

Section 7

FUEL SYSTEM

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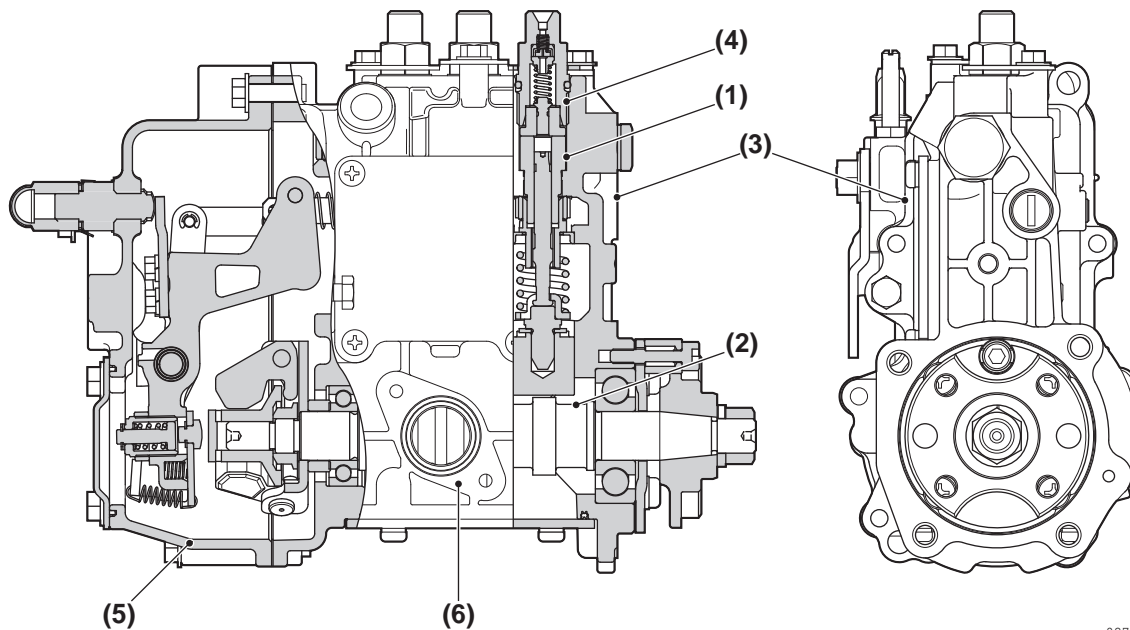
FUEL SYSTEM

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SAFETY PRECAUTIONS

Before performing any fuel system service procedures, review the *Safety section on page 3-1*.

INTRODUCTION



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Figure 7-1

This section of the *Service Manual* describes the procedures necessary to remove, install and time the MC fuel injection pump and its associated system components.

Fuel Injection Pump

Note: If the MC fuel injection pump itself requires servicing, it must be taken to an authorized Yanmar FIE (Fuel Injection Equipment) repair facility.

NOTICE:

- Contact Polaris Technical Service for assistance to have the MC fuel injection pump serviced. NEVER remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

- NEVER attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations, and then replace the tamper-proof seals.
- Tampering with or removing these devices may void the "Limited Warranty."

The following describes the features of the MC fuel injection pump, manufactured by Yanmar.

The fuel injection pump is a very important component of the engine. It is capable of making very precise fuel delivery adjustments according to the varied loads applied to the engine.

All of the fuel injection pump components are very precisely machined. It is extremely important to follow good service practices and maintain cleanliness when servicing the fuel injection pump.

The Yanmar MC Fuel Injection Pump is an in-line type pump which consists of a fuel supply plunger (**Figure 7-1, (1)**) for each cylinder, a camshaft (**Figure 7-1, (2)**) and a pump housing (**Figure 7-1, (3)**). A delivery valve (**Figure 7-1, (4)**) connects to a high-pressure fuel line for each cylinder. The fuel injection pump housing contains a governor (**Figure 7-1, (5)**).

Fuel from the fuel tank to the fuel injection pump is delivered by a low-pressure electric fuel feed pump. On a few special models, a mechanical fuel feed pump is used instead of an electric pump. The mechanical fuel feed pump is mounted to the fuel injection pump housing in place of the cover plate (**Figure 7-1, (6)**).

Fuel to be injected into the cylinders is pressurized by the up and down motion of each camshaft-driven plunger, and is then supplied by the high-pressure fuel lines to the respective fuel injector.

The fuel injector is essentially a spring-loaded valve. When fuel pressure from the fuel injection pump reaches a pre-determined level, the pintle (valve) is forced off its seat and fuel is atomized as it passes between the pintle and seat. The timing and quantity of the fuel injected into the cylinder is controlled by the fuel injection pump and governor assembly.

Stop Solenoid

The ML fuel injection pumps are equipped with a stop solenoid that controls the fuel flow inside the fuel injection pump.

With the starter switch in the OFF position, no current flows to the stop solenoid and the solenoid plunger is extended, holding the fuel injection pump fuel rack in the “closed” position and not allowing fuel to flow through the injection pump and to the engine.

When the starter switch is turned to the start position, the “pull coil” (36.5-amp draw / white wire) inside the solenoid is activated and pulls the solenoid plunger into the solenoid. This releases the fuel injection pump fuel rack, allowing fuel to flow through the injection pump and allowing the engine to start and run.

When the starter switch is returned to the ON or RUN position, the “pull coil” no longer receives current and the “hold coil” (0.5-amp draw / red wire) inside the solenoid is activated. The “hold coil” holds the solenoid plunger in the RUN position, allowing fuel to continue flowing and the engine to continue running.

To stop the engine, the key switch is turned to the OFF position. Current no longer flows to the stop solenoid “hold coil,” and the solenoid plunger extends and moves the injection pump fuel rack to the “closed” position, shutting off the fuel flow and stopping the engine.

Failure of the stop solenoid could result in the engine not starting, the engine stopping suddenly, the engine continuing to run with the key switch returned to the ON or RUN position or the engine failing to stop when the key switch is turned to the OFF position. Use a VOA multimeter or continuity light to check for a good ground and 12V at the stop solenoid in the correct sequence.

FUEL SYSTEM SPECIFICATIONS

Special Torque Chart

Component	Tightening Torque	Lubricating Oil Application (Thread Portion and Seat Surface)
Fuel Injector	36.1 - 39.1 ft-lb (49 - 53 N·m, 5.0 - 5.4 kgf·m)	Not Applied
Fuel Pump Drive Gear Nut	44 - 51 ft-lb (59 - 69 N·m; 6 - 7 kgf·m)	Not Applied
High-Pressure Fuel Injection Line Nuts	22 - 25 ft-lb (29 - 34 N·m; 3.0 - 3.5 kgf·m)	Not Applied
Fuel Return Line Nuts	18 - 24 ft-lb (24 - 33 N·m; 2.5 - 3.3 kgf·m)	Not Applied
Fuel Injection Pump Mounting Bolts	17 - 21 ft-lb (23 - 28 N·m; 2.3 - 2.9 kgf·m)	Not Applied
Fuel Injector Nozzle Case Nut	21.4 - 36.1 ft-lb (29 - 49 N·m; 3.0 - 5.0 kgf·m)	Not Applied

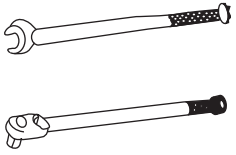
Test and Adjustment Specifications

Fuel Injector Pressure	Fuel Injection Timing
1784 - 1929 psi (12.3 - 13.3 MPa; 125 - 136 kgf/cm ²)	See <i>Checking and Adjusting Fuel Injection Timing</i> on page 7-17

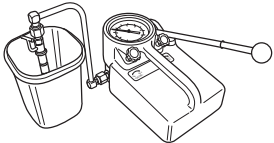
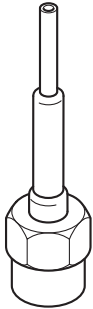
Note: Fuel injector pressures given are for used parts. New injectors (5 hours operation or less) will read approximately 72.5 psi (0.5 MPa; 5 kgf/cm²) higher.

SPECIAL SERVICE TOOLS

Note: Tools without Yanmar part numbers must be acquired locally.

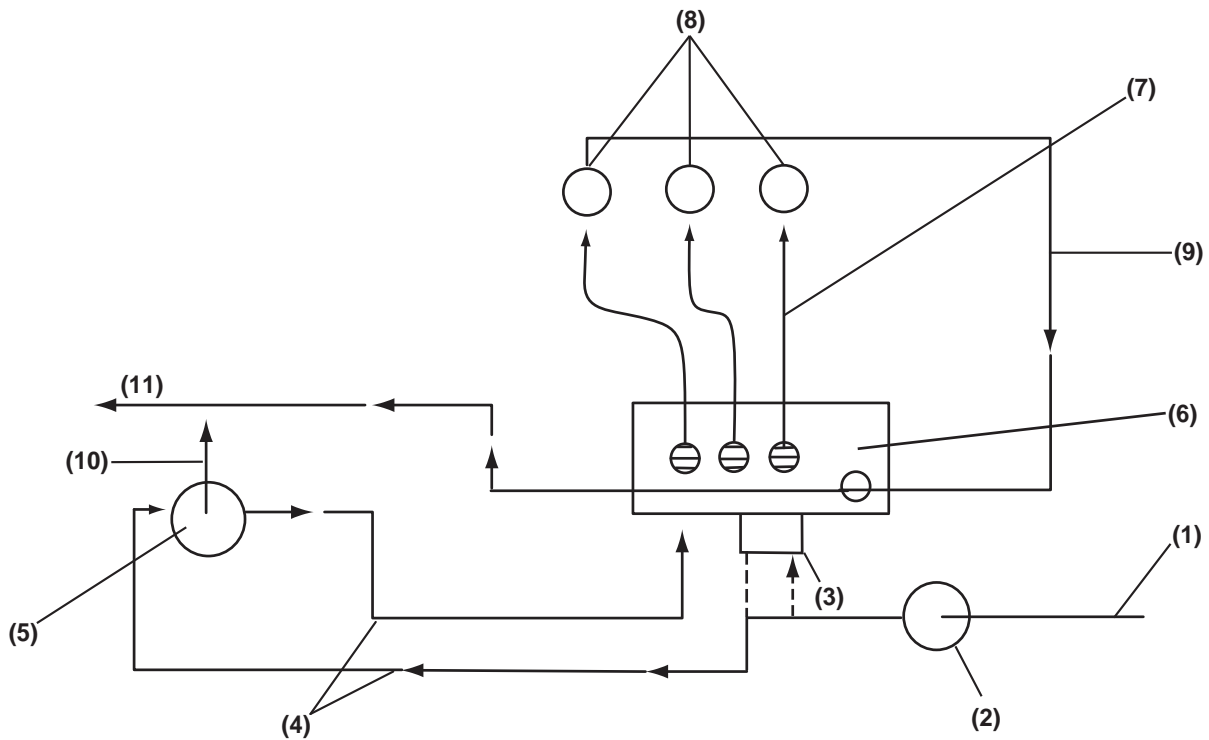
No.	Tool Name	Application	Illustration
1	Torque Wrench (Locally Available)	For tightening nuts and bolts to the specified torque	 0000840

MEASURING INSTRUMENTS

No.	Instrument Name	Application	Illustration
1	Fuel Injector Tester (Available from SPX)	For observing injection spray pattern of fuel injection nozzle and measuring injection pressure	
2	"Spill-Timing" Tool (Available from SPX)*	Used to set fuel injection timing	

* Make from a short piece of the end of a high-pressure fuel line, a high-pressure fuel line nut and a short piece of clear plastic tubing (a thin nozzle from an aerosol spray can works well). Drill out the end of the fuel line to accept the nozzle. Use a small amount of silicone sealant to seal the nozzle into the fuel line.

FUEL SYSTEM DIAGRAM

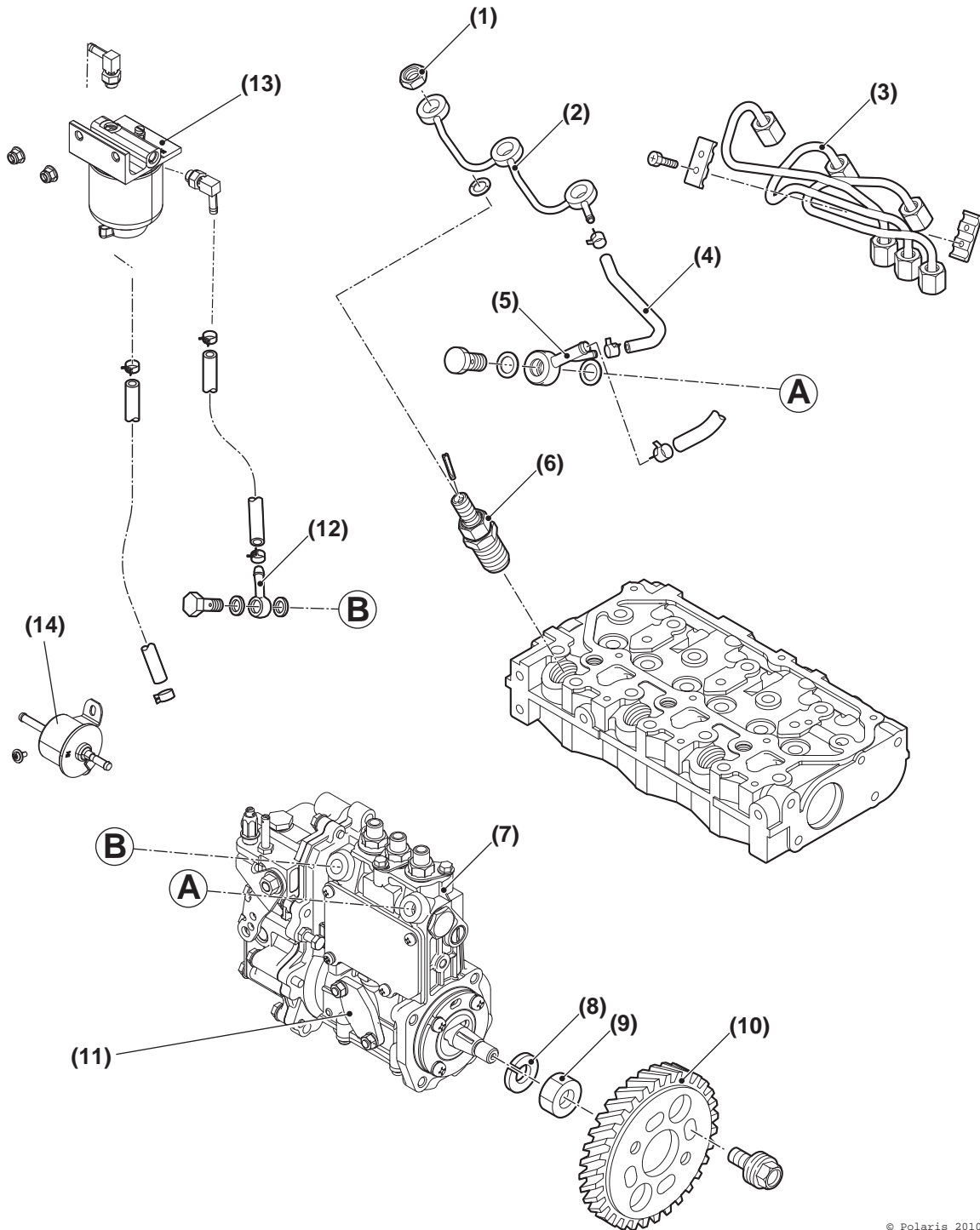


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Figure 7-2

- | | |
|--|---|
| <p>1 – Diesel Fuel Supply
 2 – Electric Fuel Lift Pump
 3 – Mechanical Fuel Pump Mount (Not Used)
 4 – Low-Pressure Fuel Supply Lines
 5 – Fuel Filter / Water Separator</p> | <p>6 – Fuel Injection Pump
 7 – High-Pressure Fuel Injection Lines
 8 – Fuel Injectors
 9 – Fuel Return from Fuel Injectors
 10 – Air Bleed Orifice
 11 – Fuel Return to Tank</p> |
|--|---|

FUEL SYSTEM COMPONENTS



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Figure 7-3

- 1 – Fuel Return Line Nut
- 2 – Fuel Return Line
- 3 – High-Pressure Fuel Injection Lines
- 4 – Fuel Return Hose
- 5 – Fuel Return Fitting
- 6 – Fuel Injector
- 7 – Fuel Injection Pump
- 8 – Lock Washer
- 9 – Fuel Injection Pump Drive Gear Nut
- 10 – Fuel Injection Pump Drive Gear Assembly
(DO NOT remove or loosen the four bolts that fasten the injection pump drive gear to the injection pump drive gear hub!)
- 11 – Mechanical Fuel Pump Boss (Not Used)
- 12 – Low-Pressure Fuel Inlet Fitting
- 13 – Fuel Filter / Water Separator
- 14 – Fuel Feed Pump (Electric)

FUEL INJECTION LINES

Removing the High-Pressure Fuel Injection Lines

NOTICE: Remove and install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to install the fuel lines.

Note: To prevent “rounding” the fuel line nuts, always use a “line” or “flare nut” wrench.

1. Close any fuel valves in the fuel supply line.
2. Clean the area to keep contaminants from entering the fuel system.
3. Place a drain pan under the fuel injection pump to catch any spillage.
4. Loosen the fuel line nuts at the fuel injection pump.
5. Next, loosen the fuel line nuts at the fuel injectors. Use one wrench to hold the fuel return line nut and fuel return line from rotating. Use a second wrench to loosen the fuel line nut (**Figure 7-4**). Repeat with the remaining fuel injectors.

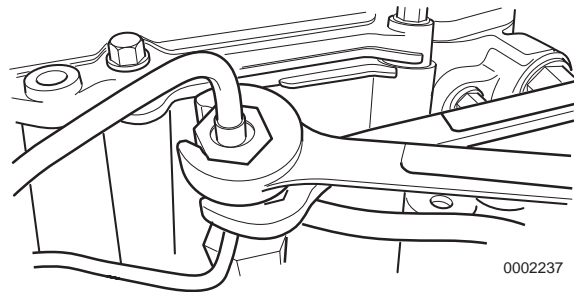


Figure 7-4

6. Finish loosening all the fuel line nuts and remove the high-pressure fuel lines as an assembly, being careful not to bend any of the fuel lines. Be sure to protect the fuel system from contamination by plugging or covering all open connections.
7. Plug or cap all openings to minimize leakage and prevent contamination.

Installing the High-Pressure Fuel Injection Lines

NOTICE: Remove and install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to install the fuel lines.

Note: To prevent “rounding” the fuel line nuts, always use a “line” or “flare nut” wrench.

1. Start all the fuel line nuts by hand. Then use a wrench to “snug” all the fuel line nuts.
2. Tighten the fuel line nuts on the fuel injection pump to the specified torque. See *Special Torque Chart* on page 7-6.
3. When tightening the fuel line nuts on the fuel injectors, use one wrench to hold the fuel return line nut and fuel return line from rotating. Use a second wrench to tighten the fuel line nuts (**Figure 7-4**). See *Special Torque Chart* on page 7-6.

Removing the Fuel Return Line

NOTICE: The fuel return line is a one-piece assembly. Use care not to bend or twist the fuel return line.

1. Clean the area to keep contaminants from entering the fuel system.
2. Remove the high-pressure fuel injection lines as an assembly. See *Removing the High-Pressure Fuel Injection Lines* on page 7-10.
3. Remove all fuel return line nuts (**Figure 7-5, (2)**) from the injectors (**Figure 7-5, (4)**).

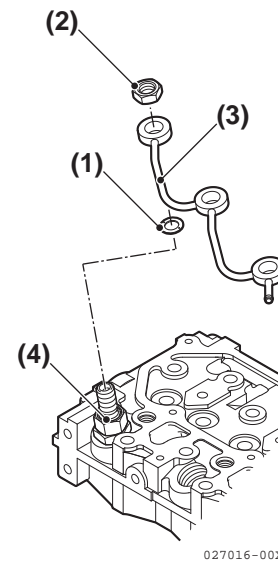


Figure 7-5

4. Remove the fuel return hose from the fuel return fitting on the fuel injection pump.
5. Carefully remove the fuel return line assembly (**Figure 7-5, (3)**).
6. Remove and discard the copper gasket (**Figure 7-5, (1)**) from each fuel injector.
7. Plug or cap all openings to minimize leakage and prevent contamination.

Installing the Fuel Return Line

NOTICE: The fuel return line is a one-piece assembly. Use care not to bend or twist the fuel return line.

1. Install a new copper gasket on each fuel injector.
2. Carefully install the fuel return line assembly.
3. Install and hand-tighten the fuel return line nuts.
4. Tighten the fuel return line nuts to the specified torque. See *Special Torque Chart* on page 7-6.
5. Install the fuel return hose.
6. Install the high-pressure fuel injection line assembly. See *Installing the High-Pressure Fuel Injection Lines* on page 7-11.

FUEL INJECTION PUMP

WARNING! Fire and Explosion Hazard. Diesel fuel is flammable and explosive under certain conditions.

- **When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.**
- **NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.**
- **NEVER use diesel fuel as a cleaning agent.**

WARNING! Exposure Hazard. Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

Removing the Fuel Injection Pump

1. Loosen the cooling pump V-belt by loosening the alternator (**Figure 7-6, (1)**).
2. Remove the engine pulley guard (if equipped), engine cooling pulley bolts (**Figure 7-6, (2)**), V-pulley (**Figure 7-6, (3)**), and V-belt.

