- c. Remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove" for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Rotate crankshaft until the required connecting rod is at bottom dead center.
2. Using tooling (A), remove carbon build-up from the top of the cylinder bore.

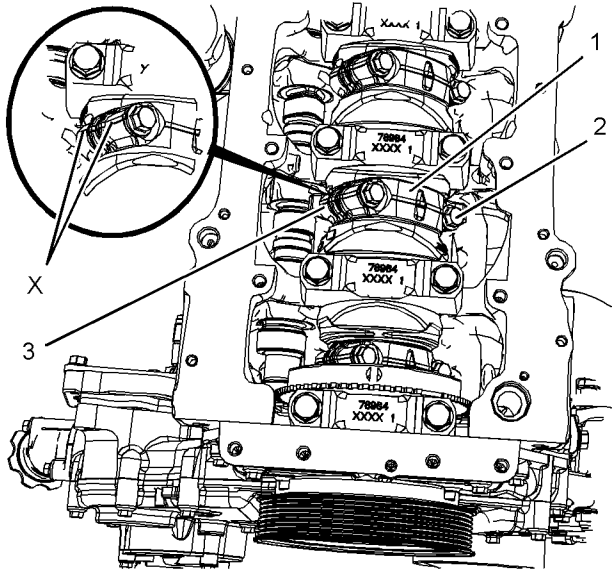


Illustration 290

g03001196

Typical example

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

3. The connecting rod and the connecting rod cap should have an etched number in Position (X). The number on the connecting rod and the connecting rod cap must match. Ensure that connecting rod (3) and connecting rod cap (1) are marked for the correct location. If necessary, make a temporary mark on the connecting rod and the connecting rod cap in order to identify the cylinder number and orientation of the assembly.
4. Remove the bolts (2) and remove connecting rod cap (1) from connecting rod (3).
5. Rotate crankshaft so that the required piston is at top center position.

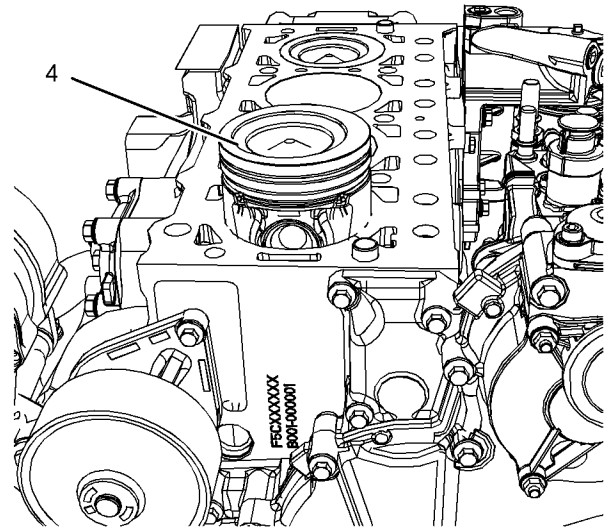


Illustration 291

g02998516

Typical example

6. Carefully push piston (4) and the connecting rod out of the cylinder bore. Lift piston (4) out of the top of the cylinder block.

**Note:** Do not apply force to the fracture split surfaces of the connecting rod as damage may result.

7. Temporarily install connecting rod cap (1) and bolts (2) to connecting rod (3) when the assembly is out of the engine. Ensure that the etched number on connecting rod cap matches the etched number on connecting rod. Ensure the correct orientation of the connecting rod cap. The locating tab for the upper bearing shell and the lower bearing shell should be on the same side. Tighten bolts (2) to a torque of 20 N·m (177 lb in).
8. Repeat Step 1 through Step 7 in order to remove the remaining pistons and connecting rods.

Fracture split connecting rods should not be left without the connecting rod caps installed.

i05279089

## Pistons and Connecting Rods - Disassemble

### Disassembly Procedure

Table 63

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Retaining Ring Pliers	1
B	-	Ring Expander	1

#### Start By:

- a. Remove the pistons and the connecting rods. Refer to Disassembly and Assembly, "Piston and Connecting Rods - Remove" for the correct procedure.

**Note:** Make a temporary mark on the components of the piston and connecting rod assembly. Making temporary marks will ensure that the components of each piston and connecting rod assembly can be reinstalled in the original location. Mark the underside of the piston on the front pin boss. Do not interchange components.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

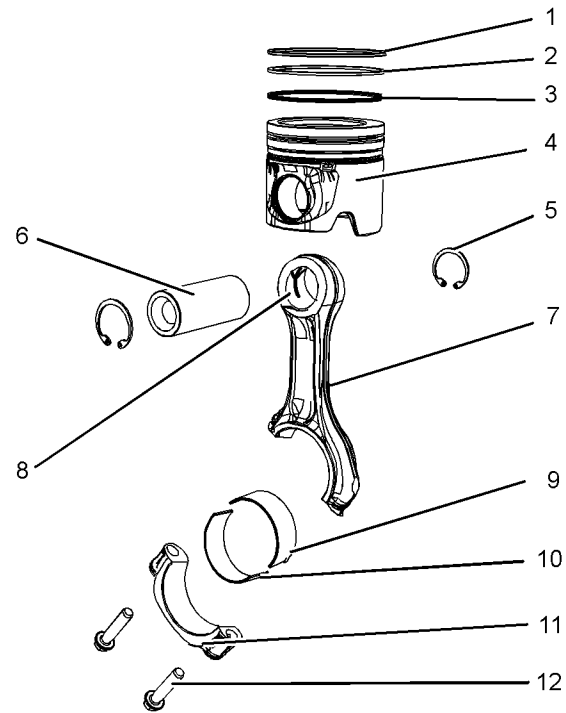


Illustration 292

g03001216

1. Remove lower bearing shell (10) from connecting rod cap (11). Remove upper bearing shell (9) from connecting rod (7). Keep the bearing shells together.
2. Place the piston and connecting rod assembly on a suitable surface with the connecting rod upward. Use Tooling (A) in order to remove circlips (5).
3. Remove piston pin (6) from bushing (8) in connecting rod (7). Remove connecting rod (7) from piston (4).

**Note:** If the piston pin cannot be removed by hand, heat the piston to a temperature of  $45 \pm 5 \text{ }^\circ\text{C}$  ( $113 \pm 9 \text{ }^\circ\text{F}$ ). Do not use a torch to heat the piston. Note the orientation of connecting rod (7) and piston (4).

4. Place the piston on a suitable surface with the crown upward. Use Tooling (B) in order to remove compression ring (1), compression ring (2), and oil control ring (3) from piston (4).

**Note:** Make temporary identification marks to identify the position and orientation of compression ring (1), compression ring (2), and oil control ring (3).

5. Inspect the connecting rod for wear and damage. If necessary, replace connecting rod (7).



- Repeat Step 1 through Step 5 in order to disassemble the remaining pistons and connecting rods.

i05282636

## Pistons and Connecting Rods - Assemble

### Assembly Procedure

Table 64

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Retaining Ring Pliers	1
B	-	Ring Expander	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

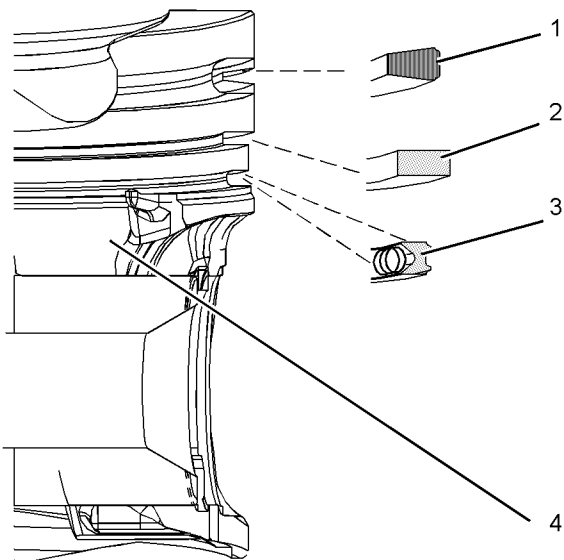


Illustration 293

g03003219

- Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.
- Position the spring for oil control ring (3) into the oil ring groove in piston (4). The central wire must be located inside the end of the spring.

- Position the oil control ring with the word "TOP" in the upward position. Use Tooling (B) to install oil control ring (3) over the piston and the spring.

**Note:** Ensure that the central wire is 180 degrees from the ring gap.

- Use Tooling (B) to install intermediate compression ring (2) into the second groove in piston (4). The word "TOP" must be upward.

- Use Tooling (B) to install top compression ring (1) into the top groove in piston (4). The word "TOP" must be upward.

- Position the piston ring gaps at approximately 120 degrees away from each other.

**Note:** A new piston assembly is supplied with new piston rings.

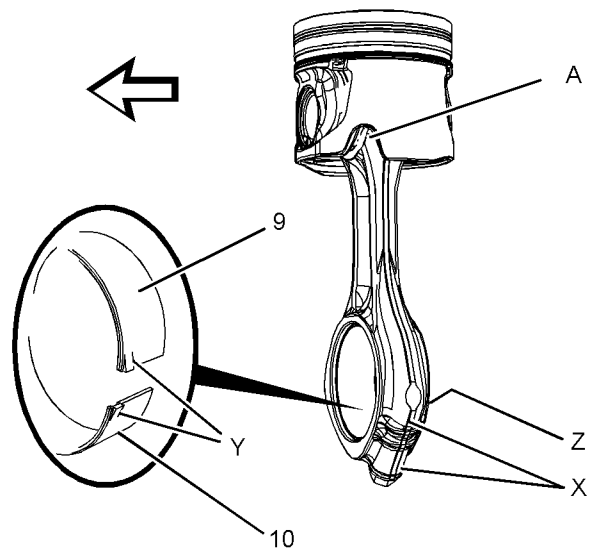


Illustration 294

g03001779

- (A) Cut away for piston cooling jet
- (9) Upper bearing shell for connecting rod
- (X) Connecting rod identification marks
- (Y) Location tag on connecting rod shells
- (Z) Location tag in connecting rod for shells (not shown)
- (10) Lower shell bearing for connecting rod cap

- Use Illustration 294 as an assembly guide.

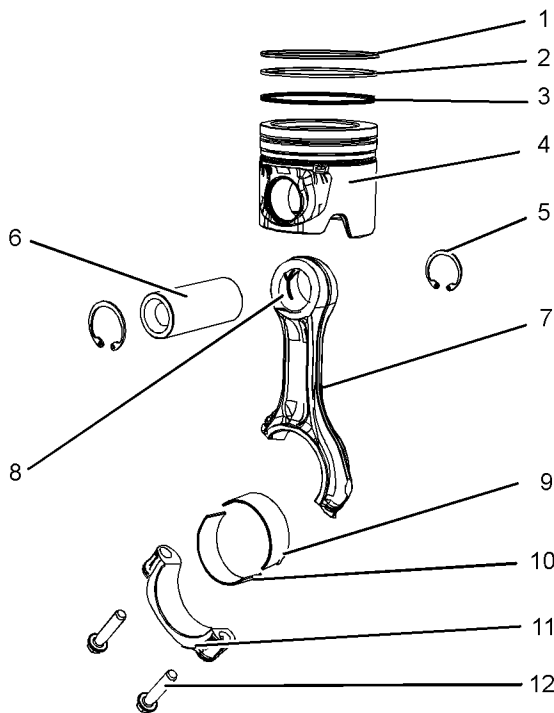


Illustration 295

g03001216

**8.** Lubricate bushing (8) for piston pin (6) in the connecting rod with clean engine oil. Lubricate the bore for the piston pin in piston (4) with clean engine oil.

**9.** Install piston pin (6) to piston (4).

**Note:** If the piston pin cannot be installed by hand, heat the piston to a temperature of  $45^{\circ} \pm 5^{\circ}\text{C}$  ( $113^{\circ} \pm 9^{\circ}\text{F}$ ).

**10.** Use Tooling (A) in order to install circlips (5) to the piston pin bore in piston (4).

**Note:** Ensure that the circlips are seated in the grooves in the piston.

**11.** Install upper bearing shell (9) into connecting rod (7). Ensure that the locating tab for the upper bearing shell is correctly seated in slot in the connecting rod.

**12.** Install lower bearing shell (10) into connecting rod cap (11). Ensure that the locating tab for the lower bearing shell is correctly seated in the slot in the connecting rod cap.

**13.** Temporarily install connecting rod cap (11) and bolts (12) to connecting rod (7) when the assembly is out of the engine. Ensure that the etched number on connecting rod cap matches the etched number on connecting rod. Ensure the correct orientation of the connecting rod cap. The locating tab for the upper bearing shell and the lower bearing shell should be on the same side. Tighten bolts (12) to a torque of 20 N·m (177 lb in).

**14.** Repeat Step 1 through Step 13 for the remaining piston and connecting rod assemblies.

**Note:** Fracture split connecting rods should not be left without the connecting rod caps installed.

#### End By:

- a. Install the pistons and the connecting rods.** Refer to Disassembly and Assembly, "Piston and Connecting Rods - Install" for the correct procedure.

i05282637

## Pistons and Connecting Rods - Install

### Installation Procedure

Table 65

Required Tools			
Tool	Part Number	Part Description	Qty
B	21825491	Piston Ring Compressor	1
C	27610289	Angle Gauge	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

- If the connecting rod caps were temporarily installed, remove the connecting rod caps. If necessary, thoroughly clean all of the components.

**Note:** Discard all used connecting rod bolts.

- Apply clean engine oil to the cylinder bore, piston, piston rings, connecting rod shell, and the shell in the connecting rod cap.
- Rotate crankshaft until the required crankshaft journal is at bottom center position. Lubricate the crankshaft journal with clean engine oil.

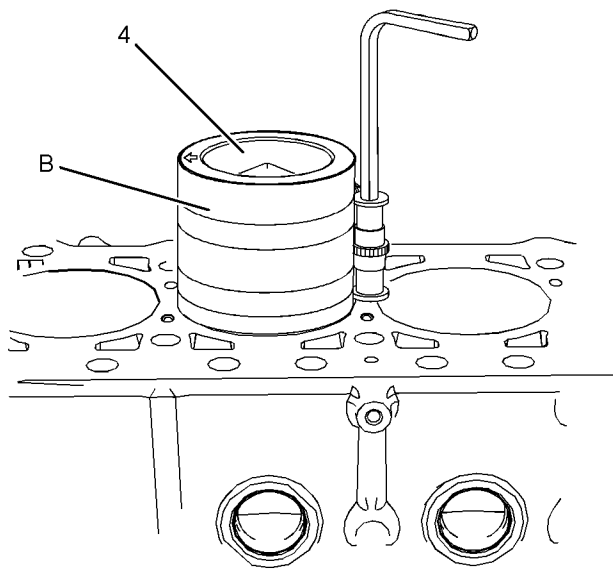


Illustration 296

g02999358

4. Lightly lubricate Tooling A with clean engine oil.  
Install Tooling (A) onto piston (4)

**Note:** Ensure that the piston assembly is installed into the correct cylinder. Also, ensure the correct orientation of the assembly, refer to Illustration 297 .

