Disassembly and Assembly

2506-15 Industrial Engine

MGA (Engine)
MGB (Engine)
MGD (Engine)
**Important Safety Information**

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

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

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

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

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

![WARNING](image)

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.

Operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

**Perkins 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. If a tool, procedure, work method or operating technique that is not specifically recommended by Perkins is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.**

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. Perkins dealers or Perkins distributors have the most current information available.

![WARNING](image)

*When replacement parts are required for this product Perkins recommends using Perkins replacement parts. Failure to heed this warning can lead to premature failures, product damage, personal injury or death.*
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Disassembly and Assembly Section

Fuel Priming Pump - Remove and Install

Removal Procedure

1. Turn the fuel supply to the “OFF” position.

2. Remove bolts (2). Remove fuel priming pump assembly (1) from fuel filter base (4).

3. Remove joint (3) from the fuel priming pump assembly and the fuel filter base.

Installation Procedure

1. Position a new joint (3) on fuel filter base (4).

  Note: Ensure correct orientation of the joint.

2. Position the fuel priming pump assembly (1) on the fuel filter base and install bolts (2). Tighten the 1/4" bolt to a torque of 12 N·m (105 lb in). Tighten the 5/16" bolt to a torque of 25 N·m (221 lb in).

3. Turn the fuel supply to the “ON” position.

4. Remove the air from the system. Refer to Systems Operation, Testing and Adjusting, “Fuel System - Prime”.

Fuel Filter Base - Remove

Removal Procedure

1. 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.

2. 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.
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Disassembly and Assembly Section

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. Place a suitable container below the fuel filter base in order to drain the fuel from the fuel filter assemblies (10) and (12).

3. Remove plugs (9) and (11). Allow the fuel to drain.

4. Disconnect harness assembly (1) from fuel temperature sensor (2).

Note: In order to disconnect the harness assembly, slide the locking tab into the unlocked position.

5. Disconnect hose assembly (3). Disconnect hose assemblies (7) and (8). Plug the open hose assemblies.

6. Use a suitable tool with a 1/2" square drive in order to remove fuel filter assemblies (10) and (12). Remove the O-ring seals. Remove the fuel filter elements. Refer to Operation and Maintenance Manual, "Fuel Filter - Replace" for more information.


Fuel Filter Base - Disassemble

Disassembly Procedure

Start By:

a. Remove the fuel filter base. Refer to Disassembly and Assembly, "Fuel Filter Base - Remove".

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Remove fuel priming pump (4) from fuel filter base assembly (1). Refer to Disassembly and Assembly, "Fuel Priming Pump - Remove and Install".

2. Remove fuel temperature sensor (2) from fuel filter base assembly (1). Refer to Disassembly and Assembly, "Fuel Temperature Sensor - Remove and Install".

3. Remove fuel bypass valve (6) from fuel filter base assembly (1). Remove the O-ring seals from the fuel bypass valve.

4. Remove fuel check valve (10) from fuel filter base assembly (1). Remove the O-ring seals from the fuel check valve.

5. Remove connections (3), (5), (7) and (8) from fuel filter base assembly (1). Remove the O-ring seals from the connections.

6. Remove plugs (9), (11) and (12) from fuel filter base assembly (1). Remove the O-ring seals from the plugs.
Fuel Filter Base - Assemble

Assembly Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

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

2. Install new O-ring seals to plugs (9), (11) and (12). Install the plugs to fuel filter base assembly (1). Tighten plug (9) to a torque of 41 N·m (30 lb ft). Tighten plugs (11) and (12) to a torque of 15 N·m (11 lb ft).

3. Install new O-ring seals to connections (3), (5), (7) and (8). Install the connections to fuel filter base assembly (1). Tighten connections (3), (5) and (7) to a torque of 15 N·m (11 lb ft). Tighten connection (8) to a torque of 41 N·m (30 lb ft).

Note: Ensure correct orientation of the connections.

4. Install new O-ring seals to fuel bypass valve (6). Install the fuel bypass valve to fuel filter base assembly (1). Tighten fuel bypass valve (6) to a torque of 35 N·m (26 lb ft).

5. Install new O-ring seals to fuel check valve (10). Install the fuel check valve in fuel filter base assembly (1). Tighten the fuel check valve to a torque of 35 N·m (26 lb ft).

6. Install fuel temperature sensor (2) to fuel filter base assembly (1). Refer to Disassembly and Assembly, “Fuel Temperature Sensor - Remove and Install”.

7. Install fuel priming pump (4) to fuel filter base assembly (1). Refer to Disassembly and Assembly, “Fuel Priming Pump - Remove and Install”.

End By:

a. Install the fuel filter base. Refer to Disassembly and Assembly, “Fuel Filter Base - Install”.

Fuel Filter Base - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Position fuel filter base (6) and install bolts (4). Tighten the bolts to a torque of 47 N·m (35 lb ft).

2. Install new O-ring seals and new fuel filter elements to fuel filter assemblies (10) and (12). Use a suitable tool with a 1/2” square drive in order to install the fuel filter assemblies.
Install new O-ring seals to plugs (9) and (11). Install the plugs to fuel filter assemblies (10) and (12).

Refer to Operation and Maintenance Manual, “Fuel Filter - Replace” for more information.

3. Connect hose assemblies (3), (5), (7) and (8).

4. Connect harness assembly (1) to fuel temperature sensor (2). Slide the locking tab into the locked position.

5. Turn the fuel supply to the “ON” position.

6. Remove the air from the system. Refer to Systems Operation, Testing and Adjusting, “Fuel System - Prime”.

Fuel Transfer Pump - Remove

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.

1. Turn the fuel supply to the “OFF” position.

2. Place a suitable container below the fuel transfer pump in order to catch any fuel that might be spilled.

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3. Disconnect hose assemblies (2) and (3) from fuel transfer pump (1). Plug the open hose assemblies.

4. Remove bolts (4) and remove fuel transfer pump (1).

5. Remove the O-ring seal from fuel transfer pump (1).

Fuel Transfer Pump - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that the fuel transfer pump is clean and free from damage.

2. Lubricate a new O-ring seal with clean engine oil. Install the O-ring seal to fuel transfer pump (1).
3. Position fuel transfer pump (1) on pump drive (5).

**Note:** Ensure that the splines on the shaft of the fuel transfer pump are correctly engaged into the pump drive.

4. Install bolts (4). Tighten the bolts to a torque of 47 N·m (35 lb ft).

5. Remove the plugs from the hose assemblies. Connect hose assemblies (2) and (3) to fuel transfer pump (1).

6. Turn the fuel supply to the "ON" position.

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

---

**Electronic Unit Injector - Remove**

**Removal Procedure**

**Table 1**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
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<tbody>
<tr>
<td>A</td>
<td>27610288</td>
<td>Pry Bar</td>
<td>1</td>
</tr>
</tbody>
</table>

**Start By:**

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

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Turn the fuel supply to the OFF position.

2. Disconnect harness assembly (1) from electronic unit injector (2).

3. Remove valve bridges (3).

**NOTICE**

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

4. Remove bolts (8) and washers (9). Remove harness assembly (1) and support bracket (7) as a unit.

5. Remove bolt (4) and spacer (5).

6. Place an identification mark on electronic unit injector (2) for installation purposes. Each electronic unit injector must be reinstalled in the original location in the cylinder head.
7. Use Tooling (A) to pry beneath the base and free electronic unit injector (2).

8. Remove electronic unit injector (2) and clamp (6) from the cylinder head.

9. Remove O-ring seals (11) and (12) from electronic unit injector (2).

### Electronic Unit Injector - Install

#### Installation Procedure

<table>
<thead>
<tr>
<th>Required Tools</th>
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<tr>
<td><strong>Tool</strong></td>
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<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>E</td>
</tr>
<tr>
<td>F</td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Use Tooling (D) to clean the carbon deposit from the inside of the electronic unit injector sleeve.

2. Use Tooling (B) to remove the fuel and oil from the cylinder. Evacuate as much fuel and oil as possible from the cylinder before installing the electronic unit injector. Several evacuations may be necessary.

3. Ensure that seat area (X) on the electronic unit injector is clean and free carbon.

4. Install new O-ring seals (11) and (12) on the electronic unit injector. Lubricate the O-ring seals with clean engine oil.
5. Install a new O-ring seal (13) on the electronic unit injector.  

**Note:** O-ring seal (13) should be installed dry.

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**NOTICE**

If a replacement electronic unit injector is installed, the calibration code must be programmed into the electronic control module. Refer to Troubleshooting Guide, "Injector Trim File" for more information.

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6. Install clamp (6) to electronic unit injector (2). Install electronic unit injector (2) into the original location in the cylinder head.

7. Install spacer (5) and bolt (4). Tighten bolt (4) to a torque of 55 N·m (41 lb ft).

---

8. Install harness assembly (1) and support bracket (7) as a unit. Install bolts (8) and washers (9). Tighten bolts (8) to a torque of 105 N·m (77 lb ft).

9. Connect harness assembly (1) to electronic unit injector (2). Use Tooling (E) to tighten the nuts to a torque of 2.5 N·m (22 lb in).

10. Install bridge assemblies (3) in the respective locations.

**Note:** Ensure that used valve bridges are reinstalled in the original location and the original orientation. Do not interchange the location or the orientation of used valve bridges.

11. Install the rocker arms and the rocker arm shaft. Refer to Disassembly and Assembly, “Rocker Arm and Shaft - Install”.

12. Turn the fuel supply to the “ON” position.

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

---

**Electronic Unit Injector Sleeve - Remove**

**Removal Procedure**

**Start By:**

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

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

1. Drain the coolant from the engine. Refer to Operation and Maintenance Manual, "Cooling System Coolant - Change".

---

**Table 3**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>GE50021</td>
<td>Injector Sleeve Tool</td>
<td>1</td>
</tr>
</tbody>
</table>
2. Install Tooling (A) in electronic unit injector sleeve (1).

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

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

**Electronic Unit Injector Sleeve - Install**

**Installation Procedure**

Table 4

<table>
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<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>GE50021</td>
<td>Injector Sleeve Tool</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>GE50023</td>
<td>Tapered Brush</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>GE50024</td>
<td>Small Bore Brush</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>GE50022</td>
<td>End Brush</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>CV60893</td>
<td>Retaining Compound</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

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

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

3. Apply a small continuous bead of Tooling (C) to surface (X) of electronic unit injector sleeve (1).

4. Lubricate O-ring seals (2) with clean engine oil.

5. Position Tooling (A) and the electronic unit injector sleeve in the cylinder head. Use care not to damage the O-ring seals on the electronic unit injector sleeve.

6. Use Tooling (A) to install electronic unit injector sleeve (1) in the cylinder head.

**Note:** Ensure that the electronic unit injector sleeve is properly seated in the cylinder head.

7. Remove Tooling (A). Use a clean towel and remove excess Tooling (C).

8. Fill the cooling system with coolant. Refer to Operation and Maintenance, "Refill Capacities" for the cooling system capacity.

**End By:**

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

**NOTICE**

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

**Removal Procedure**

**Start By:**

a. Remove the exhaust elbow. Refer to Disassembly and Assembly, "Exhaust Elbow - Remove and Install".

---

**NOTICE**

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

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. Disconnect the air hoses for the turbocharger inlet and for the turbocharger outlet.

2. Follow Steps 2.a through 2.c in order to remove the tube assembly (7) for the oil feed.
   
   a. Remove tube clamp (9) that secures tube assembly (7) to tube assembly (8). Note the position of the clamp.
   
   b. Disconnect tube assembly (7) from the engine oil filter base.
   
   c. Remove bolts (3). Remove tube assembly (7) and joint (2) from turbocharger (1).

3. Follow Steps 3 through 3.c in order to remove the tube assembly (8) for the oil drain.
   
   a. Remove bolts (6).
b. Remove tube assembly (8) and joint (5).

c. Remove O-ring seal (10) from tube assembly (8).

4. Attach a suitable lifting device to turbocharger (1). The weight of the turbocharger is approximately 30 kg (66 lb).

5. Remove the fasteners for the turbocharger. Use the lifting device to remove turbocharger (1) from the exhaust manifold. Remove gasket (4).

Turbocharger - Install

Installation Procedure

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CV60889</td>
<td>Anti-Seize Compound</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

Illustration 19

1. Clean the mating surfaces of the exhaust manifold. Position a new gasket (4) on the exhaust manifold.

2. Attach a suitable lifting device to turbocharger (1). The weight of turbocharger is approximately 30 kg (66 lb). Use the lifting device to install turbocharger (1) onto the exhaust manifold.