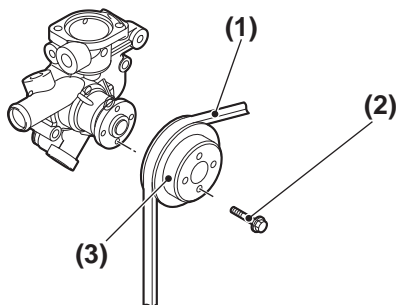


Figure 7-6

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3. Close any fuel valves in the fuel supply line.
4. Place a drain pan under the fuel injection pump to catch any spillage.
5. Clean the area to keep contaminants from entering the fuel system.

6. Remove the high-pressure fuel injection lines as an assembly. See *Removing the High-Pressure Fuel Injection Lines* on page 7-10.
7. Disconnect the fuel return lines from the fitting on the fuel injection pump (**Figure 7-7, (1)**). Plug the open ends of the lines to minimize leakage and prevent contamination.
8. Remove the fuel supply line (**Figure 7-7, (2)**) from the fitting on the fuel injection pump.
9. Plug or cap all openings to minimize leakage and prevent contamination.
10. Remove the throttle cable from the fuel injection pump.
11. Disconnect the stop solenoid wiring connector (**Figure 7-7, (3)**).

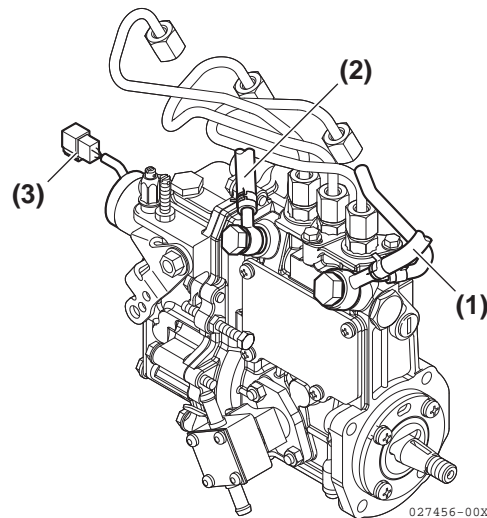


Figure 7-7

12. Remove the fuel injection pump drive gear access cover (**Figure 7-8, (1)**) from the gear case cover (**Figure 7-8, (2)**).

Note: The cover is secured with an adhesive sealant. Use a gasket scraper to separate the cover from the gear case cover.

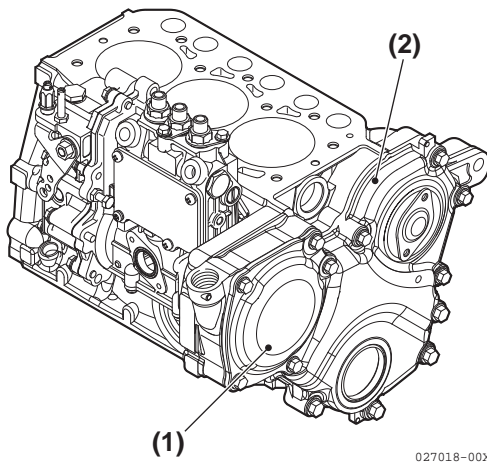


Figure 7-8

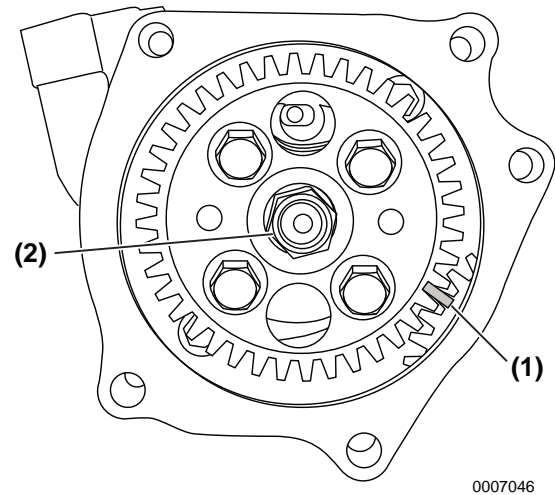


Figure 7-9

13. To aid in assembly, make alignment marks **(Figure 7-9, (1))** on the pump drive gear and idler gear. *NOTICE: Mark the gears with something that will not rub off or be affected by oil and become illegible. If the gears are not marked or are illegible during installation, the gear case cover must be removed to properly time the injection pump gear. NOTICE: After marking the position of the pump drive gear, do not rotate the engine crankshaft. Rotating the crankshaft will cause the fuel injection pump to become misaligned.*
14. Hold the gear train stationary using a wrench on the crankshaft pulley bolt. Remove the fuel injection pump drive gear retaining nut and washer **(Figure 7-9, (2))**. *NOTICE: Do not loosen or remove the four bolts retaining the fuel injection pump drive gear to the fuel injection pump hub. Do not disassemble the fuel injection pump drive gear from the hub.*

15. Thread the drive gear nut onto the injection pump shaft until it is even with the end of the shaft. This will prevent the gear from falling off of the shaft when using the puller.
16. Remove the injection pump drive gear and hub from the injection pump drive shaft as an assembly using an appropriate gear puller **(Figure 7-10)**.
17. Once the fuel injection pump drive gear and hub assembly have “popped” loose from the tapered fuel injection pump drive shaft, carefully remove the drive gear nut **(Figure 7-10, (1))** and remove gear and hub assembly.

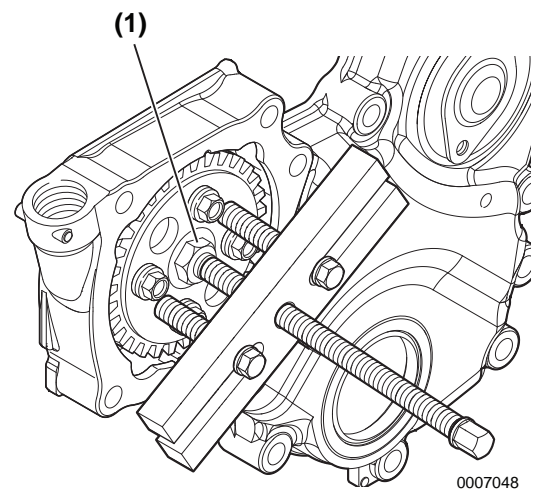


Figure 7-10

18. Remove the four bolts (**Figure 7-11, (1)**) and metal gasket (**Figure 7-11, (2)**) fastening the fuel injection pump to the cylinder block. Remove the fuel injection pump. **NOTICE: Do not rotate the crankshaft with the injection pump removed.**

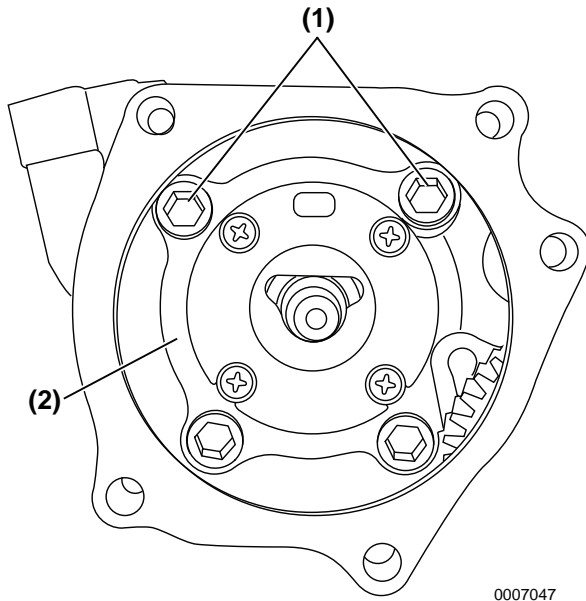


Figure 7-11

19. If the fuel injection pump requires servicing, it must be sent to an authorized Yanmar FIE repair facility for repair and calibration, or replaced with a new fuel injection pump.

NOTICE:

- Contact Polaris Technical Service to have the MC fuel injection pump serviced.

NEVER remove or attempt to remove the tamper-proof devices from the full-load fuel adjusting screw or the high-speed throttle limit screw on the fuel injection pump and governor assembly. These adjustments have been made at the factory to meet all applicable emissions regulations and then sealed.

- *NEVER* attempt to make any adjustments to these sealed adjustment screws. If adjustments are required, they can be made only by a qualified fuel injection shop that will ensure the injection pump continues to meet all applicable emissions regulations, and then replace the tamper-proof seals.
- Tampering with or removing these devices may void the "Limited Warranty."

Installing the Fuel Injection Pump

1. Install a new gasket to the mounting surface of the injection pump.
2. Install pump to the engine block using the four bolts (**Figure 7-12, (1)**) and metal gasket (**Figure 7-12, (2)**). Tighten to the specified torque.

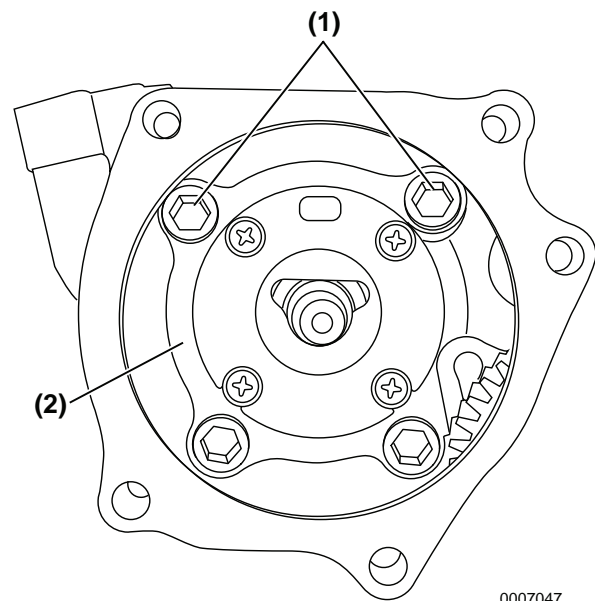


Figure 7-12

Note: Ensure the tapered surface of the fuel injection pump shaft is clean and dry.

- Align the key on the fuel injection pump shaft with the keyway in the fuel injection pump drive gear hub. Ensure the fuel injection pump drive gear is aligned with the idler gear using the reference marks made earlier (Figure 7-13, (1)).

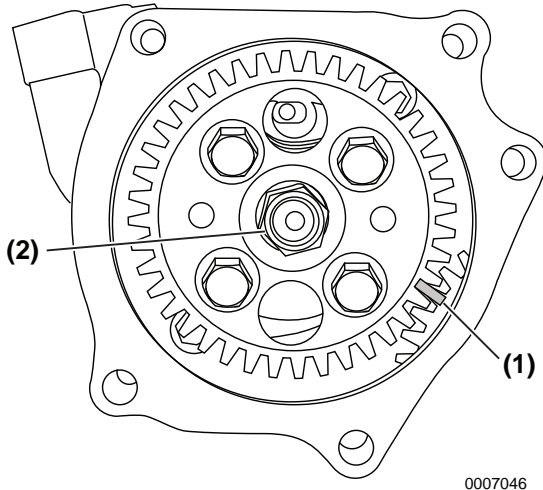
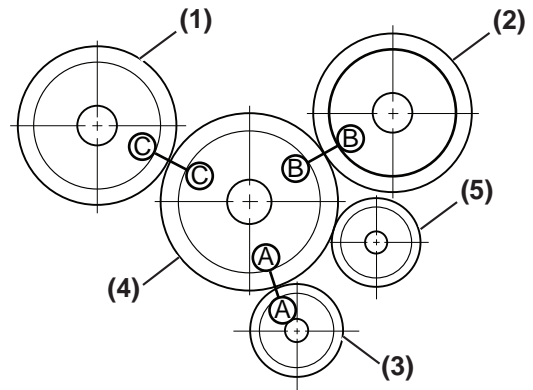


Figure 7-13

- If installing the fuel injection pump on an engine with the front gear case cover removed, the fuel injection pump drive gear can be aligned with the idler gear by aligning the stamped marks (Figure 7-14, (A, B, C)) on the fuel injection pump drive gear, idler gear, camshaft gear and crankshaft drive gear. Ensure all three timing marks (A, B, C) are aligned.

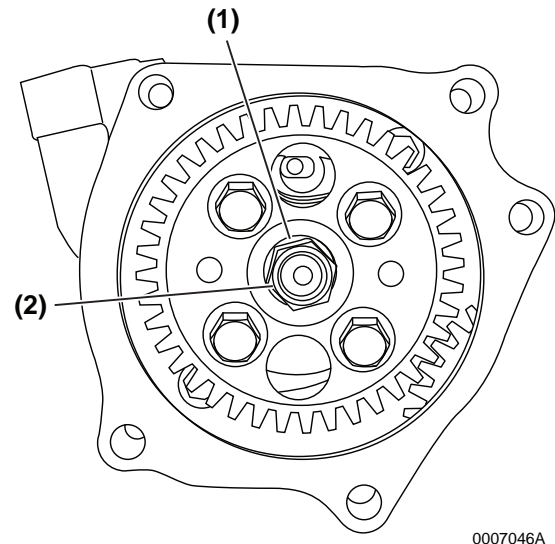


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Figure 7-14

- 1 – Fuel Injection Pump Drive Gear
- 2 – Camshaft Drive Gear
- 3 – Crankshaft Drive Gear
- 4 – Idler Gear
- 5 – Oil Pump Gear

- Install the fuel injection pump drive gear lock washer (Figure 7-15, (1)) and nut (Figure 7-15, (2)). Do not lubricate threads of the nut or shaft. Hold the crankshaft pulley bolt with a wrench and tighten the pump drive gear nut to the specified torque. See *Special Torque Chart* on page 7-6.



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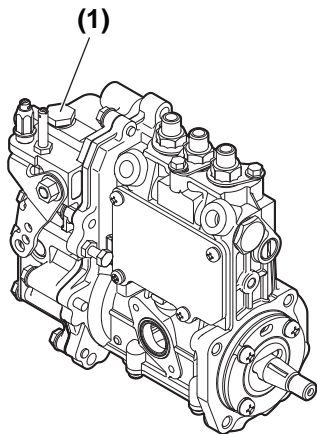
Figure 7-15

- Connect the fuel supply and return lines to the fuel injection pump.

7. Connect the throttle linkage and stop solenoid wire connector.
8. If installing a new or recalibrated fuel injection pump, check the fuel injection timing before completing the installation of the fuel injection pump. See *Checking and Adjusting Fuel Injection Timing* on page 7-17.

Note: While it is not required to check the injection timing when installing the original fuel injection pump, it is recommended that it be done.

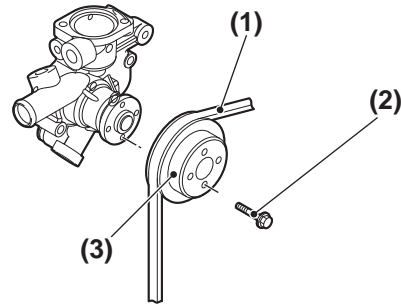
9. After adjusting the fuel injection timing, apply ThreeBond Liquid Gasket No. 1212, or equivalent sealant to the sealing surface of the fuel injection pump drive gear access cover. Install the cover on the front of the gear case and tighten the bolts.
10. Install the fuel injection high-pressure lines. See *Installing the High-Pressure Fuel Injection Lines* on page 7-11. **NOTICE:** When installing a new or repaired fuel injection pump, it is important to add engine oil to the fuel injection pump to provide lubrication for initial start-up. Add 5 to 7 oz (150 to 200 cc) of clean engine oil to the fuel injection pump at the fill plug **(Figure 7-16, (1))** located in the upper outside section of the governor housing.



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Figure 7-16

11. Install the coolant pump V-pulley **(Figure 7-17, (3))**, pulley bolts **(Figure 7-17, (2))** and V-belt **(Figure 7-17, (1))**.



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Figure 7-17

12. Install the V-belt **(Figure 7-17, (1))**. Adjust as described in *Checking and Adjusting Cooling V-Belt* on page 5-13.
13. Install the cooling pulley guard (if equipped).
14. Prime the fuel system. See *Priming the Fuel System* on page 4-14.
15. Operate the engine and check for fuel and lube oil leaks.

CHECKING AND ADJUSTING FUEL INJECTION TIMING

Note: The following procedure is performed on the No. 1 cylinder. While checking and adjusting the timing on only No. 1 cylinder is usually sufficient, the same procedure can be performed on any or all cylinders.

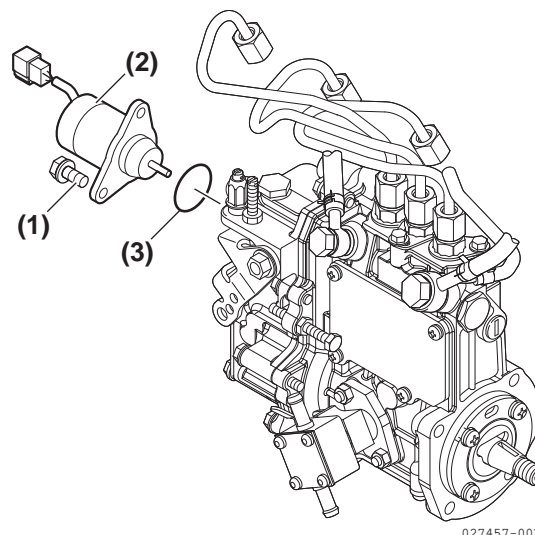
Checking Fuel Injection Timing

Some fuel may drain from the fuel injection pump during this process. Make provisions to contain any such spillage. **WARNING! Fire and Explosion Hazard. Use an approved container to catch fuel. NEVER use a shop rag to catch fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.**

1. Ensure the fuel injection pump is primed with fuel. See *Priming the Fuel System* on page 4-14.
2. Clean the area around the fuel injection pump. **NOTICE:** Clean the area around the fuel injection pump to prevent any contamination when the fuel injection pump plunger plug is removed.

Note: The stop solenoid must be removed to allow fuel to flow through the fuel injection pump.

3. Remove two screws (**Figure 7-18, (1)**).
4. Remove the stop solenoid (**Figure 7-18, (2)**) and O-ring (**Figure 7-18, (3)**).



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Figure 7-18

5. Set the throttle to the HIGH-IDLE position.
6. Using a wrench on the crankshaft pulley bolt, rotate the crankshaft in a clockwise direction while looking through the flywheel inspection port. Rotate the crankshaft until the injection timing marks on the flywheel are visible for No. 1 cylinder.
7. Typical flywheel markings are as shown in **Figure 7-19**.

Note: A typical flywheel will have multiple timing grids depending on the number of cylinders. Any grid and its corresponding cylinder can be used to check the fuel injection timing.

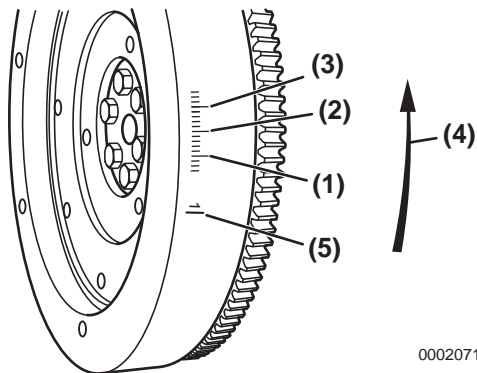
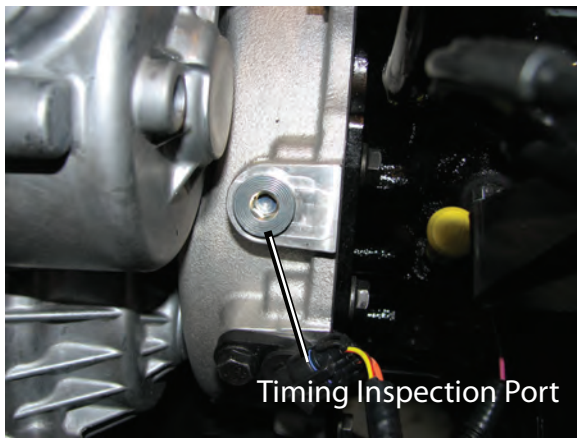


Figure 7-19

- 1 – 15° BTDC (Before Top Dead Center)
- 2 – 20° BTDC
- 3 – 25° BTDC
- 4 – Direction of Rotation
- 5 – TDC (Top Dead Center)

8. The flywheel shown in **Figure 7-19** applies to a Yanmar 3TNM72- APL engine.

Note: The TDC (Top Dead Center) mark can be identified by the cylinder numbers stamped near the TDC mark (**Figure 7-19, (5)**) on the flywheel.

9. If you are uncertain as to the timing degree designation of the timing marks on the flywheel timing grid, you can determine the timing degree designation by measuring the timing grid.

- First measure the distance between two of the “longer” marks on the timing grid. (They are 5° apart.) Then measure the distance from the TDC mark to the first “longer” mark on the timing grid. Divide that measurement by the distance between the two “longer” marks. The resulting answer will tell you how many degrees there are between the TDC mark and the first “longer” mark.