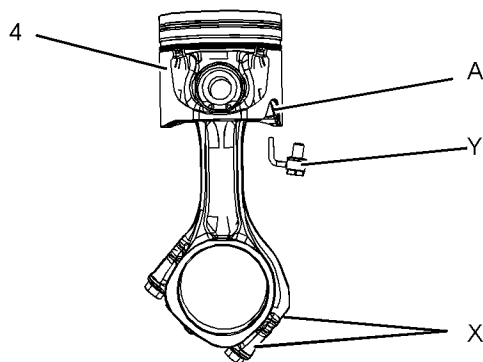


Illustration 297

g02999579

- (4) Piston  
(A) Cut out for piston cooling jet  
(Y) Cooling jet  
(X) Connecting rod identification marks

5. Ensure that Tooling (B) is installed correctly and that piston (4) can easily slide from the tool.

**Note:** Ensure alignment of the connecting rod assembly to the crankshaft journal.

6. Carefully push the piston and the connecting rod assembly into the cylinder bore and onto the crankshaft pin.

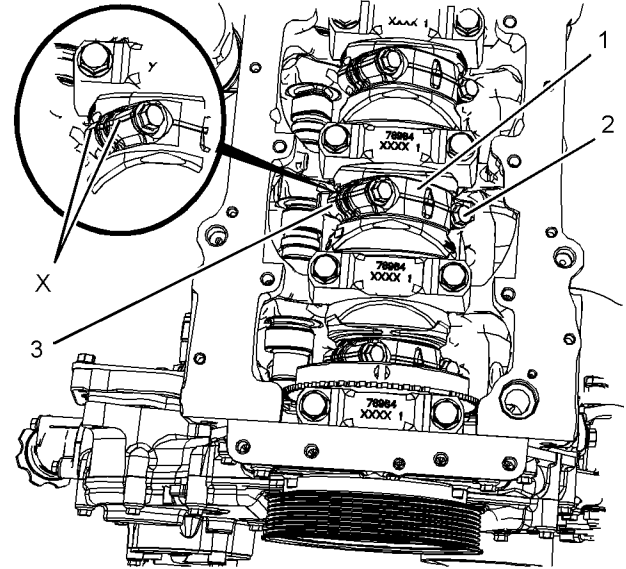


Illustration 298

g03001177

#### Typical example

7. Ensure that etched number in Position (X) on connecting rod cap (1) matches etched number in Position (X) on connecting rod (3). Ensure the correct orientation of connecting rod cap (1). The locating tab for the upper bearing shell and the lower bearing shell should be on the same side. Install the connecting rod cap (1) and install new bolts (2).
8. Tighten the new bolts to 50 N·m (37 lb ft). Turn the bolts for an additional 70 degrees in a clockwise direction. Use Tooling (C) in order to achieve the correct final torque.
9. Ensure that the installed connecting rod assembly has tactile side play. Rotate the crankshaft in order to ensure that there is no binding.
10. Repeat Step 1 through Step 9 in order to install the remaining pistons and connecting rod assemblies

**End By:**

- a. Install the cylinder head. Refer to **Disassembly and Assembly, "Cylinder Head - Install"** for the correct procedure.
- b. If necessary, install the balancer. Refer to **Disassembly and Assembly, "Balancer - Install"** for the correct procedure.
- c. Install the oil suction pipe. Refer to **Disassembly and Assembly, "Engine Oil Pan Remove and Install"** for the correct procedure.

i05282665

## Connecting Rod Bearings - Remove

(Connecting rods in position)

### Removal Procedure

**Start By:**

- a. Remove the engine oil suction pipe. Refer to **Disassembly and Assembly, "Engine Oil Pan - Remove and Install"** for the correct procedure.
- b. If necessary, remove the balancer. Refer to **Disassembly and Assembly, "Balancer - Remove"** for the correct procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Discard all used Connecting Rod fasteners.

**Note:** If all connecting rod bearings require replacement, the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 and 4 then 2 and 3. **Ensure that the installation procedure on one pair connecting rods is completed before starting the removal procedure on the next pair of connecting rods.**

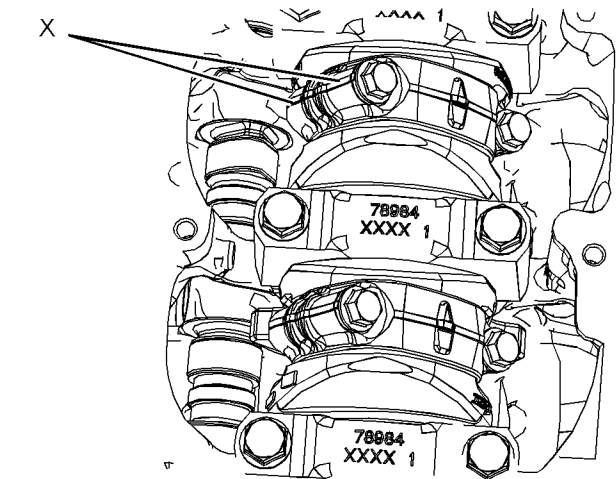


Illustration 299

g03005637

(X) Identification marks

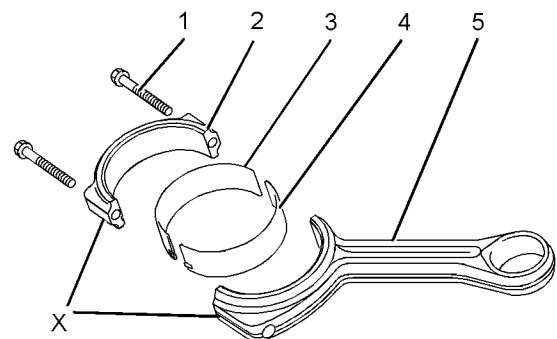


Illustration 300

g01341322

1. The connecting rod and the connecting rod cap should have an etched number in Positions (X). The number on the connecting rod and the connecting rod cap must match. If necessary, make a temporary mark on connecting rod (5) and connecting rod cap (2) in order to identify the cylinder number.

**Note:** Do not punch identification marks onto fracture split connecting rods. Do not stamp identification marks onto fracture split connecting rods.

2. Rotate the crankshaft so that required connecting rods are at bottom center position. Remove bolts (1) and discard the bolts.
3. Remove connecting rod cap (2) from connecting rod (5).

4. Remove lower bearing shell (3) from connecting rod cap (2). Keep the bearing shell and the connecting rod cap together.
5. Carefully push connecting rod (5) into the cylinder bore until connecting rod (5) is clear of the crankshaft. Remove upper bearing shell (4) from the connecting rod. Keep the bearing shells together.

**Note:** Do not push the fracture split surfaces of the connecting rod as damage may result. Do not allow the connecting rod to contact the piston cooling jet.

6. Repeat Step 1 through Step 5 in order to remove the remaining bearing shells.

**Note:** Fracture split connecting rods should not be left without the connecting rod caps installed. After the removal procedure for the bearing shells is complete, carry out the installation procedure as soon as possible. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install" for the correct procedure.

i05282667

## Connecting Rod Bearings - Install

(Connecting rods in position)

### Installation Procedure

Table 66

Required Tools			
Tool	Part Number	Part Description	Qty
A	27610289	Angle Gauge	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Discard all used Connecting Rod fasteners.

1. Inspect the pins of the crankshaft for damage. If the crankshaft is damaged, replace the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Remove" and Disassembly and Assembly, "Crankshaft - Install" for the correct procedure. Ensure that the main bearing shells are clean and free from wear and damage. If necessary, replace the main bearing shells.

**Note:** If the main bearing shells are replaced, check whether oversize main bearing shells were previously installed.

2. Ensure that the crankshaft is in the bottom center position.

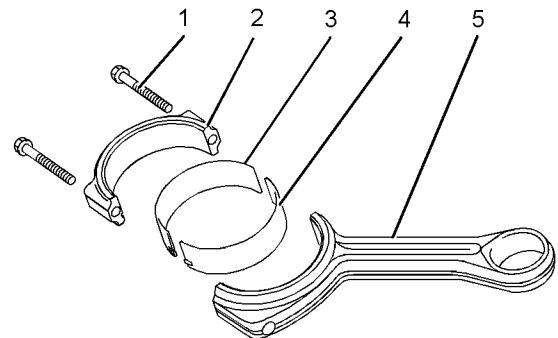


Illustration 301

g02015553

3. Install upper bearing shell (4) into connecting rod (5). Ensure that the locating tab for the upper bearing shell is correctly seated in the slot in the connecting rod.

**Note:** The ends of the upper bearing shell must be centered in the connecting rod. The ends of the upper bearing shell must be equally positioned in relation to the mating faces of the connecting rod.

4. Lubricate upper bearing shell (4) with clean engine oil.
5. Carefully guide connecting rod (5) against the crankshaft pin.

**Note:** Do not allow the connecting rod to contact the piston cooling jet.

6. Clean connecting rod cap (2). Install lower bearing shell (3) into connecting rod cap (2). Ensure that the locating tab for the lower bearing shell is correctly seated in the slot in the connecting rod cap.
7. Lubricate the pin of the crankshaft and lubricate lower bearing shell (3) with clean engine oil.

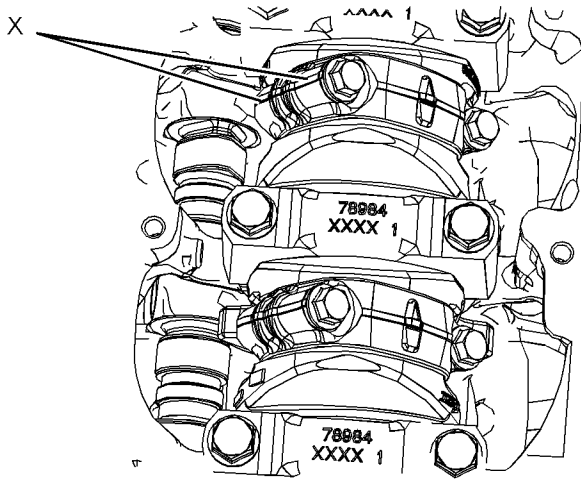


Illustration 302

g03005637

8. Install connecting rod cap (2) to connecting rod (5).

**Note:** Ensure that etched number in Position (X) on connecting rod cap (2) matches etched number in Position (X) on connecting rod (5). Ensure the correct orientation of the connecting rod cap. The locating tab for the upper bearing shell and the lower bearing shell should be on the same side.

**Note:** Do not reuse the old bolts in order to secure the connecting rod cap.

9. Install new bolts (1) and tighten to 50 N·m (36 lb ft). Turn the bolts an additional 70 degrees in a clockwise direction. Use Tooling (A) in order to achieve the required torque.

10. Ensure that the installed connecting rod assembly has tactile side play. Rotate the crankshaft in order to ensure that there is no binding.

**Note:** If all connecting rod bearings require replacement, the procedure can be carried out on two cylinders at the same time. The procedure can be carried out on the following pairs of cylinders. 1 and 4 then 2 and 3. **Ensure that the installation procedure on one pair connecting rods is completed before starting the removal procedure on the next pair of connecting rods.**

11. Repeat Step 1 through Step 10 in order to install the remaining connecting rod bearings.

**End By:**

- a. If necessary, install the balancer. Refer to Disassembly and Assembly, “Balancer Install” for the correct procedure.
- b. Install the engine oil suction pipe. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for the correct procedure.

i05282668

## Crankshaft Main Bearings - Remove and Install

### Removal Procedure

Table 67

Required Tools			
Tool	Part Number	Part Description	Qty
A <sup>(1)</sup>	T400157	Housing	1
	T400156	Engine Turning Tool	1

<sup>(1)</sup> This tool is used in the aperture for the electric starting motor.

**Start By:**

- a. Remove the engine oil pan and suction pipe. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for the correct procedure.
- b. If necessary, remove the balancer. Refer to Disassembly and Assembly, “Balancer - Remove” for the correct procedure.

#### NOTICE

This procedure must only be used to remove and install the main bearing shells with the crankshaft in position.

The removal procedure and the installation procedure must be completed for each pair of main bearing shells before the next pair of main bearing shells are removed.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the main bearing cap is marked for the correct location and orientation.

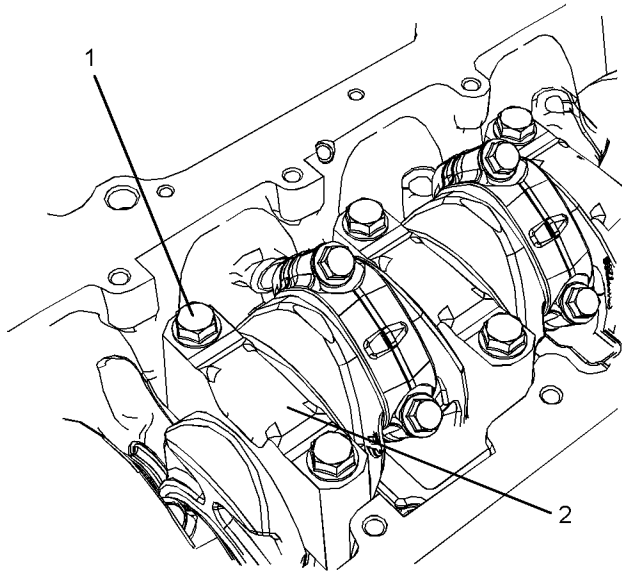


Illustration 303

g03003177

Typical example

2. Remove bolts (1) and remove main bearing cap (2) from the cylinder block.

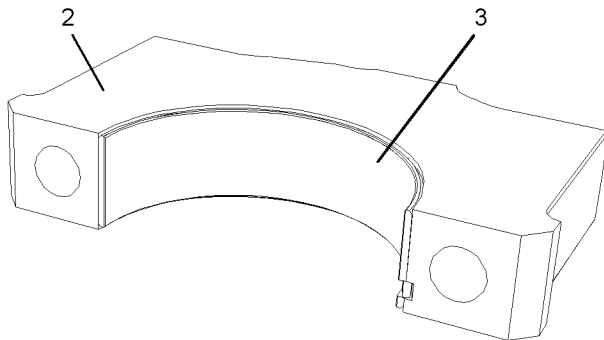


Illustration 304

g03003178

Typical example

3. Remove lower main bearing shell (3) from main bearing cap (2). Keep the main bearing shell and the main bearing cap together.

**Note:** The lower main bearing shell is a plain bearing that has no oil holes.

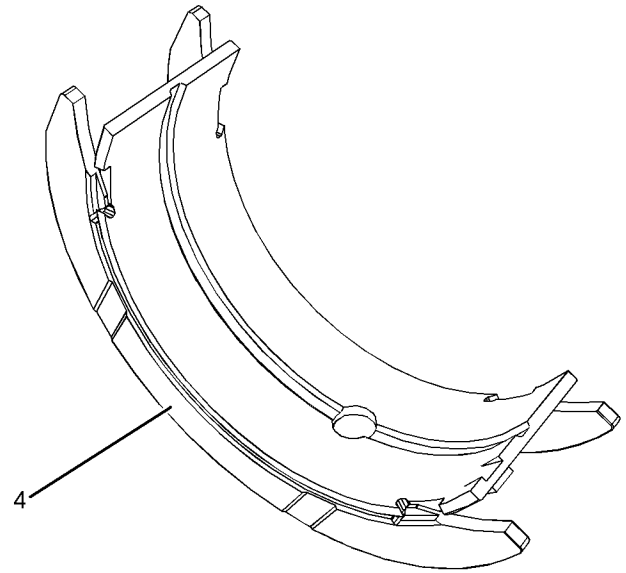


Illustration 305

g03003457

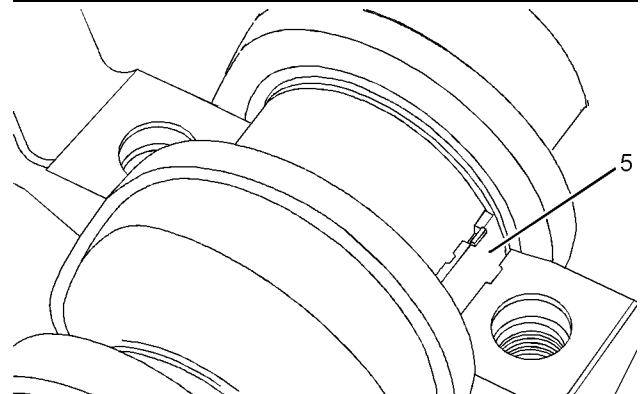


Illustration 306

g03003257

4. Push out upper main bearing shell (5) with a suitable tool from the side opposite the locating tab. Use Tooling (A) in order to rotate the crankshaft while you push on the bearing shell. Remove upper main bearing shell (5) from the cylinder block. Keep the bearing shells together. The thrust washers (4) are attached to number three upper main bearing shell. Make a note of the orientation of the thrust washers for installation purposes.

**Note:** The upper main bearing shell has a groove and oil hole.

## Installation Procedure

Table 68

Required Tools			
Tool	Part Number	Part Description	Qty
B	27610289	Angle Gauge	1
C	21825617	Dial Indicator	1
	-	Magnetic Base and Stand	1

### NOTICE

This procedure must only be used to remove and install the main bearing shells with the crankshaft in position.

The removal procedure and the installation procedure must be completed for each pair of main bearing shells before the next pair of main bearing shells are removed.