3. Apply Tooling (A) to the threads of the exhaust manifold bolts. Install the bolts and install locknuts finger tight.

4. Install a new O-ring seal (10) to tube assembly (8). Install tube assembly (7) and new joint (5). Install bolts (6) finger tight.

5. Install tube assembly (7) and a new joint (2). Install bolts (3) finger tight. Connect the lower end of tube assembly (7) to the engine oil filter base.
6. Install tube clamp (9) to tube assembly (7) to tube assembly (8).

**Note:** Ensure that the clamp is installed in the correct position.

7. Tighten the fasteners for the turbocharger to a torque of 55 N·m (41 lb ft).

8. Tighten the bolts for tube assemblies (7) and (8) to a torque of 47 N·m (35 lb ft).

9. Connect the air hoses for the turbocharger inlet and for the turbocharger outlet.

5. If necessary, remove the taperlock studs from the cylinder head.

### Installation Procedure

#### Table 6

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CV60889</td>
<td>Anti-Seize Compound</td>
<td>-</td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

1. Install the taperlock studs in the cylinder head and tighten to a torque of 35 N·m (26 lb ft).

2. Assemble exhaust manifolds (4), (5) and (6).

3. Install the exhaust manifold gaskets onto the taperlock studs.

4. Install the assembly of the exhaust manifolds on the taperlock studs.

**Note:** Ensure that the holes in exhaust manifolds are centralized with the taperlock studs.

5. Apply Tooling (A) to the threads of the taperlock studs. Install spacers (1), washers (2) and locknuts (3).

### Exhaust Manifold - Remove and Install

#### Removal Procedure

**Start By:**

a. Remove the turbocharger. Refer to Disassembly and Assembly, “Turbocharger - Remove”.

b. Remove the water temperature regulator housing. Refer to Disassembly and Assembly, “Water Temperature Regulator Housing - Remove and Install”.

1. Remove locknuts (3), washers (2) and spacers (1).

2. Remove exhaust manifolds (4), (5) and (6).

**Note:** Remove manifolds as one assembly.

3. Remove the exhaust manifold gaskets.

4. Remove exhaust manifolds (4) and (6) from exhaust manifold (5).
6. Tighten the locknuts in a numerical sequence that is shown in Illustration 22. Tighten the locknuts to a torque of 38 N·m (28 lb ft).

End By:

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

b. Install the turbocharger. Refer to Disassembly and Assembly, "Turbocharger - Install".

Exhaust Elbow - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Use an allen wrench in order to loosen clamp (1) that secures the exhaust elbow.

2. Remove the exhaust elbow and the clamp from the turbocharger.

Installation Procedures

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the exhaust elbow and the outlet of the turbocharger. Inspect the components for wear or damage. Replace any components that are worn or damaged.

2. Position clamp (1) and install the exhaust elbow to the turbocharger. Ensure correct orientation of the band clamp.

3. Tighten the allen head bolt to a torque of 13.5 N·m (10 lb ft).

Inlet and Exhaust Valve Springs - Remove and Install

Removal Procedure

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CH11148</td>
<td>Engine Turning Tool</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>GE50026</td>
<td>Valve Spring Compressor</td>
<td>1</td>
</tr>
</tbody>
</table>
Start By:

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

**NOTICE**

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

**Note:** The following procedure should be adopted in order to remove the valve springs when the cylinder head is installed to the engine. Refer to Disassembly and Assembly Manual, “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.

1. Use Tooling (A) to position the appropriate piston at the top center position before the valve spring is removed.

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

**NOTICE**

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

**Note:** Valve springs must be replaced in pairs for the inlet valves or the exhaust valves 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 6, 2 with 5, and 3 with 4. Ensure that all of the valve springs are installed before changing from one pair of cylinders to another pair of cylinders.

**WARNING**

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

Make sure to wear all necessary protective equipment.

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

2. Install Tooling (B) in the electronic unit injector sleeve. Secure Tooling (B) with unit injector clamp (1).

3. Tighten the nut until valve keepers (3) are loose on valves (2).

4. Remove valve keepers (3).

5. Loosen the nut in order to release the pressure on Tooling (B). Remove unit injector clamp (1). Carefully remove Tooling (B).

6. Remove valve rotators (4).

7. Remove outer valve springs (6) and inner valve springs (5).

8. Remove washers (7) from the valve guide.
Installation Procedure

Table 8

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Inspect the valve springs for damage and for the correct length. Refer to Specifications Manual, “Cylinder Head Valves”.

2. Lubricate the valve stems with clean engine oil.

3. Install washers (7).

4. Install inner valve springs (5) and outer valve springs (6).

5. Position valve rotators (4) on the valve springs.

6. Use Tooling (B) to compress the valve springs. Install valve keepers (3).

7. Loosen the nut in order to release the pressure on Tooling (B). Remove unit injector clamp (1). Carefully remove Tooling (B).

8. Lightly strike the top of the valve with a soft faced hammer in order to ensure that valve keepers (2) are properly installed.

End By:

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

Inlet and Exhaust Valves - Remove and Install

Removal Procedure

Table 9

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

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.
Installation Procedure

Table 10

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Valve Spring Compressor</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>GE50027</td>
<td>Seal Installer</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

1. Inspect the valve springs for damage and for the correct length. Refer to Specifications Manual, “Cylinder Head Valves”.

**Note:** Valve springs must be replaced in pairs for the inlet valve or the exhaust valve of each cylinder.

2. Inspect the valves. Refer to Specifications, “Cylinder Head Valves” for additional information on the inlet and exhaust valves.

3. Use Tooling (B) in order to install new valve stem seals onto the valve guides.

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

4. Lubricate the valves with clean engine oil. Install the valves in the cylinder head.
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 washer (6).
6. Install inner valve spring (4) and outer valve spring (5).
7. Position valve rotator (3) on the valve springs.
8. Use Tooling (A) to compress valve springs. Install valve keepers (2).

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 remove Tooling (A). Lightly strike the top of the valve with a soft faced hammer in order to ensure that valve keepers (2) are properly installed.

End By:

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

Inlet and Exhaust Valve Guides - Remove and Install

Removal Procedure

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Start By:

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

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Use Tooling (A) and a hammer to remove valve guide (1) from the cylinder head.
**Installation Procedure**

### Table 12

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>GE50043</td>
<td>Valve Guide Tool</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>GE50044</td>
<td>Valve Guide Sleeve</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Lubricate the bores for the valve guides with clean engine oil.

2. Install valve guide (1) in the cylinder head with Tooling (A) and Tooling (B).

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

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

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

**End By:**

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

---

**Engine Oil Filter Base - Remove**

### Removal Procedure

**Start By:**

a. Remove the oil cooler. Refer to Disassembly and Assembly, “Engine Oil Cooler - Remove”.

**NOTICE**

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

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. Use a suitable tool with a 1/2” square drive in order to remove engine oil filter (5). Remove the O-ring seal. Remove the filter element. Refer to Operation and Maintenance Manual, “Engine Oil - Change” for more information.
2. Disconnect tube assembly (1).

3. Remove bolts (2) and bolts (4).

4. Remove engine oil filter base (3). Remove the O-ring seals from the engine oil filter base.

Engine Oil Filter Base - Disassemble

Disassembly Procedure

Start By:

a. Remove the engine oil filter base. Refer to Disassembly and Assembly, “Engine Oil Filter Base - Remove”.

---

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. Remove bolts (3). Remove elbow (1) from engine oil filter base (2). Remove the O-ring seals from the elbow.

2. Remove plug (5). Remove the O-ring seal from plug (5).

3. Remove spring (7).

4. Remove plunger (6).

5. If necessary, remove oil sampling valve (4) from the engine oil filter base. Remove the O-ring seal from the oil sampling valve.

---

Engine Oil Filter Base - Assemble

Assembly Procedure

---

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.
**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.

---

1. Inspect the components for wear or damage. Replace any components that are worn or damaged.

2. Lubricate plunger (6) and spring (7) with clean engine oil. Install the plunger and the spring into engine oil filter base (2).

3. Install a new O-ring seal to plug (5). Install plug (5) to engine oil filter base (2). Tighten plug (5) to a torque of 100 N·m (74 lb ft).

4. Install new O-ring seals to elbow (1). Position elbow (1) on the engine oil filter base and install bolts (3).

5. If necessary, install a new O-ring seal to oil sampling valve (4). Install oil sampling valve (4) to engine oil filter base (2). Tighten the oil sampling valve to a torque of 24 N·m (18 lb ft).

---

**End By:**

- Install the engine oil filter base. Refer to Disassembly and Assembly, “Engine Oil Filter Base - Install”.

---

**Engine Oil Filter Base - Install**

**Installation Procedure**

**NOTICE**

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

---

1. Install new O-ring seals to engine oil filter base (3).

2. Position engine oil filter base (3) on the engine and install bolts (2) and bolts (4). Tighten the bolts to a torque of 47 N·m (35 lb ft).

3. Connect tube assembly (1).

4. Install the oil cooler. Refer to Disassembly and Assembly, “Engine Oil Cooler - Install”.

5. Install a new O-ring seal to engine oil filter (5). Install engine oil filter (5) to engine oil filter base (3). Refer to Operation and Maintenance Manual, “Engine Oil - Change” for more information.
**Engine Oil Cooler - Remove**

**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.

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”.

2. Remove bolts (1). Remove outlet bonnet (3) from the cylinder block and from the engine oil cooler. Remove joint (2) and O-ring seal (7) from the outlet bonnet.

3. Remove bolts (8). Rotate core assembly (4) and slide the core assembly toward the rear of the engine in order to remove the core assembly from the engine oil filter base. Remove O-ring seals (9) from the engine oil filter base.

4. Remove bolts (11). Remove oil cooler bonnet (5) from the water pump. Remove joint (6) and O-ring seal (10) from the oil cooler bonnet.

**Engine Oil Cooler - Install**

**Installation Procedure**

**Table 13**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>-</td>
</tr>
</tbody>
</table>

**NOTICE**
Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

1. Install a new O-ring seal (10) to oil cooler bonnet (5). Apply Tooling (A) to the O-ring seal. Install joint (6) to oil cooler bonnet (5). Position the oil cooler bonnet on the water pump and install bolts (11). Tighten the bolts finger tight.

2. Install two new O-ring seals (9) to the engine oil filter base.

3. Slide core assembly (4) toward the front of the engine. Rotate the core assembly into position. Install bolts (8). Tighten the bolts finger tight.

4. Install a new O-ring seal (7) to outlet bonnet (3). Apply Tooling (A) to the O-ring seal. Install joint (2) to outlet bonnet (3). Position outlet bonnet (3) on the core assembly and install bolts (1). Tighten the bolts finger tight.

5. Tighten bolts (8), (1) and (11) to a torque of 47 N·m (35 lb ft).
6. Fill the cooling system. Refer to Operation and Maintenance Manual, “Cooling System Coolant - Change”.

7. Check the level of the engine lubricating oil. Refer to Operation and Maintenance Manual, “Engine Oil Level - Check”.

Engine Oil Pump - Remove

Removal Procedure

Start By:

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

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

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. Remove the fasteners and remove tube assembly (6). Remove the O-ring seal from the tube assembly.

2. Remove the fasteners and remove the assembly of the suction pipe (2). Remove the O-ring seal from the tube assembly.

3. Remove bolts (5) and remove engine oil pump (1) from the cylinder block.

4. If necessary, remove bolts (4) and remove underframe assembly (3).

Engine Oil Pump - Disassemble

Disassembly Procedure

**Start By:**

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

**NOTICE**
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

Table 14

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Puller (Three Leg)</td>
<td>1</td>
</tr>
</tbody>
</table>

Illustration 38

Typical example

Illustration 39
Disassembly and Assembly Section

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

![Illustration 40](g01101672)

**WARNING**

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

Spring force will be released when covers are removed.

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

2. Remove bolts (8). Remove retainer (5), spring (6), and relief plunger (7) from pump body (3).

3. Remove bolts (9) and cover (10).

4. Remove idler gear (12) and drive gear (13) from the pump body.

5. Use a suitable tool to remove sleeve bearings (4) from the pump body.

6. Use a suitable tool to remove sleeve bearings (11) from the cover.

![Illustration 41](g01103246)

Engine Oil Pump - Assemble

**Assembly Procedure**

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Use a press and a suitable tool to install sleeve bearings (4) in pump body (3). The bearing joint should be 30 ± 15 degrees from the center line of the two bearing bores. Install the sleeve bearings so the sleeve bearings are even with the outside of the pump body.