- EXAMPLE: If the distance between the two “longer” marks is approximately 2.0 cm and the distance from the TDC mark is approximately 4.0 cm, the answer is approximately 2. This indicates there is 10° (2 x 5°) between the TDC mark and the first “longer” mark on the timing grid. That means the first “longer” mark on the timing grid indicates 10° BTDC, the second “longer” mark indicates 15° BTDC and the third timing mark indicates 20°. If the answer is 3, that indicates there is 15° (3 x 5°) between the TDC mark and the first “longer” mark and that the first “longer” mark indicates 15° BTDC with the second and third “longer” marks indicating 20° BTDC and 25° BTDC respectively.

10. Highlight the timing reference mark on the flywheel housing (**Figure 7-20, (2)**) or engine back plate (**Figure 7-21, (2)**). Highlight the TDC mark (**Figure 7-20, (1)**), (**Figure 7-21, (1)**) on the flywheel.

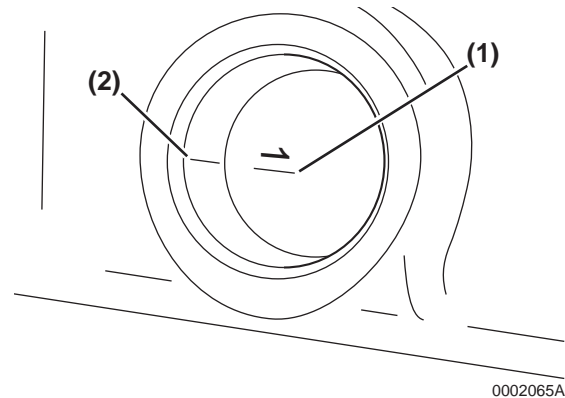


Figure 7-20

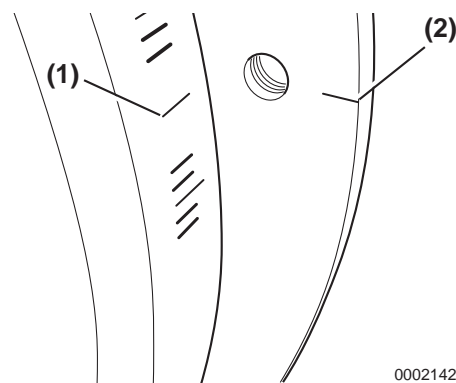


Figure 7-21

11. Highlight the target timing mark (Figure 7-21, (1)), (Figure 7-22, (1)) on the flywheel timing grid as the injection timing measured before the fuel injection pump removal.

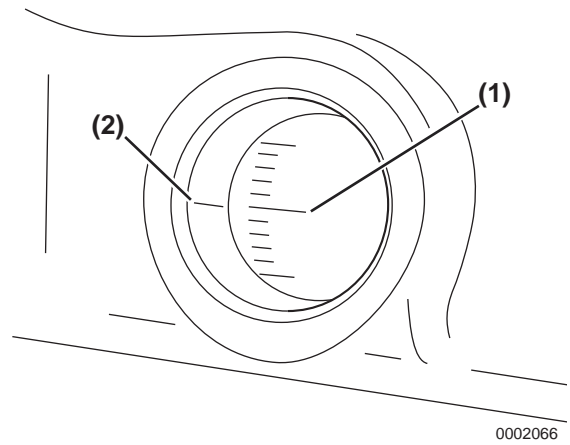


Figure 7-22

Injection Timing (FID)

	VH
rpm (min-1)	3600
3TNM72	20.0

12. Remove all high-pressure fuel injection lines. See *Removing the High-Pressure Fuel Injection Lines* on page 7-10.
13. Turn on all fuel supply valves.

Note: As the injection pump injects fuel to a cylinder only once every two engine revolutions, it may be necessary to rotate the crankshaft twice to see fuel being pumped from the timing tool or delivery valve of the cylinder you are using to check injection timing.

14. Install the “spill-timing” tool (Figure 7-23, (1)) onto the delivery valve for the cylinder being checked. See *Measuring Instruments* on page 7-7.

Note: If a timing tool is not available, timing can be checked by watching the fuel in the delivery valve itself.

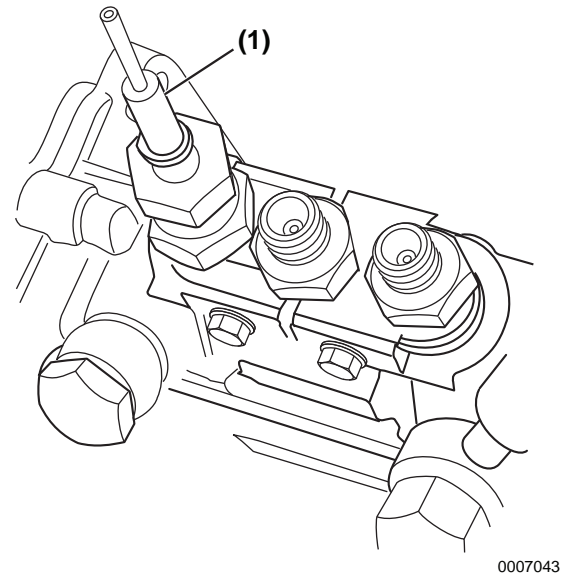


Figure 7-23

Note: The following references to the direction of rotation are made facing the cooling pump end of the engine and are adjusted by turning the crankshaft.

15. Slowly rotate the crankshaft clockwise using a wrench on the crankshaft pulley bolt until fuel is pumped from the nozzle of the “spill-timing” tool or delivery valve.
16. Slowly rotate the crankshaft clockwise approximately two more revolutions until the timing grid on the flywheel (for the cylinder being checked) is at approximately 30° BTDC.

Note: The fuel injection pump injects fuel to a cylinder only once every two engine revolutions.

17. “Flick” the nozzle of the timing tool with a finger to remove bubbles and establish a fuel level of approximately half the height of the nozzle.
18. Very slowly rotate the crankshaft clockwise until the fuel level in the nozzle of the “spill-timing” tool, or in the delivery valve, just begins to move. Immediately stop rotating the crankshaft.
19. Check the position of the flywheel target timing mark (**Figure 7-22, (1)**) on the flywheel grid in relation to the timing reference mark (**Figure 7-22, (2)**) on the flywheel housing or back plate. If the two marks are aligned, the fuel injection timing is correct. If the marks do not align, the fuel injection timing must be adjusted. See *Adjusting Fuel Injection Timing* on page 7-20.
20. Repeat Steps 14-18 two or three times to verify timing.
21. Remove the “spill-timing” tool.
22. Install the shut-off solenoid.
23. Install the high-pressure fuel injection lines. See *Installing the High-Pressure Fuel Injection Lines* on page 7-11.
24. Replace the flywheel inspection port cover.
25. Prime the fuel system. Operate the engine and check for leaks.

Adjusting Fuel Injection Timing

If the timing marks did not align when performing the *Checking Fuel Injection Timing* on page 7-17, the following steps must be performed to properly time the engine.

The fuel injection pump of TNM engines is fixed with four bolts. Adjust the injection timing by rotating the pump drive gear on the pump flange.

1. Leave the “spill-timing” tool installed in the fuel injection pump.
2. Determine if the timing is “advanced” or “retarded” by comparing the position of the target timing mark on the flywheel grid (**Figure 7-24, (1)**) with the timing mark on the flywheel housing or back plate (**Figure 7-24, (2)**).

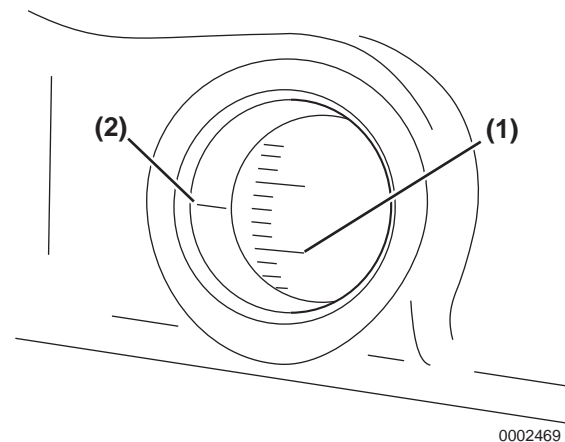


Figure 7-24

3. The new injection pump will come with a timing grid sticker. Each line on the timing grid sticker is 1°. Each line on the flywheel grid is also 1°.

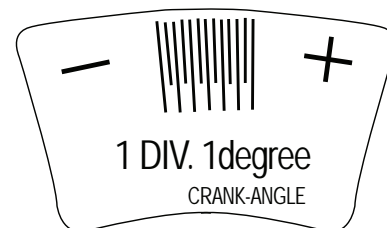
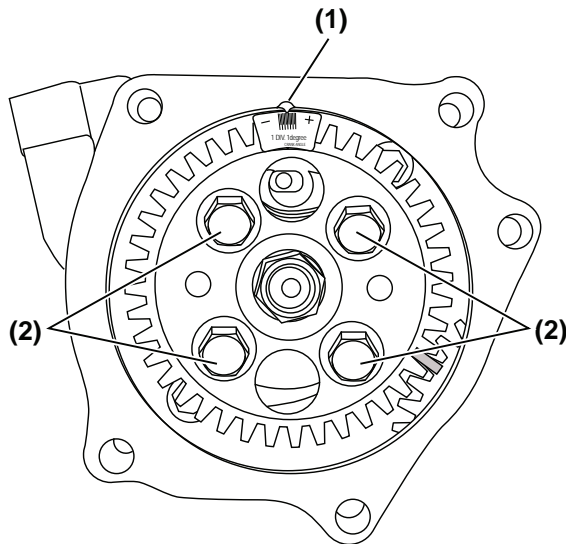


Figure 7-25

4. Observe the flywheel grid again and determine how many degrees you need to advance or retard the timing.
5. Clean the area of the gear by the pointer on the timing cover and put the sticker on the drive gear, aligning the timing mark on the timing cover (Figure 7-26, (1)) with the center of the sticker.
6. Loosen the four bolts (Figure 7-26, (2)) fastening the injection pump drive gear to the flange.



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Figure 7-26

7. If the injection timing was less than the target timing, the injection timing is “retarded” and will need to be “advanced.”

To “advance” the injection timing: Rotate the crankshaft counterclockwise.

If the injection timing was greater than the target timing, the injection timing is “advanced” and will need to be “retarded.”

To “retard” the injection timing: Rotate the crankshaft clockwise.

8. Slowly rotate the crankshaft while watching the pointer on the timing cover and the timing grid sticker on the injection pump gear. Turn it the required number of degrees that was determined earlier when observing the flywheel grid.
9. Tighten the pump drive gear mounting bolts.
10. Recheck the fuel injection timing. Repeat the fuel injection timing and adjustment procedures until the timing is correct.
11. Remove the sticker from the pump drive gear.
12. Remove the “spill-timing” tool.
13. Install the shut-off solenoid.
14. Install the high-pressure fuel injection lines. See *Installing the High-Pressure Fuel Injection Lines* on page 7-11.
15. Apply ThreeBond Liquid Gasket No. 1212 or equivalent sealant to the sealing surface of the fuel injection pump drive gear access cover. Install the cover on the front of the gear case and tighten the bolts.
16. Replace the flywheel inspection port cover.
17. Prime the fuel system. Operate the engine and check for leaks.

FUEL INJECTORS

Removing the Fuel Injectors

WARNING! Fire and Explosion Hazard. Diesel fuel is flammable and explosive under certain conditions.

- **When you remove any fuel system component to perform maintenance (such as changing the fuel filter), put an approved container under the opening to catch the fuel.**
- **NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately.**
- **NEVER use diesel fuel as a cleaning agent.**

WARNING! Exposure Hazard. Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

1. Close any fuel valves in the fuel supply line.
2. Clean the area around the fuel injection pump and fuel injectors to keep contaminants from entering the engine or fuel system.
3. Remove the intake manifold / valve cover assembly. See *Removing the Intake Manifold / Valve Cover* on page 6-18.
4. Remove the high-pressure fuel injection lines as an assembly. See *Removing the High-Pressure Fuel Injection Lines* on page 7-10.
5. Remove nut (**Figure 7-27, (1)**). Remove the fuel return line (**Figure 7-27, (2)**) and copper washer (**Figure 7-27, (3)**) from the fuel injectors. See *Removing the Fuel Return Line* on page 7-11.

Note: The fuel injectors used on IDI engines screw into the cylinder head.

6. Remove the fuel injectors (**Figure 7-27, (4)**).

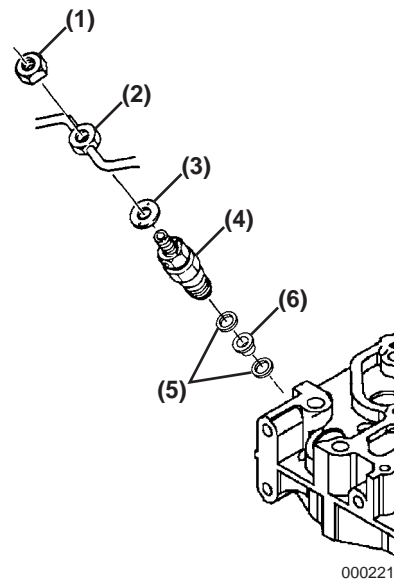


Figure 7-27

7. Remove the injector nozzle gaskets (**Figure 7-27, (5)**) and protector (**Figure 7-27, (6)**) from the cylinder head.

Testing the Fuel Injectors

NOTICE: Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Thoroughly clean the fuel injector nozzle using clean diesel fuel and a brass wire brush.
2. Visually inspect the fuel injectors and nozzle protectors for deposits or damage. Clean, repair or replace as necessary.

Note: Test the fuel injector using an injection nozzle tester. Operate the tester following the information provided by the tester manufacturer. Use clean, filtered fuel or FIE calibration fluid for the test.

3. Using the correct adapter, connect a fuel injector to a nozzle tester. Aim the fuel injector into a suitable container to catch the fuel spray (**Figure 7-28**).

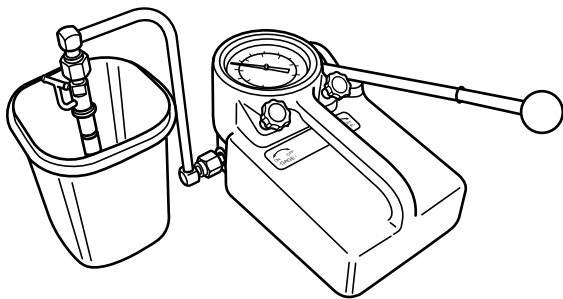


Figure 7-28

WARNING! High-Pressure Hazard. NEVER inject fuel toward you. Since the fuel is injected at high pressure from the nozzle, it may penetrate the skin, resulting in injury.

WARNING! Fire and Explosion Hazard. NEVER inject fuel toward a fire source. Atomized fuel is highly flammable and may cause a fire or burn skin.



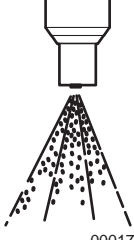


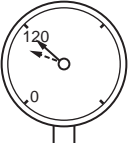
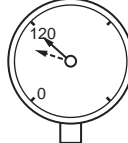
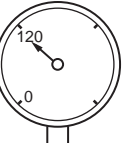
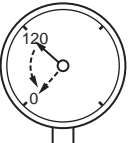
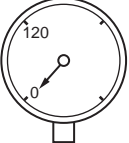
CAUTION! Flying Object Hazard. ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

4. Pump the operating lever of the tester slowly, observing the pressure reading at the point where the fuel injector begins spraying fuel. See *Test and Adjustment Specifications on page 7-6* for correct pressure readings.

Note: Opening pressure of a new fuel injector will be approximately 72.5 psi (0.5 MPa; 5 kgf/cm²) higher than one that has been operated for 5 hours or longer.

5. Pump the operating lever slowly to hold the pressure steady at a point just below the opening pressure and hold that pressure for 5 seconds. Observe the injector to see that it is sealing properly and is not “dripping.” If fuel leaks from the return line fitting, check that the nozzle case nut is tight. Service or replace the injector if fuel continues to leak from either the return line fitting or nozzle.
6. Pump the operating lever more rapidly to repeatedly “pop” the injector and observe the spray pattern. The pattern should be a very fine uniform spray. If dripping or an uneven pattern is seen, service or replace the injector. See *Fuel Injector Test Results on page 7-24*.

Fuel Injector Test Results

	A	B	C	D	E
Injection Pattern	 0001742	 0001743	 0001744		
Pressure Gauge Reading	 0001747 Gauge needle fluctuates around the valve opening pressure.	 0001748 Gauge needle fluctuates around the valve opening pressure.	 0001749 Gauge needle stays at a position near the valve opening pressure.	 0001750 Although the gauge needle reaches the valve opening pressure, the pressure drop is large.	 0001751 Pressure does not increase even when the tester lever is operated.
Atomization Pattern	5°-10° cone and roughly uniform.	Atomization is excessively one-sided.	Although atomized (burner like shape), the needle does not pulsate.	Bar shape with excessive after drops.	Drops.
Possible Cause	(Normal, injector is good)	Normally caused by carbon contamination of the nozzle tip. Sometimes caused by flaws in or damage to the needle tip.	Caused by excessive carbon contamination of the nozzle tip. Sometimes caused by internal contamination.	Damage to the seat. Contamination of seat by fine foreign particles. Excessively worn seat.	Sticking of needle. Excessively damaged or worn seat. Contamination of seat by foreign matter. Damaged or broken internal parts or nozzle case nut.

Note: If the fuel injector fails any tests, it should be serviced or replaced as necessary. If the pressure is outside specified limits, adjust the pressure. See *Adjusting Fuel Injector Pressure* on page 7-26.

Disassembling and Inspecting the Fuel Injectors

NOTICE: Never use a steel wire brush to clean fuel injectors. Damage to the nozzle and other components is likely to result.

1. Clean carbon from used injectors using clean diesel fuel. Hardened deposits or varnish can be cleaned using a brass wire brush.

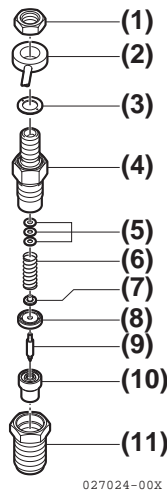


Figure 7-29

- 1 – Return Fuel Fitting Nut
- 2 – Return Fuel Fitting
- 3 – Seal (PK)
- 4 – Injector Body
- 5 – Pressure Adjusting Shims
- 6 – Spring
- 7 – Spring Seat
- 8 – Valve Stop Spacer
- 9 – Nozzle Valve
- 10 – Nozzle Body
- 11 – Nozzle Case Nut

2. Place the fuel injector in a soft-jawed vise with the nozzle pointing up.
3. Remove the nozzle case nut.
4. Carefully remove the injector from the vise.
5. Turn the injector over and remove the nozzle body, nozzle valve, valve stop spacer, nozzle spring seat, nozzle spring and shims.

6. Inspect the sealing surfaces (**Figure 7-30, (2)**) between the valve stop spacer and nozzle body for nicks or scratches. Check the contact area between the valve stop spacer and the nozzle valve (**Figure 7-30, (1)**) for scoring or pitting. Use a magnifying glass to inspect.

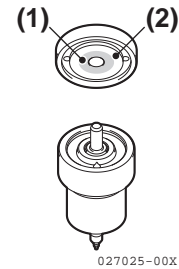


Figure 7-30

7. Perform a nozzle valve slide test:
 - (a) Wash nozzle body and valve in clean diesel fuel.
 - (b) While holding the nozzle body vertical, pull the nozzle valve about 2/3 of the way out (**Figure 7-31**).
 - (c) Release the valve. It should fall smoothly to its seat by its own weight.

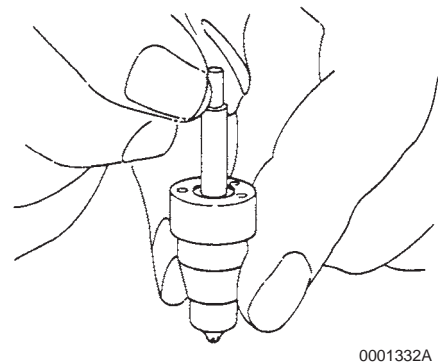


Figure 7-31

NOTE: Replace the fuel injector assembly if it fails any inspection or if an injector tester is not available.

Adjusting Fuel Injector Pressure

The fuel injectors open when pressure reaches a predetermined pressure threshold. They close when the pressure is reduced below that threshold. The pressure threshold can be adjusted by adding or removing shims.

Fuel Injector Shim Kit	
Yanmar Part No. 114250-53400	
(Includes one each of the following shims)	
114250-53420	0.0197 in. (0.50 mm)
114250-53500	0.0217 in. (0.55 mm)
114250-53430	0.0236 in. (0.60 mm)
114250-53510	0.0256 in. (0.65 mm)
114250-53440	0.0276 in. (0.70 mm)
114250-53520	0.0295 in. (0.75 mm)
114250-53450	0.0315 in. (0.80 mm)
114250-53530	0.0335 in. (0.85 mm)
114250-53540	0.0354 in. (0.90 mm)
114250-53550	0.0374 in. (0.95 mm)
114250-53560	0.0394 in. (1.00 mm)

The injection pressure will change by approximately 100 to 142 psi (0.69 to 0.98 MPa; 7 to 10 kgf/cm²) for every 0.004 in. (0.1 mm) shim thickness.

See the parts catalog for available shims.