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the main bearing shells are clean and free from wear and damage. If necessary, replace the main bearing shells.

**Note:** If the main bearing shells are replaced, check whether oversize main bearing shells were previously installed. If the thrust washers are replaced, check whether oversize thrust washers were previously installed.

2. Clean the journals of the crankshaft. Inspect the journals of the crankshaft for damage. If necessary, replace the crankshaft or recondition the crankshaft.

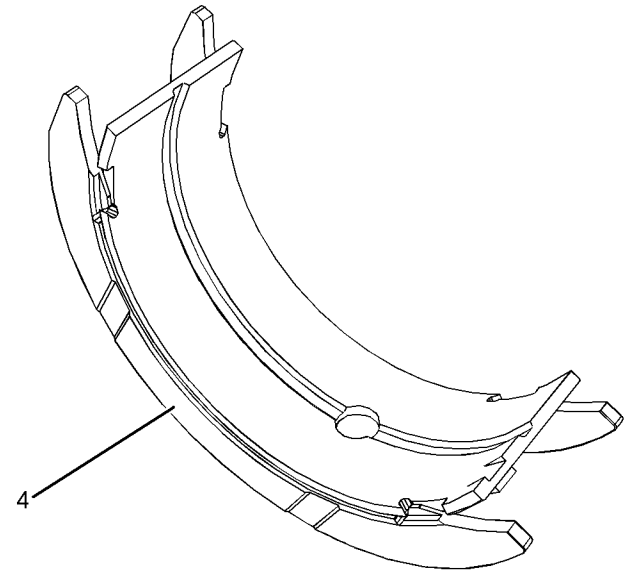


Illustration 307

g03003457

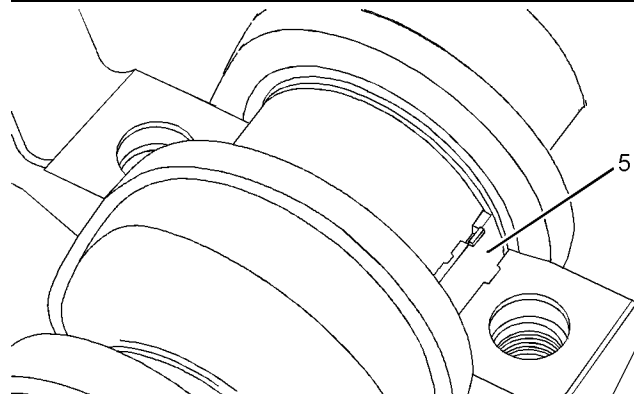


Illustration 308

g03003257

3. For number three main bearing, ensure that two thrust washers (4) are clean and free from wear and damage. If necessary, replace the thrust washers. Lubricate thrust washers (4) with clean engine oil.

**Note:** The upper main bearing shell has a groove and oil hole.

4. Lubricate the crankshaft journal and upper main bearing shell (8) with clean engine oil. Slide upper main bearing shell (8) into position between the crankshaft journal and the cylinder block. Ensure that the locating tab for the upper main bearing shell is correctly seated in the slot in the cylinder block.



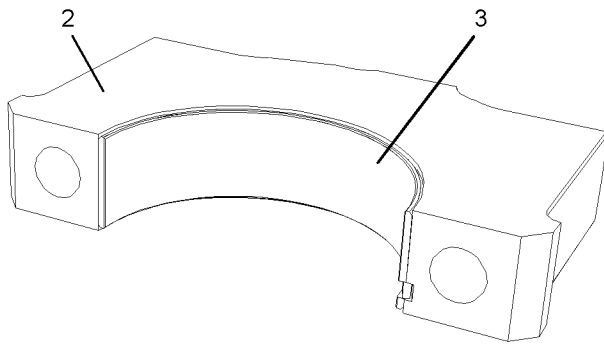


Illustration 309

g03003178

5. Install lower main bearing shell (3) into main bearing cap (2). Ensure that the locating tab for the lower main bearing shell is correctly seated into the slot in the bearing cap.

**Note:** The lower main bearing shell is a plain bearing that has no oil holes.

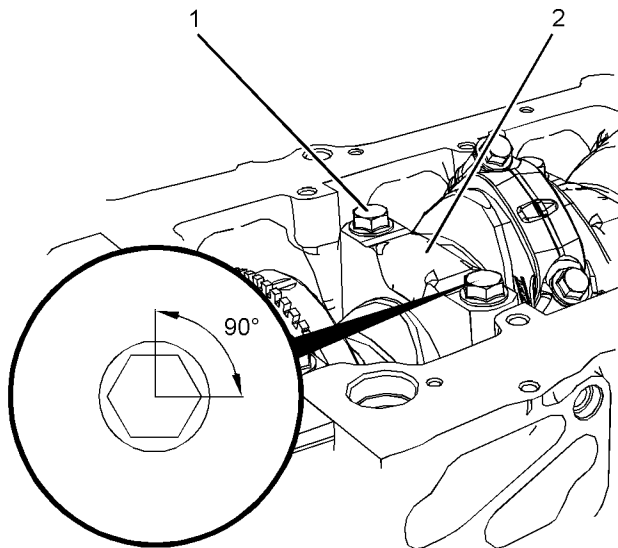


Illustration 310

g03003700

6. Lubricate the crankshaft journal and the lower main bearing shell with clean engine oil. Install main bearing cap (5) to the cylinder block.

**Note:** Ensure the correct orientation of the main bearing cap. The locating tab for the upper and the lower bearing should be on the same side of the engine.

7. Lubricate the threads of bolts (4) with clean engine oil. Lubricate the underside of the heads of bolts (4) with clean engine oil.

8. Install bolts (4) to main bearing cap (5). Evenly tighten the bolts in order to pull cap (5) into position. Ensure that the cap is correctly seated.

**Note:** Do not tap the main bearing cap into position as the bearing shell may be dislodged.

9. Tighten bolts (4) to an initial torque of 50 N·m (37 lb ft).  
10. Tighten bolts (4) to a torque of 80 N·m (59 lb ft).

Use Tooling (C) in order to turn the bolts through an additional 90 degrees in a clockwise direction in order to achieve the correct final torque.

11. Check the crankshaft end play. Use Tooling (C) to measure the crankshaft end play. Refer to Specifications, "Crankshaft" for the correct information.

12. Remove Tooling (C).

#### End By:

- a. If necessary, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install" for the correct procedure.  
b. Install the suction pipe and engine oil pan. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install" for the correct procedure.

i05282671

## Crankshaft - Remove

### Removal Procedure

Table 69

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Lifting Sling	2

**Start By:**

- a. Remove the engine oil suction pipe. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install" for the correct procedure.
- b. If necessary, remove the balancer. Refer to Disassembly and Assembly, "Balancer - Remove" for the correct procedure.
- c. Remove the flywheel housing. Refer to Disassembly and Assembly, "Flywheel housing - Remove and Install" for the correct procedure.
- d. Remove the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Remove" for the correct procedure.
- e. If necessary, remove the power take-off drive. Refer to Disassembly and Assembly, "Power Take-Off Drive - Remove and Install" for the correct procedure.
- f. If necessary, remove the cylinder head. Refer to Disassembly and Assembly, "Cylinder Head - Remove" for the correct procedure.
- g. If necessary, remove the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Remove" for the correct procedure.
- h. Remove the main bearing caps. Refer to Disassembly and Assembly, "Crankshaft Main Bearings - Remove and Install" for the correct procedure.

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. The engine should be mounted on a suitable stand and placed in the inverted position.
2. If the cylinder head, the pistons and the connecting rods have not been removed already, remove the connecting rod bearings. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Remove" for the correct procedure.

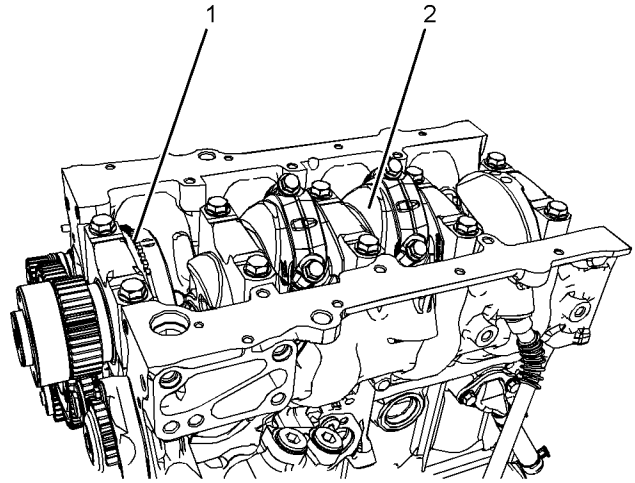


Illustration 311

g03008176

3. Attach Tooling (A) and a suitable lifting device to crankshaft (2). Lift the crankshaft out of the cylinder block. The weight of the crankshaft is approximately 35 kg (77 lb).

**Note:** Do not damage any of the finished surfaces on the crankshaft. When the crankshaft is removed from the engine, the crankshaft must be supported on a suitable stand in order to prevent damage to the crankshaft timing ring.

4. Remove upper main bearing shells from the cylinder block. Refer to Disassembly and Assembly, "Crankshaft Main Bearings - Remove and Install" for the correct procedure.

**Note:** The upper main bearing shells have a groove and an oil hole.

5. If necessary, remove the crankshaft timing ring (1). Refer to Disassembly and Assembly, "Crankshaft Timing Ring - Remove and Install" for the correct procedure.

i05282673

## Crankshaft - Install

### Installation Procedure

Table 70

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Lifting Sling	2
B	21825617	Dial Indicator	1
	-	Magnetic Base and Stand	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the crankshaft and inspect the crankshaft for wear and damage. Refer to Specifications, "Crankshaft" for more information. If necessary, replace the crankshaft or recondition the crankshaft.

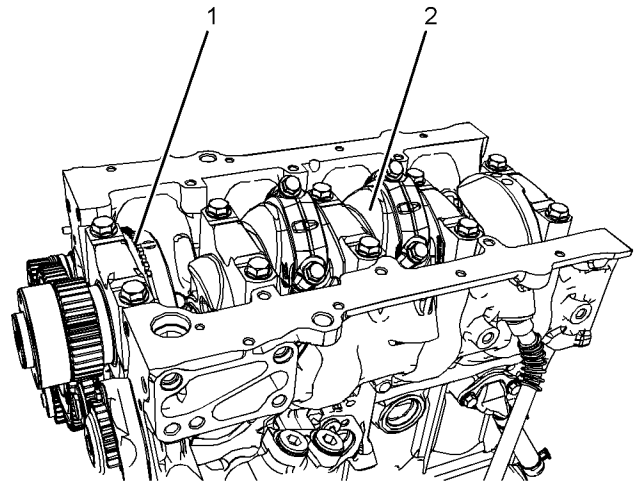


Illustration 312

g03008302

2. If necessary, install a new crankshaft timing ring (1). Refer to Disassembly and Assembly, "Crankshaft Timing Ring - Remove and Install" for the correct procedure.
  3. Ensure that parent bores for bearing shells in the cylinder block are clean. Ensure that the threads for the main bearing bolts in the cylinder block are clean and free from damage.
  4. Clean the main bearing shells and the thrust washers. Inspect the main bearing shells and the thrust washers for wear and damage. If necessary, replace the main bearing shells and the thrust washers.
- Note:** If the main bearing shells are replaced, check whether oversize main bearing shells were previously installed. If the thrust washers are replaced, check whether oversize thrust washers were previously installed.
5. Install upper main bearing shells to the cylinder block. Refer to Disassembly and Assembly, "Crankshaft Main Bearings - Remove and Install" for the correct procedure.
- Note:** The upper main bearing shells have a groove and an oil hole.
6. Lubricate upper main bearing shells with clean engine oil.
  7. Attach Tooling (A) and a suitable lifting device to crankshaft (2). Lift the crankshaft into the cylinder block. The weight of the crankshaft is approximately 35 kg (77 lb).

**Note:** Do not damage any of the finished surfaces on the crankshaft. Do not damage the main bearing shells.

8. Lubricate lower main bearing shells and lubricate the journals of the crankshaft with clean engine oil. Install lower main bearing caps. Refer to Disassembly and Assembly, "Crankshaft Main Bearings - Remove and Install" for the correct procedure.

**Note:** The lower main bearing shells are plain bearings that do not have an oil hole.

9. Rotate the crankshaft in order to ensure that there is no binding.
10. Check the crankshaft end play. Push the crankshaft toward the front of the engine. Install Tooling (B) to the cylinder block and the rear face of the crankshaft. Push the crankshaft toward the rear of the engine. Use Tooling (B) to measure the crankshaft end play. Refer to Specifications, "Crankshaft" for the correct information.
11. If necessary, install the pistons and connecting rods. Refer to Disassembly and Assembly, "Pistons and Connecting Rods - Install" for the correct procedure.
12. If the crankshaft has not been replaced or the crankshaft has not been reconditioned, install the connecting rod bearings. Refer to Disassembly and Assembly, "Connecting Rod Bearings - Install" for the correct procedure.

#### End By:

- a. If necessary, install the power take-off drive. Refer to Disassembly and Assembly, "Power Take-Off Drive - Remove and Install" for the correct procedure.
- b. If necessary, install the balancer. Refer to Disassembly and Assembly, "Balancer - Install" for the correct procedure.
- c. Install the engine oil suction pipe. Refer to Disassembly and Assembly, "Engine Oil Pan - Remove and Install" for the correct procedure.
- d. If necessary, install the cylinder head. Refer to Disassembly and Assembly, "Cylinder head - Install" for the correct procedure.
- e. Install the flywheel housing. Refer to Disassembly and Assembly, "Flywheel Housing - Remove and Install" for the correct procedure.
- f. Install the front housing. Refer to Disassembly and Assembly, "Housing (Front) - Install" for the correct procedure.

i05282676

## Crankshaft Timing Ring - Remove and Install

### Removal Procedure

#### Start By:

- a. Remove the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Remove" for the correct procedure.

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#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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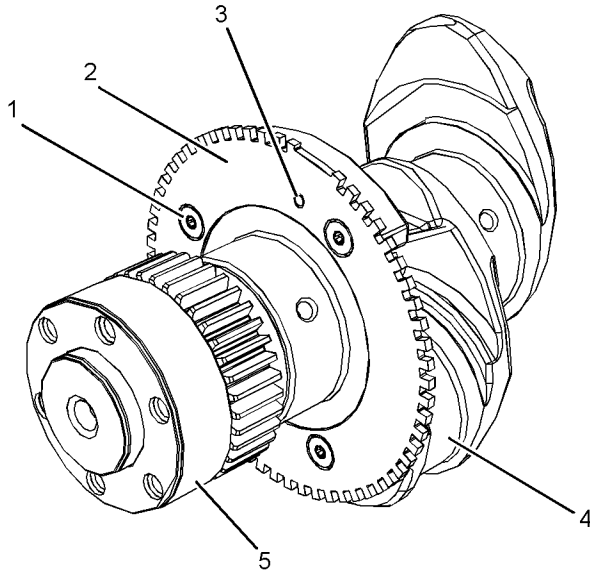


Illustration 313

g03010798

1. Support crankshaft (4) on a suitable stand.
2. Remove Torx screws (1) from crankshaft timing ring (2). Do not reuse the Torx screws.
3. Carefully remove crankshaft timing ring (2) from crankshaft (4).

**Note:** Ensure that the seal surface on adaptor (5) is not damaged when the crankshaft timing ring is removed.

**Note:** Do not remove dowel (3) from the crankshaft unless the dowel is damaged.

### Installation Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the teeth of the crankshaft timing ring are clean and free from damage.
2. Support crankshaft (4) on a suitable stand.