2. Use a press and a suitable tool to install sleeve bearings (11) in cover (10). The bearing joint should be 30 ± 15 degrees from the center line of the two bearing bores. Install the sleeve bearings so the sleeve bearings are even with the outside of the cover.
**WARNING**

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

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

3. Lubricate the idler gear and the drive gear with clean engine oil. Lubricate sleeve bearings (4) with clean engine oil. Install idler gear (12) and drive gear (13) in pump body (3).

4. Lubricate sleeve bearings (11) with clean engine oil. Install cover (10). Install bolts (9).

**Note:** The engine oil pump must turn freely after assembly. Turn the engine oil pump by hand. Reposition cover (10) if the engine oil pump does not turn freely.

5. Install relief plunger (7), spring (6), retainer (5), and bolts (8).

6. Install the key on the shaft.

---

### Engine Oil Pump - Install

#### Installation Procedure

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

![Illustration 44](g01101743)

Typical example

1. Position underframe assembly (3) on the cylinder block. Install bolts (4). Tighten the bolts to a torque of 47 N·m (35 lb ft).

2. Position engine oil pump (1) on the dowels in the cylinder block. Install bolts (5). Tighten the bolts to a torque of 47 N·m (35 lb ft).

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

3. Install a new O-ring seal to tube assembly (6). Lubricate the bore in the engine oil pump with clean engine oil. Install tube assembly (6). Install the bolts that secure the tube assembly. Tighten the bolts to a torque of 47 N·m (35 lb ft).

4. Install a new O-ring seal to the assembly of suction pipe (2). Lubricate the bore in the engine oil pump with clean engine oil. Install the assembly of suction pipe (2). Install the bolts and washers that secure the tube assembly. Tighten the bolts to a torque of 47 N·m (35 lb ft).

---

Illustration 45

[g01077736]

**End By:**

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

---

![Illustration 44](g01101743)

7. Install drive gear (1) on the shaft of engine oil pump (2). Install bolt (14). Tighten the bolt to a torque of 55 N·m (41 lb ft).

---

**End By:**

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

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.

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”.

2. Remove bolts (2) from water temperature regulator housing (1). Remove water temperature regulator housing (1) and pipe (3) as a unit. Remove the O-ring seals from the water temperature regulator housing and the pipe.

3. Remove bolts (5). Remove water pump cover (4) from water pump (8). Remove the O-ring seal from the water pump cover.

4. Remove bolts (7). Remove oil cooler bonnet (6) from the engine oil cooler. Remove the joint and the O-ring seal from the oil cooler bonnet.

5. Remove the belt tightener. Refer to Disassembly and Assembly, “Belt Tightener - Remove”.

6. Attach a suitable lifting device to water pump (8). Support the weight of the water pump. The water pump weighs approximately 18.3 kg (40 lb).

7. Remove bolts (9).

8. Use the lifting device in order to remove water pump (8) from the front housing. Remove the O-ring seal from the water pump.
Water Pump - Install

Installation Procedure

Table 15

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

2. Use a suitable lifting device in order to position water pump (8) on the front housing. The water pump weighs approximately 18.3 kg (40 lb).

3. Install bolts (9). Tighten the bolts to a torque of 47 N·m (35 lb ft).

4. Install the belt tightener. Refer to Disassembly and Assembly, “Belt Tightener - Install”.

5. Install a new O-ring seal on oil cooler bonnet (6). Apply Tooling (A) to the O-ring seal. Position the joint and install oil cooler bonnet (6) to the engine oil cooler. Install bolts (7). Tighten the bolts to a torque of 47 N·m (35 lb ft).

6. Install a new O-ring seal to water pump cover (4). Position water pump cover (4) on water pump (8) and install bolts (5). Tighten the bolts to a torque of 47 N·m (35 lb ft).

7. Install new O-ring seals to pipe (3). Apply Tooling (A) to the O-ring seals. Install the pipe in the water temperature regulator housing (1). Install a new O-ring seal to water temperature regulator housing (1).

8. Insert pipe (3) into water pump cover (4). Install the assembly of the water temperature regulator housing and pipe as a unit. Install bolts (2). Tighten the bolts to a torque of 47 N·m (35 lb ft).


Water Temperature Regulator Housing - 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.

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

Illustration 48
Typical example

2. Slide the locking tab into the unlocked position and disconnect the harness assembly from coolant temperature sensor (5).

3. Remove bolts (3). Remove pipe (4), water temperature regulator housing (1), and housing manifold (2).

Illustration 49
g01282552
VIEW A-A

4. Remove water temperature regulator housing (1) from housing manifold (2). Remove O-ring seal (7) and O-ring seal (6) from the housing manifold.

5. Remove water temperature regulators (8).

6. Remove lip seal (10).

7. Remove pipe (4) from the water temperature regulator housing. Remove O-ring seals (9) from pipe (4).

8. If necessary, remove coolant temperature sensor (5). Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install".

Installation Procedure

Table 16

| Required Tools |

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>27610309</td>
<td>Seal Installer</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>218200221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.
1. Use Tooling (A) to install lip seals (10) into water temperature regulator housing (1).

2. Install new O-ring seals (9) onto pipe (4). Apply Tooling (B) to the O-ring seals. Install pipe (4) to the water pump.

3. Install O-ring seal (6) and O-ring seal (7) to housing manifold (2).

4. Install water temperature regulators (8) into the water temperature regulator housing (1).

5. Loosely install bolts (3) to water temperature regulator housing (1) and housing manifold (2). Position water temperature regulator housing (1) and housing manifold (2) onto pipe (4). Tighten the bolts to a torque of 47 N·m (35 lb ft).

6. If necessary, install coolant temperature sensor (5). Refer to Disassembly and Assembly, "Coolant Temperature Sensor - Remove and Install".

7. Connect the harness assembly to coolant temperature sensor (5). Slide the locking tab into the locked position.

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

Engine Support (Front) - Remove and Install

Removal Procedure

Table 17

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tool</strong>, <strong>Part Number</strong>, <strong>Part Description</strong>, <strong>Qty</strong></td>
</tr>
<tr>
<td>A, -</td>
</tr>
</tbody>
</table>

Start By:

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

1. Support the front of the engine.
2. Remove bolts (1) and install Tooling (A). Remove the remaining bolts.

3. Remove engine support (2) from the cylinder block. The weight of engine support (2) is approximately 33.5 kg (74 lb).

Installation Procedure

<table>
<thead>
<tr>
<th>Table 18</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required Tools</strong></td>
</tr>
<tr>
<td><strong>Tool</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

1. Support the front of the engine.

Illustration 53  
Illustration 54

2. Position engine support (2) on Tooling (A). The weight of engine support (2) is approximately 33.5 kg (74 lb).

3. Install bolts (1) finger tight. Remove Tooling (A) and install the remaining bolts.

End By:

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

Flywheel - Remove

Removal Procedure

<table>
<thead>
<tr>
<th>Table 19</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required Tools</strong></td>
</tr>
<tr>
<td><strong>Tool</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Start By:

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

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Illustration 55

Typical example

1. Use a suitable tool to lock the flywheel. Loosen bolts (1).

2. Attach a suitable lifting device to flywheel (1). Support the weight of the flywheel. The weight of flywheel (2) is approximately 130 kg (286 lb).

3. Remove two bolts (1). Install Tooling (A).
4. Remove the remaining bolts (1). Use the lifting device in order to remove flywheel (2).

5. Inspect flywheel (2) and ring gear (3) for wear or damage. Replace any components that are worn or damaged.

6. To remove the flywheel ring gear, follow Steps 6.a and 6.b.

   a. Place the flywheel assembly on a suitable support.

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

   b. Use a hammer and a punch in order to remove ring gear (3) from flywheel (2).

Flywheel - Install

Installation Procedure

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tool</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

1. If the flywheel ring gear was removed, follow Steps 1.a through 1.c in order to install a new ring gear to the flywheel.

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

   Note: The chamfered side of the ring gear teeth must face toward the starting motor when the flywheel is installed. This will ensure the correct engagement of the starting motor.

   b. Heat flywheel ring gear (3) in an oven to a maximum temperature of 316 °C (600 °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 (2).

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".
3. Install a suitable lifting device to flywheel (1). The weight of flywheel (2) is approximately 130 kg (287 lb).

4. Install Tooling (A) on the crankshaft.

5. Use the lifting device in order to position flywheel (1) onto Tooling (A).

6. Apply clean engine oil to the threads of bolts (1).


8. Use a suitable tool to prevent the flywheel from rotating. Tighten bolts (1) to a torque of 270 N·m (200 lb ft).

9. Remove the lifting device from flywheel (1).

10. Check the runout of the flywheel. Refer to Systems Operations, Testing and Adjusting, "Flywheel - Inspect".

**End By:**

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

---

**Start By:**

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

---

**Notice**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

**Crankshaft Rear Seal - Remove**

**Removal Procedure**

**Table 21**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>27610311</td>
<td>Slide Hammer Puller</td>
<td>1</td>
</tr>
</tbody>
</table>

1. Use a 4 mm (0.158 inch) drill in order to make three or more holes in wear sleeve (2).

2. Use Tooling (A) to remove the wear sleeve.

3. Use a 4 mm (0.158 inch) drill in order to make three or more holes in crankshaft rear seal (1).

4. Use Tooling (A) to remove crankshaft rear seal (1).
Crankshaft Rear Seal - Install

Installation Procedure

Table 22

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>GE50008</td>
<td>Seal Locator</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>GE50009</td>
<td>Bolt</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>GE50014</td>
<td>Nut (Seal Installer)</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>GE50013</td>
<td>Seal Installer</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**Note:** Do not lubricate the crankshaft seal or the wear sleeve. The crankshaft seal must be installed dry.

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

2. Clean the outside diameter of the crankshaft and the inside diameter of the wear sleeve.

3. Fasten Tooling (B) to the crankshaft with Tooling (C).

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

4. Position wear sleeve (2) and crankshaft rear seal (1) on Tooling (B). Install Tooling (E) on Tooling (B). Lubricate the face of the washer on Tooling (D). Install Tooling (D) on Tooling (B).

5. Tighten Tooling (D) until Tooling (E) contacts Tooling (B).

6. Remove Tooling (D) and Tooling (E) from Tooling (B).

7. Remove Tooling (C) and Tooling (B) from the crankshaft.

8. Check the crankshaft rear seal and the wear sleeve for the correct installation.

End By:

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

Flywheel Housing - Remove and Install

Removal Procedure

Table 23

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Guide Stud (3/8 - 16 x 4 inch)</td>
<td>2</td>
</tr>
</tbody>
</table>
Start By:

a. Remove the electric starting motor. Refer to Disassembly and Assembly, “Electric Starting Motor - Remove”.

b. Remove the crankshaft rear seal. Refer to Disassembly and Assembly, “Crankshaft Rear Seal - Remove”.

c. Remove the engine oil pan. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install”.

NOTICE

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

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. Install a suitable lifting device to flywheel housing (1). The weight of the flywheel housing is approximately 86 kg (190 lb).

2. Remove two bolts (2). Install Tooling (A).

3. Remove remaining bolts (2). Use the suitable lifting device to remove the flywheel housing from the cylinder block.

Note: It is not necessary to remove the dowels in the cylinder block that locate the flywheel housing.

Installation Procedure

Table 24

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Guide Stud (3/8 - 16 x 4inch)</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>CH10879</td>
<td>Sealant</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the flywheel housing and the rear surface of the cylinder block. Ensure that the dowels in the cylinder block protrude 1.91 cm (0.75 inch) from the mating surface.

2. Install Tooling (A) in the cylinder block.

3. Install a suitable lifting device to flywheel housing (1). The weight of the flywheel housing is approximately 86 kg (190 lb).

4. Apply Tooling (B) to the rear face of the cylinder block.
Note: The flywheel housing must be installed within ten minutes of applying Tooling (B).

5. Use the suitable lifting device to align flywheel housing (1) with Tooling (A). Install the flywheel housing to the cylinder block. Install bolts (2) finger tight. Remove Tooling (A) and install the remaining bolts.

6. Tighten the bolts, as follows:

   a. In the numerical sequence, tighten bolt 1 through bolt 9 to a torque of 100 N·m (74 lb ft).

   b. In the numerical sequence, tighten bolt 10 through bolt 24 to a torque of 40 N·m (30 lb ft).

   c. In the numerical sequence, tighten bolt 1 through bolt 9 to a torque of 135 N·m (100 lb ft).

   d. In the numerical sequence, tighten bolt 10 through bolt 24 to a torque of 55 N·m (41 lb ft).