1. Disassemble the fuel injector assembly. See *Disassembling and Inspecting the Fuel Injectors on page 7-25*.
2. Remove or add adjusting shims as needed.
3. Assemble the fuel injector assembly. See *Assembling the Fuel Injectors on page 7-26*.
4. Test the fuel injector. See *Testing the Fuel Injectors on page 7-23*. If the injector cannot be adjusted to the appropriate pressure, discard the fuel injector.

Assembling the Fuel Injectors

1. Secure the injector in a soft-jawed vise with the nozzle end up.
2. Install the shims, nozzle spring, nozzle spring seat, valve stop spacer, nozzle valve and nozzle body.
3. Install the nozzle case nut. Tighten it to specification.

Installing the Fuel Injectors

1. Insert the nozzle gaskets (**Figure 7-32, (5)**) and nozzle protector (**Figure 7-32, (6)**) in the cylinder head.
2. Install the fuel injector (**Figure 7-32, (4)**) in the cylinder head and tighten to specification.
3. Install new copper washers (**Figure 7-32, (3)**) and high-pressure and return fuel lines (**Figure 7-32, (2)**). See *Installing the High-Pressure Fuel Injection Lines on page 7-11* and *Installing the Fuel Return Line on page 7-11*. Tighten fuel line nuts (**Figure 7-32, (1)**) to specifications.
4. Install the intake manifold / valve cover. See *Assembling the Intake Manifold / Valve Cover on page 6-29*.
5. Prime the fuel system. See *Priming the Fuel System on page 4-14*.
6. Operate the engine and check for fuel leaks.

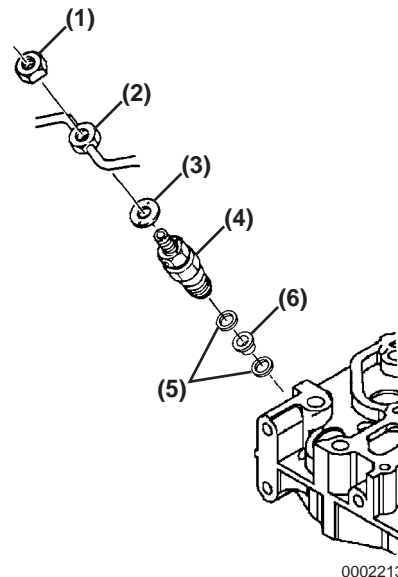


Figure 7-32

Section 8

COOLING SYSTEM

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Safety Precautions	8-3
Introduction.....	8-3
Cooling System Diagram.....	8-4
Engine Coolant Pump Components	8-5
Engine Coolant System Check.....	8-6
Engine Coolant Pump	8-6
Disassembly of Engine Coolant Pump	8-6
Cleaning and Inspection	8-7
Reassembly of Engine Coolant Pump.....	8-8

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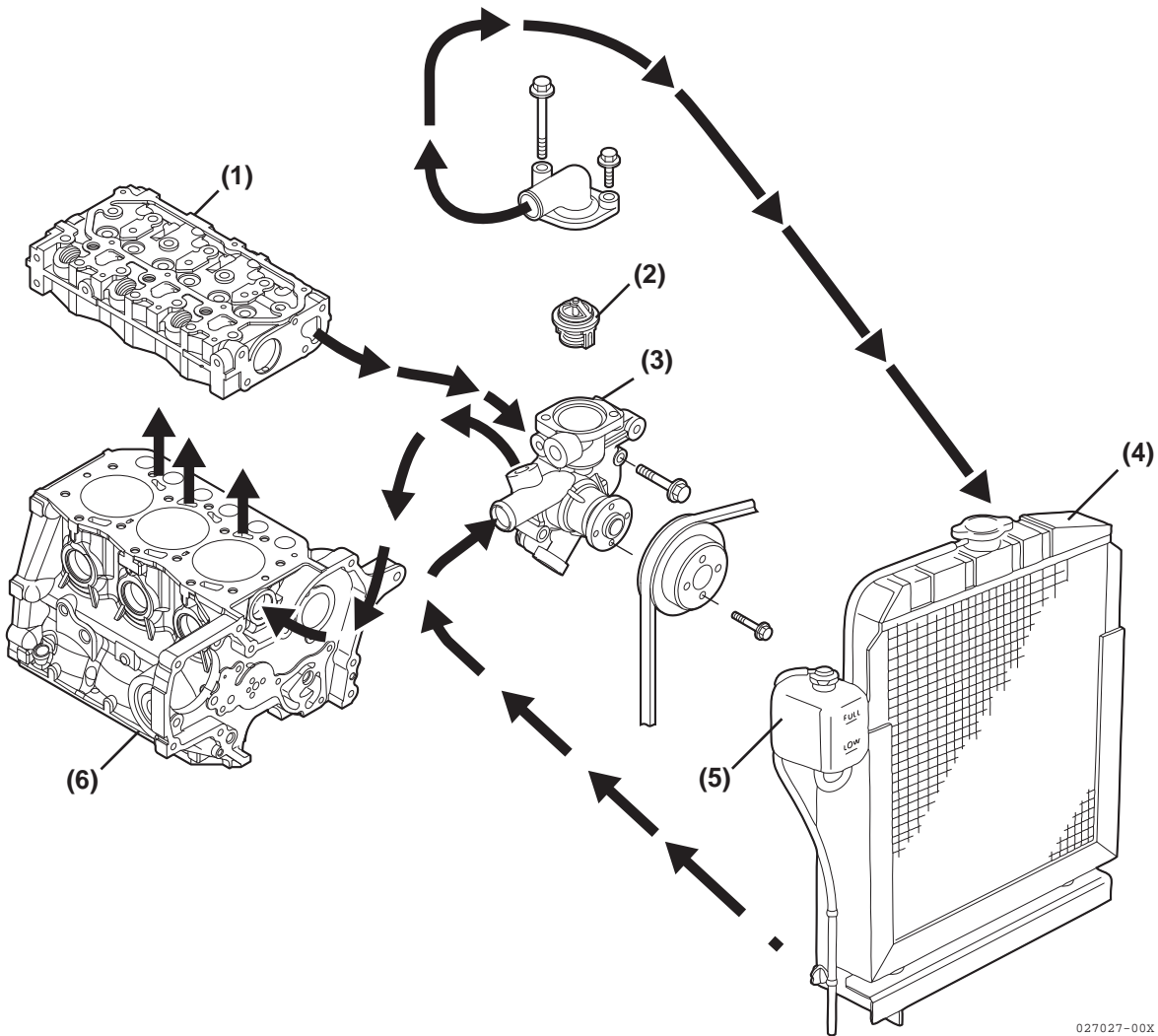
SAFETY PRECAUTIONS

Before performing any cooling system service procedures, review the *Safety section on page 3-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures necessary to service the 3TNM72 engine coolant pump.

COOLING SYSTEM DIAGRAM



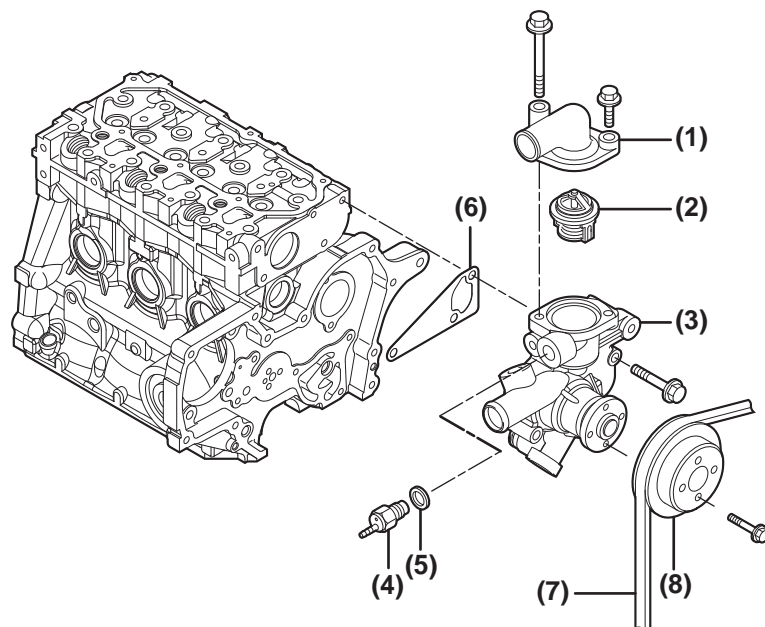
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Figure 8-1

- 1 – Cylinder Head
- 2 – Thermostat
- 3 – Engine Coolant Pump

- 4 – Radiator
- 5 – Coolant Recovery Tank
- 6 – Cylinder Block

ENGINE COOLANT PUMP COMPONENTS



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Figure 8-2

- 1 – Thermostat Cover
- 2 – Thermostat
- 3 – Engine Coolant Pump
- 4 – Temperature Sensor
- 5 – Gasket

- 6 – Engine Coolant Pump Gasket
- 7 – V-Belt
- 8 – Engine Coolant Pump V-Pulley

ENGINE COOLANT SYSTEM CHECK

Check the engine coolant system for leakage.

1. With the radiator properly filled, install a cooling system tester (**Figure 8-3, (1)**).

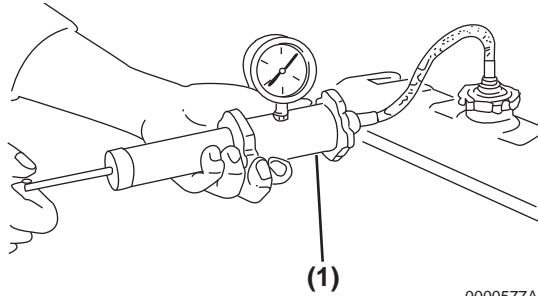


Figure 8-3

2. Apply 10.8 to 14.8 psi (75 to 105 kPa; 0.75 to 1.05 kgf/cm²) to the cooling system. If the pressure reading drops, the engine coolant system is leaking. Identify the source of the leak and repair.

ENGINE COOLANT PUMP

WARNING! Burn Hazard. Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.

Disassembly of Engine Coolant Pump

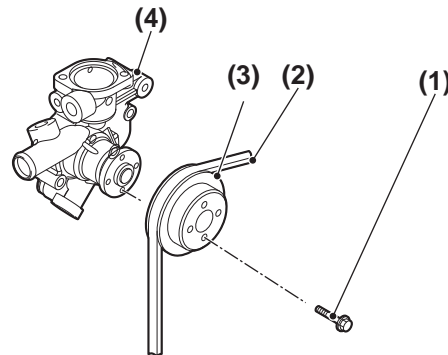
Verify the condition of the engine coolant pump before disassembling it from the engine. Check the engine coolant pump shaft bearing for abnormal noise, sticking, excessive play and water leakage. Replace the coolant pump if any of these conditions are present.

NOTICE: If the engine coolant pump must be replaced, replace the engine coolant pump as an assembly only. Do not attempt to repair the engine coolant pump or replace individual components.

1. Make sure the engine and engine coolant are not hot.

2. Before removing the engine coolant pump or thermostat, it will be necessary to drain the engine coolant. Drain the coolant into a clean container if the coolant is to be reused. Otherwise, properly dispose of the coolant.
 - Drain the coolant from the radiator. See steps 1-4 in *Drain, Flush and Refill Cooling System with New Coolant* on page 5-17.
3. Loosen the alternator mounting bolts. Loosen and remove the V-belt and rotate the alternator away from the engine and out of the way.

CAUTION! Pinch Hazard. Carefully rotate the alternator toward the cylinder block while loosening the V-belt.
4. Remove the engine coolant pulley guard (if equipped), Pulley bolts (**Figure 8-4, (1)**), belt (**Figure 8-4, (2)**) and engine coolant pump V-pulley (**Figure 8-4, (3)**).



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Figure 8-4

5. Disconnect the coolant hoses and the temperature switch lead wire from the engine coolant pump.
6. Remove the engine coolant pump (**Figure 8-4, (4)**). Discard the gasket.

- Remove the thermostat cover (**Figure 8-5, (1)**).

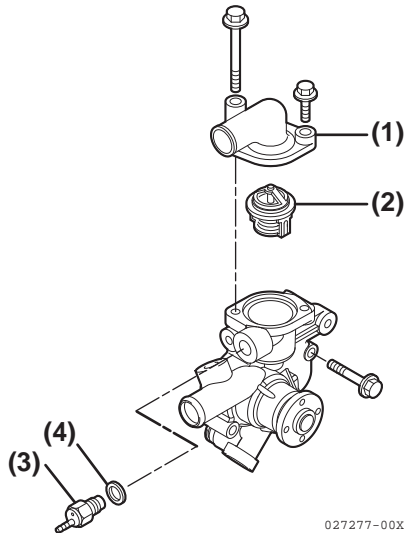


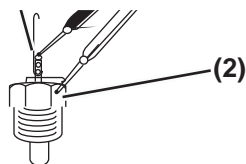
Figure 8-5

- Remove the thermostat (**Figure 8-5, (2)**).
Remove the temperature sensor and adaptor (**Figure 8-5, (3)**) and gasket (**Figure 8-5, (4)**).
Discard the gasket.

Cleaning and Inspection

Temperature Sensor

- To check for proper operation of the temperature sensor, refer to Chapter 10.

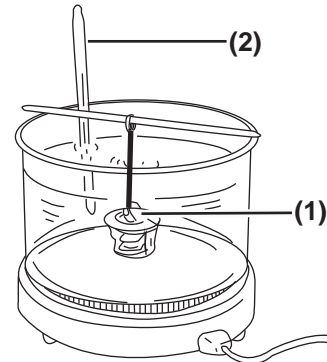


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Figure 8-6

Thermostat

- Check for proper operation of the thermostat.
Place the thermostat (**Figure 8-7, (1)**) and an accurate thermometer (**Figure 8-7, (2)**) in warm water.



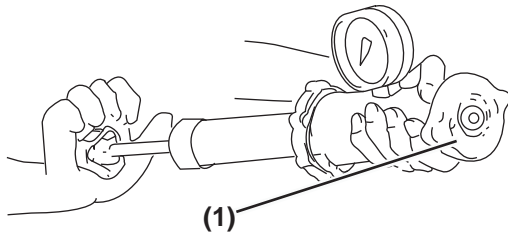
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Figure 8-7

- Slowly increase temperature of the water using an external heat source.
- The thermostat is normal if it starts to open at the temperature value stamped on the flange of the thermostat, and fully opens as the temperature of the water is increased.

Radiator Cap

1. Check for proper operation of the radiator cap. Install the radiator cap (Figure 8-8, (1)) on a cooling system tester.



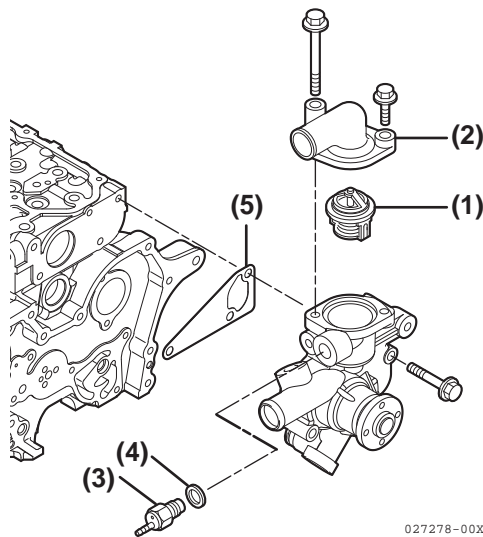
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Figure 8-8

2. Apply 13 psi (89.63 kPa; .91 kgf/cm²) to the radiator cap. The radiator cap relief valve must open within the specified range.

Reassembly of Engine Coolant Pump

1. Reinstall the thermostat (Figure 8-9, (1)).

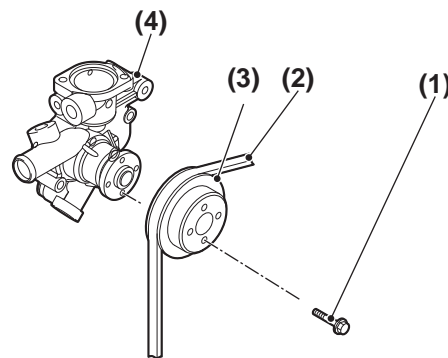


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Figure 8-9

2. Reinstall the thermostat cover (Figure 8-9, (2)). Tighten the thermostat cover bolts.
3. Reinstall the temperature sensor, adaptor (Figure 8-9, (3)) and a new gasket (Figure 8-9, (4)).

4. Position the engine coolant pump on the engine and install a new gasket (Figure 8-9, (5)). *NOTICE: Use a new special O-ring between the engine coolant pump and the joint. Be sure to use the special O-ring for each engine model. Although the O-ring dimensions are the same as a commercially available O-ring, the material is different.*
5. Reinstall the engine coolant pump bolts. Tighten the bolts.
6. Inspect and reinstall the coolant hoses and the temperature switch lead wire.
7. Reinstall the engine coolant pump V-pulley (Figure 8-10, (3)), Belt (Figure 8-10, (2)), and bolts (Figure 8-10, (1)). Install engine coolant pulley guard (if equipped).



027276-00X

Figure 8-10

8. Inspect the condition of the V-belt. There must be clearance (**Figure 8-11, (1)**) between the V-belt and the bottom of the pulley groove. If there is no clearance (**Figure 8-11, (2)**) between the V-belt and the bottom of the pulley groove, replace the V-belt.

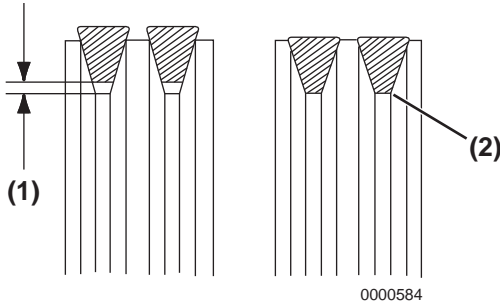


Figure 8-11

9. Reinstall the V-belt. Tighten the V-belt to the proper tension. See *Check and Adjust Cooling Pulley V-Belt* on page 5-13.
10. Reinstall and tighten the drain plug or close the drain cock in the radiator. Reinstall and tighten the engine block drain plug or reconnect the coolant hose at the oil cooler.
11. Fill radiator and engine with engine coolant. See *Drain, Flush and Refill Cooling System with New Coolant* on page 5-17.

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Section 9

LUBRICATION SYSTEM

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SAFETY PRECAUTIONS

Before performing any lubrication system service procedures, review the *Safety section on page 3-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures necessary to service the 3TNM72 trochoid oil pumps.

See *Replace Engine Oil and Engine Oil Filter on page 5-12* for engine oil and engine oil filter replacement procedures.

OIL PUMP SERVICE INFORMATION

Engine Oil Pressure

Model	at Rated Engine rpm	at Low Idle Speed
3TNM72-VH	42 - 64 psi (0.29 - 0.44 MPa 2.96 - 4.49 kgf/cm ²)	8.8 psi (0.06 MPa; 0.6 kfg/cm ²) or greater

Outer Rotor Outside Clearance

Model	Standard	Limit
3TNM72	0.0039 - 0.0063 in. (0.10 - 0.16 mm)	0.0098 in. (0.25 mm)

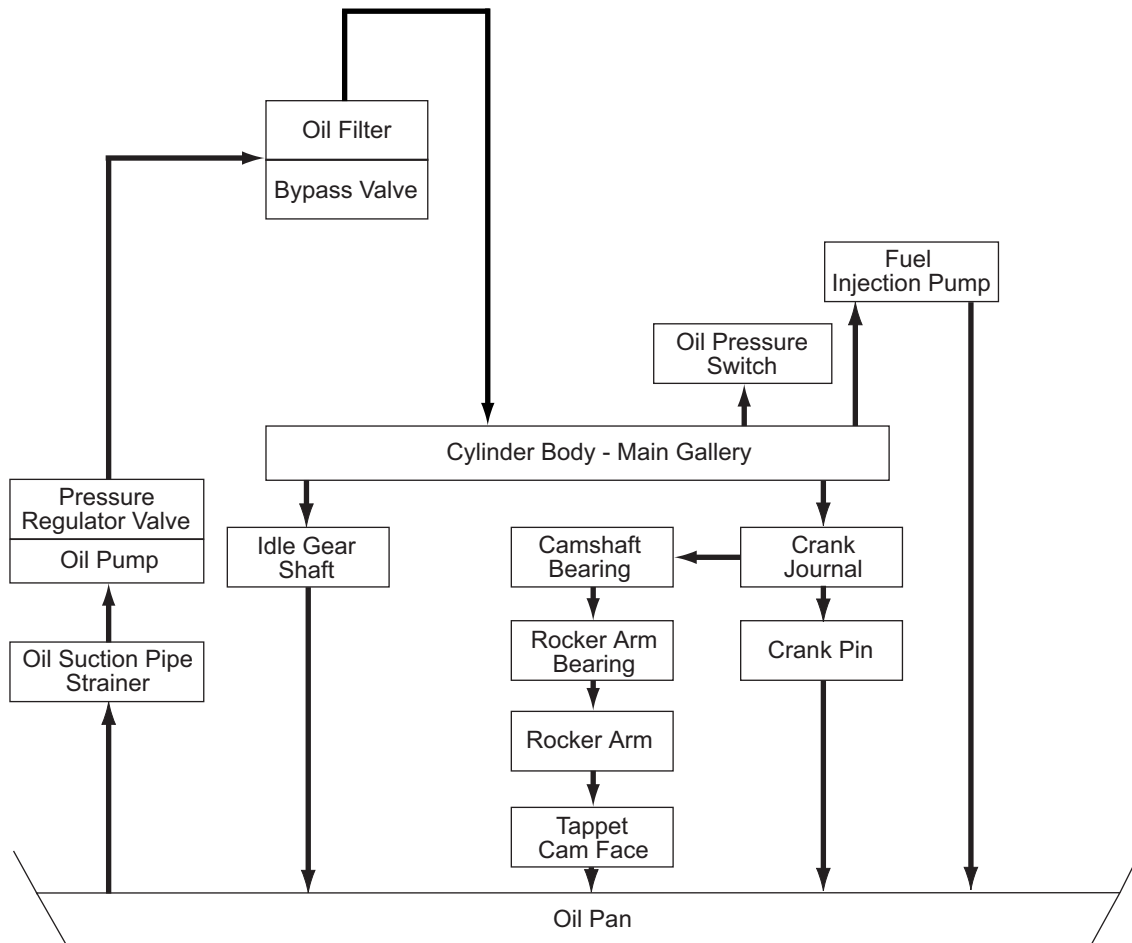
Outer Rotor Side Clearance

Model	Standard	Limit
3TNM72	0.0019 - 0.0039 in. (0.05 - 0.10 mm)	0.0059 in. (0.15 mm)

Outer Rotor to Inner Rotor Tip Clearance

Model	Standard	Limit
3TNM72	-	0.0063 in. (0.16 mm)

LUBRICATION SYSTEM DIAGRAM



0001624

Figure 9-1

TROCHOID OIL PUMP

Components

The oil pump on these model engines is located in the front gear case and is driven by the same gear train that drives the camshaft and fuel injection pump. You must remove the front gear case cover to gain access to the oil pump.