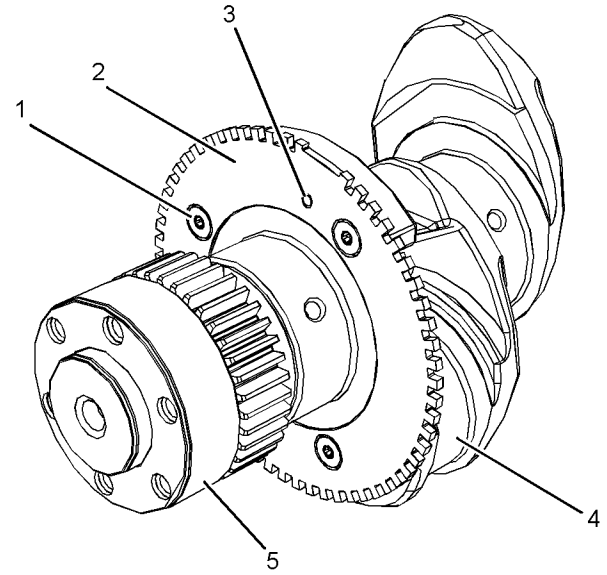


Illustration 314

g03010798

3. If dowel (3) was removed, install a new dowel to crankshaft (4).
4. Position crankshaft timing ring (2) onto the crankshaft with the chamfer toward the crankshaft web. Align the hole in crankshaft timing ring with dowel (3) in the crankshaft. Carefully install the crankshaft timing ring to the crankshaft.

**Note:** Ensure that the seal surface on adaptor (5) is not damaged when the crankshaft timing ring is installed.

5. Install new Torx screws (1). Tighten the Torx screws to a torque of 10 N·m (89 lb in).

**End By:**

- a. **Install the crankshaft. Refer to Disassembly and Assembly, "Crankshaft - Install" for the correct procedure.**

i05980323

## Bearing Clearance - Check

### Measurement Procedure

Table 71

Required Tools			
Tool	Part Number	Part Description	Qty

(continued)

## Disassembly and Assembly Section

(Table 71, contd)

A	-	Plastigauge (Green) 0.025 to 0.076 mm (0.001 to 0.003 inch)	1
	-	Plastigauge (Red) 0.051 to 0.152 mm (0.002 to 0.006 inch)	1
	-	Plastigauge (Blue) 0.102 to 0.229 mm (0.004 to 0.009 inch)	1
	-	Plastigauge (Yellow) 0.230 to 0.510 mm (0.009 to 0.020 inch)	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Perkins does not recommend the checking of the actual clearances of the bearing shells particularly on small engines. Checking of the actual clearances of the bearing shells is because of the possibility of obtaining inaccurate results and of damaging the bearing shell or the journal surfaces. Each Perkins bearing shell 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 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 315 .

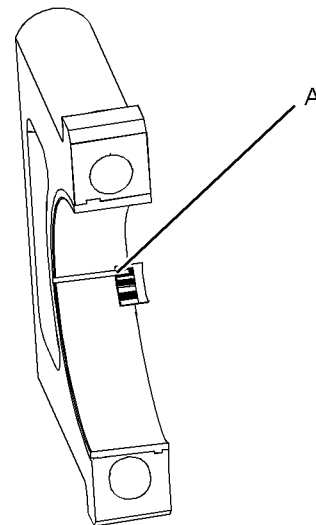


Illustration 315

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.

i05282685

## Camshaft Position Sensor - Remove and Install

### Removal Procedure

**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.

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.

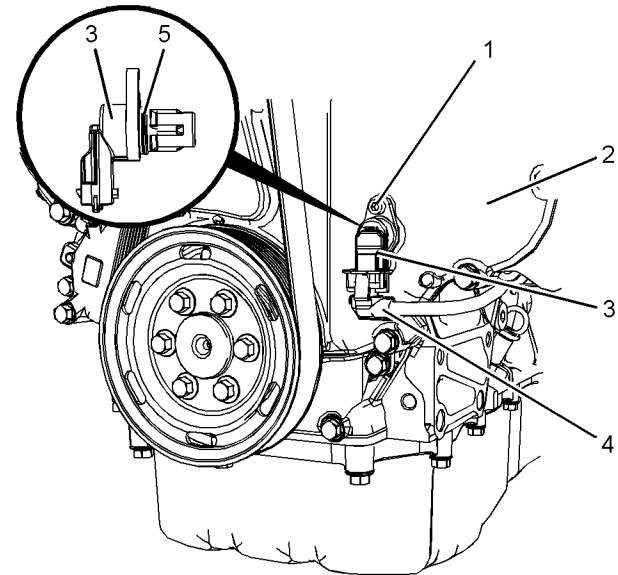


Illustration 316

g02672140

1. Slide the locking tab into the unlocked position and disconnect harness assembly (4) from camshaft position sensor (3).
2. Remove bolt (1). Carefully remove camshaft position sensor (3) from front cover (2).

**Note:** Do not use a lever to remove the camshaft position sensor. Make a note of the orientation of the camshaft position sensor for installation purposes.

3. Remove O-ring seal (5) from camshaft position sensor (3).

### Installation Procedure

Table 72

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Loctite 506	1

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

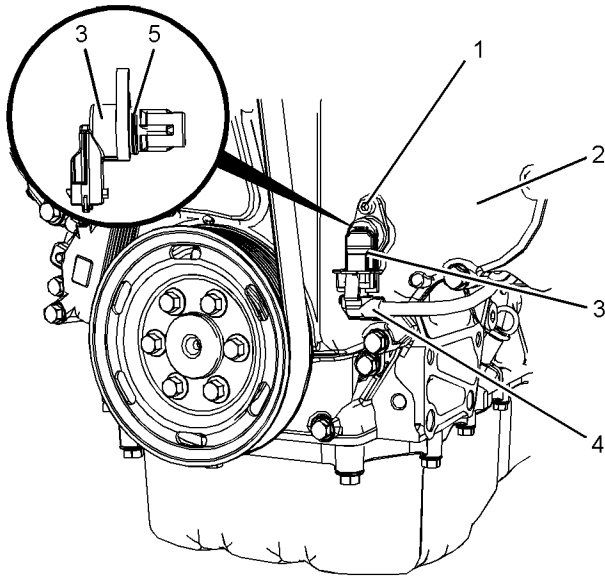


Illustration 317

g02672140

1. Install a new O-ring seal (5) to camshaft position sensor (3).
2. Install camshaft position sensor (3) to front cover (2). Ensure that the camshaft position sensor is correctly orientated.
3. Apply Tooling (A) onto the threads of bolt (1). Install bolt (1) to the camshaft position sensor. Tighten the bolt to a torque of 10 N·m (89 lb in)
4. Connect harness assembly (4) to camshaft position sensor (3). Slide the locking tab into the locked position.

i05282713

## Crankshaft Position Sensor - Remove and Install

### Removal Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

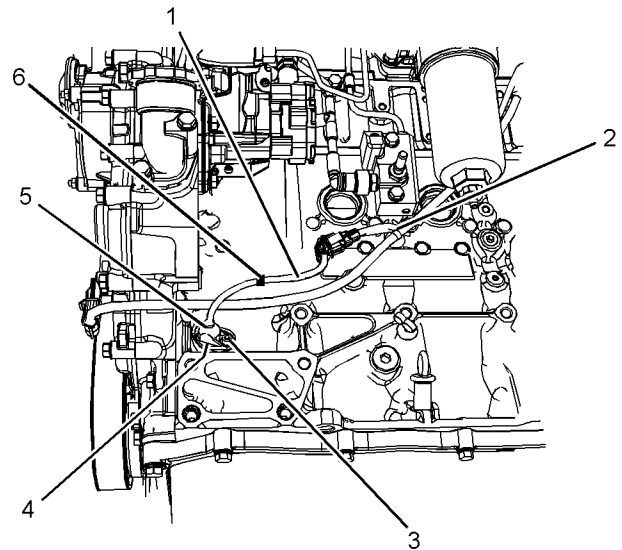


Illustration 318

g02673817

1. Slide the locking tab into the unlocked position. Disconnect harness assembly (2) from crankshaft position sensor harness (1).
2. Cut cable strap (6).
3. Remove bolt (3) from the cylinder block.
4. Carefully remove crankshaft position sensor (5) from the cylinder block.

**Note:** Do not use a lever to remove the crankshaft position sensor from the cylinder block.

5. Remove O-ring seal (4) (not shown) from crankshaft position sensor (5).

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.



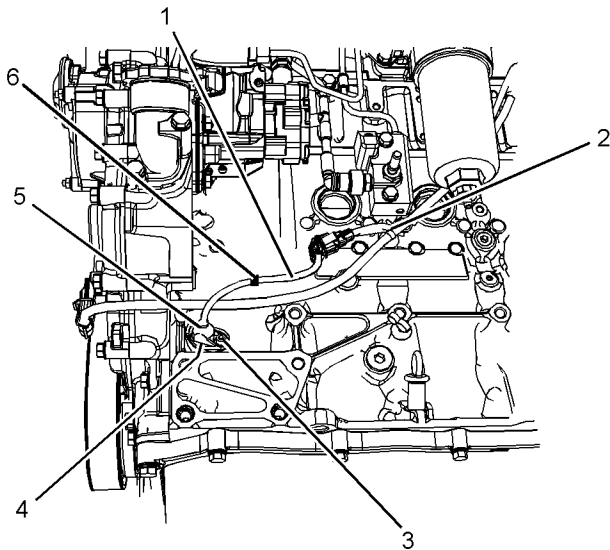


Illustration 319

g02673817

1. Install a new O-ring seal (4) (not shown) to crankshaft position sensor (5).
2. Install crankshaft position sensor (5) to the cylinder block. Install bolt (3) and tighten the bolt to a torque of 10 N·m (89 lb in).
3. Connect harness assembly (2) to crankshaft position sensor harness (1). Slide the locking tab into the locked position.
4. Install a new cable strap (6).

**Note:** Ensure that the cable strap meets the Original Equipment Manufacturers (OEM) specification.

i05282714

## Coolant Temperature Sensor - Remove and Install

### Removal Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**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.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant from the cooling system to a level below the coolant temperature sensor. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct draining procedure.

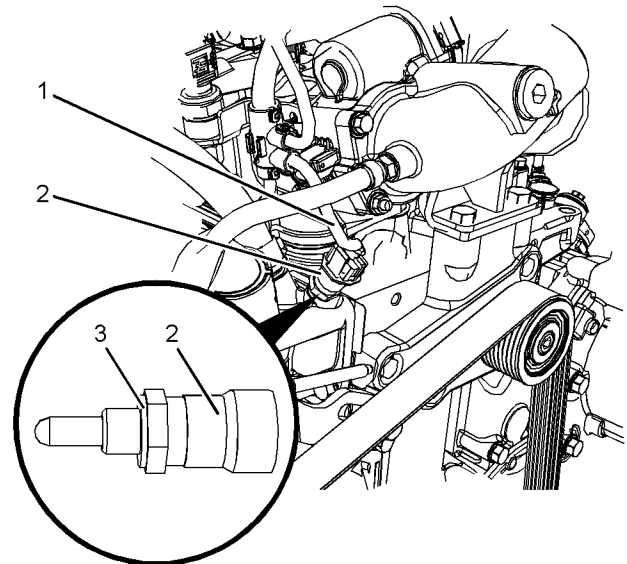


Illustration 320

g02671576

2. Slide the locking tab into the unlocked position. Disconnect harness assembly (1) from coolant temperature sensor (2).
3. Remove coolant temperature sensor (2) from the water temperature regulator housing.
4. Remove seal washer (3) from coolant temperature sensor (2).

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

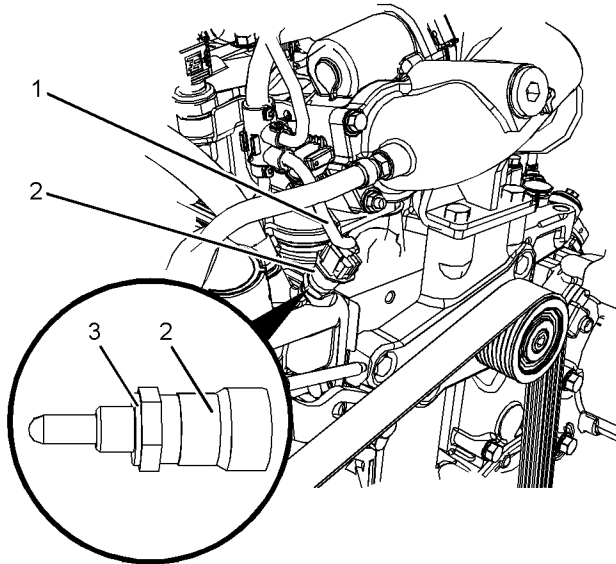


Illustration 321

g02671797

1. Install a new seal washer (3) onto coolant temperature sensor (2).
2. Install coolant temperature sensor (2) to the water temperature regulator housing. Tighten the coolant temperature sensor to a torque of 25 N·m (221 lb in).
3. Connect harness assembly (1) to coolant temperature sensor (2). Slide the locking tab into the locked position.
4. Fill the cooling system to the correct level. Refer to Operation and Maintenance Manual, "Cooling System Coolant Level - Check" and refer to Operation and Maintenance Manual, "Cooling System Coolant - Change" for the correct filling procedures.

i05282729

## Engine Oil Pressure Switch - Remove and Install

### Removal Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

#### 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.

Dispose of all fluids according to local regulations and mandates.

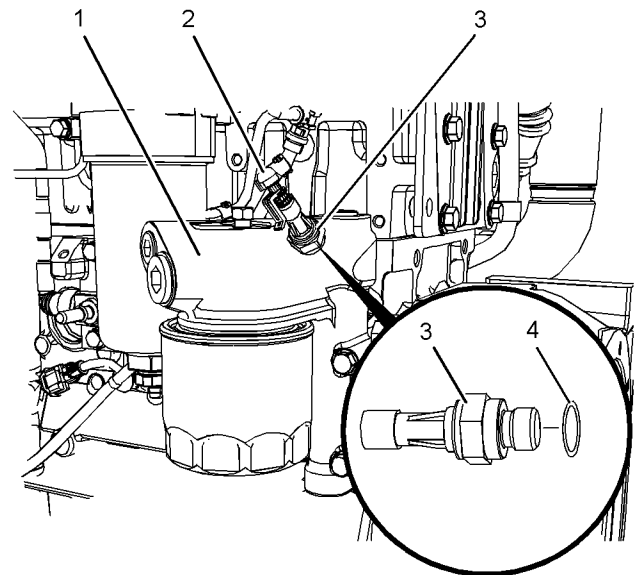


Illustration 322

g02673736

1. Disconnect harness assembly (2) from engine oil pressure switch (3).
2. Using a deep socket remove engine oil pressure switch (3) from oil filter head (1).
3. Remove O-ring seal (4) from the engine oil pressure switch.

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

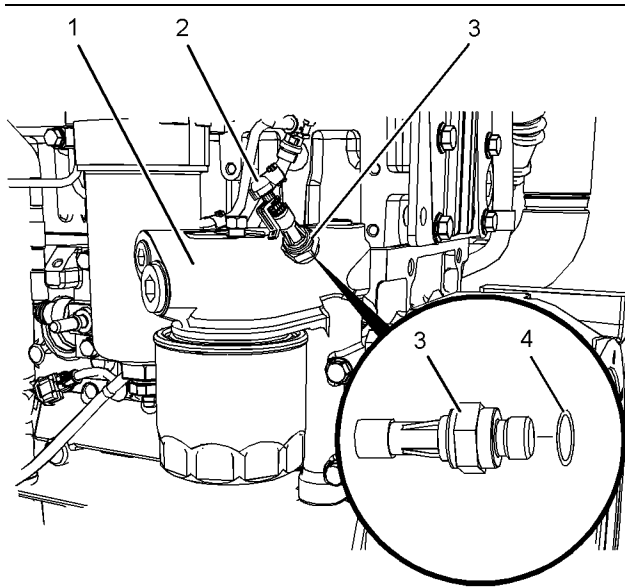


Illustration 323

g02673736

1. Install a new O-ring seal (4) onto engine oil pressure switch (3).
2. Install engine oil pressure switch (3) to oil filter head (1).
3. Using a deep socket tighten the oil pressure switch to a torque of 25 N·m (221 lb in).
4. Connect harness assembly (2) to engine oil pressure switch (3).

i05282736

## Fuel Temperature Sensor - Remove and Install

### Removal Procedure

Table 73

Required Tools			
Tool	Part Number	Part Description	Qty
A	T412504	Capping Kit	1

### WARNING

Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.

### NOTICE

Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorized personnel that have the correct training.

Before beginning ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.