End By:

   a. Install the crankshaft rear seal. Refer to Disassembly and Assembly, "Crankshaft Rear Seal - Install".

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

   c. Install the electric starting motor. Refer to Disassembly and Assembly, "Electric Starting Motor - Remove and Install".

Vibration Damper and Pulley - Remove and Install

Removal Procedure

Table 25

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>Guide Stud (5/8 - 18 x 9 inch)</td>
<td>2</td>
</tr>
</tbody>
</table>

Start By:

   a. Remove the fan. Refer to Disassembly and Assembly, “Fan - Remove and Install”.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

End By:

1. Loosen nut (1). Rotate bolt (2) in order to release the tension on the V-belts.
2. Remove the V-belts from crankshaft pulley (6). Temporarily secure the V-belts in a position that is clear of vibration damper (4).

3. Remove two bolts (5). Install Tooling (A).

4. Remove remaining bolts (5). Remove crankshaft pulley (6).

**Note:** Ensure that the weight of the assembly of vibration damper (4) and adapter (3) is adequately supported.

5. Install a suitable lifting device to the assembly of vibration damper (4) and adapter (3). The weight of the assembly of the vibration damper and the adapter is approximately 50 kg (110 lb).

6. Use the lifting device to remove the assembly of vibration damper (4) and adapter (3) from the crankshaft.

7. Remove Tooling (A) from the crankshaft.

8. Remove bolts (7). Remove vibration damper (4) from adapter (3). The weight of vibration damper (4) is approximately 34 kg (75 lb).

---

### Installation Procedure

#### Table 26

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Guide Stud (5/8 - 18 x 9 inch)</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>CV60890</td>
<td>Anti-Seize Compound</td>
<td>-</td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

**NOTICE**

Thoroughly inspect the viscous damper for signs of leakage or for signs of a dented (damaged) case. Either of these conditions can cause the weight to make contact with the case. This can affect the viscous damper’s operation.

1. Inspect the components for damage. Replace any components that are damaged.

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

3. Position vibration damper (4) on adapter (3). The weight of vibration damper (4) is approximately 34 kg (75 lb).

4. Use Tooling (B) to lubricate threads of bolts (7). Install bolts (7) and tighten the bolts to a torque of 105 N·m (77 lb ft).
5. Install Tooling (A) in the crankshaft.

6. Install a suitable lifting device to the assembly of vibration damper (4) and adapter (3). The weight of the assembly of the vibration damper and the adapter is approximately 50 kg (110 lb). Use the lifting device to align the assembly of the vibration damper and the adapter with Tooling (A).

7. Install the assembly of adapter (3) and vibration damper (4) to the crankshaft.

8. Remove the lifting device.

**Note:** Ensure that the weight of the assembly of vibration damper (4) and adapter (3) is adequately supported.

9. Install crankshaft pulley (6) on Tooling (A).

10. Apply Tooling (B) to bolts (5). Install the bolts. Remove Tooling (A) and install the remaining bolts. Tighten the bolts to a torque of 270 N·m (200 lb ft).

11. Position the V-belts on crankshaft pulley (6) and the pulley of the belt tightener.

12. Rotate bolt (2) in order to adjust the tension of the V-belts. Refer to Operation and Maintenance Manual, "Belt Tension Chart".

13. Tighten nut (1).

**End By:**

a. Install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

---

**Crankshaft Front Seal - Remove**

**Removal Procedure**

<table>
<thead>
<tr>
<th>Table 27</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Required Tools</strong></td>
</tr>
<tr>
<td><strong>Tool</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

**Start By:**

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

NOTICE
Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

Note: The crankshaft front seal and the wear sleeve must be replaced as a unit. Once the crankshaft front seal and the wear sleeve are separated, these components cannot be used again.

Illustration 70
Typical example

1. Use a 4 mm (0.158 inch) drill in order to make three or more holes in wear sleeve (2).
2. Use Tooling (A) to remove the wear sleeve.
3. Use a 4 mm (0.158 inch) drill in order to make three or more holes in crankshaft front seal (1).
4. Use Tooling (A) to remove crankshaft front seal (1).

Crankshaft Front Seal - Install

Installation Procedure

Table 28

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>GE50008</td>
<td>Seal Locator</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>GE50009</td>
<td>Bolt</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>GE50014</td>
<td>Nut (Seal Installer)</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>GE50013</td>
<td>Seal Installer</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

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

Note: Do not lubricate the crankshaft seal or the wear sleeve. The crankshaft seal must be installed dry.

1. Before installation of the crankshaft front seal and the wear sleeve, inspect the crankshaft for scratches. Also, inspect the crankshaft for any distortion on the surface that may lead to an out of round condition. Use a polishing cloth in order to remove any imperfections on the crankshaft.
2. Clean the outside diameter of the crankshaft.
3. Fasten Tooling (B) to the crankshaft with Tooling (C).

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

4. Position wear sleeve (2) and crankshaft front seal (1) on Tooling (B). Install Tooling (E) on Tooling (B). Lubricate the face of the washer on Tooling (D). Install Tooling (D) on Tooling (B).

5. Tighten Tooling (D) until Tooling (E) contacts Tooling (B).

6. Remove Tooling (D) and Tooling (E) from Tooling (B).

7. Remove Tooling (C) and Tooling (B) from the crankshaft.

**End By:**

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

---

**Front Cover - Remove**

**Removal Procedure**

**Start By:**

a. Remove the fan drive. Refer to Disassembly and Assembly, "Fan drive - Remove".

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

---

**NOTICE**

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

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. Loosen bolts (2). Remove front cover (3) from front housing (1).
2. Remove bolts (2) and seal (4) from front cover (3).

Front Cover - Install

Installation Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Install seal (4) and bolts (2) to front cover (3).

2. Position front cover (3) on front housing (1). Tighten the bolts to a torque of 20 N·m (15 lb ft) in the numerical sequence that is shown in Illustration 74.

End By:

a. Install the assembly of the vibration damper and the crankshaft pulley. Refer to Disassembly and Assembly, “Vibration Damper and Pulley - Remove and Install”.

b. Install the fan drive. Refer to Disassembly and Assembly, “Fan drive - Install”.

Gear Group (Front) - Remove

Removal Procedure

Start By:

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

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.
NOTICE
Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.

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

1. Remove bolts (2) and thrust plate (1).
2. Remove sealing plate (3) and adapter (4).
3. Remove O-ring seal (5) and O-ring seal (6) from sealing plate (3).

5. Remove bolts (11), plate (12), and idler gear assembly (10).

6. Remove bolts (14), plate (15), and cluster gear assembly (13).

4. Remove bolts (8), plate (9), and adjustable idler gear assembly (7).
Note: The backlash for the camshaft gear and the adjustable idler gear assembly will need to be readjusted at assembly.

7. Remove fasteners (17) and remove stub shaft assembly (16).

8. Remove fasteners (19) and remove stub shaft (18).

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

**Gear Group (Front) - Install**

**Installation Procedure**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820117</td>
<td>POWERPART Threadlock and Nutlock</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

**NOTICE**

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

---

1. Install stub shaft (20). Apply Tooling (B) to bolts (21). Install bolts (21) and tighten to a torque of 55 N·m (40 lb ft) in sequence. (1, 3, 4, 5, 2, 1, 2, 3, 4, 5, 1)

**Note:** If any studs are loose or the threads are damaged, install new studs to the front housing.

2. Install stub shaft (18). Apply Tooling (A) to the studs and the bolt for stub shaft (18). Tighten nuts (19) and the bolt to a torque of 55 N·m (40 lb ft).

3. Install stub shaft assembly (16). Do not tighten nuts (17) and the bolt for the shaft assembly at this time. The nuts and the bolt for stub shaft assembly (16) will need to be tightened when the backlash is adjusted.

**Note:** If shaft assembly (16) is removed, the backlash for the camshaft gear and the adjustable idler gear will need to be readjusted. Refer to Systems Operation, Testing and Adjusting, “Gear Group (Front) - Time”.

---
4. Install new O-ring seals (5) and (6) to sealing plate (3). Lubricate O-ring seal (5) with Tooling (B).

5. Install adapter (4). Ensure that the dowel in the adapter engages the hole in the camshaft.

6. Install sealing plate (3) and thrust plate (1) in the front housing. Apply Tooling (A) to bolts (2). Install bolts (2) and tighten the bolts to a torque of 12 N·m (106 lb in). Ensure that sealing plate (3) and O-ring seal (6) are seated against the cylinder head.

**Note:** Ensure that No. 1 piston at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

7. Put cluster gear assembly (13) on the stub shaft. Ensure that Timing Marks (V) are aligned on the cluster gear assembly and the crankshaft gear.

8. Apply Tooling (A) to bolts (14). Position plate (15) with the oil groove toward the gear face. Install bolts (14) and tighten to a torque of 28 N·m (21 lb ft).


10. Apply Tooling (A) to bolts (11). Position plate (12) with the oil groove toward the gear face. Install bolts (11) and tighten to a torque of 28 N·m (21 lb ft).

11. Install the camshaft gear. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install." for the correct procedure.

12. Check the backlash for the camshaft gear and the adjustable idler gear. If necessary, adjust the backlash. Refer to Systems Operation, Testing and Adjusting, “Gear Group (Front) - Time”.

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

13. Once the correct backlash has been obtained, follow Steps 13.a through 13.d in order to secure stub shaft assembly (16).
a. Remove one nut (17).
b. Apply Tooling (A) to the nut.
c. Install nut (17) and tighten to a torque of 55 N·m (40 lb ft).
d. Repeat the procedure for the remaining nuts and the bolt.

**Note:** Removing and installing one nut at time will ensure that the position of the stub shaft assembly is not affected.

**Note:** Ensure that the timing mark on the camshaft gear is aligned with the timing mark on the front housing before the adjustable idler gear assembly is installed.

---

Illustration 85

Typical example

14. Put adjustable idler gear assembly (7) on the stub shaft assembly. Position plate (9) with the oil groove toward the face of the gear. Apply Tooling (A) to bolts (8). Install bolts (8). Tighten bolts (8) to a torque of 28 N·m (21 lb ft).

End By:

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

---

Housing (Front) - Remove

Removal Procedure

Start By:

a. Remove the camshaft position sensor. Refer to Disassembly and Assembly, “Camshaft Position Sensor - Remove and Install”.

---

**NOTICE**

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

Dispose of all fluids according to local regulations and mandates.

---

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

**NOTICE**

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.
1. Remove bolts (3) and bracket (2).

2. Remove the brackets that support the harness assembly.

3. Use a suitable lifting device to support the weight of front housing (1). The front housing weighs approximately 62 kg (137 lb).

4. Remove bolts (4).

5. Use the lifting device to remove front housing (1).

6. Remove joint (5).

**Note:** It is not necessary to remove the dowels in the cylinder block that locate the front housing.

---

### Housing (Front) - Install

**Installation Procedure**

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Thoroughly clean the mating surfaces of the cylinder block and front housing (1). Ensure that the dowels in the cylinder block protrude 1.91 cm (0.75 inch) from the mating surface.

2. Install a new joint (5) on the dowels in the cylinder block.

**Note:** Trim the joint even with the bottom of the front housing after assembly.

3. Use a suitable lifting device to align front housing (1) with the dowels in the cylinder block. The front housing weighs approximately 62 kg (137 lb).

4. Install front housing (1) to the cylinder block. Install bolts (4). Tighten the bolts to a torque of 50 N·m (37 lb ft).

5. Position bracket (2) and install bolts (3). Ensure that the bracket that supports the harness assembly is secured by the appropriate bolt. Tighten the bolts to a torque of 47 N·m (35 lb ft).

6. Install the remaining bracket that supports the harness assembly.

**NOTICE**

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

a. Install the engine support. Refer to Disassembly and Assembly, "Engine Support (Front) - Remove and Install".

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

c. Install the crankshaft front seal. Refer to Disassembly and Assembly, "Crankshaft Front Seal - Install".

d. Install the gear group (front). Refer to Disassembly and Assembly, "Gear Group (Front) - Install".

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

f. Install the fuel transfer pump. Refer to Disassembly and Assembly, "Fuel Transfer Pump - Install".

g. Install the belt tightener. Refer to Disassembly and Assembly, "Belt Tightener - Install".

h. Install the crankshaft position sensor. Refer to Disassembly and Assembly, "Crankshaft Position Sensor - Remove and Install".

i. Install the camshaft position sensor. Refer to Disassembly and Assembly, "Camshaft Position Sensor - Remove and Install".