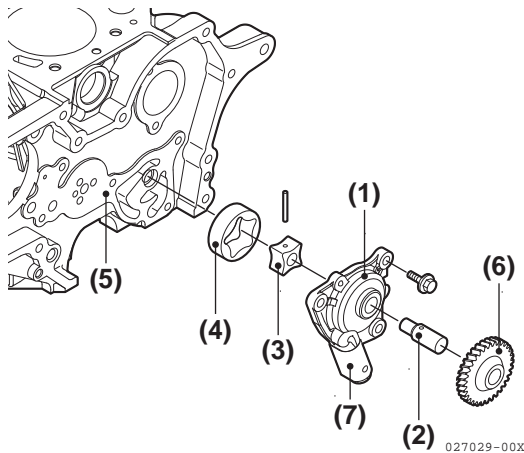


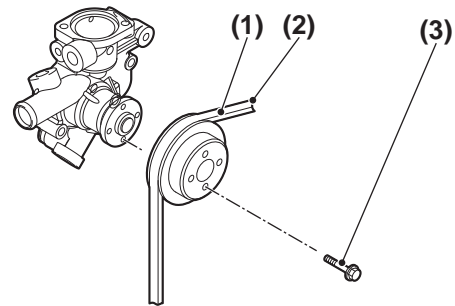
Figure 9-2

- 1 – Body
- 2 – Shaft
- 3 – Inner rotor
- 4 – Outer rotor
- 5 – Cover
- 6 – Drive Gear
- 7 – Pressure Regulator Valve

Disassembly of Oil Pump

NOTICE: If the oil pump must be replaced, replace it as an assembly only. Do not replace individual components.

Remove the coolant pulley guard (if equipped), pulley bolts (**Figure 9-3, (3)**), belt (**Figure 9-3, (2)**), coolant pump V-pulley (**Figure 9-3, (1)**).



027030-00X

Figure 9-3

1. Remove the crank shaft pulley and gear case cover. See *Removal of Timing Gear Case Cover* on page 6-34.
2. Remove the lubricating oil pump assembly mounting bolts. Remove the lubricating oil pump assembly (**Figure 9-4, (1)**) from the gear case flange (**Figure 9-4, (2)**).
3. You can remove by hand the lubricating oil pump cover (**Figure 9-2, (5)**) and outer rotor (**Figure 9-2, (4)**).

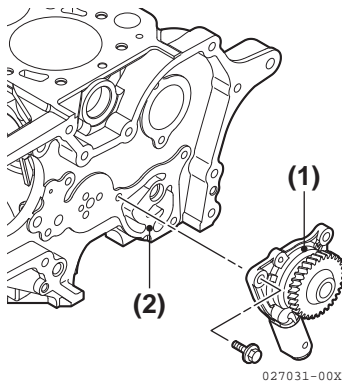


Figure 9-4

Cleaning and Inspection

Clean the lubricating oil pump, pressure regulator valve (Figure 9-2, (7)) and rotor inserting portion. Check the parts for wear or flaw. Replace the parts with new ones as needed.

NOTICE: If any oil pump component clearance exceeds its limit, the oil pump must be replaced as an assembly.

Check Outer Rotor Outside Clearance

Inspect the outside diameter clearance of the outer rotor. To inspect this, insert a feeler gauge between the outer rotor (Figure 9-5, (1)) and the lubricating oil pump body (Figure 9-5, (2)).

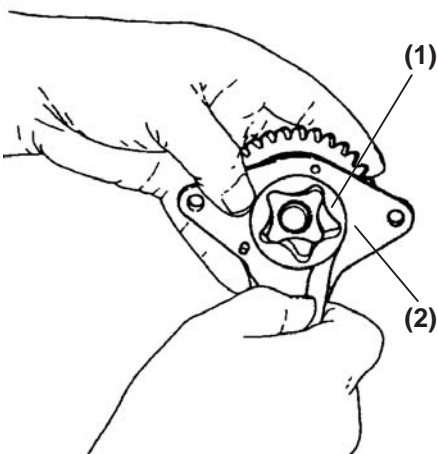


Figure 9-5

Record the measurement(s) and see Outer Rotor Outside Clearance on page 9-3 for the service limits.

Outer Rotor to Inner Rotor Tip Clearance

Inspect the tip clearance between the outer and inner rotors. To inspect this, insert a feeler gauge between the inner rotor tooth tip (Figure 9-6, (1)) and the outer rotor tooth tip (Figure 9-6, (2)), and measure the clearance.

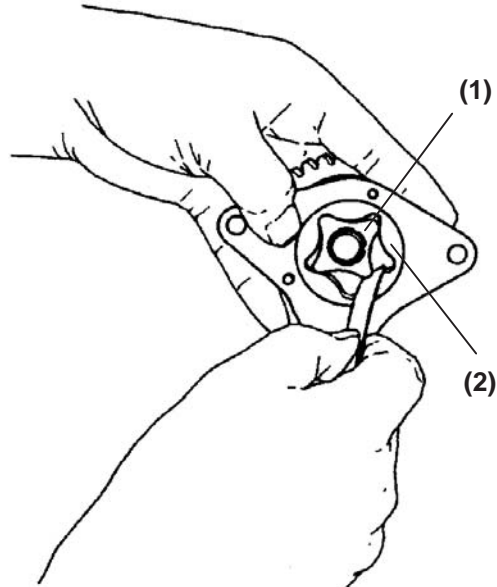


Figure 9-6

Record the measurement(s) and see Outer Rotor to Inner Rotor Tip Clearance on page 9-3 for the service limits.

Check Outer Rotor Side Clearance

Inspect the side clearance between the lubricating oil pump body and the outer rotor. To measure the side clearance, use a straight edge and feeler gauge (as shown in **Figure 9-7**) or a depth micrometer.

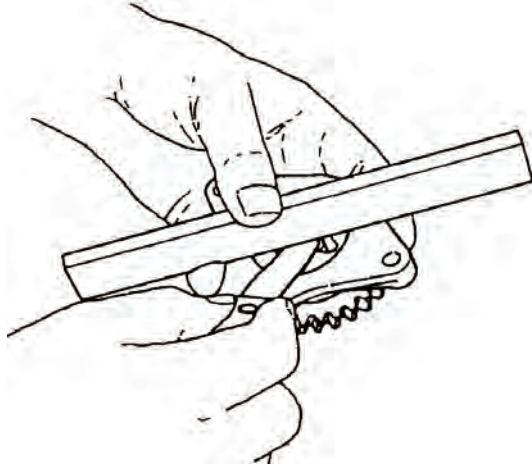


Figure 9-7

Record the measurement(s) and see *Outer Rotor Outside Clearance* on page 9-3 for the service limits.

Check Rotor Shaft Clearance

Inspect the rotor shaft clearance. Measure the outside diameter of the rotor shaft (**Figure 9-8, (1)**) and the inside diameter of the cover.

Determine the clearance by subtracting the outside diameter of the rotor from the inside diameter of the cover.

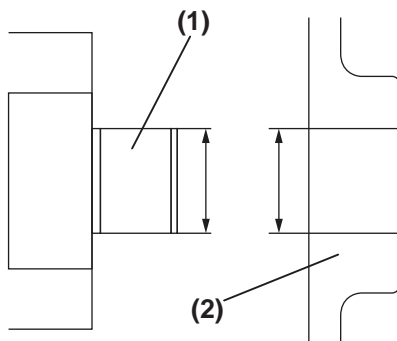
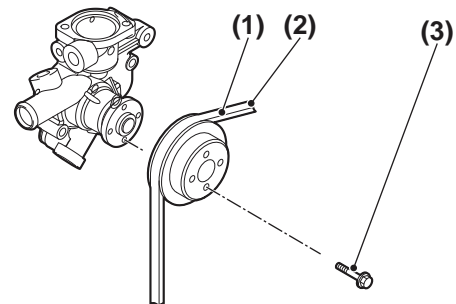


Figure 9-8

Reassembly of Oil Pump

1. Apply clean lubricating oil to the lubricating oil pump body and inner rotor assembly as well as to the outer rotor.
2. Insert the outer rotor into the lubricating oil pump body and inner rotor assembly and install the cover.
3. Replace the packing with new one.
4. Install the lubricating oil pump assembly to the gear case flange by tightening the bolts with the specified torque.
5. Install the gear case cover. For more information, see *Installation of Gear Case Cover* on page 6-57.
6. Install the crankshaft pulley.
7. Install the coolant pump V-pulley (**Figure 9-9, (1)**), belt (**Figure 9-9, (2)**), pulley bolts (**Figure 9-9, (3)**) and pulley guard (if equipped).



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Figure 9-9

8. Install the V-belt. Adjust the belt to uniform tensile strength in accordance with the instructions given in *Check and Adjust Cooling Fan V-Belt* on page 5-7.

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Section 10

STARTER MOTOR

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SAFETY PRECAUTIONS

Before performing any starter motor service procedures, review the following messages and the *Safety section on page 3-1*.

NOTICE:

- *The starter motor is waterproofed according to JIS D 0203, R2, which protects the motor from rain or general cleaning. Do not use high-pressure wash or submerge the starter motor in water.*
- *Make sure that the combined total resistance of the battery cable in both directions between the starter motor and the battery is within the value indicated in the Battery Cable Resistance chart in the Electric Wiring Section of this manual. The starter motor will malfunction and fail if the resistance is higher than the specified value.*
- *The starter motor can be damaged if operated continuously longer than 10 seconds at a time. Allow a 30-second pause between each use of the starter motor if operated continuously.*
- *NEVER engage the starter motor while the engine is running. This may damage the starter motor pinion and / or ring gear.*

INTRODUCTION

This section of the *Service Manual* covers the servicing of starter motor. Hitachi Part No. S114-940 is standard equipment on 3TNM72-APL model engines and is used in this section to show the service procedures for a representative starter motor. For specific part detail, see the *Polaris Parts Catalog*.

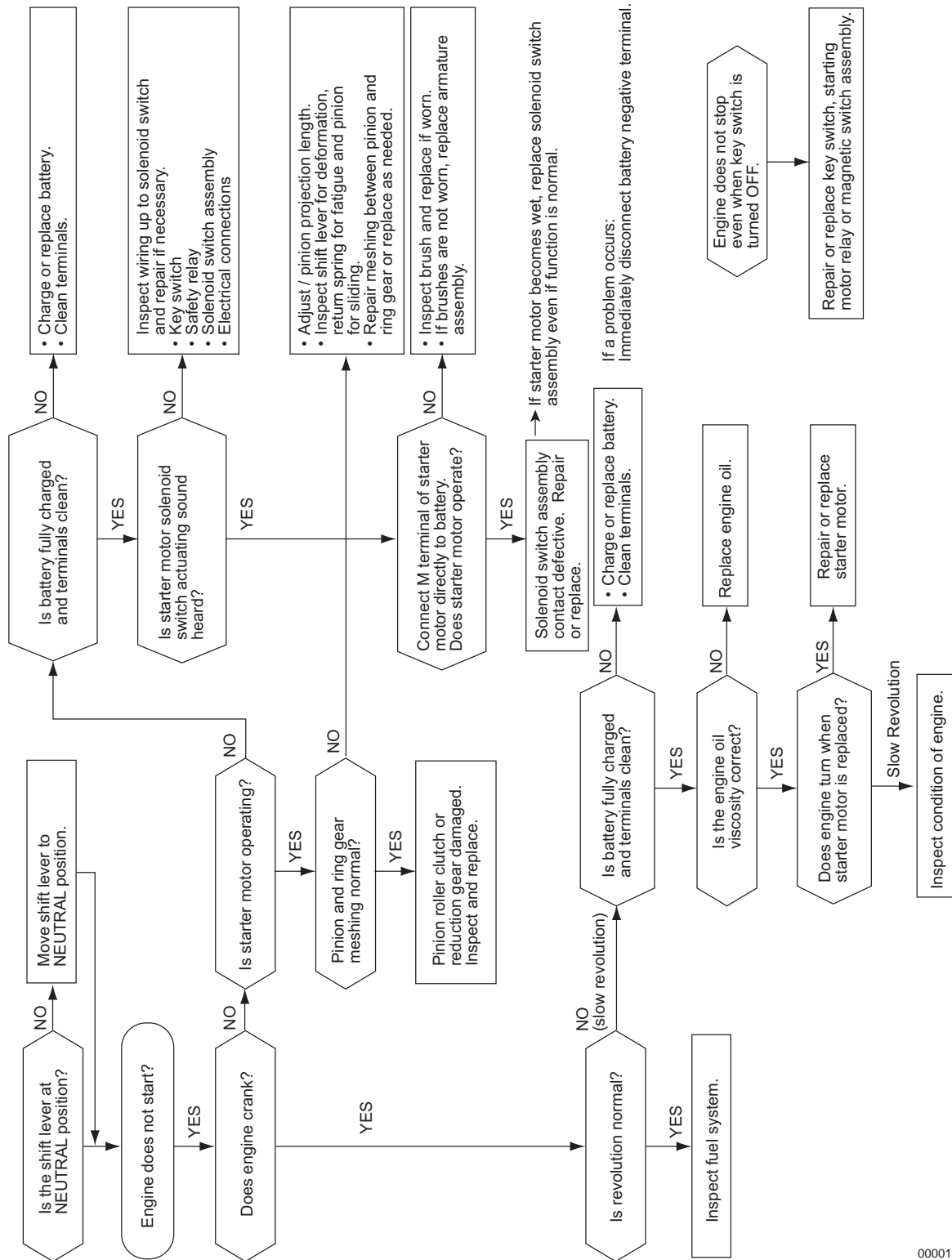
STARTER MOTOR INFORMATION

Mfg.	Mfg. Model Number	Specification	No Load			Loaded			
			Terminal Voltage	Amperage Draw	RPM	Terminal Voltage	Amperage Draw	Torque	RPM
Hitachi	S114-940	DC12V -1.6 hp (1.2 kW)	11.0	90A (Max.)	3440 (Min.)	8.4	250 (Max.)	51 in.-lb (5.8 N·m; 0.59 kgf·m)	1500 (Min.)

STARTER MOTOR SPECIFICATIONS

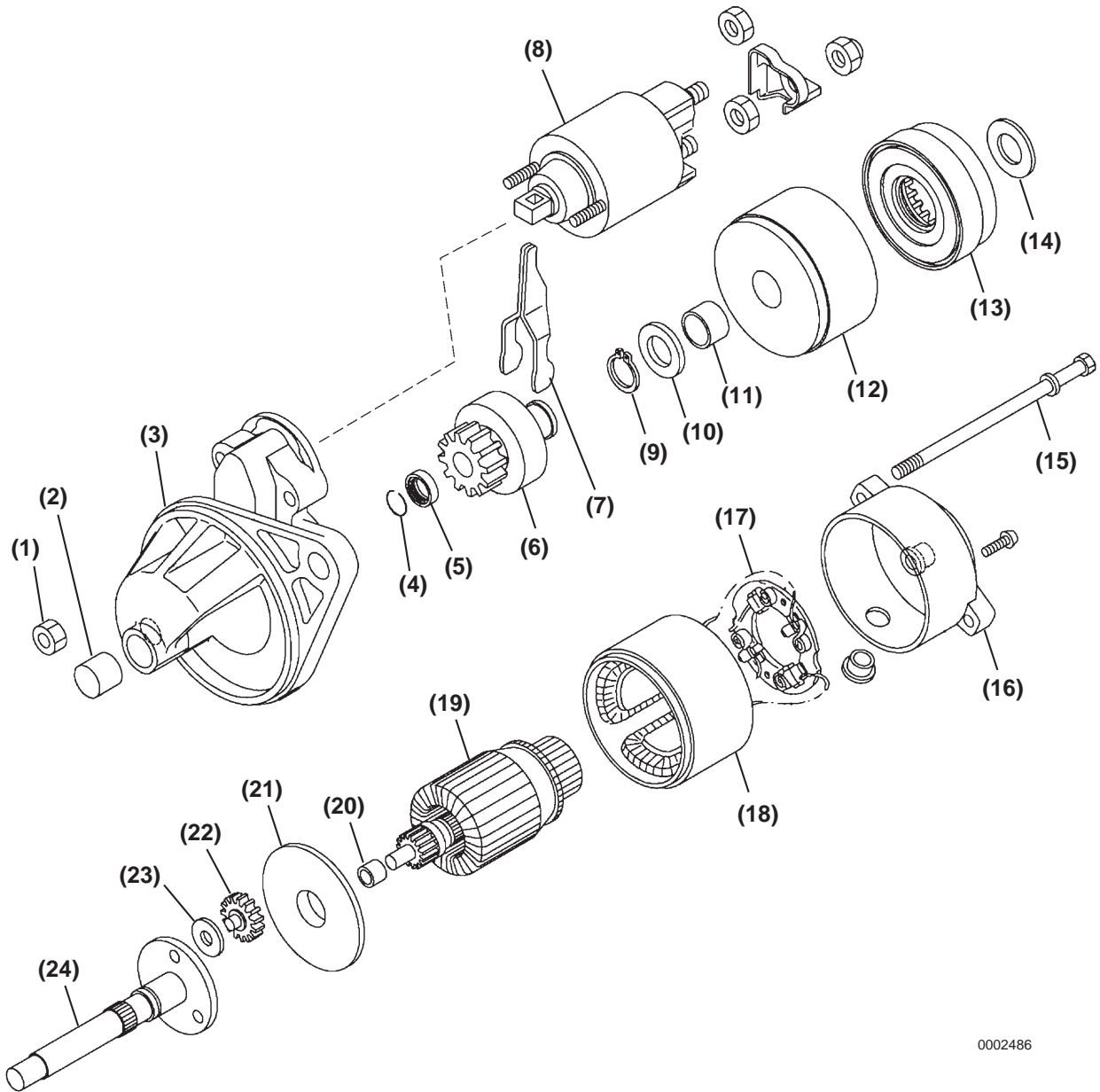
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STARTER MOTOR TROUBLESHOOTING



0000102

STARTER MOTOR COMPONENTS



0002486

Figure 10-1

- 1 – Nut
- 2 – Needle Bearing
- 3 – Pinion Housing
- 4 – Pinion Retaining Ring
- 5 – Pinion Stop
- 6 – Pinion
- 7 – Shift Lever
- 8 – Solenoid Switch Assembly
- 9 – Snap Ring
- 10 – Washer
- 11 – Bushing
- 12 – Intermediate Housing
- 13 – Reduction Gear
- 14 – Washer
- 15 – Through Bolt
- 16 – End Housing
- 17 – Brush Plate and Holder
- 18 – Field Assembly
- 19 – Armature
- 20 – Bushing
- 21 – Plate
- 22 – Planetary Gear (3 used)
- 23 – Washer (3 used)
- 24 – Pinion Shaft

STARTER MOTOR

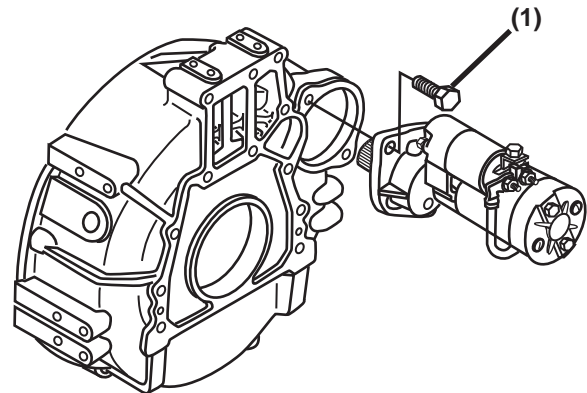
WARNING! Shock Hazard.