Refer to System Operation, Testing and Adjusting, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.

### 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.

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.

1. Turn the fuel supply to the OFF position.
2. Turn the battery disconnect switch to the OFF position.

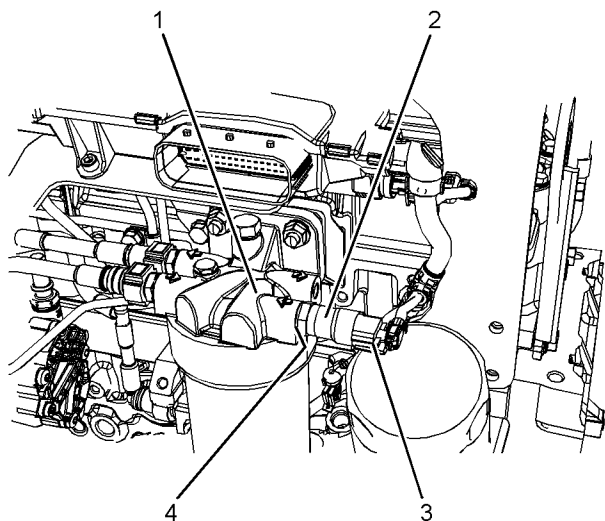


Illustration 324

g02876777

3. Disconnect harness assembly (3) from fuel temperature sensor (2).
4. Use a deep socket in order to remove fuel temperature sensor (2) from fuel filter base (1).
5. Use Tooling (A) to plug the open port of the fuel injection pump.
6. Remove sealing washer (4) (not shown) from fuel temperature sensor (2).

## Installation Procedure

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components are free from wear and damage. Replace any components that are worn or damaged.

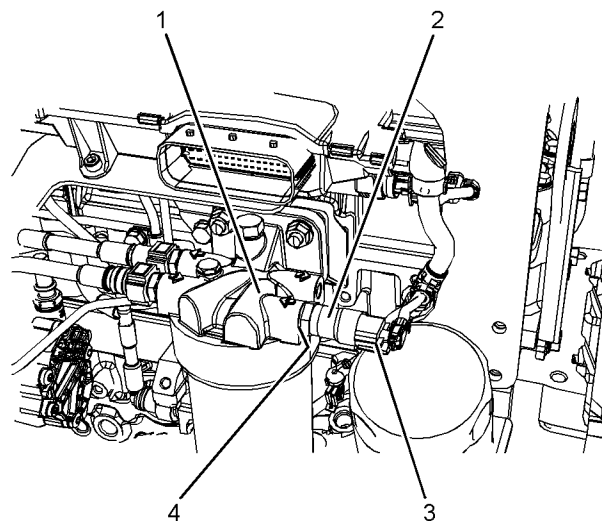


Illustration 325

g02876777

2. Ensure that the new sealing washer (4) (not shown) on the fuel temperature sensor (2) is free from damage.
3. Remove the plug from the fuel filter base (1).
4. Install fuel temperature sensor (2) to the fuel filter base. Use a deep socket to tighten the fuel temperature sensor to a torque of 22 N·m (195 lb in).
5. Connect harness assembly (3) to fuel temperature sensor (2).
6. Turn the fuel supply to the ON position.

7. Turn the battery disconnect switch to the ON position.

i05282745

## Oxygen Sensor - Remove and Install (Catalytic Converter)

### Removal Procedure

#### Start By:

- a. Turn the battery disconnect switch to the OFF Position.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

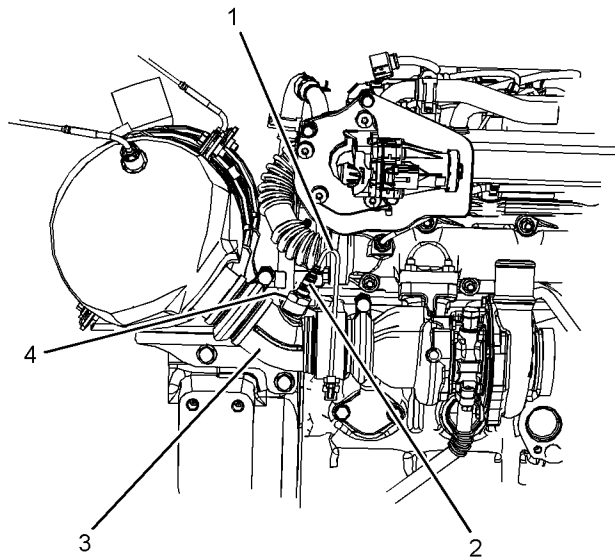


Illustration 326

g02725166

1. Disconnect harness assembly (1).
2. Remove oxygen sensor (2) from exhaust tube assembly (3).
3. Remove sealing washer (4) from the oxygen sensor.

### Installation Procedure

Table 74

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bostik Pure Nickel Anti-Seize Compound	1

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

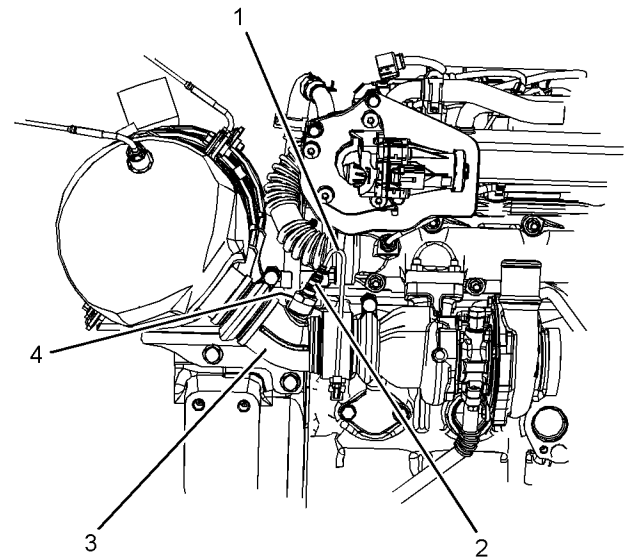


Illustration 327

g02725166

1. Install a new sealing washer (4) (not shown) to oxygen sensor (2).
2. Apply Tooling (A) to the threads of oxygen sensor (4) (not shown).
3. Install oxygen sensor (2) to exhaust tube assembly (3). Tighten the oxygen sensor to a torque of 50 N·m (37 lb ft).
4. Connect harness assembly (1).

**End By:**

- a. Turn the battery disconnect switch to the ON Position.
- b. When a new oxygen sensor is installed, it will be necessary to use the Electronic Service Tool (EST) in order to perform the "Lambda Sensor Replacement Reset", "Lambda Sensor Learn Reset" and "Lambda Sensor Temperature Learn Reset" procedures.

i05282750

## Temperature Sensor (Exhaust) - Remove and Install

### Removal Procedure

1. If necessary, remove the diesel particulate filter mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.

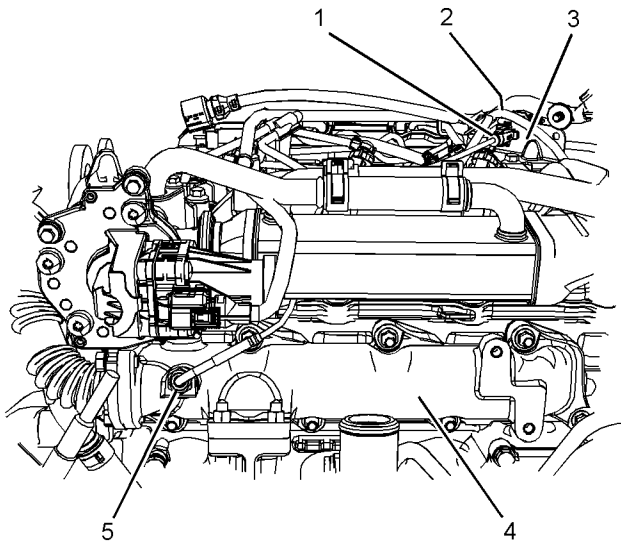


Illustration 328

g02876918

2. Disconnect harness assembly (2) (not shown) from exhaust temperature sensor connection (1).
3. Slide exhaust temperature sensor connection (1) out of bracket (3).
4. Remove exhaust temperature sensor (5) from exhaust manifold (4).

### Installation Procedure

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.

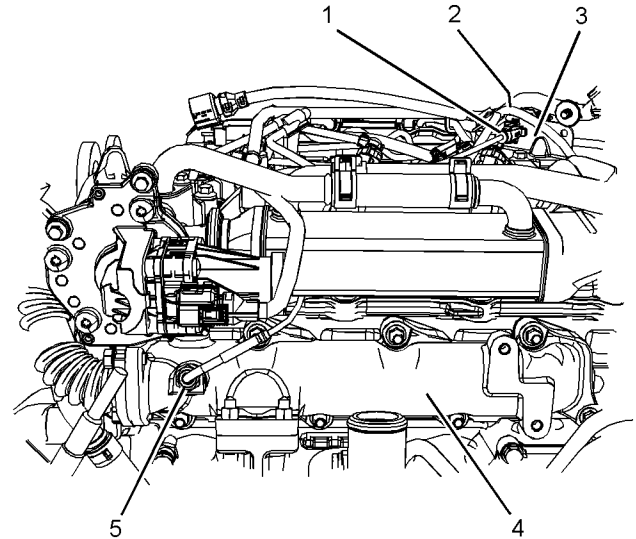


Illustration 329

g02876918

2. Install exhaust temperature sensor (5) to exhaust manifold (4). Tighten the exhaust temperature sensor to a torque of 45 N·m (33 lb ft)

**Note:** Ensure that the harness for the exhaust temperature sensor is correctly routed.

3. Slide exhaust temperature sensor connection (1) into bracket (3).
4. Connect harness assembly (2) (not shown) to exhaust temperature sensor connection (1).

- If necessary, install the diesel particulate filter mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.

i05282753

## Temperature Sensor (DPF) - Remove and Install

### Removal Procedure

#### NOTICE

Do not strike any part of the assembly of the Diesel Particulate Filter (DPF). Do not allow any object to contact the internal element of the DPF. If the internal element of the DPF becomes damaged, the assembly must be replaced.

#### NOTICE

The temperature sensors for the Diesel Particulate Filter (DPF) are of different lengths and should be installed in the original position.

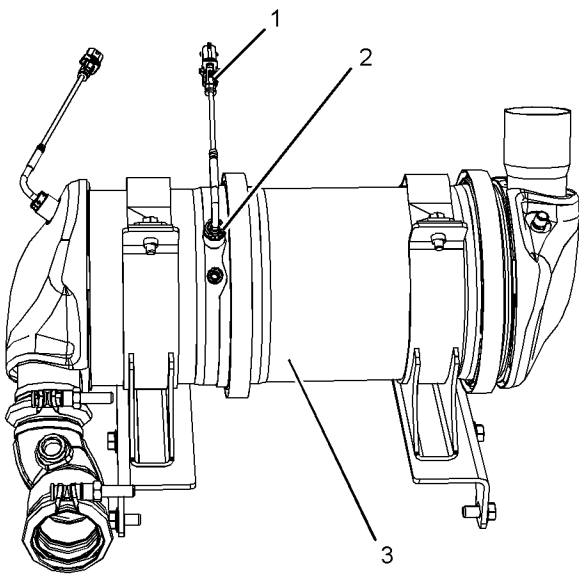


Illustration 330

g02728556

- Disconnect the harness assembly from connection (1).
- Make temporary identification marks on temperature sensor (2) for installation purpose. Remove the temperature sensor from Diesel Particulate Filter (DPF) (3).

- If necessary, repeat Step 1 through Step 2 in order to remove the remaining temperature sensor from the DPF.

### Installation Procedure

Table 75

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Bostik Pure Nickel Anti-Seize Compound	1

- Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.

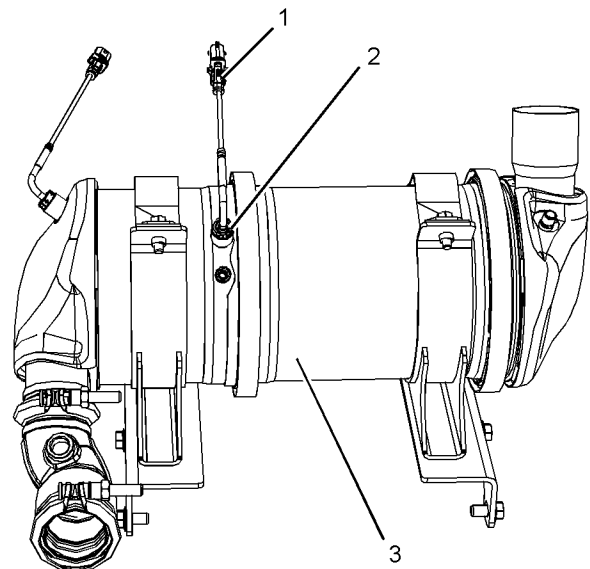


Illustration 331

g02728556

- Use tooling (A) in order to lubricate the thread of temperature sensor (2).
- Install temperature sensor (2) to DPF (3). Tighten temperature sensor to a torque of 50 N·m (37 lb ft)

**Note:** Ensure correct positioning of the temperature sensor.

- Connect harness assembly (1).

- If necessary, repeat Step 2 through Step 4 in order to install the remaining temperature sensor to the DPF.

i05282755

## Pressure Sensor (DPF) -Remove and Install

### Removal Procedure

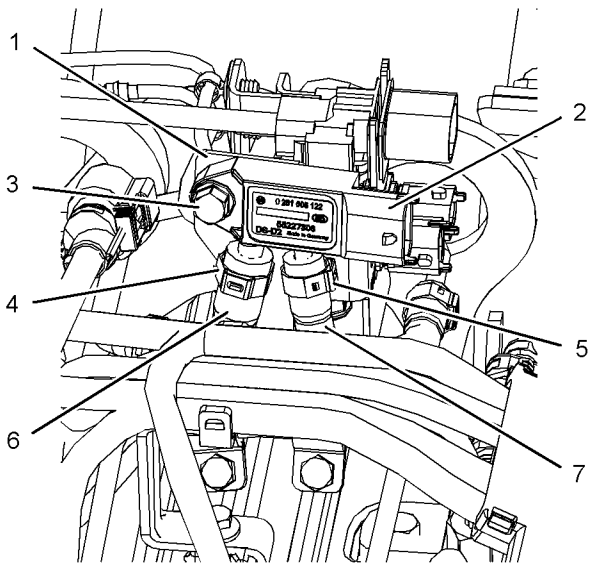


Illustration 332

g03005940

- Disconnect the harness connector from Diesel Particulate Filter (DPF) differential pressure sensor (2).
- Remove clip (4) from hose assembly (6). Remove clip (5) from hose assembly (7).
- Disconnect hose assembly (6) and hose assembly (7) from DPF differential pressure sensor (2).
- Remove bolt (3) from DPF differential pressure sensor (2).
- Remove DPF differential pressure sensor (2) from bracket (1).

### Installation Procedure

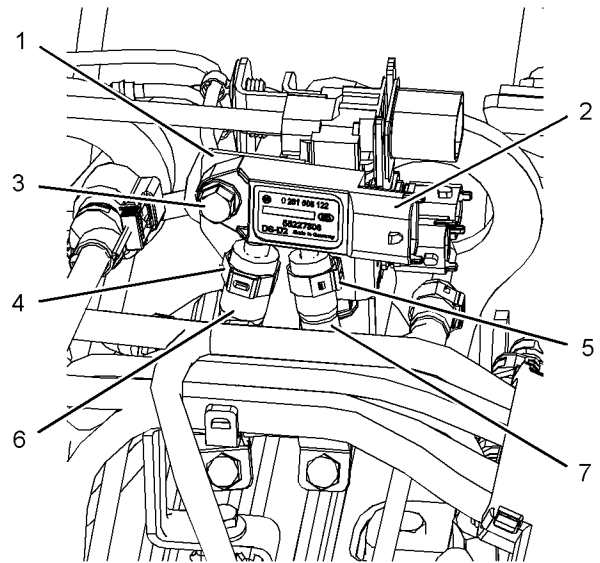


Illustration 333

g03005940

- Position DPF differential pressure sensor (2) onto bracket (1).
  - Install bolt (3) finger tight to DPF differential pressure sensor (2). Tighten the bolt to a torque of 9 N·m (80 lb in).
  - Position a new clip (4) onto hose assembly (6).
  - Install hose assembly (6) and clip (4) onto DPF differential pressure sensor (2). Tighten clip (4) securely.
- Note:** Do not over tighten clip (4).
- Position a new clip (5) onto hose assembly (7).
  - Install hose assembly (7) and clip (5) onto DPF differential pressure sensor (2). Tighten clip (5) securely.
- Note:** Do not over tighten clip (5).
- Connect the harness assembly to DPF differential pressure sensor (2).