Crankcase Breather - Remove and Install (Open Breather)

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Loosen clamp (2) and remove hose (3) from connection (1) on the valve mechanism cover. Remove the hose.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Ensure that hose (3) is clean and free from damage.

2. Install hose (3) to connection (1) on the valve mechanism cover. Tighten clamp (2).
Valve Mechanism Cover - Remove and Install

Removal Procedure

1. Loosen clip (5) and remove breather hose (6) from valve mechanism cover (2).
2. Disconnect the harness assembly from connector (3). Remove the bolts and the washers that secure the connector to valve mechanism cover (2).

Installation Procedure

1. Install isolated bolts (1) and a new joint (4) to valve mechanism cover (2).

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Illustration 90

Illustration 91

Illustration 92
Illustration 93
Tightening sequence for the valve mechanism cover

2. Install valve mechanism cover (2). Gradually tighten the isolated bolts (1) to a torque of 20 N·m (15 lb ft) in the numerical sequence that is shown in Illustration 93.

3. Position connector (3) into valve mechanism cover (2). Install the bolts and the washers that secure the connector to the valve mechanism cover. Torque the bolts to a torque of 1.5 N·m (13 lb in). Connect the harness assembly to the connector.

4. Install clip (5) and breather hose (6) to valve mechanism cover (2).

Rocker Arm and Shaft - Remove

Removal Procedure

Table 30

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tool</strong></td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Start By:

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Illustration 94

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

1. Remove bolts (2).

2. Use Tooling (A) to remove rocker arm shaft assembly (4), valve rocker arms (3), and electronic unit injector rocker arms (1) as a unit.

3. Make a temporary mark on the valve bridges in order to show the location and the orientation. Remove the valve bridges from the cylinder head.

Note: Identification will ensure that the valve bridges can be reinstalled in the original location and the original orientation. Do not interchange the location or the orientation of used valve bridges.

Rocker Arm - Disassemble

Disassembly Procedure

Start By:

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

Illustration 95
NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

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

Rocker Arm - Assemble

Assembly Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

Illustration 95

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

Illustration 96
End By:

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

Rocker Arm and Shaft - Install

Installation Procedure

Table 31

<table>
<thead>
<tr>
<th>Required Tools</th>
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</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Install the valve bridges.

Note: Install used valve bridges in the original location and in the original orientation. Ensure that the valve bridges are correctly seated on the valves. New valve bridges may be installed in either orientation.

2. Use Tooling (A) in order to position rocker arm shaft assembly (4), valve rocker arms (3), and electronic unit injector rocker arms (1) as a unit, on the cylinder head.

3. Install bolts (2) and tighten to a torque of 109 N·m (80 lb ft).


End By:

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

Cylinder Head - Remove

Removal Procedure

Table 32

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>

Start By:

a. Remove the turbocharger. Refer to Disassembly and Assembly, “Turbocharger - Remove”.

b. Remove the electronic unit injectors. Refer to Disassembly and Assembly, “Electronic Unit Injector - Remove”.

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

d. Remove the water temperature regulator housing. Refer to Disassembly and Assembly, “Water Temperature Regulator Housing - Remove and Install”.

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

Dispose of all fluids according to local regulations and mandates.
**NOTICE**
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

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

1. Remove bolts (2) and thrust plate (1).
2. Remove sealing plate (3) and adapter assembly (4).
3. Remove O-ring seal (5) and O-ring seal (6) from sealing plate (3).

4. Disconnect hose assembly (8) from the front of the cylinder head. Remove the bolt and the clip that secures the hose assembly to the cylinder head.
5. Disconnect hose assembly (9) from the rear of the cylinder head. Remove the bolt and the clip that secures the hose assembly to the cylinder head.
6. Remove bolt (14), the clip and the spacer. Remove the crankcase breather from the cylinder head.
7. Remove bolts (7) and remove the bracket from the cylinder head.
8. Slide the locking tab into the unlocked position and disconnect the harness assembly from inlet manifold pressure sensor (10).
9. Slide the locking tab into the unlocked position and disconnect the harness assembly from inlet manifold temperature sensor (13).
10. Remove the bolts and the clips that secure the harness assembly to the cylinder head.
11. Remove bolts (12), the bracket and air inlet elbow (11) from the cylinder head. Remove the O-ring seal from the air inlet elbow.

**Note:** Be sure to mark the orientation of the air inlet elbow for installation purposes.
12. Remove bolts (15) from the front lifting bracket.

13. Use Tooling (A) in order to remove cylinder head bolts (16).

14. Attach Tooling (B) and a suitable lifting device to cylinder head (17). The weight of the cylinder head assembly is approximately 235 kg (518 lb). Ensure that all of the following items are clear from the cylinder head: harness assemblies, tube assemblies, and hose assemblies.

15. Use the lifting device to carefully remove cylinder head (17).

16. Remove cylinder head gasket (18) and O-ring seal (19).

17. Remove seal (22) and seals (24).

18. Remove spacer plate (21).

19. Remove O-ring seal (20) from the dowel in the cylinder block. Remove spacer plate gasket (24).

Cylinder Head - Install

Installation Procedure

<table>
<thead>
<tr>
<th>Table 33</th>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
<td>Part Number</td>
</tr>
<tr>
<td>A</td>
<td>GE50020</td>
</tr>
<tr>
<td>B</td>
<td>VP12712</td>
</tr>
<tr>
<td>C</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>CV60895</td>
</tr>
<tr>
<td>E</td>
<td>21820221</td>
</tr>
<tr>
<td>F</td>
<td>2182638</td>
</tr>
</tbody>
</table>
NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

Illustration 103
Typical example

Note: Thoroughly clean the spacer plate and the bottom surface of the cylinder head and the top of the cylinder block. A new spacer plate gasket and a cylinder head gasket must be installed when the cylinder head is removed.

1. Install O-ring seal (20) on the dowel in the cylinder block.

Note: Ensure that the dowel protrudes from the face of the cylinder block by 20 ± 0.5 mm (0.79 ± 0.02 inch).

2. Install spacer plate gasket (23) on the cylinder block.

3. Install spacer plate (21).

4. Install seals (24) and seal (22).

5. Install cylinder head gasket (18) on the spacer plate. Install O-ring seal (19) on the dowel in the cylinder block.

Illustration 104
Typical example

6. Install Tooling (C) to the cylinder block in the positions that are shown in Illustration 104.

Illustration 105
Typical example

7. Attach Tooling (A) and a suitable lifting device to cylinder head (17). The weight of cylinder head assembly (17) is approximately 235 kg (518 lb).

8. Use the lifting device to align cylinder head (17) with Tooling (C). Carefully install the cylinder head onto the dowel pins in the cylinder block.


10. Apply Tooling (D) to the threads of cylinder head bolts (16) and both sides of the washers. Install cylinder head bolts (16).
Note: The bolts that are Marked “X” are 216 mm (8.5 inch) long: 11, 12, 13, 14, 16, 18, 20, 22, 24, and 26. The rest of the bolts are 194 mm (7.6 inch) long.

11. Tighten the cylinder head bolts according to the following procedure.
   a. In the numerical sequence, tighten Bolts 1 through 26 to a torque of 270 N·m (200 lb ft).
   b. In the numerical sequence, tighten Bolts 1 through 26 to a torque of 450 N·m (330 lb ft).
   c. In the numerical sequence, again tighten Bolts 1 through 26 to a torque of 450 N·m (330 lb ft).

12. Install bolts (15) to the front lifting bracket. Tighten the bolts to a torque of 105 N·m (77 lb ft).

13. Install a new O-ring seal to air inlet elbow (11). Position the bracket and air inlet elbow (11) on the cylinder head. Install bolts (12) and tighten to a torque of 47 N·m (35 lb ft).

Note: Ensure that the air inlet elbow is installed in the correct orientation.

14. Connect hose assembly (9) to the cylinder head. Install the bolt and the clip that secures the hose assembly to the cylinder head.

15. Connect hose assembly (8) to the cylinder head. Install the bolt and the clip that secures the hose assembly to the cylinder head.

16. Install bolt (14), the clip and the spacer that secures the breather tube to the cylinder head. Tighten bolt (14) to a torque of 10 N·m (89 lb in).

17. Position the bracket on the cylinder head and install bolts (7). Tighten the bolts to a torque of 47 N·m (35 lb ft).

18. Connect the harness assembly to inlet manifold pressure sensor (10). Slide the locking tab into the locked position.

19. Connect the harness assembly to inlet manifold temperature sensor (13). Slide the locking tab into the locked position.

20. Install the bolts and the clips that secure the harness assembly to the cylinder head.

21. Install O-ring seal (5) and O-ring seal (6) on sealing plate (3). Lubricate O-ring seal (5) with Tooling (E).

22. Install adapter assembly (4) and sealing plate (3). Ensure that the dowel in adapter assembly (4) engages the hole in the camshaft.

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

23. Install thrust plate (1). Apply Tooling (F) to bolts (2). Hold the thrust plate in position and install bolts (2). Evenly tighten bolts (2) to a torque of 12 N·m (106 lb in).
Note: Ensure that the O-ring seal stays in the groove in sealing plate (3).

End By:

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

b. Install the electronic unit injectors. Refer to Disassembly and Assembly, “Electronic Unit Injector - Install”.

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

d. Install the turbocharger. Refer to Disassembly and Assembly, “Turbocharger - Install”.

Camshaft - Remove

Removal Procedure

Table 34

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>GE50018</td>
<td>Cradle</td>
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</tr>
<tr>
<td>B</td>
<td>GE50017</td>
<td>Guide</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>GE50015</td>
<td>Camshaft Pilot</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>GE50025</td>
<td>Camshaft Hook</td>
<td>2</td>
</tr>
</tbody>
</table>

Start By:

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

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

NOTICE

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

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Illustration 110

1. Remove bolts (2) and thrust plate (1).
2. Remove sealing plate (3) from the front housing. Remove adapter assembly (4) from the camshaft.
3. Remove O-ring seal (5) and O-ring seal (6) from sealing plate (3).

NOTICE

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

Illustration 111

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

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

6. Remove Torx screws (9) and cover (10). Remove the O-ring seal from the cover.

7. Move camshaft (8) forward and install one Tooling (C) to the end of the camshaft. Again, move the camshaft forward and install remaining Tooling (C) to the back of first Tooling (C). Align camshaft (8) with the bore of Tooling (B). Tighten the bolts that hold Tooling (B) to front housing (7).

Note: Tooling (C) will support the rear of the camshaft as the camshaft is moved out of the cylinder head and into Tooling (B).

8. Use Tooling (D) to move camshaft (8) toward the front of the engine. Reposition Tooling (D), as required.

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

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

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

10. Remove Tooling (C) from the camshaft.

11. Remove Tooling (B) from front housing (7).

12. Remove Tooling (A) from the cylinder head.
Camshaft - Install

Installation Procedure

Table 35

Required Tools

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>GE50018</td>
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<td>B</td>
<td>GE50017</td>
<td>Guide</td>
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</tr>
<tr>
<td>C</td>
<td>GE50015</td>
<td>Camshaft Pilot</td>
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<td>D</td>
<td>GE50025</td>
<td>Camshaft Hook</td>
<td>2</td>
</tr>
<tr>
<td>H</td>
<td>GE50016</td>
<td>Alignment Sleeve</td>
<td>1</td>
</tr>
<tr>
<td>J</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
<tr>
<td>K</td>
<td>21820117</td>
<td>POWERPART Thread Lock and Nut Lock</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

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

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

1. Ensure that the camshaft and camshaft bearings are thoroughly clean. Lubricate the camshaft bearings with clean engine oil.

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

3. Install Tooling (B) on front housing (7). Do not tighten the bolts that hold Tooling (B) to front housing (7) at this time.

4. Use Tooling (H) to align Tooling (B) with the camshaft bearings. Tighten the bolts that hold Tooling (B) to front housing (7). Remove Tooling (H).

Note: Tooling (H) should move freely from the bore of Tooling (B).
5. Install both Tooling (C) to the rear of camshaft (8).

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

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

7. Remove Tooling (C) when camshaft (8) is fully installed in the bore.

8. Remove Tooling (A) from the cylinder head.

9. Remove Tooling (B) from the front housing.

10. Install a new O-ring seal on cover (10). Position the cover on the rear of the cylinder head. Install torx screws (9) and tighten to a torque of 6 N·m (53 lb in).