- **Turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.**
- **Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.**

Note: While starter motor design varies between models, the basic repair procedures are the same. The following procedures are typical and may differ from the starter being serviced.

Removal of Starter Motor

1. Disconnect the battery cables at the battery, negative (-) cable first.
2. Remove the electrical wires from the solenoid switch assembly.
3. Remove the starter mounting bolts **(Figure 10-2, (1))**. Remove the starter motor from the flywheel housing.

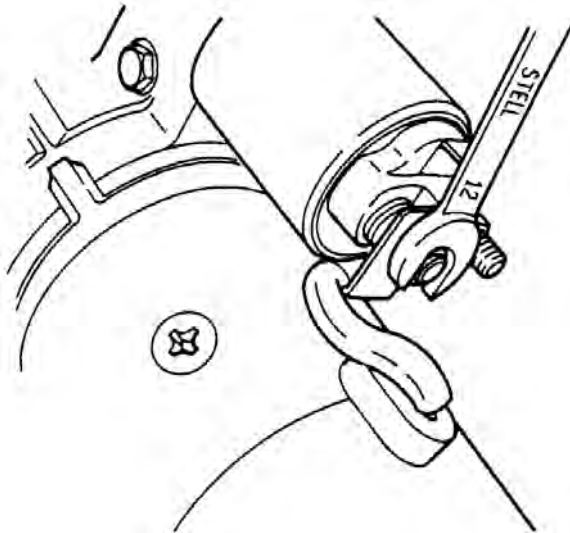


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Figure 10-2

Disassembly of Starter Motor

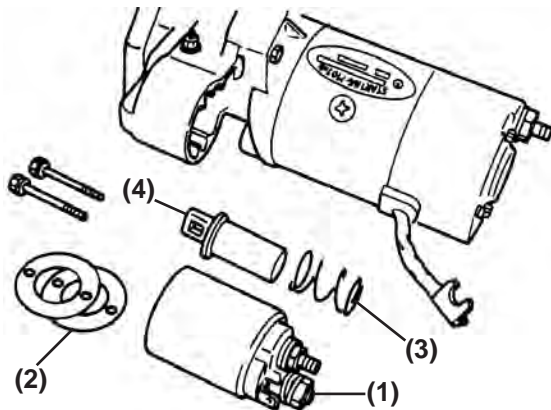
1. Make alignment marks across all mating joints.
2. Disconnect the field wire from the solenoid switch (Figure 10-3).



0000138

Figure 10-3

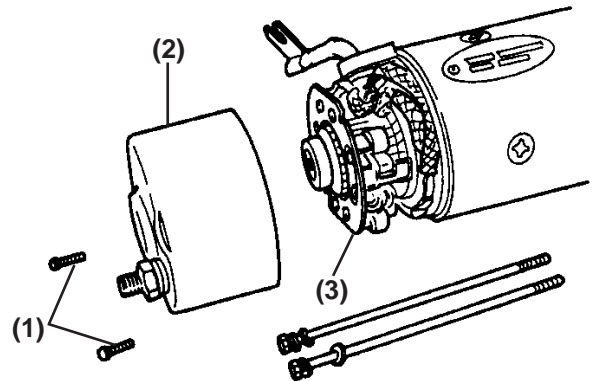
3. Remove the two bolts or nuts retaining the solenoid switch assembly (Figure 10-4, (1)) to the pinion housing. Remove the solenoid switch assembly and dust covers (Figure 10-4, (2)). Remove the plunger (Figure 10-4, (4)) and torsion spring (Figure 10-4, (3)) from the pinion housing.



0000140A

Figure 10-4

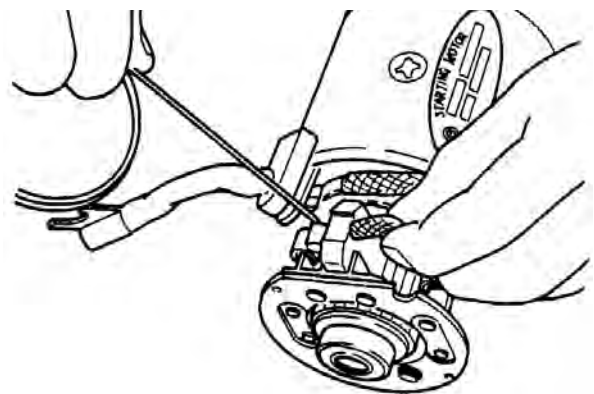
4. Remove the two bolts (Figure 10-5, (1)) securing the rear cover (Figure 10-5, (2)) to the brush holder assembly (Figure 10-5, (3)).



0000142A

Figure 10-5

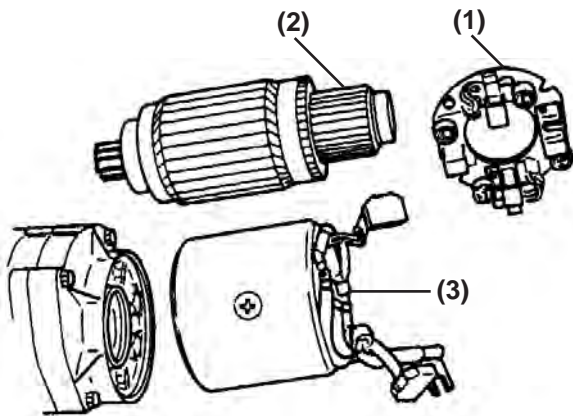
5. Remove the two through bolts. Remove the rear cover (Figure 10-5, (2)).
6. Pull the brush springs up using a brush spring puller. On the negative (-) side, bring the brush spring into contact with the side of the brushes to hold the brushes clear of the commutator surface. On the positive (+) side, remove the brushes from the brush holder assembly (Figure 10-6).



0000143

Figure 10-6

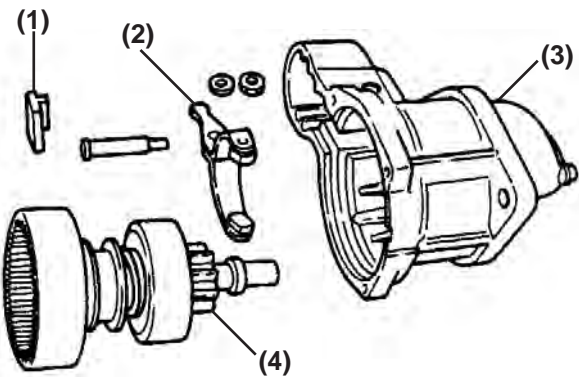
- Remove the brush plate and holder (Figure 10-7, (1)).



0000144A

Figure 10-7

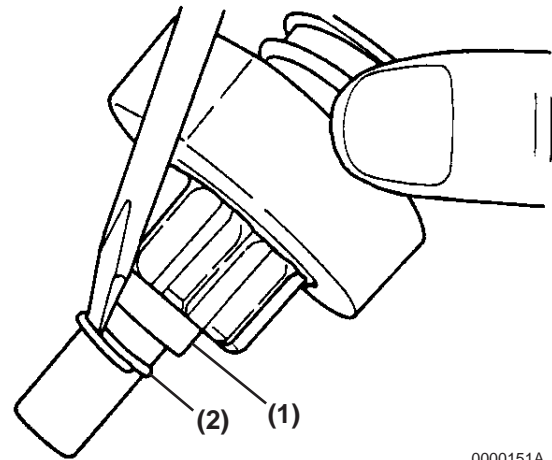
- Pull the field assembly (Figure 10-7, (3)) off from the armature assembly (Figure 10-7, (2)).
- Remove the armature from the intermediate housing.
- Remove the intermediate housing, gear and pinion shaft assembly (Figure 10-8, (4)) from the pinion housing (Figure 10-8, (3)). Disengage from the shift lever as it is removed.
- Remove the shift lever (Figure 10-8, (2)), pin, and spacer (Figure 10-8, (1)).



0000148A

Figure 10-8

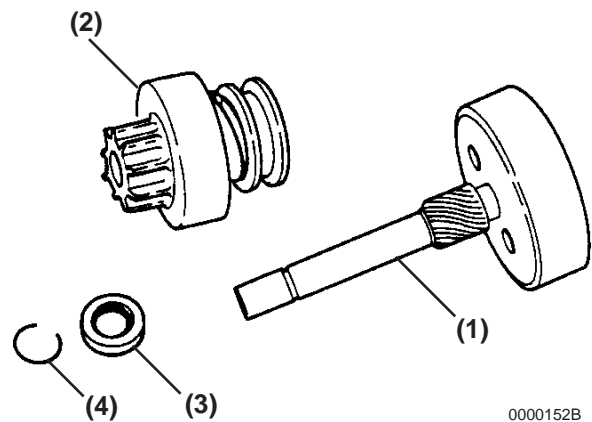
- Pull the pinion stop (Figure 10-9, (1)) down to expose the retaining ring. Using a flat-blade screwdriver, remove the retaining ring (Figure 10-9, (2)) from the pinion shaft.



0000151A

Figure 10-9

- Remove the pinion stop (Figure 10-10, (3)), return spring (if equipped) and pinion clutch assembly (Figure 10-10, (2)) from the pinion shaft (Figure 10-10, (1)).



0000152B

Figure 10-10

14. Remove the snap ring (**Figure 10-11, (1)**). Remove the pinion shaft (**Figure 10-11, (5)**), planetary gears (**Figure 10-11, (6)**), washers and reduction gear (**Figure 10-11, (4)**) from the intermediate housing (**Figure 10-11, (3)**).

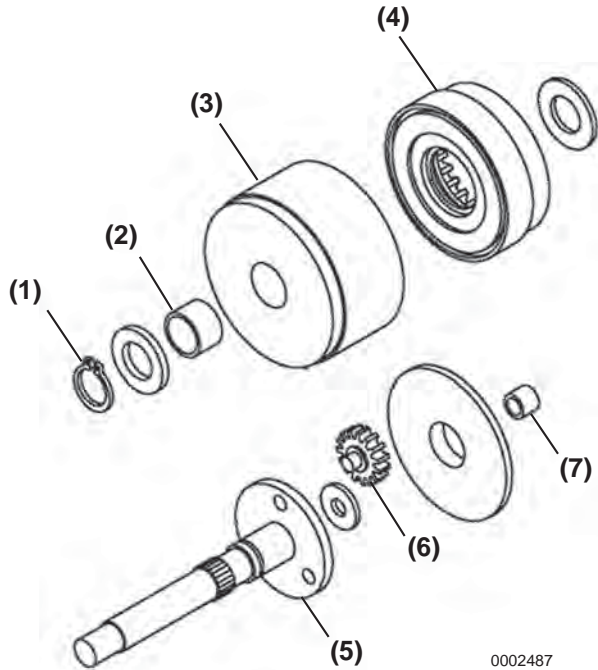


Figure 10-11

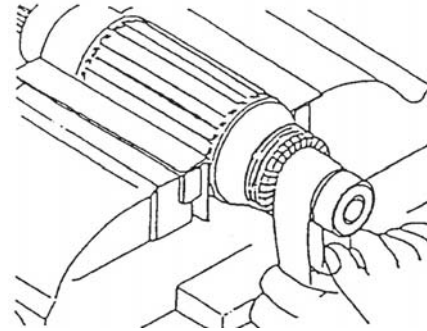
15. Inspect the intermediate bushing (**Figure 10-11, (2)**) and replace if worn or damaged.
16. Inspect armature bushing (**Figure 10-11, (7)**) and replace if worn or damaged.

Cleaning and Inspection

Armature

Commutator Surface Inspection

If the commutator surface is rough, polish the surface with a #500 to #600 emery cloth.

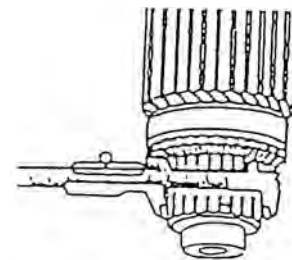


0000117

Figure 10-12

Measure Commutator Outside Diameter

Measure the commutator outside diameter. Replace the armature if the measurement is less than the limit. See *Starter Motor Specifications* on page 10-5.



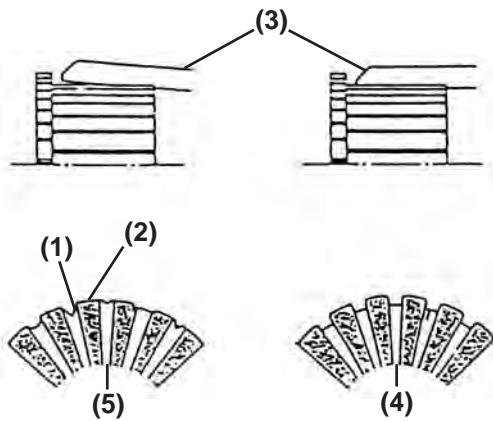
0000113

Figure 10-13

Measure Commutator Insulation Depth

Measure the depth of the insulating material (**Figure 10-14, (1)**) between commutator segments (**Figure 10-14, (2)**). If the depth measures less than the limit, use a hacksaw blade (**Figure 10-14, (3)**) to remove the insulating material until the depth is within the limit. See *Starter Motor Specifications on page 10-5 for service limit*.

A normal commutator condition is indicated in **Figure 10-14, (4)**. An abnormal commutator condition is indicated in **Figure 10-14, (5)**.



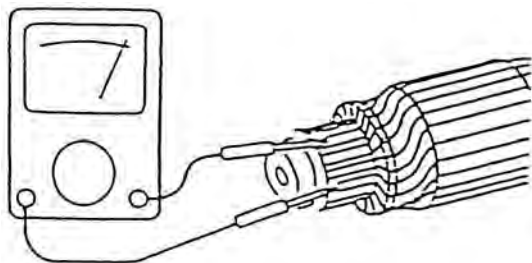
0000118

Figure 10-14

Armature Coil Continuity Test

Check for continuity between the commutator segments using a multimeter (**Figure 10-15**). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the armature.



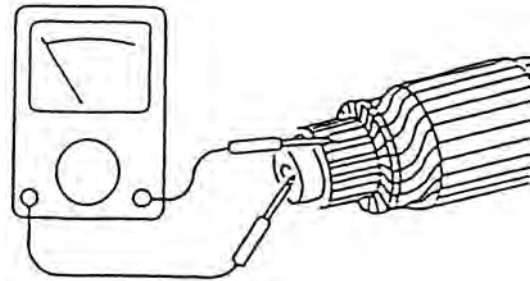
0000114

Figure 10-15

Armature Coil Insulation Test

Check for continuity between a commutator segment and the shaft or armature using a multimeter (**Figure 10-16**). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the armature.

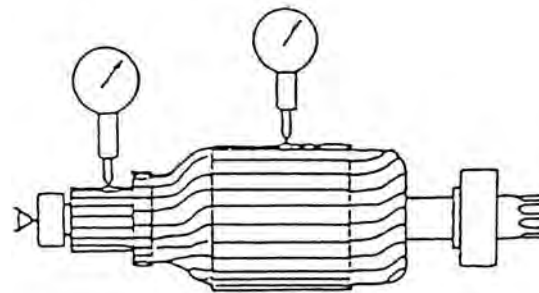


0000115

Figure 10-16

Measure Armature and Commutator Run-Out

Measure the armature core run-out and the commutator run-out using a dial indicator (**Figure 10-17**). Replace the armature if either of the measurements is not within specifications. See *Starter Motor Specifications on page 10-5 for service limit*.



0000116

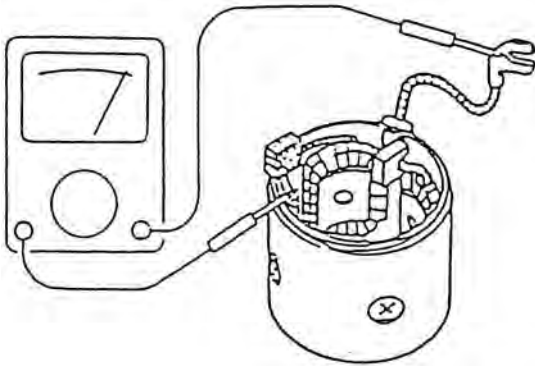
Figure 10-17

Field Coil

Field Coil Continuity Test

Check for continuity between the field coil terminals using a multimeter (**Figure 10-18**). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the field coil assembly.



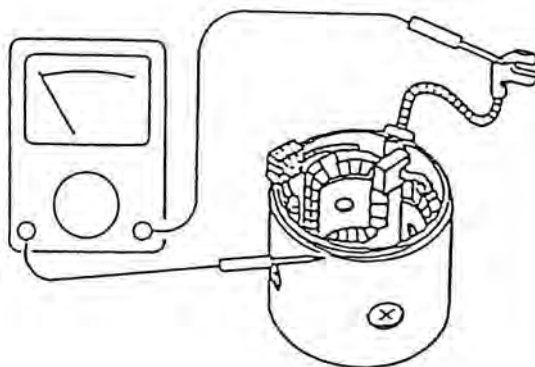
0000119

Figure 10-18

Field Coil Insulation Test

Check for continuity between either field coil terminal and the yoke using a multimeter (**Figure 10-19**). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the field coil assembly.

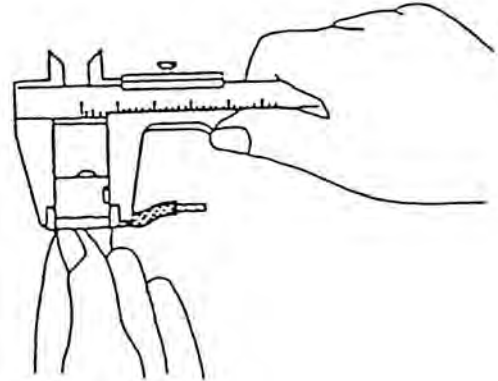


0000120

Figure 10-19

Measure Brush Length

Measure the length of the brush (**Figure 10-20**). Replace the brush if the length is less than the limit. See *Starter Motor Specifications* on page 10-5 for service limit.



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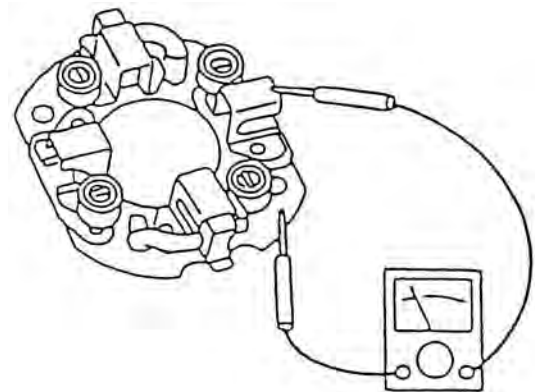
Figure 10-20

Brush Holder

Brush Holder Insulation Test

Check for continuity between each brush holder and the base using a multimeter (**Figure 10-21**). The multimeter should not indicate continuity.

If the multimeter indicates continuity, replace the brush holder.

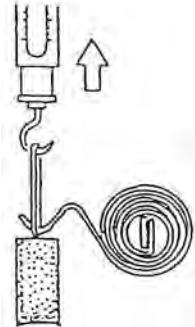


0000122

Figure 10-21

Brush Spring Test

Test the spring force for each brush spring (Figure 10-22). Replace the brush spring if the force is not within the range. See *Starter Motor Specifications on page 10-5 for the service limit.*



0000123

Figure 10-22

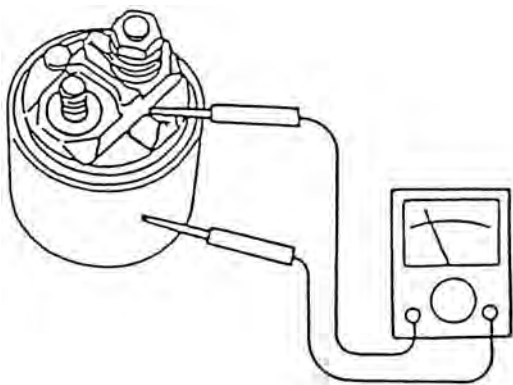
Solenoid Switch

If the starter motor becomes wet, replace the solenoid switch even if the solenoid switch assembly function is normal.

Shunt Coil Continuity Test

Check for continuity between the “S” terminal and the switch body using a multimeter (Figure 10-23). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the solenoid switch.



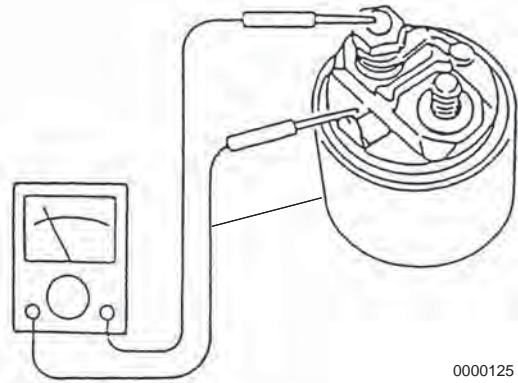
0000124

Figure 10-23

Series Coil Continuity Test

Check for continuity between the “S” and “M” terminals using a multimeter (Figure 10-24). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the solenoid switch.