**End By:**

- a. When a new DPF differential pressure sensor is installed, use the Electronic Service Tool (EST) in order to perform the "DPF Differential Pressure Sensor Replacement" procedure.

i05284598

## Pressure Sensor (Exhaust Back Pressure) - Remove and Install

### Removal Procedure

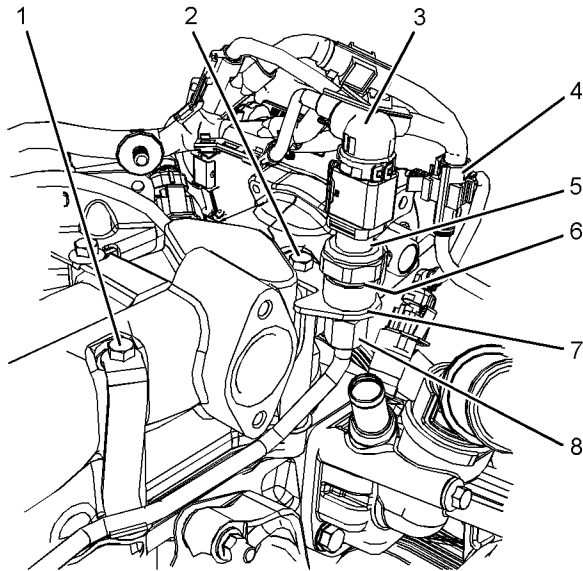


Illustration 334

g02917036

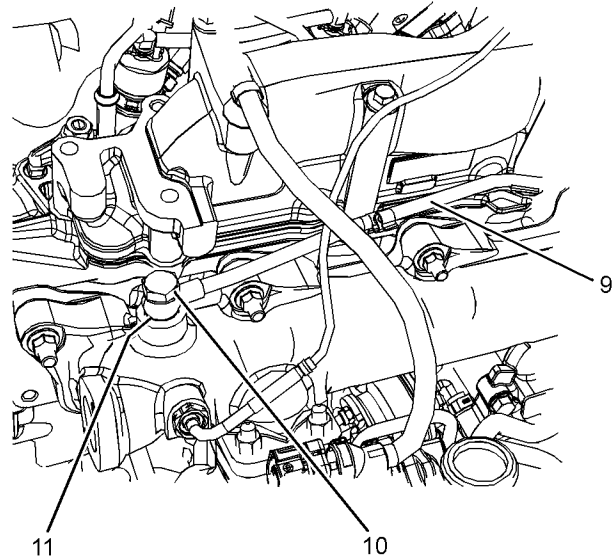


Illustration 335

g02915178

1. Slide the locking tab into the unlocked position and disconnect harness assembly (3) from exhaust back pressure sensor (5).
2. Using a deep socket in order to remove exhaust back pressure sensor (5) from adaptor bracket (7).
3. Remove O-ring (6) (not shown) from exhaust back pressure sensor (5).
4. If necessary, follow Step 4.a through Step 4.j in order to remove tube assembly (6).
  - a. If necessary, remove the diesel particulate mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.
  - b. If necessary, remove the exhaust gas recirculation cooler. Refer to Disassembly and Assembly, "Exhaust Cooler (NRS) - Remove and Install" for the correct procedure.
  - c. If necessary, remove the exhaust gas temperature sensor. Refer to Disassembly and Assembly, "Temperature Sensor (Exhaust) - Remove and Install" for the correct procedure.
  - d. Disconnect harness assembly (4) from the retaining clip.
  - e. Loosen nut (8) and disconnect tube assembly (9).
  - f. Remove bolt (2) and remove adaptor bracket (7) from the induction manifold.
  - g. Remove banjo bolt (10) from tube assembly (9).

## Disassembly and Assembly Section

- h. Remove bolt (1) from the bracket for tube assembly (9).
- i. Remove tube assembly (9) from the exhaust manifold.
- j. Remove and sealing washers (11) (not shown).

## Installation Procedure

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.

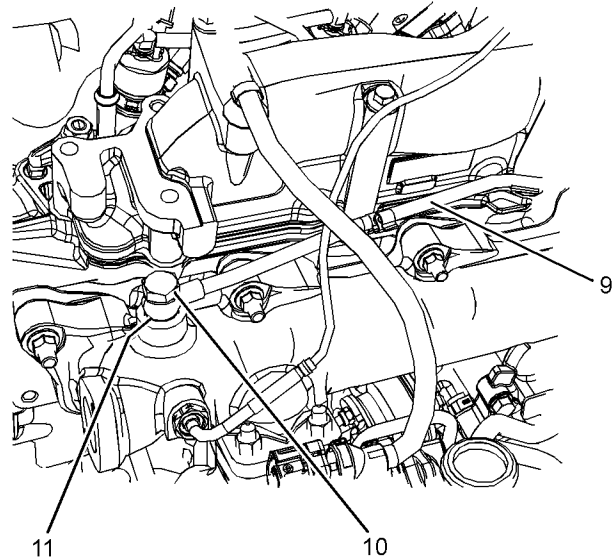


Illustration 336

g02915178

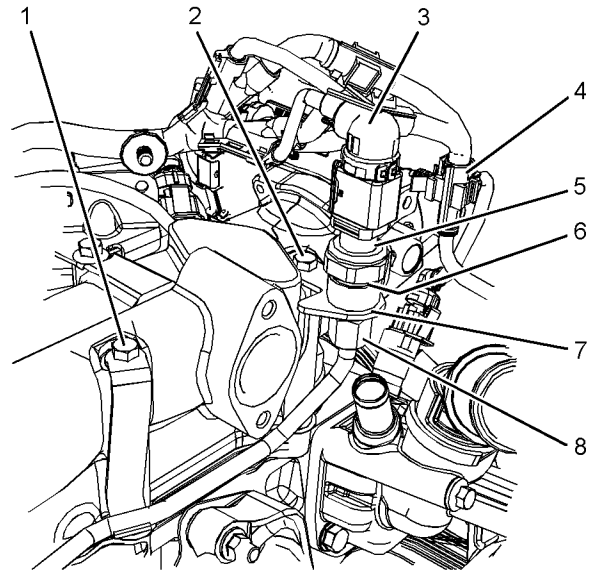


Illustration 337

g02917036

2. If necessary, follow Step 2.a through Step 2.i in order to install tube assembly (6).
  - a. Install a new sealing washer (11) (not shown) to banjo bolt (10).
  - b. Install banjo bolt assembly (10) into tube assembly (9). Install the remaining new sealing washer (11) (not shown) to banjo bolt assembly (10).
  - c. Install tube assembly (9) onto the exhaust manifold and exhaust back pressure sensor

- bracket (7). Tighten banjo bolt assembly (10) finger tight.
- d. Install bolt (1) to the bracket for tube assembly (6).
  - e. Position adaptor bracket (7) onto the induction manifold and install bolt (2).
  - f. Tighten nut (8) finger tight.
  - g. Tighten bolt (1) and bolt (2) to a torque of 25 N·m (221 lb in).
  - h. Tighten banjo bolt (10) to a torque of 15 N·m (133 lb in).
  - i. Tighten nut (8) to a torque of 15 N·m (133 lb in).
3. Install new O-ring seal (6) (not shown) to exhaust back pressure sensor (5).
  4. Install exhaust back pressure sensor (5). Tighten the sensor to a torque of 15 N·m (133 lb in)
  5. Connect harness assembly (3) to exhaust back pressure sensor (5) and slide the locking tab into the locked position.
  6. If necessary, install the exhaust gas temperature sensor. Refer to Disassembly and Assembly, "Temperature Sensor (Exhaust) - Remove and Install" for the correct procedure.
  7. If necessary, install the exhaust gas recirculation cooler. Refer to Disassembly and Assembly, "Exhaust Cooler (NRS) - Remove and Install" for the correct procedure.
  8. If necessary, install the diesel particulate mounting bracket. Refer to Disassembly and Assembly, "Support and Mounting (CEM) - Remove and Install" for the correct procedure.
  9. Install harness assembly (4) onto exhaust back pressure sensor bracket (7).

10. Install bolt (2) to exhaust back pressure sensor (4). Tighten the bolt to a torque of 25 N·m (221 lb in).

i05296475

## Inlet Manifold Temperature Sensor - Remove and Install

### Removal Procedure

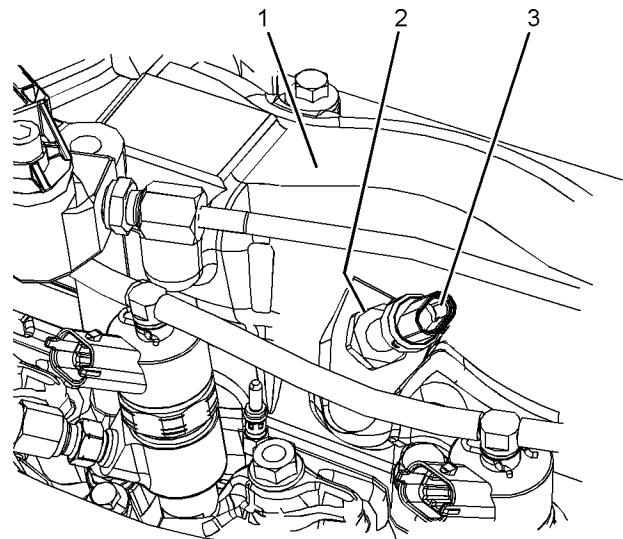


Illustration 338

g03366344

1. Disconnect the wiring harness assembly (not shown) from inlet manifold temperature sensor (3).
2. Remove inlet manifold temperature sensor (3) from inlet manifold (1).
3. Remove seal (2) (not shown) from the inlet manifold temperature sensor.

## Installation Procedure

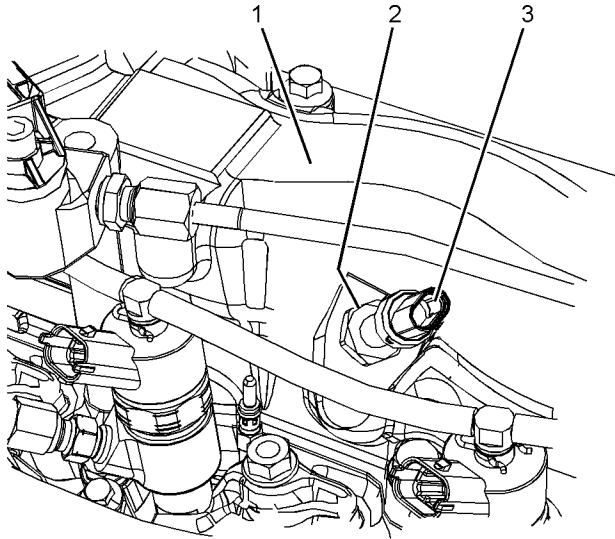


Illustration 339

g03366344

1. Install new seal (2) (not shown) to the inlet manifold temperature sensor (3).
2. Install inlet manifold temperature sensor (3) to inlet manifold (1). Tighten the inlet manifold temperature sensor to a torque of 25 N·m (221 lb in).

3. Connect the wiring harness assembly (not shown) to inlet manifold temperature sensor (3).

i05296471

## Inlet Manifold Pressure Sensor - Remove and Install

### Removal Procedure

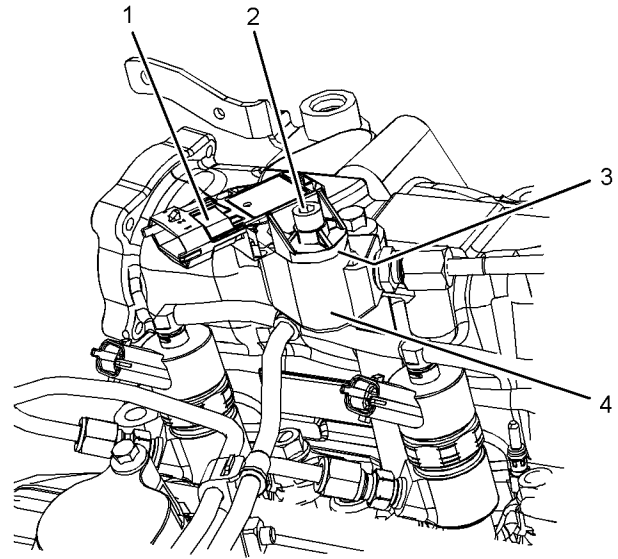


Illustration 340

g03364100

1. Disconnect the wiring harness assembly (not shown) from inlet manifold temperature sensor (1).
2. Remove Allen head bolt (2) from inlet manifold temperature sensor (1).
3. Remove inlet manifold temperature sensor (1) from inlet manifold temperature sensor housing (4).
4. Remove seal (3) (not shown).
5. If necessary, follow Step 5.a through Step 5.f in order to remove inlet manifold temperature sensor housing (7) and tube assembly (6).

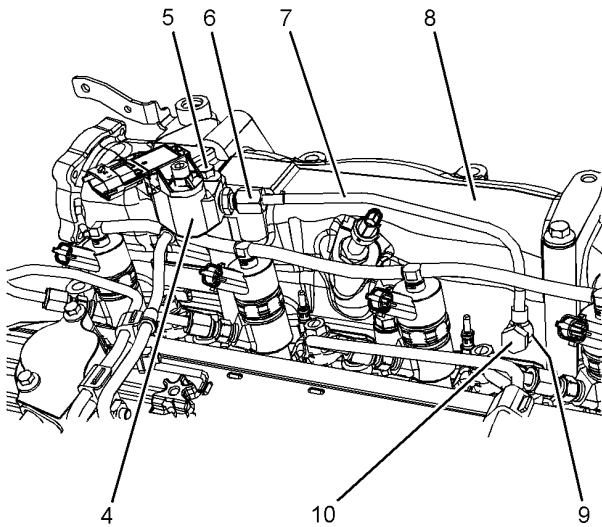


Illustration 341

g03364176

- a. Loosen nut (6) on tube assembly (7).
- b. Remove bolt (5) from inlet manifold temperature sensor housing (7).
- c. Disconnect tube assembly (7) from inlet manifold temperature sensor housing (4).
- d. Remove inlet manifold temperature sensor housing (4) from inlet manifold (8).
- e. Remove banjo bolt (10) and sealing washers (9) (not shown).
- f. Remove tube assembly (7).

## Installation Procedure

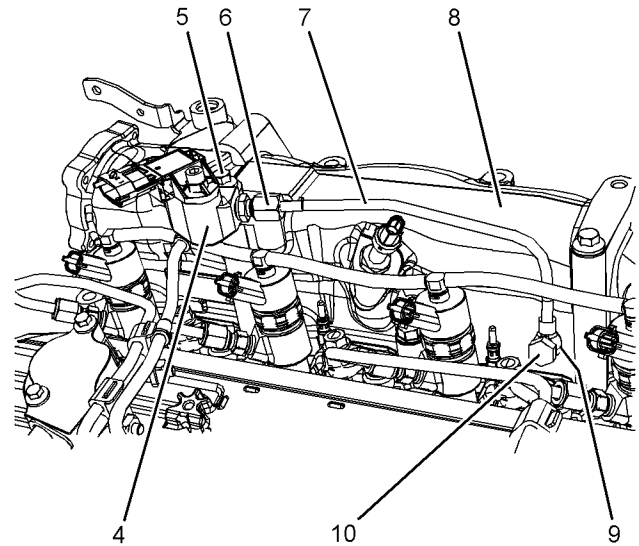


Illustration 342

g03364176

1. If necessary, follow Step 1.a through Step 1.f in order to install the inlet manifold temperature sensor housing (4) and tube assembly (7).
  - a. Install new sealing washers (9) (not shown) and banjo bolt (10) to tube assembly (7).
  - b. Position tube assembly onto induction manifold (8) and loosely install banjo bolt (10).
  - c. Position inlet manifold temperature sensor housing (4) onto inlet manifold (8). Tighten nut (6) finger tight.
  - d. Install bolt (5). Tighten the bolt to a torque of 10 N·m (89 lb in).
  - e. Tighten nut (6) to a torque of 10 N·m (89 lb in).
  - f. Tighten banjo bolt (10) to a torque of 10 N·m (89 lb in).