11. Install O-ring seals (5) and (6) in sealing plate (3). Lubricate O-ring seal (5) with a Tooling (J).

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

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

13. Install thrust plate (1). Apply Tooling (K) to bolts (2). Hold the thrust plate in position and install bolts (2). Evenly tighten bolts (2) to a torque of 12 N·m (106 lb in).

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

14. Lubricate the camshaft lobes with clean engine oil.

End By:

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

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

Illustration 119  g01056675
Illustration 120  g01287358
Camshaft Gear - Remove and Install

Removal Procedure

Table 36

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Start By:

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

    NOTICE

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

    NOTICE

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

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

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

3. Remove one bolt (2). Install Tooling (A).

4. Remove the remaining bolts (2) and remove camshaft gear (1).

Installation Procedure

Table 37

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

    NOTICE

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

    NOTICE

Do not turn the crankshaft or the camshaft while the camshaft gear is removed. If the front gear group is not correctly timed during installation, interference can occur between the pistons and the valves, resulting in damage to the engine.
1. Align the hole in the back of camshaft gear (1) with the dowel in the adapter. Position camshaft gear (1) onto Tooling (A) and install the camshaft gear.

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

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

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

3. Install bolts (2) finger tight. Remove Tooling (A) and install the remaining bolt (2).

4. Tighten the bolts for the camshaft gear in a numeric sequence 1, 4, 2, 5, 3, 6, 1, 4 to a torque of 240 N·m (180 lb ft).

5. Check the backlash between the camshaft gear and the adjustable idler gear. The backlash should be 0.216 ± 0.114 mm (0.0085 ± 0.0045 inch). Refer to Systems Operation, Testing and Adjusting, “Gear Group (Front) - Time” for the backlash adjustment procedure.

End By:

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

Camshaft Bearings - Remove

Removal Procedure

Table 38

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>27610271</td>
<td>Camshaft Bearing Tool Group</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>27610312</td>
<td>Camshaft Bearing Pilot</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>27610313</td>
<td>Taperlock Stud 1/2 - 13 by 1 9/16 inch</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>27610314</td>
<td>Puller Plate</td>
<td>1</td>
</tr>
</tbody>
</table>

Start By:

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

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

Illustration 126

1. Remove the No. 7 camshaft bearing (rear). Work from the rear of the engine to the front of the engine.

2. Install the small end of Tooling (B) in camshaft bearing (1).

3. Position Tooling (C) over Tooling (A). Install Tooling (A) through the cylinder head on Tooling (B).

Note: Tooling (C) is installed on the outside of the cylinder head. Tooling (C) is required in order to remove all the camshaft bearings from the cylinder head.

4. Use Tooling (A) to remove camshaft bearing (1) from the cylinder head.

5. Remove Tooling (B) from Tooling (A) and remove the camshaft bearing.

Illustration 127

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

a. Insert the large end of Tooling (B) into the No. 7 camshaft bore.

b. Position Tooling (C) over Tooling (A). Install Tooling (A) through the cylinder head on Tooling (B).

### Camshaft Bearings - Install

#### Installation Procedure

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>27610271</td>
<td>Camshaft Bearing Tool Group</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>27610312</td>
<td>Camshaft Bearing Pilot</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>27610313</td>
<td>Taperlock Stud 1/2 - 13 by 1 9/16 inch</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>27610314</td>
<td>Puller Plate</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>27610315</td>
<td>Alignment Bushing</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>27610316</td>
<td>Backup Plate</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>27610317</td>
<td>Bolt 1/2 - 13 by 1 inch</td>
<td>1</td>
</tr>
<tr>
<td>F</td>
<td>27610318</td>
<td>Spacer Plate</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.
c. Position camshaft bearing (1) on Tooling (B). Install Tooling (E) on Tooling (B).

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

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

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

---

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

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

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

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

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

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

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

---

3. Install the No. 1 camshaft bearing (front), as follows:

a. Insert the large end of Tooling (B) into the No. 1 camshaft bore. Assemble Tooling (A) and Tooling (D) on Tooling (B).

b. Position camshaft bearing (1) on Tooling (B). Install Tooling (E) and Tooling (F) on Tooling (B).

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

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

c. Use Tooling (A) in order to pull the No. 1 camshaft bearing into the No. 1 camshaft bore. When the chamfer of Tooling (E) contacts the face of the camshaft bore, the camshaft bearing is properly installed.

**End By:**

a. Install the camshaft. Refer to Disassembly and Assembly, “Camshaft - Install”.
Engine Oil Pan - 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 130](g01284906)

**Typical example**

1. Drain the engine oil into a suitable container for storage or disposal. Refer to Operation and Maintenance Manual, “Engine Oil - Change”.

2. Remove drain plug (3). Remove washer (2) from drain plug (3).

3. Loosen bolts (5). Remove engine oil pan (4).

4. Remove bolts (5) and seal (1) from engine oil pan (4).

Installation Procedure

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CH10888</td>
<td>Silicone Gasket</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Clean the mating surfaces of the engine oil pan, cylinder block, front housing, and the flywheel housing.
2. Install seal (1) and bolts (5) to engine oil pan (4).

3. Apply a bead of Tooling (A) to positions (X).

4. Install engine oil pan (4). Tighten bolts (5) in the numerical sequence that is shown in Illustration 133. Tighten the bolts to a torque of 47 N·m (35 lb ft).

5. Install a new washer (2) to drain plug (3). Install drain plug (3) to engine oil pan (4). Tighten the drain plug to a torque of 45 N·m (33 lb ft).

6. Fill the engine oil pan to the correct level. Refer to Operation and Maintenance Manual, “Engine Oil Change”.

Cylinder Liner - Remove

Removal Procedure

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>GE50001</td>
<td>Cylinder Liner Puller</td>
<td>1</td>
</tr>
</tbody>
</table>

Start By:

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

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.
1. Make temporary identification marks in order to show the location of the cylinder liners.

2. Use Tooling (A) to remove cylinder liner (1).

3. Remove liner seals (3) and filler band (2) from cylinder liner (1).

Cylinder Liner - Install

Installation Procedure

Table 42

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
</tbody>
</table>

- **NOTICE**
  - Keep all parts clean from contaminants.
  - Contaminants may cause rapid wear and shortened component life.

**Note:** Ensure that the cylinder liners and the cylinder block are clean and free from damage.


2. Install liner seals (3) on cylinder liner (1).

3. Apply Tooling (C) on the cylinder block liner bore surfaces and liner seals (3).

4. Dip filler band (2) in clean engine oil for a moment. Install the filler band on the cylinder liner immediately.

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

End By:

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

Piston Cooling Jets - Remove and Install

Removal Procedure

Table 43

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Start By:

- a. Remove the engine oil pump. Refer to Disassembly and Assembly, "Engine Oil Pump - Remove".
NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

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

Installation Procedure

Table 44

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

2. Position piston cooling jet (2) in the cylinder block. Install bolt (1). Tighten the bolt to a torque of 40 N·m (30 lb ft).

Note: Ensure that the nozzles of the piston cooling jet are not damaged or distorted.

End By:

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

Pistons and Connecting Rods - Remove

Removal Procedure

Table 45

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Start By:

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

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

c. Remove the piston cooling jets. Refer to Disassembly and Assembly, “Piston Cooling Jets - Remove and Install”.

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.
1. Use Tooling (A) to rotate the crankshaft until the piston is at the bottom center.

2. Remove the carbon ridge from the top inside surface of the cylinder liner.

3. Inspect the connecting rod and connecting rod cap for the proper identification mark. The connecting rod and the connecting rod cap should have an etched number on the side. The number should match the cylinder number. Mark the connecting rod and the connecting rod cap, if necessary.

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

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

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

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

### Pistons and Connecting Rods - Disassemble

#### Disassembly Procedure

#### Table 46

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Retaining Ring Pliers</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>Piston Ring Expander</td>
<td>1</td>
</tr>
</tbody>
</table>

#### Start By:

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

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

---

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.
1. Remove connecting rod bearing (9) from connecting rod bearing cap (10). Remove connecting rod bearing (9) from connecting rod (6).

2. Use Tooling (A) to remove circlips (5) from piston (4).

3. Remove piston pin (8) and connecting rod (6) from piston (4).

4. Use Tooling (B) to remove piston rings (1), (2), and (3) from piston (4).

5. Do not remove bearing (7) from connecting rod (6).

### Pistons and Connecting Rods - Assemble

#### Assembly Procedure

Table 47

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>Retaining Ring Pliers</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>Piston Ring Expander</td>
<td>1</td>
</tr>
</tbody>
</table>

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

---

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

1. Check the clearance between the ends of piston rings (1), (2), and (3). Refer to the Specifications Manual, "Pistons And Rings" for the specifications.

2. Position the spring for oil control ring (3) in the oil ring groove in piston (4).

3. Position oil control ring (3) over the spring. Position the oil control ring so that the gap is 180 degrees from the joint in the spring. Install the oil control ring on the piston with Tooling (B).

4. Use Tooling (B) to install intermediate piston ring (2) with the side that has the identification "UP-2" toward the top of the piston.

5. Use Tooling (B) to install top piston ring (1) with the side that has the identification "UP-1" toward the top of the piston.

6. Position piston rings (1), (2), and (3) so the gaps are 120 degrees from each other.

7. Put piston (4) in position on connecting rod (6). Apply clean engine oil to piston pin (8) and install piston pin (8). Install circlips (5) with Tooling (A). Make sure that the circlips are fully seated in the grooves of piston (4).

8. Install connecting rod bearings (9) in connecting rod (6) and connecting rod cap (10). Make sure that rod bearings (9) are installed so that the bearing tabs fit into the notches in connecting rod (6) and in connecting rod cap (10).

9. Ensure that the dowels are installed in connecting rod cap (10) or in connecting rod (6).

**End By:**

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

#### Installation Procedure

<table>
<thead>
<tr>
<th>Required Tools</th>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>CH11148</td>
<td>Engine Turning Tool</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>GE50045</td>
<td>Piston Ring Compressor</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>21825607</td>
<td>Angle Gauge</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

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

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

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

2. Use Tooling (A) to rotate the crankshaft until the connecting rod journal is at the top center. Lubricate the connecting rod bearings and the connecting rod journal with clean engine oil.

3. Use Tooling (B) to install piston (3) and the connecting rod in the cylinder liner. Ensure that the connecting rod is seated on the crankshaft journal.

**Note:** Install the connecting rod so that the bearing tab is located on the side of the piston cooling jet. Ensure that the gaps for the piston rings are at 120 degrees away from each other.

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

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

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

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

7. Tighten bolts (1), as follows:
   a. Tighten Bolt (A) and Bolt (C) to a torque of 70 N·m (52 lb ft).
   b. Tighten Bolt (B) and Bolt (D) to a torque of 70 N·m (52 lb ft).
   c. Turn Bolt (B) and Bolt (D) for an additional 60 degrees (1/6 turn).
   d. Tighten Bolt (A) and Bolt (C) to a torque of 70 N·m (52 lb ft).
   e. Turn Bolt (A) and Bolt (C) for an additional 60 degrees (1/6 turn).
f. Ensure that the installed connecting rod assembly has tactile side play. Carefully rotate the crankshaft in order to ensure that there is no binding.

End By:

a. Install the piston cooling jets. Refer to Disassembly and Assembly, "Piston Cooling Jets - Remove and Install".

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

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

Connecting Rod Bearings - Remove
(Connecting rods in position)

Removal Procedure

Table 49

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Start By:

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

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

2. Inspect the connecting rod and connecting rod cap for the proper identification mark. The connecting rod and the connecting rod cap should have an etched number on the side. The number should match the cylinder number. Mark the connecting rod and the connecting rod cap, if necessary.

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

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

4. Remove the lower half of the connecting rod bearing from the connecting rod bearing cap.

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

Connecting Rod Bearings - Install
(Connecting rods in position)

Installation Procedure

Table 50

<table>
<thead>
<tr>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tool</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
</tbody>
</table>
NOTICE

Keep all parts clean from contaminants. Contaminants may cause rapid wear and shortened component life.

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

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

2. Install lower half connecting rod bearing (3) in connecting rod bearing cap (2). Ensure that bearing tab (4) is located in the notch of the connecting rod bearing cap.

3. Install the upper half connecting rod bearing in the connecting rod. Ensure that the bearing tab is located in the notch of the connecting rod.