0000125

Figure 10-24

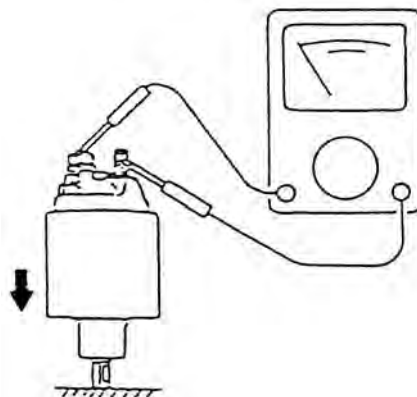
Coil Resistance Test

See *Starter Motor Specifications on page 10-5 for service limit.*

Contact Continuity Test

Depress the plunger at the bottom of the solenoid switch. Check for continuity between the “B” and “M” terminals using a multimeter (Figure 10-25). The multimeter should indicate continuity.

If the multimeter does not indicate continuity, replace the solenoid switch.



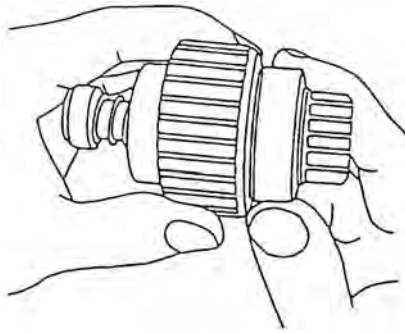
0000126

Figure 10-25

Pinion Clutch Assembly

Pinion Clutch Assembly Inspection

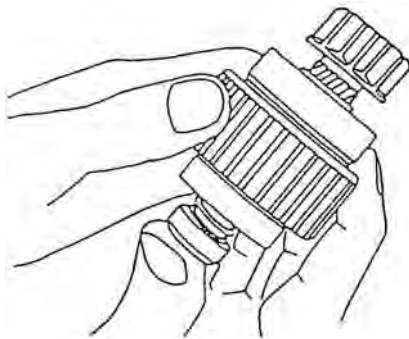
Manually rotate the pinion clutch assembly in the drive direction. It should rotate freely in the drive direction and is locked by turning it in the opposite direction (**Figure 10-26**). Replace the pinion clutch assembly if the results are different.



0000127

Figure 10-26

Slide the pinion clutch assembly on the shaft (**Figure 10-27**). It should slide smoothly on the shaft. Rust, too much grease or damage could prevent the pinion clutch from sliding smoothly. If the pinion clutch assembly does not slide smoothly, clean the shaft and pinion clutch assembly or replace the damaged component.

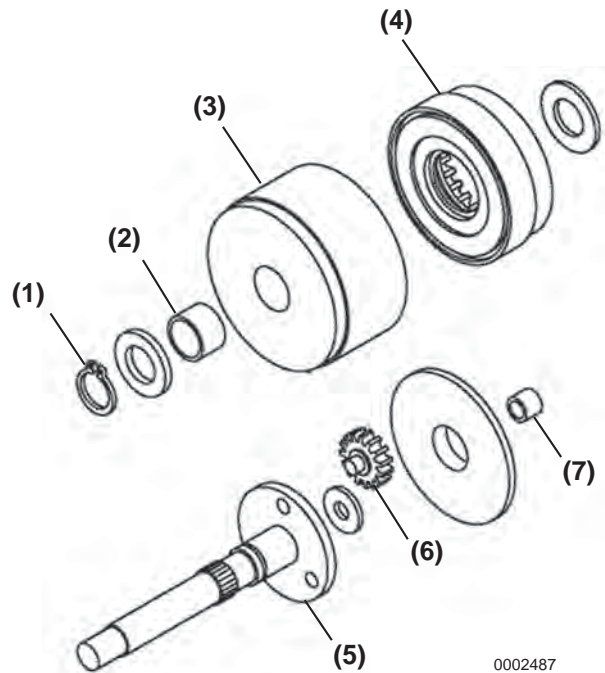


0000128

Figure 10-27

Reassembly of Starter Motor

1. Apply a appropriate starter bendix grease (obtain locally) to the pinion shaft.
2. Reassemble the reduction gear (**Figure 10-28, (4)**), pinion shaft (**Figure 10-28, (5)**), planetary gears (**Figure 10-28, (6)**) and washers into the intermediate housing (**Figure 10-28, (3)**). Reinstall snap ring (**Figure 10-28, (1)**).



0002487

Figure 10-28

- Reinstall the pinion clutch assembly (**Figure 10-29, (2)**), return spring (if equipped), and pinion stop (**Figure 10-29, (3)**) onto the pinion shaft (**Figure 10-29, (1)**). Reinstall the retaining ring (**Figure 10-29, (4)**) in the groove in the pinion shaft. Slide the pinion stop over the retaining ring.

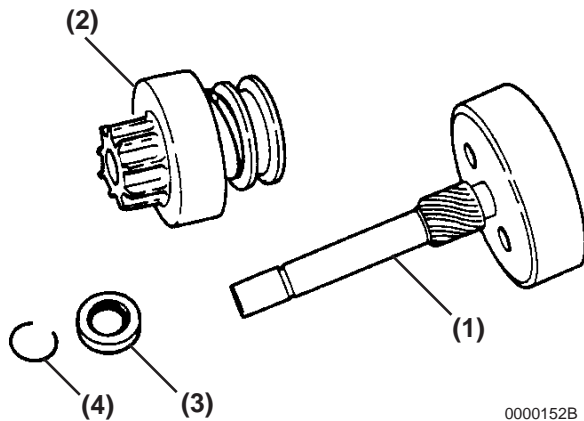


Figure 10-29

- Apply a small amount of high temperature lithium grease (obtain locally) to the contact surfaces of the shift lever. Reassemble the shift lever (**Figure 10-30, (2)**), spacer (if equipped) (**Figure 10-30, (1)**) and pin.
- Reinstall the pinion shaft assembly (**Figure 10-30, (4)**) in the pinion housing (**Figure 10-30, (3)**). Be sure the shift lever properly engages the pinion.

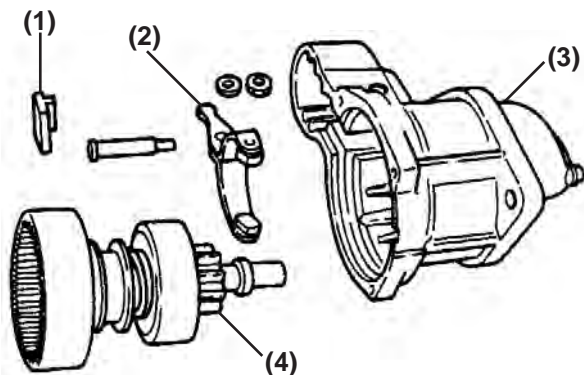


Figure 10-30

- Apply a small amount of high temperature lithium grease (obtain locally) to the surface of the plunger and the hole that engages the shift lever.
- Attach the plunger to the shift lever.
- Reinstall the plate onto the intermediate housing and carefully reinstall the armature assembly (**Figure 10-31, (2)**) into the pinion shaft assembly.

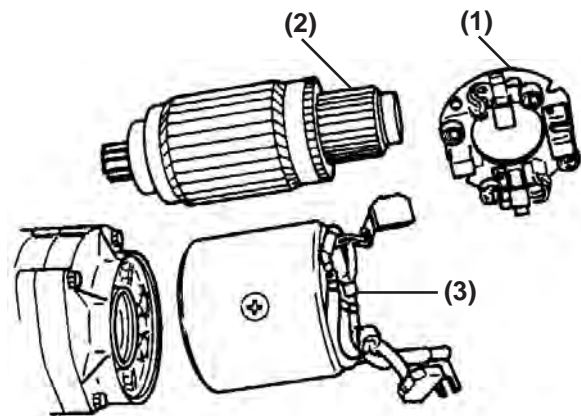
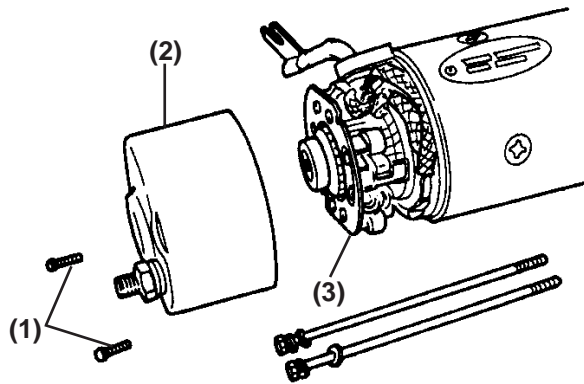


Figure 10-31

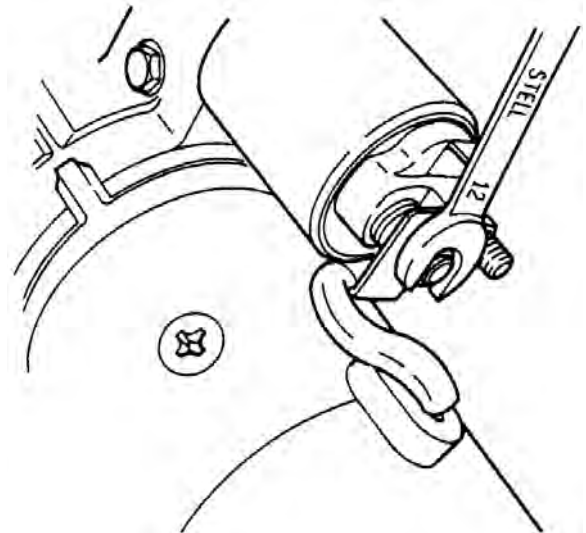
- Reinstall the field assembly (**Figure 10-31, (3)**) over the armature assembly and align to the pinion housing.
- Position the brush springs in brush holders. Reinstall the brushes in the brush holders. Reversing the brushes will cause the starter motor to turn backwards.

11. Carefully reinstall the brush holder (Figure 10-32, (3)) assembly.
12. Reinstall the rear cover (Figure 10-32, (2)) and secure with two bolts (Figure 10-32, (1)).



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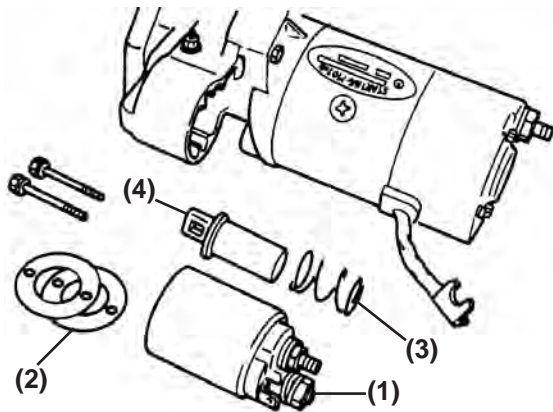
Figure 10-32



0000131

Figure 10-34

13. Reinstall the two through bolts and tighten securely.
14. Reinstall the return spring (if equipped) (Figure 10-33, (3)) on the solenoid plunger (Figure 10-33, (4)). Reinstall the solenoid switch coil (Figure 10-33, (1)) and dust covers (Figure 10-33, (2)). Secure with nuts or bolts.



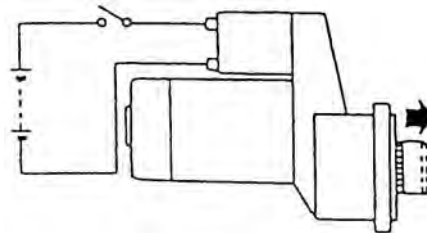
0000140A

Figure 10-33

15. Reconnect the wire to the solenoid switch assembly. Tighten the nut. Reinstall the cover over the connection.

Check Pinion Projection Length

1. Connect the positive (+) lead from a battery to the “S” terminal.
2. Connect the negative (-) lead to the “M” terminal.
3. Lightly pull the pinion away from the gear housing.
4. Turn the switch on and measure the pinion moving distance L in the thrust direction (Figure 10-35). Perform this test within 10 seconds.

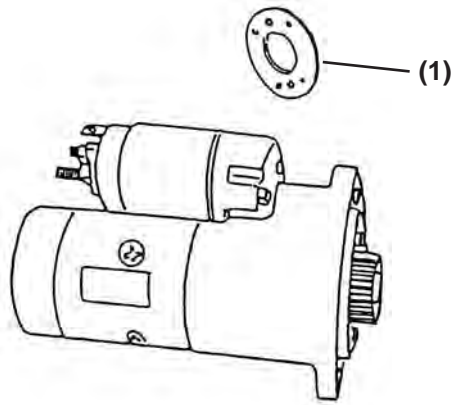


0000132

Figure 10-35

See Starter Motor Specifications on page 10-5 for service limit.

- If the measured L dimension is outside the standard range, adjust the dust covers to obtain the standard range. Dust covers **(Figure 10-36, (1))** are available in 0.020 in. (0.5 mm) and 0.031 in. (0.8 mm) thicknesses.



0000133

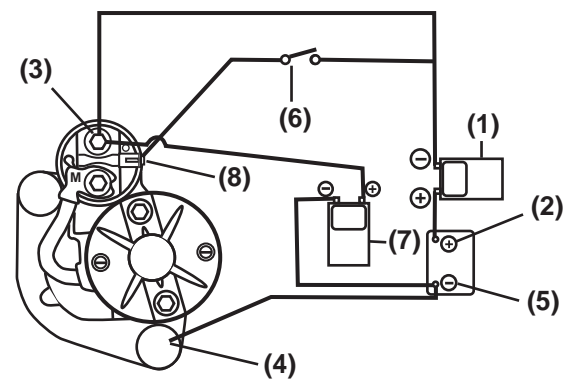
Figure 10-36

No-Load Test

Test the characteristics of the starter motor by performing a no load test. *NOTICE: The starter motor can be damaged if operated continuously longer than 10 seconds while performing the no-load test. Allow a 30-second pause between each use of the starter motor if operated continuously.*

- Secure the starting motor in a vise or other suitable fixture.
- Connect an ammeter **(Figure 10-37, (1))** in series between the battery positive (+) terminal **(Figure 10-37, (2))** and the main positive (+) terminal **(Figure 10-37, (3))** on the starter motor.

Note: The ammeter and all wire leads used in this test must have a capacity equal to or greater than the amperage draw specification for the starter motor being tested.



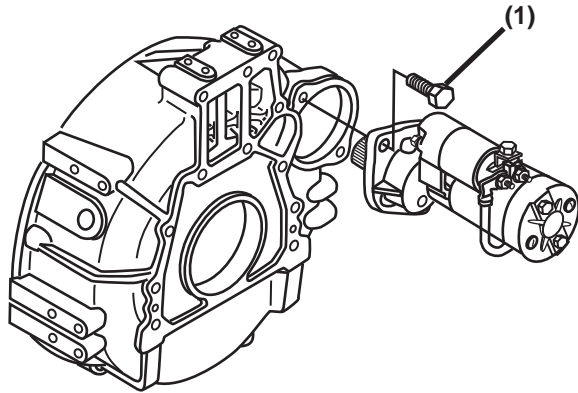
0002127A

Figure 10-37

- Connect a wire lead between the mounting base of the starter motor **(Figure 10-37, (4))** and the battery negative terminal **(Figure 10-37, (5))**.
- Connect a voltmeter **(Figure 10-37, (7))** to the battery negative (-) terminal **(Figure 10-37, (5))** and the main positive (+) battery terminal **(Figure 10-37, (3))** on the starter motor.
- Install a switch **(Figure 10-37, (6))** in a circuit between the battery positive (+) terminal **(Figure 10-37, (2))** and the starter solenoid switch terminal **(Figure 10-37, (8))** on the starter motor.
- Use a suitable tachometer to monitor the rpm of the starter.
- Turn the switch to the ON position to energize the solenoid and operate the starter. Monitor the rpm, amperage draw and voltage. For test specifications, see *Starter Motor Information on page 10-4* for the appropriate starter motor.

Installation of Starter Motor

1. Reinstall the starter motor to the flywheel housing.
2. Reinstall the starter mounting bolts (**Figure 10-38, (1)**). Tighten the bolts to specification. See *Tightening Torques for Standard Bolts and Nuts* on page 4-24.



0002126

Figure 10-38

3. Reconnect the electrical wires to the solenoid switch assembly. Be sure to place the cover over the battery positive (+) cable connection.
4. Reconnect the battery, negative (-) cable last.

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Section 11

ALTERNATOR

	Page
Safety Precautions	11-3
Introduction.....	11-3
Standard and Optional Dynamo Information	11-4
Standard and Optional Alternator Information.....	11-4
Alternator Specifications.....	11-5
Dynamo Specifications.....	11-5
Alternator Troubleshooting	11-6
Alternator Components	11-7
Alternator Wiring Diagram	11-8
Alternator Standard Output	11-9
Alternator	11-10
Removal of Alternator.....	11-10
Disassembly of Alternator.....	11-10
Reassembly of Alternator	11-12
Installation of Alternator.....	11-14

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SAFETY PRECAUTIONS

Before performing any alternator service procedures, review the following messages and the *Safety section on page 3-1*.

NOTICE:

- *Do not operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.*
- *Do not turn the battery switch off while the engine is operating. Damage to the alternator will result.*
- *Do not use a high-pressure wash directly on the alternator. Water will damage the alternator and result in inadequate charging.*

INTRODUCTION

This section of the *Service Manual* describes the servicing of alternators. Yanmar generic alternator parts images are used in this section to show the service procedures for the representative alternator. The 3TNM72-APL engine uses a 55 amp alternator.

For specific part detail, see the *Parts Catalog* for the engine you are working on.

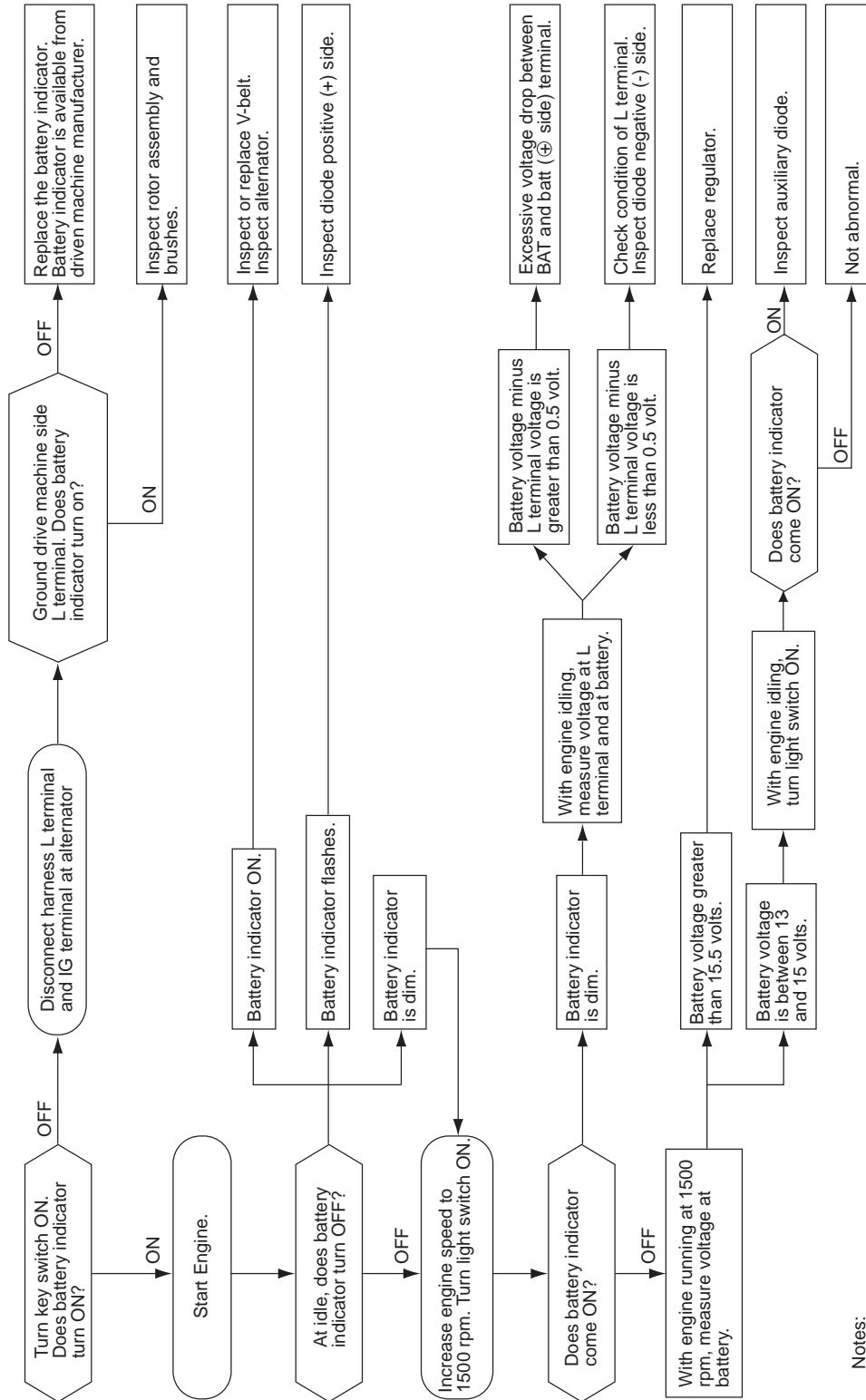
STANDARD AND OPTIONAL ALTERNATOR INFORMATION

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ALTERNATOR SPECIFICATIONS

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ALTERNATOR TROUBLESHOOTING



Notes:

- 1) Use a fully charged battery
- 2) DC voltmeter: 0 to 30 V, 0.5 class
- 3) The check method is also applicable to the bench test

ALTERNATOR COMPONENTS

Generic alternator images are being used in this section to show the service procedures for the representative alternator. For specific part detail, see the *Parts Catalog* for the engine you are working on.