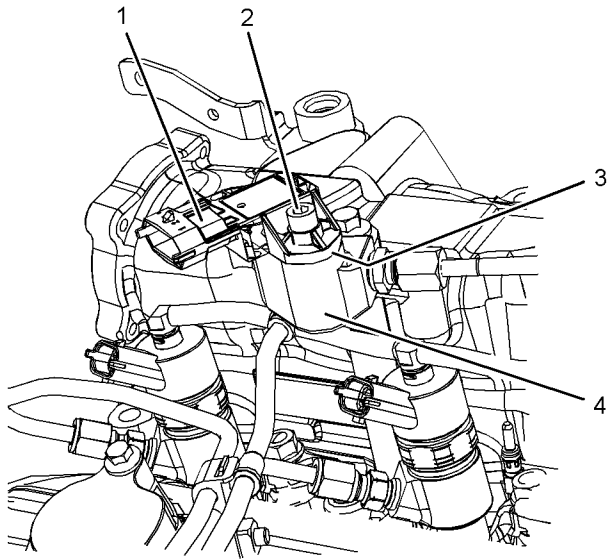


Illustration 343

g03364100

2. Install new seal (3) (not shown) to inlet manifold temperature sensor (1).
3. Install inlet manifold temperature sensor (1) to inlet manifold temperature sensor housing (4).
4. Install Allen head bolt (2). Tighten the Allen head bolt to a torque of 10 N·m (89 lb in)

i05284612

## Glow Plugs - Remove and Install

### Removal Procedure

#### Start By:

- a. Remove the combined inlet manifold temperature and pressure sensor. Refer to Disassembly and Assembly, "Inlet Manifold Temperature and Pressure Sensor - Remove and Install" for the correct procedure.

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the battery disconnect switch to the OFF position.

2. If necessary, remove the Exhaust Gas Recirculation (EGR) valve. Refer to Disassembly and Assembly, "Exhaust Gas Recirculation Valve - Remove and Install" for the correct procedure.

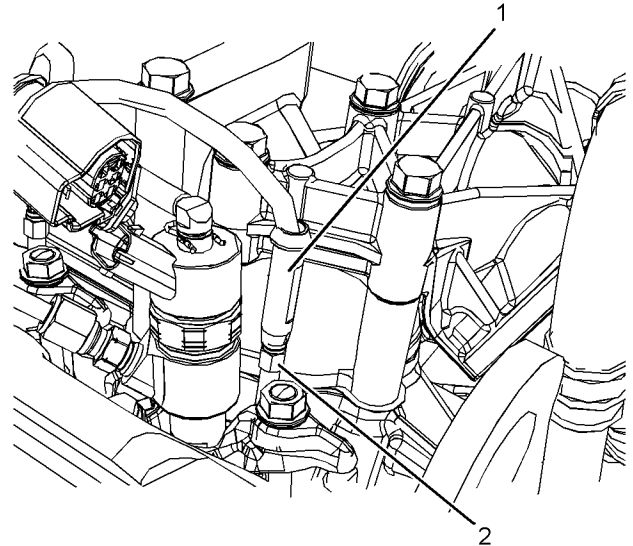


Illustration 344

g02837996

3. Disconnect wiring harness (1) from the glow plugs (2).

**Note:** Make temporary identification marks on the wiring harness assembly for installation purposes.

4. Clean the area around the glow plugs. Ensure that the area is free from contamination before removal of the glow plugs.
5. Use a deep socket in order to remove glow plugs (2) from the cylinder head.

### Installation Procedure

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

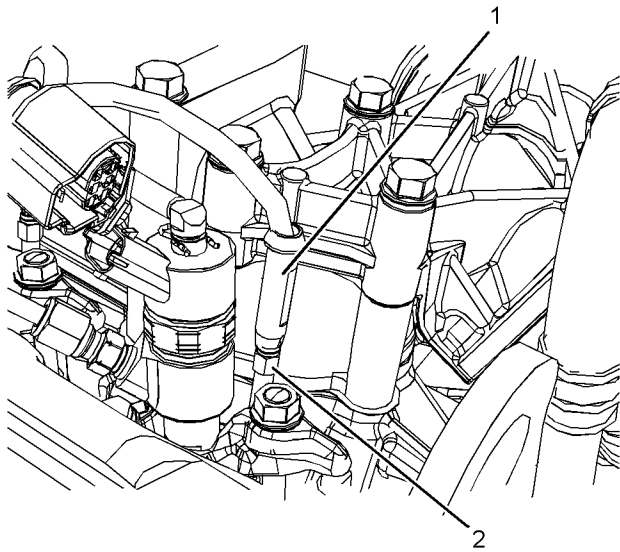


Illustration 345

g02837996

1. Before installing glow plugs (5), ensure that the glow plugs are operating correctly. Refer to Troubleshooting, "Glow Plug Starting Aid - Test" "Check the Operation of the Glow Plugs" for the correct procedure.
2. Ensure that the threads of the glow plugs are clean and free from damage. Replace any damaged glow plugs.
3. Install glow plugs (2) into the cylinder head . Tighten the glow plugs to a torque of 9 N·m (80 lb in).
4. Connect wiring harness (1) to glow plugs (2).
5. Turn the battery disconnect switch to the ON position.
6. If necessary, install the Exhaust Gas Recirculation (EGR) valve. Refer to Disassembly and Assembly, " Exhaust Gas Recirculation Valve - Remove and Install" for the correct procedure.

**End By:**

- a. Install the combined inlet manifold temperature and pressure sensor. Refer to Disassembly and Assembly, "Inlet Manifold Temperature and Pressure Sensor - Remove and Install" for the correct procedure.

i05284613

## Alternator Belt - Remove and Install

### Removal Procedure

1. If the engine has guards, remove the guards. Refer to the Original Equipment Manufacture (OEM) for the correct procedure.

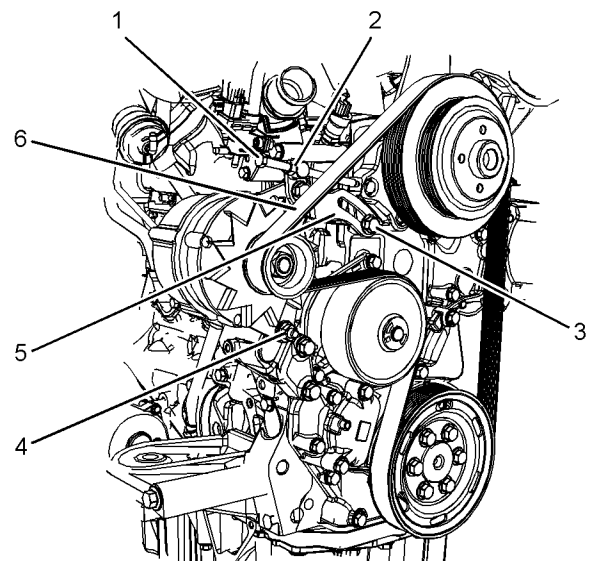


Illustration 346

g02553437

#### Typical example

2. Loosen locking nut (2) and alternator tensing bolt (1).
3. Loosen nut and bolt (4).
4. Loosen bolt (3) for adjusting bracket (5).
5. Remove alternator belt (6).

**Note:** Note the routing of the alternator belt before removal.

## Installation Procedure

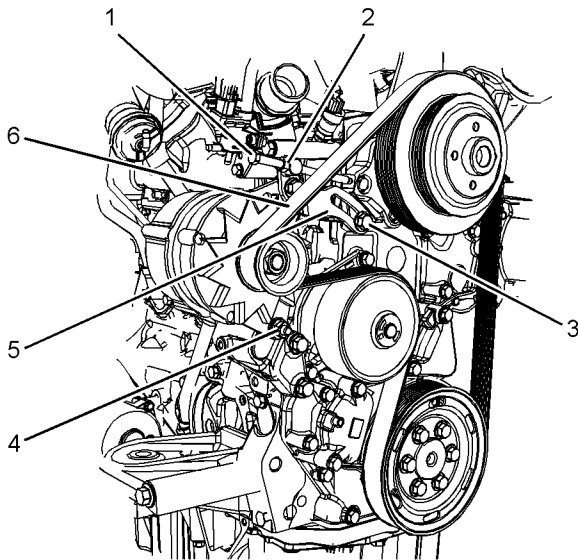


Illustration 347

g02553437

Typical example

**Note:** The ribs on the alternator belt must be located into the grooves of all pulleys.

4. Tighten bolt (1) until adjusting bracket (5) has reached the full extent of the available adjustment in Position (A).
5. Tighten bolt (3) to a torque of 50 N·m (37 lb ft).
6. Tighten nut and bolt (4) to a torque of 50 N·m (37 lb ft).
7. Rotate tensioning bolt (1) two complete revolutions in a counterclockwise direction. Tighten locking nut (2) to a torque of 30 N·m (266 lb in).
8. If the engine has guards, install the guards. Refer to the OEM for the correct procedure.

i05284614

## Idler Pulley - Remove and Install

### Removal Procedure

**Start By:**

- a. **Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove" for the correct procedure.**

#### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

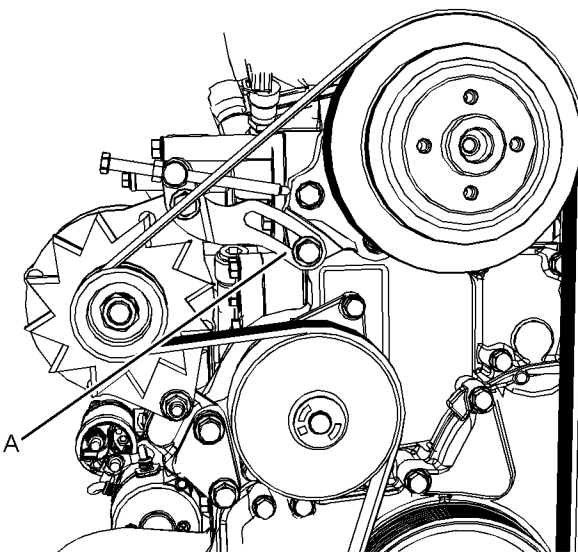


Illustration 348

g02553697

1. Ensure that all components of the pulleys and guide rollers are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.
2. Ensure that the pulleys and guide rollers are free from dirt and build up from the old belt.
3. Position new alternator belt (6). Ensure that the alternator belt is centered on all pulleys.



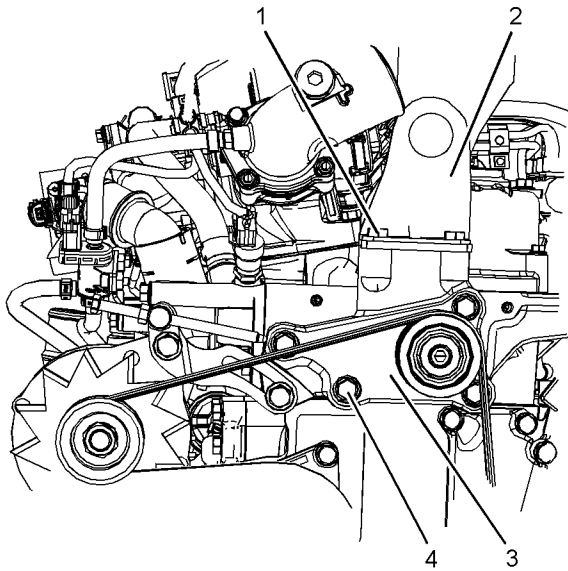


Illustration 349

g02710322

Typical example

1. If necessary, remove bolts (1) and remove engine lifting bracket (2).
2. Remove bolt (4) and remove idler pulley (3).

## Installation Procedure

### NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that all components of the idler pulley are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.

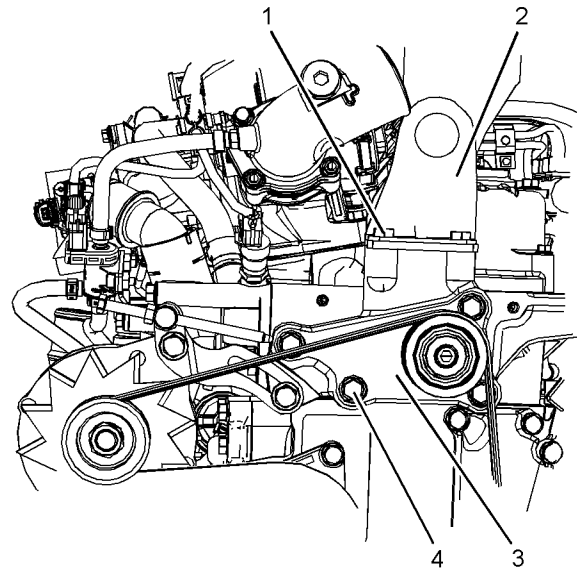


Illustration 350

g02710444

Typical example

2. Install bolts (4) to idler pulley (3). Position idler pulley (3) onto the cylinder head.
3. Tighten bolt (4) to a torque of 40 N·m (30 lb ft).
4. If necessary, install bolts (1) to engine lifting bracket (2). Position the engine lifting bracket onto the idler pulley.
5. Tighten bolt (1) to a torque of 40 N·m (30 lb ft).

**End By:**

- a. Install a new alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Install" for the correct procedure.

i05284618

**Fan - Remove and Install****Removal Procedure****Start By:**

- a. Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

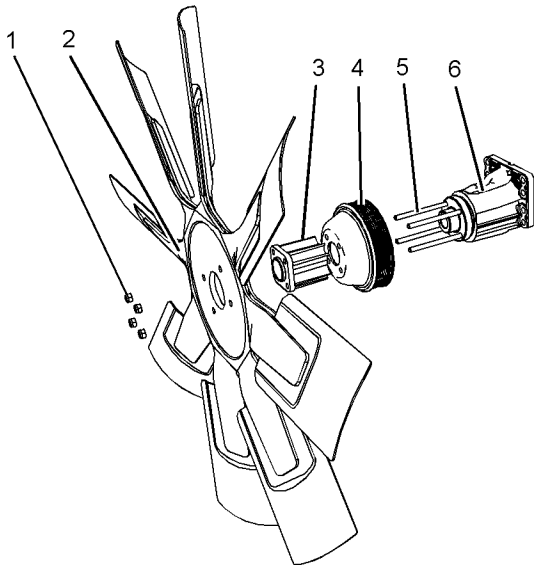


Illustration 351

g02829456

Typical example

1. Remove nuts (1).
  2. Remove fan (2).
- Note:** Note the orientation of the fan.
3. Remove fan adapter (3).
  4. Remove fan pulley (4).
  5. If necessary, remove studs (5) from fan drive (6).

**Installation Procedure**

1. Ensure that all the components are free from wear and damage. If necessary, replace any components that are worn or damaged.

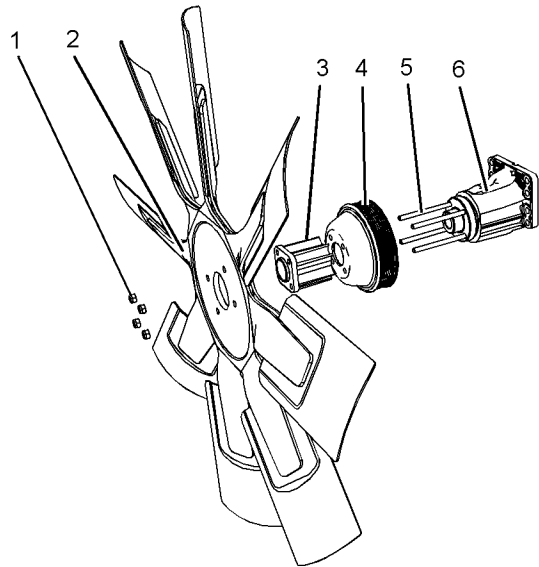


Illustration 352

g02829456

Typical example

2. If necessary, install studs (5) to fan drive (6). Tighten studs (5) to a torque of 11 N·m (97 lb in).
  3. If studs (5) have not been previously removed from fan drive (6). Check for the correct installation of the studs to the fan drive. Tighten studs (5) to a torque of 25 N·m (221 lb in).
  4. Install fan pulley (4).
  5. Install fan adapter (3).
  6. Install fan (2).
- Note:** Ensure that the fan is correctly oriented.
7. Inspect the condition of locking nuts (1). If necessary, replace the locking nuts. Install locking nuts (1). Tighten locking nuts (1) to a torque of 22 N·m (195 lb in).