**Note:** The upper half connecting rod bearing has an oil hole.

4. Ensure that the dowels are installed in connecting rod cap (2) or in the connecting rod.

5. Pull the connecting rod onto the crankshaft.

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

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

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

8. Tighten bolts (1), as follows:
   a. Tighten Bolt (A) and Bolt (C) to a torque of 70 N·m (52 lb ft).
   b. Tighten Bolt (B) and Bolt (D) to a torque of 70 N·m (52 lb ft).
   c. Turn Bolt (B) and Bolt (D) for an additional 60 degrees (1/6 turn).
   d. Tighten Bolt (A) and Bolt (C) again to a torque of 70 N·m (52 lb ft).
   e. Tighten Bolt (A) and Bolt (C) for an additional 60 degrees (1/6 turn).
   f. Ensure that the installed connecting rod assembly has tactile side play. Carefully rotate the crankshaft in order to ensure that there is no binding.

**End By:**

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

Illustration 145  
Illustration 146
Crankshaft Main Bearings - Remove

Removal Procedure

Table 51

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>27610319</td>
<td>Bearing Tool</td>
<td>1</td>
</tr>
</tbody>
</table>

Start By:

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

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

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

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

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

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

4. Remove thrust plates (4) from each side of the No. 4 main bearing.

5. Remove the lower halves of the main bearings from the main bearing caps.
Crankshaft Main Bearings - Install

Installation Procedure

Table 52

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>27610319</td>
<td>Bearing Tool</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>21825617</td>
<td>Dial Indicator</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>21825607</td>
<td>Angle Gauge</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

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

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

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

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

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

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

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

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

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

**Note:** Ensure that the numbers on the main bearing caps match the numbers on the cylinder block. Also ensure that the “FRONT” on the main bearing cap is installed toward the front of the cylinder block.
5. Lubricate the threads of bolts (1) with clean engine oil. Install the bolts to the main bearing caps. Evenly tighten the bolts in order to pull the cap into position. Ensure that the cap is correctly seated.

Note: Do not tap the cap into position as the bearing shell may be dislodged.

6. Tighten bolts (1) for the main bearing caps, as follows:
   a. Tighten Bolt (A) to a torque of 258 N·m (190 lb ft).

   Note: Bolt (A) is on the bearing tab side of the main bearing cap.
   b. Tighten Bolt (B) to a torque of 258 N·m (190 lb ft).

   Note: Bolt (B) is on the opposite side of the bearing tab of the main bearing cap.
   c. Use Tooling (C) to tighten Bolt (B) for an additional 120 degrees (2 flats).
   d. Use Tooling (C) to tighten Bolt (A) for an additional 120 degrees (2 flats).
   e. Rotate the crankshaft in order to ensure that the crankshaft turns freely.

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

Crankshaft - Remove

Removal Procedure

Table 53

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>Bearing Puller</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Puller</td>
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<td></td>
<td></td>
<td>Crossblock</td>
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<tr>
<td></td>
<td></td>
<td>Puller Leg</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>Dowel Extractor</td>
<td>1</td>
</tr>
</tbody>
</table>

Start By:

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

b. Remove the flywheel housing. Refer to Disassembly and Assembly, “Flywheel Housing - Remove and Install”.

c. Remove the piston cooling jets. Refer to Disassembly and Assembly, “Piston Cooling Jets - Remove and Install”.

   NOTICE
   Keep all parts clean from contaminants.

   Contaminants may cause rapid wear and shortened component life.

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

   2. Check the connecting rod and the connecting rod bearing caps for identification and the location in the cylinder block.

Illustration 153

Typical example

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

   Crankshaft end play (new thrust plates) ....... 0.11 to 0.57 mm (0.004 to 0.022 inch)
3. Remove bolts (1) for connecting rod bearing cap (2). Remove the connecting rod bearing caps.

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

5. Install a suitable lifting device on each end of crankshaft (5). The weight of crankshaft (5) is approximately 177 kg (390 lb).

6. Remove the crankshaft from the cylinder block.

7. Remove the thrust plates from each side of the No. 4 main bearing.

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

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

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

10. If necessary, use Tooling (B) to remove dowel (7) and dowel (8) from crankshaft (5).
Crankshaft - Install

Installation Procedure

Table 54

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>21825617</td>
<td>Dial Indicator Group</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>21825607</td>
<td>Angle Gauge</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. If necessary, install dowel (7) in the crankshaft.
   Protrusion of dowel (7) from the crankshaft face ............................... 6.4 mm (0.25 inch)

2. If necessary, install dowel (8) in the crankshaft.
   Protrusion of dowel (8) from the crankshaft ................................. 4.1 ± 0.5 mm (0.16 ± 0.02 inch)

3. The crankshaft gear is an interference fit on the crankshaft. Heat crankshaft gear (6) in an oven to 177 °C (350 °F).

4. Align the keyway in crankshaft gear (6) to dowel (8) on the crankshaft. The Timing Mark “V” on the gear should face away from crankshaft (5).

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

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

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

7. Install a suitable lifting device to crankshaft (5). The weight of crankshaft (5) is approximately 177 kg (390 lb).

8. Install crankshaft (5) to the cylinder block.

9. Install thrust plates (10) on each side of the No. 4 main bearing.
Note: Install the thrust plates with the words “Block Side” toward the cylinder block.

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

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

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

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

12. Lubricate the threads of bolts (3) with clean engine oil. Install the bolts to the main bearing caps. Evenly tighten the bolts in order to pull the cap into position. Ensure that the cap is correctly seated.

Note: Do not tap the cap into position as the bearing shell may be dislodged.

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

a. Tighten Bolt (A) to a torque of 258 N·m (190 lb ft).

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

b. Tighten Bolt (B) opposite the bearing tab side to a torque of 258 N·m (190 lb ft).

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

c. Use Tooling (D) to tighten Bolt (B) through an additional 120 degrees (2 flats).

d. Use Tooling (D) to tighten Bolt (A) through an additional 120 degrees (2 flats).

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

14. Use Tooling (C) to check the crankshaft end play. Ensure that Tooling (C) is against a machined surface. The end play is controlled by the thrust plates of No. 4 main bearing (center).

Crankshaft end play (new thrust plates) ....... 0.11 to 0.57 mm (0.004 to 0.022 inch)

Note: Install the connecting rod bearings dry when clearance checks are performed. Refer to Disassembly and Assembly, “Bearing Clearance - Check”. Apply clean engine oil on the face of the connecting rod bearings for final assembly.
15. Position the connecting rod against the crankshaft. Install connecting rod bearing cap (2) on the connecting rod.

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

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

17. Tighten bolts (1), as follows:

   a. Tighten Bolt (A) and Bolt (C) to a torque of 70 N·m (52 lb ft).
   
   b. Tighten Bolt (B) and Bolt (D) to a torque of 70 N·m (52 lb ft).
   
   c. Use Tooling (D) to turn Bolt (B) and Bolt (D) for an additional 60 degrees (1/6 turn).
   
   d. Tighten Bolt (A) and Bolt (C) to a torque of 70 N·m (52 lb ft).
   
   e. Use Tooling (D) to turn Bolt (A) and Bolt (C) for an additional 60 degrees (1/6 turn).
   
   f. Ensure that the installed connecting rod assembly has tactile side play. Carefully rotate the crankshaft in order to ensure that there is no binding.

**End By:**

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

### Bearing Clearance - Check

**Measurement Procedure**

<table>
<thead>
<tr>
<th>Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic Gauge (Green) 0.025 to 0.076 mm (0.001 to 0.003 inch)</td>
<td>1</td>
</tr>
<tr>
<td>Plastic Gauge (Red) 0.051 to 0.152 mm (0.002 to 0.006 inch)</td>
<td>1</td>
</tr>
<tr>
<td>Plastic Gauge (Blue) 0.102 to 0.229 mm (0.004 to 0.009 inch)</td>
<td>1</td>
</tr>
<tr>
<td>Plastic Gauge (Yellow) 0.230 to 0.510 mm (0.009 to 0.020 inch)</td>
<td>1</td>
</tr>
</tbody>
</table>

**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. This 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. However, if the technician still wants to measure the clearance of the bearing shell, the use of Plastigauge is an acceptable method. Plastigauge is less accurate on journals with small diameters if clearances are less than 0.10 mm (0.004 inch).

**Note:** The bearing clearance for the crankshaft should be within specifications if the crankshaft journals and the crankshaft pins were checked before installing the crankshaft and the correct bearing shells are installed. No further checks should be necessary.

**NOTICE**

Lead wire, shim stock or a dial bore gauge can damage the bearing surfaces.

The technician must be very careful to use Plastigauge correctly. The following points must be observed:

- Ensure that the backs of the bearing shells and the bores of the bearing shells are clean and dry.
• If the bearing shells have locating tabs ensure that the locating tabs are properly seated in the tab grooves.

• The crankshaft must be clean and free of oil at the contact points of the Plastigauge.

Note: When Plastigauge is used, the readings can sometimes be unclear. For example, all parts of the Plastigauge are not the same width. Measure the major width in order to ensure that the parts are within the specification range. Refer to the Specifications Manual, "Connecting Rod Bearing Journal" and refer to the Specifications Manual, "Main Bearing Journal" for the correct clearances.

Atmospheric Pressure Sensor - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Slide the locking tab into the unlocked position. Disconnect harness assembly (1) from atmospheric pressure sensor (2).

2. Remove atmospheric pressure sensor (2) from the adapter on the cylinder block.

3. Remove the O-ring seal from atmospheric pressure sensor (2).
Installation Procedure

Table 56

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Install a new O-ring seal to atmospheric pressure sensor (2). Lubricate the O-ring seal with Tooling (A).

2. Use a deep socket to install atmospheric pressure sensor (2) to the adapter on the cylinder block. Tighten the atmospheric pressure sensor to a torque of 10 N·m (89 lb in).

3. Connect harness assembly (1) to atmospheric pressure sensor (2). Slide the locking tab into the locked position.

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.

1. Slide the locking tab into the unlocked position. Disconnect harness assembly (4).

2. Remove bolt (3). Carefully remove camshaft position sensor (1) from adapter (2).

**Note:** Do not use a lever to remove the camshaft position sensor from the adapter.

3. Remove the O-ring seal from camshaft position sensor (1).
Installation Procedure

Table 57

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Install a new O-ring seal to the camshaft position sensor (1). Lubricate the O-ring seal with Tooling (A).

2. Position camshaft position sensor (1) into adapter (2) and install bolt (3). Tighten the bolt to a torque of 25 N·m (18 lb ft).

3. Connect harness assembly (4). Slide the locking tab into the locked position.

Crankshaft 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.

1. Slide the locking tab into the unlocked position. Disconnect harness assembly (3). Cut the cable tie that secures the sensor wire.

2. Remove bolt (2) that fastens crankshaft position sensor (1) to the front housing. Carefully remove the crankshaft position sensor.

3. Remove the O-ring seal from the crankshaft position sensor (1).
**Installation Procedure**

**Table 58**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

---

1. Install a new O-ring seal on the crankshaft position sensor (1). Lubricate the O-ring seal with Tooling (A).

2. Install crankshaft position sensor (1) into the front housing. Install bolt (2). Tighten the bolt to a torque of 25 N·m (18 lb ft).

3. Connect harness assembly (3). Slide the locking tab into the locked position. Use a new cable tie in order to secure the sensor wire.

---

**Coolant Temperature 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.

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

2. Slide the locking tab into the unlocked position. Disconnect the harness assembly from coolant temperature sensor (1).
3. Use a deep socket in order to remove coolant temperature sensor (1) from the water temperature regulator housing.

4. Remove the O-ring seal from the coolant temperature sensor.

**Installation Procedure**

**Table 59**

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Install a new O-ring seal on the coolant temperature sensor. Lubricate the O-ring seal with Tooling (A).

2. Install coolant temperature sensor (1) to the water temperature regulator housing. Use a deep socket to tighten the coolant temperature sensor to a torque of 20 N·m (15 lb ft).

3. Connect the harness assembly to coolant temperature sensor (1). Slide the locking tab into the locked position.

4. Fill the cooling system with coolant. Refer to Operation and Maintenance Manual, “Cooling System Coolant - Change”.

**Engine Oil Pressure 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.

1. Slide the locking tab into the unlocked position. Disconnect harness assembly (1) from engine oil pressure sensor (2).

2. Remove engine oil pressure sensor (2) from adapter (3).

3. Remove the O-ring seal from adapter (3).
Installation Procedure

Table 60

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Lubricate a new O-ring seal with Tooling (A). Install the O-ring seal to adapter (3).
2. Install engine oil pressure sensor (2) to adapter (3). Tighten the engine oil pressure sensor to a torque of 10 N·m (89 lb in).
3. Connect harness assembly (1) to engine oil pressure sensor (2). Slide the locking tab into the locked position.