**End By:**

- a. Install the Alternator Belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

i05284619

**Fan Drive - Remove and Install****Removal Procedure**

1. If necessary, remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install" for the correct procedure.

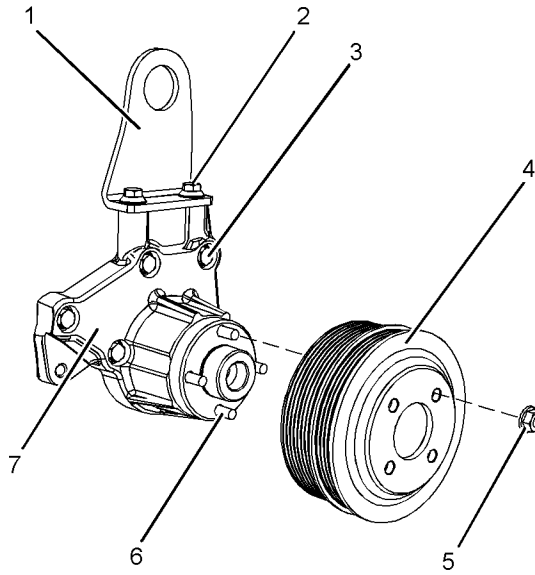


Illustration 353

g02827145

2. If necessary, remove nuts (5) from studs (6).
3. Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.
4. Remove fan drive pulley (4).
5. Remove the alternator belt tensioning bracket. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.
6. Remove bolts (3) and remove the fan drive assembly (7) from the cylinder head.
7. If necessary, follow Step 7.a through Step 7.b in order to disassemble the fan drive assembly.
  - a. Remove studs (6) from the fan drive (7).
  - b. Remove bolts (2) and remove lifting bracket (1).

## Installation Procedure

1. Check all components for wear and damage. If necessary, replace any components that are worn or damaged.

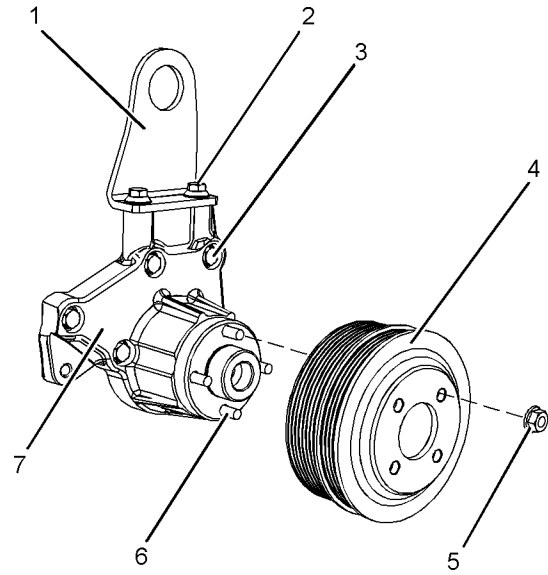


Illustration 354

g02827145

2. If necessary, follow Step 2.a through Step 2.b in order to assemble the fan drive.
  - a. Install studs (6) to fan drive (7). Tighten the studs to a torque of 18 N·m (159 lb in)
  - b. Position lifting bracket (1) onto fan drive (7). Install bolts (2) to lifting bracket (1). Tighten the bolts to a torque of 45 N·m (33 lb ft).
3. Position fan drive (7) onto the cylinder head. Install bolts (3) and tighten the bolts to a torque of 25 N·m (221 lb in).
4. Position fan drive pulley (4) onto studs (6).
5. If necessary, install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install" for the correct procedure.
6. Install the alternator belt tensioning bracket. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.
7. Install nuts (5) and tighten the nuts to a torque of 25 N·m (221 lb in).

8. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

i05284622

## Alternator - Remove

### Removal Procedure

#### Start By:

- a. **Remove the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.**
1. Turn the battery disconnect switch to the OFF position.

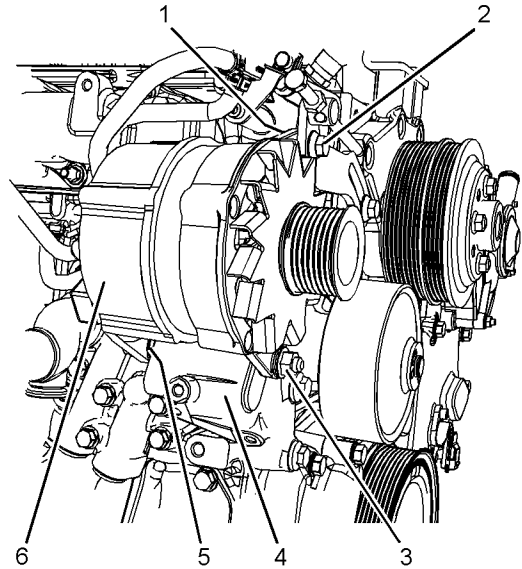


Illustration 355

g02673920

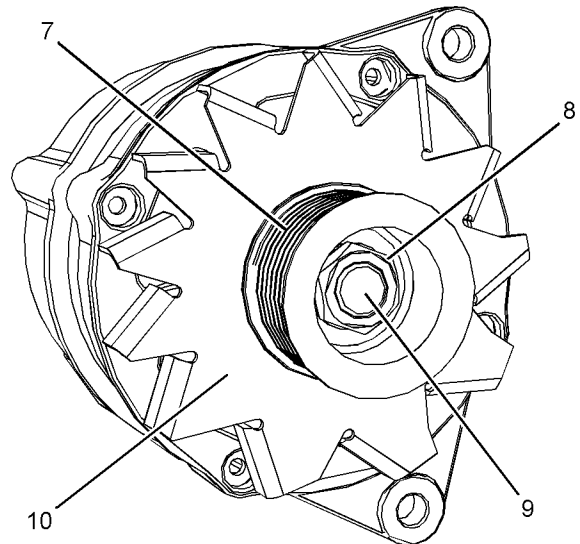


Illustration 356

g02815777

2. Make temporary marks on the alternator harness in order to identify the locations for the connections during the assembly procedure.
3. Disconnect the harness assembly from alternator (6).
4. Support the weight of the alternator and remove nut (1) and bolt (2).
5. Remove nut (3) and bolt (5) (not shown) from alternator (6).
6. Remove alternator (6) from alternator bracket (4).

7. If necessary, follow Step 7.a through Step 7.e in order to remove pulley (7) from alternator (6).

**Note:** A suitable tool may be required in order to carry out the removal of the alternator pulley.

- a. Place the alternator in a suitable support.
- b. Hold shaft (9) of alternator (6) with a suitable tool. Use a cranked ring spanner to loosen nut (8).
- c. Make a temporary mark on pulley (7) in order to show the correct orientation.
- d. Remove nut (8) and pulley (7) from shaft (9).
- e. Remove fan (10) from shaft (9).

**Note:** Support the weight of the alternator bracket as the bolts are removed.

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## Alternator - Install

### Installation Procedure

1. Ensure that all components are clean and free from wear and damage. If necessary, replace any components that are worn or damaged.
2. If necessary, follow Step 2.e through Step 2.f in order to install alternator bracket (11) onto the cylinder block.

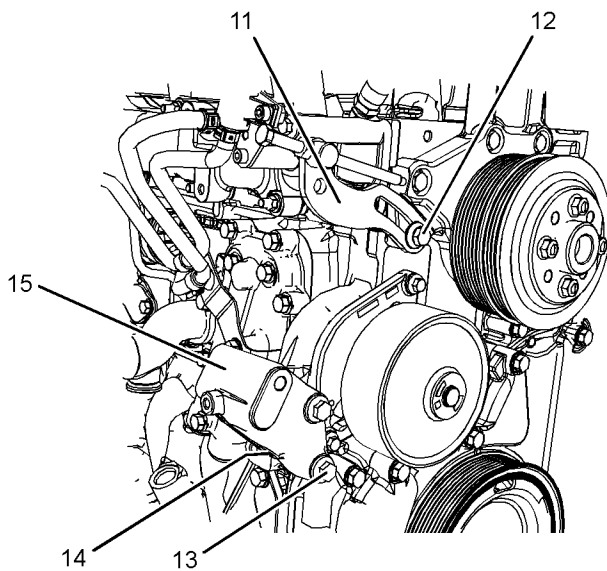


Illustration 357

g02815797

8. If necessary, follow Step 8.a through Step 8.c in order to remove tensioner (11) and alternator bracket (14) from the cylinder block.
- a. Remove bolt (12) and remove tensioner bracket (11).
  - b. If necessary, remove bolt (14) (not shown) from the coolant tube assembly.
  - c. Remove bolts (13) from alternator bracket (15). Remove the alternator bracket from the cylinder block.

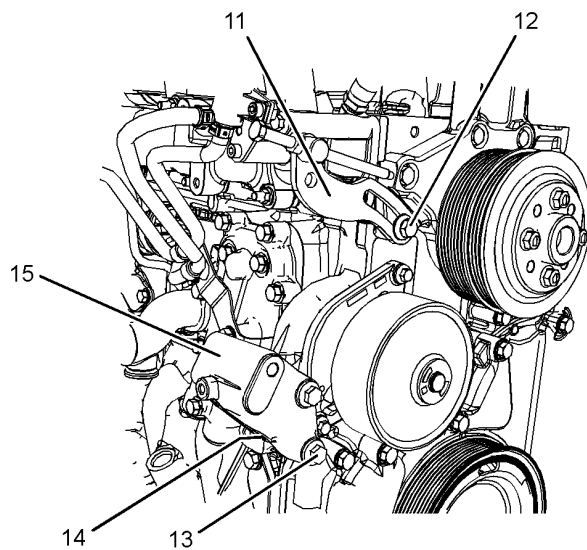


Illustration 358

g02815797

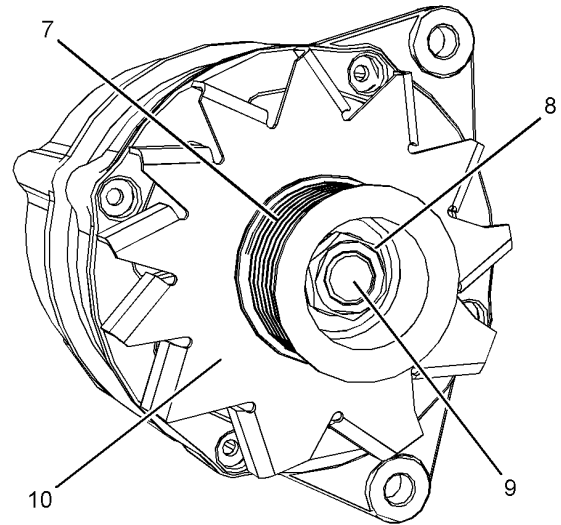


Illustration 360

g02815777

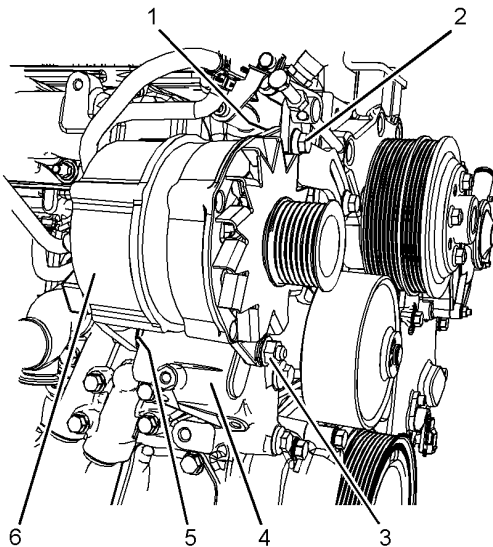


Illustration 359

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- a. Position bracket (14) onto the cylinder block.
  - b. Install bolts (13) to bracket (14).
  - c. If necessary, install bolt (13) to the coolant tube assembly.
  - d. Tighten bolts (13) to a torque of 50 N·m (37 lb ft).
  - e. Position tensioner (11) onto the fan drive assembly.
  - f. Install bolt (12) to tensioner (11) finger tight.
3. If necessary, follow Step 3.a through Step 3.f in order to install pulley (8) to alternator (2).
    - a. Place alternator (6) in a suitable support.
    - b. Ensure that fan (10) is correctly oriented.
    - c. Install fan (10) to shaft (9).
    - d. Ensure that pulley (7) is correctly oriented.
    - e. Install pulley (7) and a new nut (8) to alternator shaft (9).
    - f. Position a cranked ring spanner onto nut (9). Use a suitable tool in order to turn the shaft of the alternator in a counterclockwise direction. Tighten the nut to the correct torque. Refer to Specifications, "Alternator" for the correct torque.
  4. Position the alternator onto bracket (4) and tensioner (11).
  5. Install bolt (5) (not shown) and nut (3) finger tight.

6. Install bolt (2) and nut (1) (not shown) finger tight.
7. Install the alternator belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.
8. Tighten the nut and bolt (2) to a torque of 50 N·m (37 lb ft).
9. Tighten nut and bolt (5) to a torque of 50 N·m (37 lb ft).
10. Connect the wiring harness assembly to the alternator. Refer to Specifications, "Alternator" for the correct torque.
11. Turn the battery disconnect switch to the ON position.

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## Electric Starting Motor - Remove and Install

### Removal Procedure

#### 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. Turn the battery disconnect switch to the OFF position.
2. Place identification marks on the harness assembly that is connected to the electric starting motor and the solenoid.

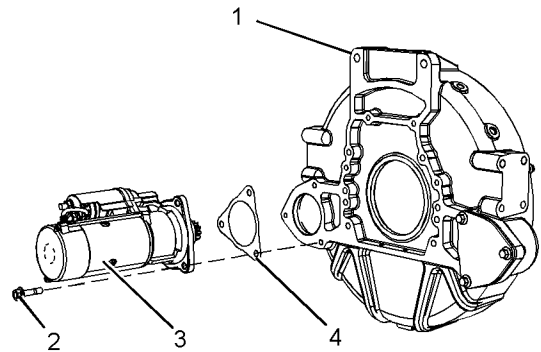


Illustration 361

g02844537

#### Typical example

3. Disconnect the harness assembly from the electric starting motor and the solenoid.
4. Support electric starting motor (3).
5. Remove bolts (2) from electric starting motor (3).
6. Remove electric starting motor (3).
7. If a gasket is installed, remove gasket (4).

### Installation Procedure

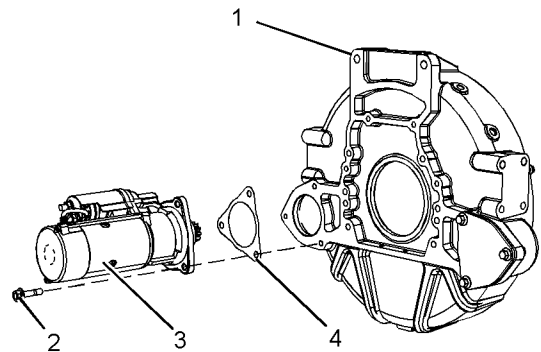


Illustration 362

g02844537

#### Typical example

1. If necessary, position a new gasket (4) onto electric starting motor (3).
2. Position electric starting motor (3) onto flywheel housing (1).

**Note:** Ensure that the electric starting motor is seated correctly in the starter motor pocket.

3. Install bolts (2) to electric starting motor (3). Tighten the bolts to a torque of 45 N·m (33 lb ft).
4. Connect the harness assembly to the electric starting motor and the solenoid.

5. Turn the battery disconnect switch to the ON position.



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