Fuel Temperature 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.

1. Slide the locking tab into the unlocked position. Disconnect the harness assembly from fuel temperature sensor (1).
2. Use a deep socket in order to remove fuel temperature sensor (1) from the fuel filter base.
3. Remove the O-ring seal from the fuel temperature sensor.
Installation Procedure

Table 61

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Install a new O-ring seal to fuel temperature sensor (1). Lubricate the O-ring seal with Tooling (A).

2. Install fuel temperature sensor (1) to the fuel filter base. Use a deep socket to tighten the fuel temperature sensor to a torque of 20 N·m (15 lb ft).

3. Connect the harness assembly to fuel temperature sensor (1). Slide the locking tab into the locked position.

Illustration 177

Illustration 178

Inlet Manifold Temperature Sensor - Remove and Install

Removal Procedure

**NOTICE**
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

Table 62

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTICE**
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.
Illustration 179

Typical example

1. Install a new O-ring seal to inlet manifold temperature sensor (1). Lubricate the O-ring seal with Tooling (A).

2. Use a deep socket to install inlet manifold temperature sensor (1) to the cylinder head. Tighten the inlet manifold temperature sensor to a torque of 20 N·m (15 lb ft).

3. Connect the harness assembly to inlet manifold temperature sensor (1). Slide the locking tab into the locked position.

Inlet Manifold Pressure Sensor - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

Illustration 180

1. Slide the locking tab into the unlocked position. Disconnect the harness assembly from inlet manifold pressure sensor (1).

2. Use a deep socket to remove inlet manifold pressure sensor (1) from the adapter in the cylinder head.

3. Remove the O-ring seal from inlet manifold pressure sensor (1).

Installation Procedure

Table 63

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part Number</th>
<th>Part Description</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>21820221</td>
<td>POWERPART Rubber Grease</td>
<td>1</td>
</tr>
</tbody>
</table>

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.
Disassembly and Assembly Section

1. Install a new O-ring seal to inlet manifold pressure sensor (1). Lubricate the O-ring seal with Tooling (A).

2. Use a deep socket to install inlet manifold pressure sensor (1) to the adapter in the cylinder head. Tighten the inlet manifold pressure sensor to a torque of 10 N·m (89 lb in).

3. Connect the harness assembly to inlet manifold pressure sensor (1). Slide the locking tab into the locked position.

Belt Tightener - Remove

Removal Procedure

Start By:

a. Remove the alternator. Refer to Disassembly and Assembly, “Alternator - Remove and Install”.

1. Loosen nut (1).

2. Rotate bolt (2) in order to release the tension on the V-belts. Remove the V-belts from the pulley of belt tightener (3).

3. Remove bolts (4) and remove belt tightener (3).
**Belt Tightener - Install**

**Installation Procedure**

1. Position belt tightener (3) and install bolts (4). Tighten the bolts to a torque of 47 N·m (35 lb ft).
2. Install the V-belts on the pulley of belt tightener (3).
3. Rotate bolt (2) in order to adjust the tension of the V-belts. Refer to Operation and Maintenance Manual, “Belt Tension Chart”.
4. Tighten nut (1).

**End By:**

a. Install the alternator. Refer to Disassembly and Assembly, “Alternator - Remove and Install”.

---

**Fan - Remove and Install**

**Removal Procedure**

1. Remove the engine fan guards.
2. Remove bolts (1).

**Note:** Ensure that the radiator is protected during removal of the fan assembly.

3. Remove fan (3) and adapter (2) as a assembly.
4. If necessary, remove fan (3) from adapter (2). Note the orientation of fan.

**Installation Procedure**

1. Ensure that all the components are free damage. If necessary, replace any components that are damaged.
2. If necessary, install fan (3) to adapter (2). Ensure that the fan is correctly oriented. Install bolts (4) and tighten to a torque of 47 N·m (35 lb ft).

3. Install the assembly of the fan and the adapter.

Note: Ensure that the radiator is protected during installation of the fan assembly.

4. Install bolts (1). Tighten bolts (1) to a torque of 47 N·m (35 lb ft).

5. Install the engine fan guards.

Fan Drive - Remove

Removal Procedure

Start By:

a. Remove the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

1. Remove the V-belt from the alternator pulley. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.

2. Loosen nut (1). Rotate bolt (2) in order to release the tension on the V-belts.

3. Remove the V-belts from the pulley of fan drive (3).

4. Attach a suitable lifting strap to the assembly of fan drive (3). Support the weight of the fan drive. The assembly of the fan drive weighs approximately 17 kg (37 lb).

5. Remove nuts and washers (4) from the assembly of fan drive (3).
6. Use the lifting strap in order to remove the assembly of the drive (3).

**Fan Drive - Install**

**Installation Procedure**

1. Use a suitable lifting strap in order to position the assembly of fan drive (3) on the front housing. The assembly of the fan drive weighs approximately 17 kg (37 lb).

2. Install washers and nuts (4). Tighten the nuts to a torque of 105 N·m (77 lb ft).

3. Remove the lifting strap.

4. Position the V-belts on the pulley of fan drive (3) and the pulley of the belt tightener.

5. Rotate bolt (2) in order to adjust the tension of the V-belts. Refer to Systems Operation, Test and Adjusting, “Belt Tension Chart”.

6. Tighten nut (1).

7. Install the V-belt to the alternator pulley. Refer to Disassembly and Assembly, “Alternator - Remove and Install” for the correct procedure.

**End By:**

a. Install the fan. Refer to Disassembly and Assembly, "Fan - Remove and Install".

**Pump Drive - Remove**

(Transfer pump)

**Removal Procedure**

**Start By:**

a. Remove the fuel transfer pump. Refer to Disassembly and Assembly, “Fuel Transfer Pump - Remove”.
NOTICE
Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

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. Remove bolts (2).

2. Use a soft hammer in order to remove assembly of pump drive (3) from front housing (1). Remove the O-ring seal from the assembly of the pump drive.

Start By:

a. Remove the pump drive. Refer to Disassembly and Assembly, "Pump Drive - Remove".

NOTICE
Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

1. Remove bolts (3) and washers (4) that secure adapter (7) to bearing (6).
2. Place the pump drive onto a suitable support. Press the assembly of gear (2) and bearings (1) and (6) out of adapter (7).

3. Use Tooling (A) to remove retaining ring (5).

4. Use Tooling (B) or use a suitable press in order to remove bearings (1) and (6) from gear (2).

Pump Drive - Assemble (Transfer pump)

Assembly Procedure

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NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Inspect the condition of the teeth and the splines of gear (2) for wear or damage. Inspect bearings (1) and (6), retaining ring (5), and adapter (7) for wear or damage. Replace any components that are worn or damaged.

2. Place the gear shaft on a suitable support. Press on the inner race of bearing (1) until the bearing is against gear (2).

3. Place the inner race of bearing (6) onto a suitable support. Press the shaft of gear (2) into bearing (6) until the shoulder on the gear is against the bearing.

4. Use Tooling (A) to install retaining ring (5).

5. Place adapter (7) on a suitable support. Press the assembly of the gear and the bearings into the adapter. Ensure that bearing (6) is against the front face of the recess in adapter (7).

6. Install bolts (3) and washers (4). Tighten the bolts to a torque of 12 N·m (105 lb in).

End By:
a. Install the pump drive. Refer to Disassembly and Assembly, “Pump Drive - Install”.

Pump Drive - Install (Transfer pump)

Installation Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Install a new O-ring seal to the assembly of pump drive (3).

2. Install the assembly of pump drive (3) to front housing (1).
3. Install bolts (2). Tighten the bolts to a torque of 47 N·m (35 lb ft).

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

**End By:**

a. Install the fuel transfer pump. Refer to Disassembly and Assembly, "Fuel Transfer Pump - Install".

### Electronic Control Module - Remove and Install

#### Removal Procedure

1. Disconnect the negative battery terminal at the battery.

2. Remove nuts (6). Loosen allen head screw (4). Disconnect the OEM harness (5) from electronic control module (10).

3. Cut cable tie (3). Loosen allen head screw (1). Disconnect engine harness assembly (2) from electronic control module (10).

4. Remove bolts (8) and remove the assembly of electronic control module (10). Note the position of any brackets that are secured by the bolts.

5. Remove washers and the isolation mounts (9) from the electronic control module.

6. If necessary, remove the brackets that support the harness assemblies.

### Installation Procedure

1. If a replacement electronic control module is installed, the module must be programmed with the correct information. Refer to Troubleshooting, "Replacing the ECM" and refer to Troubleshooting, "Flash Programming" for the correct procedure.

2. If necessary, install the brackets that support the wiring harnesses.

3. Install isolation mounts and spacers (9) to electronic control module (10). Install washers and bolts (8) to electronic control module (10). Ensure that ground strap (7) for the electronic control module is clamped between the washer and the appropriate bolt.

4. Install the assembly of the electronic control module. Tighten bolts (8) to a torque of 25 N·m (18 lb ft).

**Note:** Ensure that the ground strap is not strained as the bolt is tightened.

5. Connect engine wiring harness (2) to electronic control module (10). Tighten allen head screw (1) to a torque of 5 N·m (44 lb in).

**Note:** Care must be taken in order to avoid damage to the connector pins during installation of the harness.

6. Position engine wiring harness (2) against the support bracket. Use a new cable tie (3), in order to secure the engine wiring harness to the bracket.
7. Connect OEM wiring harness (5) to electronic control module (10). Tighten allen head screw (4) to a torque of 5 N·m (44 lb in).

**Note:** Care must be taken in order to avoid damage to the connector pins during installation of the harness.

8. Position OEM wiring harness (5) against the support bracket. Install nuts (6) in order to secure OEM wiring harness (5) to the bracket.

9. Connect the negative battery terminal at the battery.

3. Disconnect the wiring harness assembly from alternator (5).

4. Loosen bolt (1) and nut (6). Loosen the bolt for link (3). Push the alternator toward the engine. Remove the V-belt from the alternator pulley.

5. Remove bolt (1), washer (2) and spacer (4) from alternator (5).

6. Remove nut (6) and washer (7). Remove bolt (8), washer (10) and spacer (9) from alternator (5). Remove the alternator.

**Installation Procedure**

1. Put alternator (5) in position and install bolt (8), washer (10) and spacer (9). Install nut (6) and washer (7) finger tight.

2. Put link (3) into position on the alternator and loosely install bolt (1), washer (2) and spacer (4).


4. Tighten bolt (1) to a torque of 70 N·m (52 lb ft). Tighten nut (6) to a torque of 105 N·m (77 lb ft). Tighten the bolt for link (3) to a torque of 105 N·m (77 lb ft).

5. Connect the harness assemblies to the alternator. Refer to Specifications, “Alternator” for the torque values.

6. Connect the battery.
Electric Starting Motor - Remove and Install

Removal Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

WARNING
Accidental engine starting can cause injury or death to personnel working on the equipment.

To avoid accidental engine starting, disconnect the battery cable from the negative (−) battery terminal. Completely tape all metal surfaces of the disconnected battery cable end in order to prevent contact with other metal surfaces which could activate the engine electrical system.

Place a Do Not Operate tag at the Start/Stop switch location to inform personnel that the equipment is being worked on.

1. Disconnect the batteries.

2. Put an identification mark on the harness assemblies that are connected to the electric starting motor and the solenoid.

3. Disconnect the harness assemblies from solenoid (1).

4. Disconnect the harness assembly from electric starting motor (2).

5. Attach a suitable lifting device to electric starting motor (2). The weight of electric starting motor is approximately 26.5 kg (58.4 lb).

6. Remove bolts (3). Remove electric starting motor (2) from the flywheel housing.

Installation Procedure

NOTICE
Keep all parts clean from contaminants.
Contaminants may cause rapid wear and shortened component life.

1. Attach a suitable lifting device to electric starting motor (2). The weight of electric starting motor is approximately 26.5 kg (58.4 lb).

2. Position electric starting motor (2) on the flywheel housing. Install bolts (3). Tighten the bolts to a torque of 215 N·m (160 lb ft). Remove the lifting device from the electric starting motor.

3. Connect the harness assemblies to solenoid (1). Tighten the nuts. Refer to Specifications, “Electric Starting Motor” for the correct torque values.

4. Connect the harness assemblies to electric starting motor (2). Tighten the nuts. Refer to Specifications, “Electric Starting Motor” for the correct torque value.

5. Connect the batteries.
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