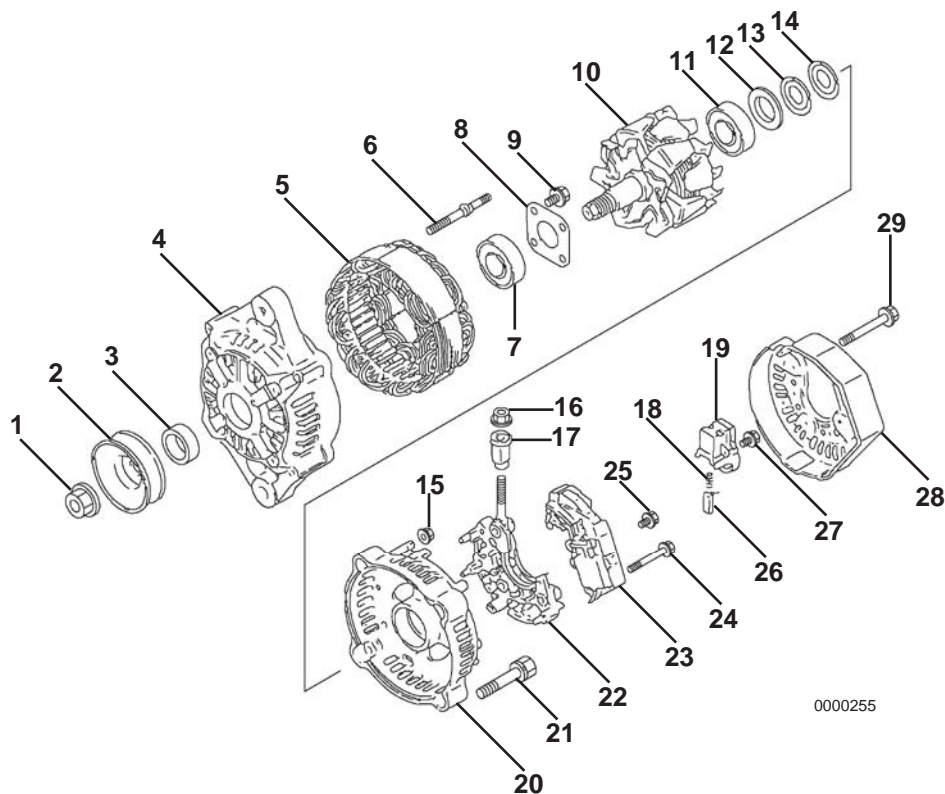


Figure 11-1

- | | |
|---------------------------------|----------------------------|
| 1 – Nut | 16 – Nut |
| 2 – Pulley | 17 – Insulation Bushing |
| 3 – Collar | 18 – Spring (2 used) |
| 4 – Front Frame Housing | 19 – Brush Holder |
| 5 – Stator Assembly | 20 – Rear Frame Housing |
| 6 – Stud (2 used) | 21 – Bolt (2 used) |
| 7 – Front Frame Housing Bearing | 22 – Holder |
| 8 – Bearing Cover | 23 – IC Regulator Assembly |
| 9 – Bearing Cover Bolt (4 used) | 24 – Bolt (2 used) |
| 10 – Rotor Assembly | 25 – Bolt |
| 11 – Rear Frame Housing Bearing | 26 – Brush (2 used) |
| 12 – Bearing Cover | 27 – Bolt |
| 13 – Thrust Washer | 28 – Rear Cover |
| 14 – Thrust Washer | 29 – Bolt (3 used) |
| 15 – Nut (2 used) | |

ALTERNATOR WIRING DIAGRAM

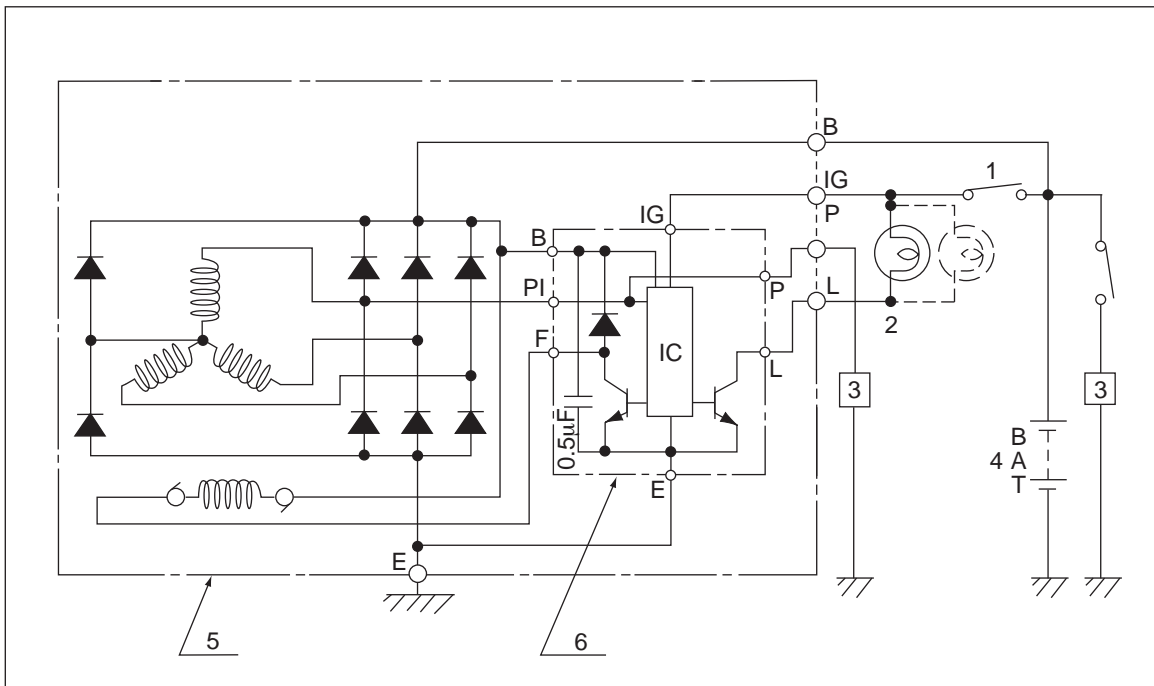


Figure 11-2

1 – Key Switch

2 – Charge Lamp (3.4 Watts Max.)

3 – Load

4 – Battery

5 – Alternator Assembly

6 – IC Regulator Assembly

NOTICE:

- Do not short-circuit the charging system between alternator terminals IG and L. Damage to the alternator will result.
- Do not connect a load between alternator terminals L and E. Damage to the alternator will result.
- Do not remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.
- Agricultural or other chemicals, especially those with a high sulfur content, can adhere to the IC regulator. This will corrode the conductor and result in battery over-charging (boiling) and charging malfunctions.

ALTERNATOR STANDARD OUTPUT

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ALTERNATOR

WARNING! Electrical Shock Hazard.

- **Turn off the battery switch (if equipped) or disconnect the negative (-) battery cable before servicing the electrical system.**
- **Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.**

Removal of Alternator

1. Disconnect the electrical wires from the alternator.
2. Loosen the V-belt. **CAUTION! Pinch Hazard. Carefully rotate the alternator toward the cylinder block while loosening the V-belt.**
3. Remove the V-belt adjuster from the alternator bolt (**Figure 11-4, (1)**).
4. Remove the nut (**Figure 11-4, (2)**) from the gear case stud. Remove the alternator.

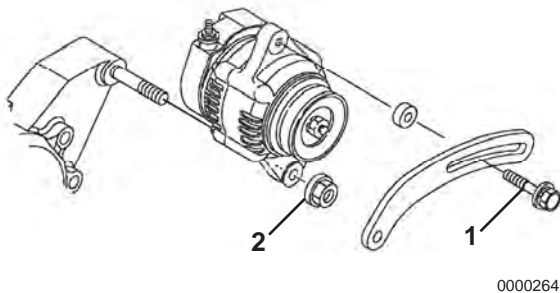


Figure 11-4

Disassembly of Alternator

1. Remove the nut (**Figure 11-5, (1)**) from the shaft of the rotor assembly. Remove the pulley (**Figure 11-5, (2)**).

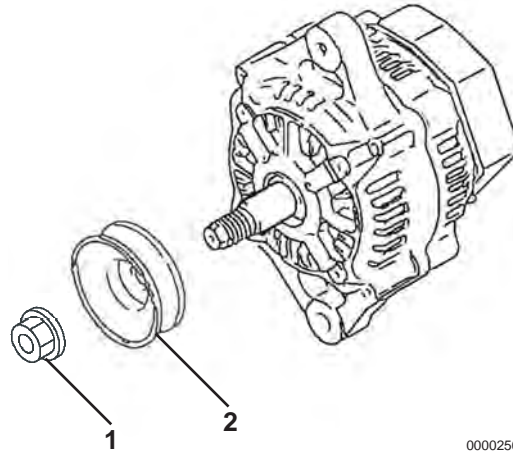


Figure 11-5

2. Remove the three bolts (**Figure 11-6, (1)**) retaining the rear cover (**Figure 11-6, (2)**) to the rear frame assembly.

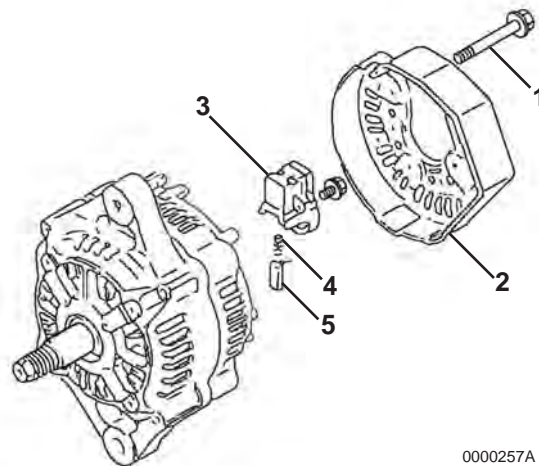


Figure 11-6

3. Remove the brush holder (**Figure 11-6, (3)**). Remove the brush springs (**Figure 11-6, (4)**) and brushes (**Figure 11-6, (5)**).
4. Remove the bolt retaining the regulator assembly (**Figure 11-7, (1)**) to the holder (**Figure 11-7, (2)**).

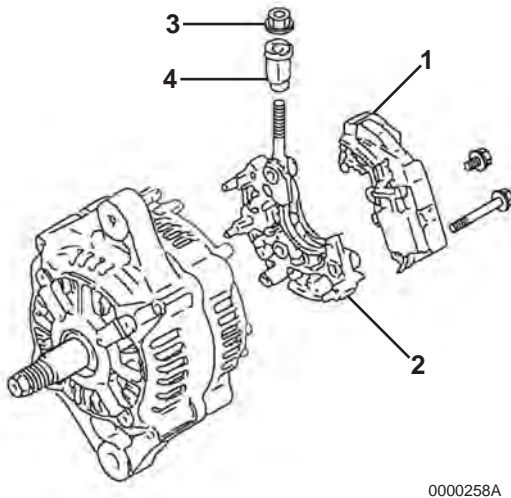


Figure 11-7

5. Remove the bolts retaining the holder (**Figure 11-7, (2)**) to the rear frame housing. Remove the holder.
6. Remove the nut (**Figure 11-7, (3)**) retaining the insulation bushing (**Figure 11-7, (4)**). Remove the insulation bushing.

7. Remove the two bolts (**Figure 11-8, (1)**) and two nuts (**Figure 11-8, (2)**) securing the rear frame housing to the front frame housing.

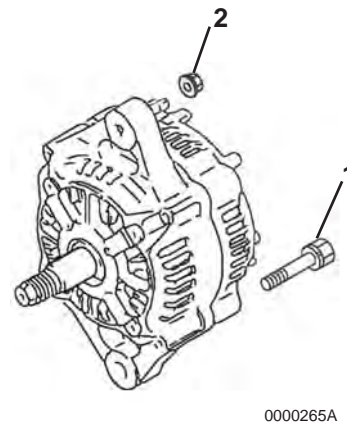


Figure 11-8

8. Using a press, remove the rotor assembly (**Figure 11-9, (1)**) from the front frame housing (**Figure 11-9, (2)**) and rear frame housing (**Figure 11-9, (3)**).

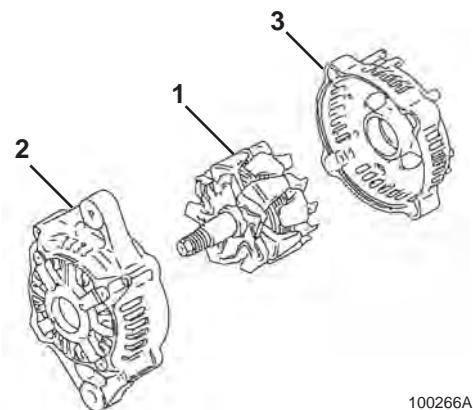


Figure 11-9

- Remove the stator assembly (**Figure 11-10, (1)**) from the front frame housing.

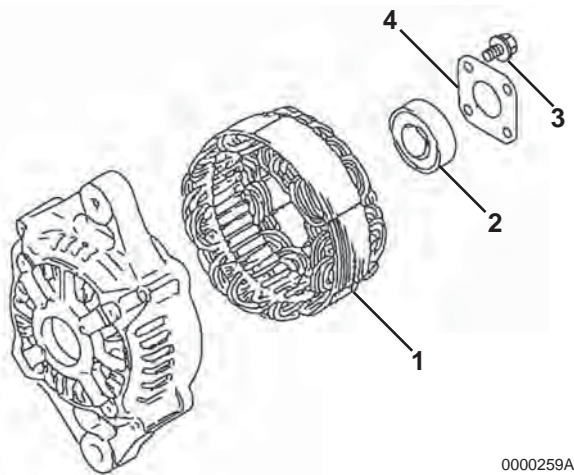


Figure 11-10

- If it is necessary to replace the bearing (**Figure 11-10, (2)**) in the front frame housing, remove the four bolts (**Figure 11-10, (3)**) securing the plate (**Figure 11-10, (4)**) to the front frame housing. Remove the plate. Use a puller to remove the bearing. Discard the bearing.
- If it is necessary to replace the bearing (**Figure 11-11, (1)**) in the rear frame housing, use a puller to remove. Discard the bearing. Remove the bearing cover (**Figure 11-11, (2)**) and two thrust washers (**Figure 11-11, (3)**).

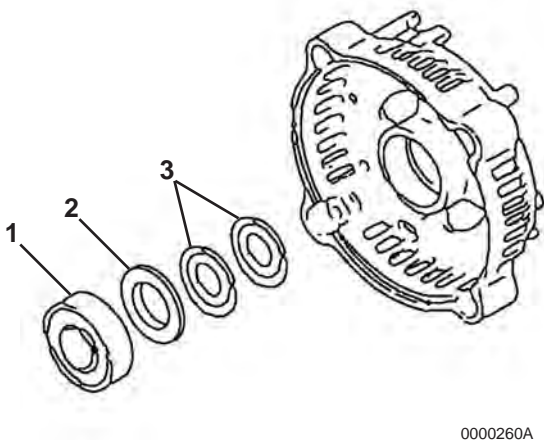


Figure 11-11

Reassembly of Alternator

- If removed, reinstall the two thrust washers (**Figure 11-12, (3)**) and bearing cover (**Figure 11-12, (2)**) in the rear frame housing. Lubricate the outside diameter of a new bearing (**Figure 11-12, (1)**). Press the bearing into the rear frame housing.

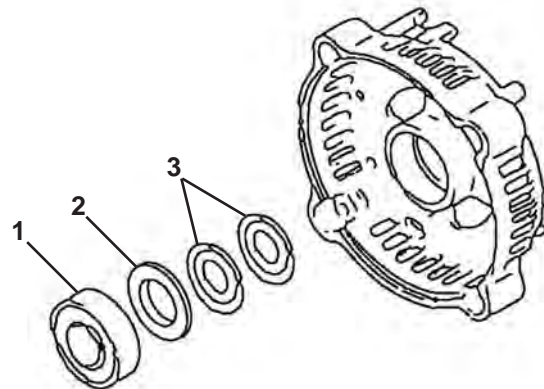


Figure 11-12

- If removed, lubricate the outside diameter of a new front frame housing bearing. Press the bearing (**Figure 11-13, (2)**) into the front frame housing. Reinstall the plate (**Figure 11-13, (4)**) to the front housing. Tighten the four bolts (**Figure 11-13, (3)**).

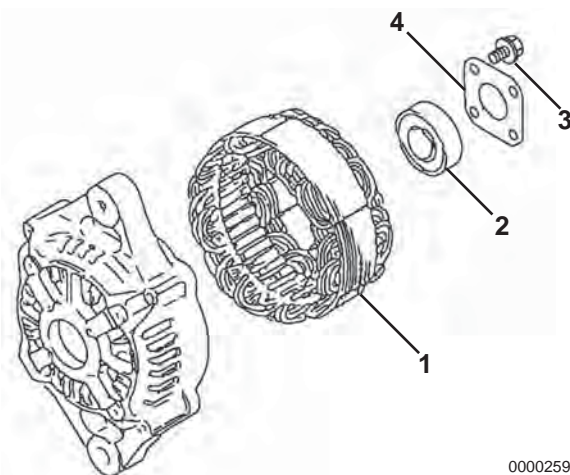


Figure 11-13

3. Position the stator assembly (**Figure 11-13, (1)**) on the front frame housing studs.
4. Lubricate the shaft of the rotor assembly (**Figure 11-14, (1)**). Press the rotor assembly into the front frame housing (**Figure 11-14, (2)**) and rear frame housing (**Figure 11-14, (3)**).

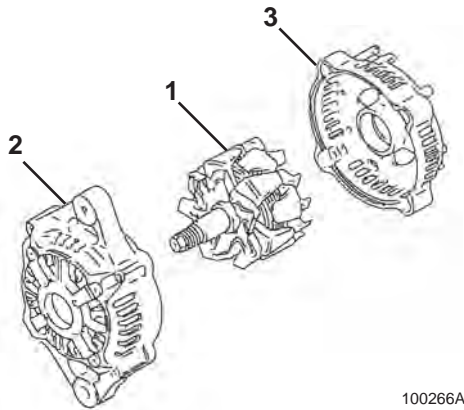


Figure 11-14

5. Align the front frame housing with the rear frame housing. Reinstall the two bolts (**Figure 11-15, (1)**) and two nuts (**Figure 11-15, (2)**).

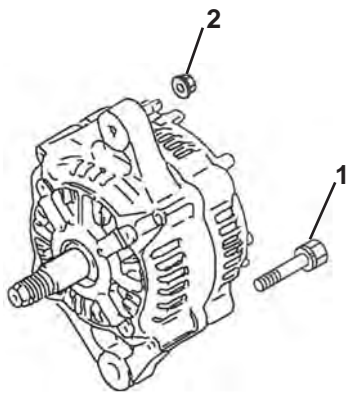


Figure 11-15

6. Reinstall the insulation bushing (**Figure 11-16, (4)**) and nut (**Figure 11-16, (3)**).

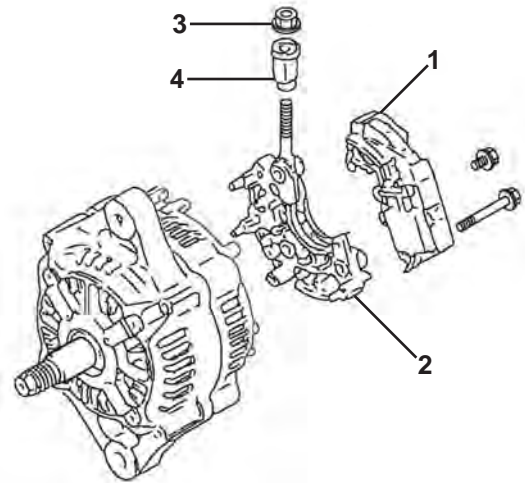


Figure 11-16

7. Reassemble the regulator assembly (**Figure 11-16, (1)**) to the holder (**Figure 11-16, (2)**).
8. Reinstall the brush holder (**Figure 11-17, (3)**), springs (**Figure 11-17, (4)**) and brushes (**Figure 11-17, (5)**).
9. Reattach the regulator assembly and holder to the rear frame housing.

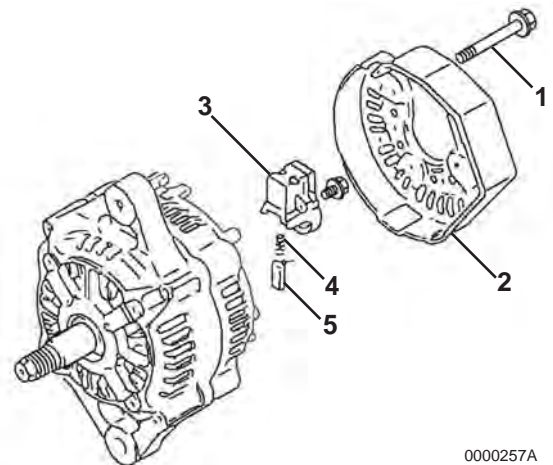


Figure 11-17

10. Reinstall the rear cover (**Figure 11-17, (2)**) to the rear frame housing with three bolts (**Figure 11-17, (1)**).

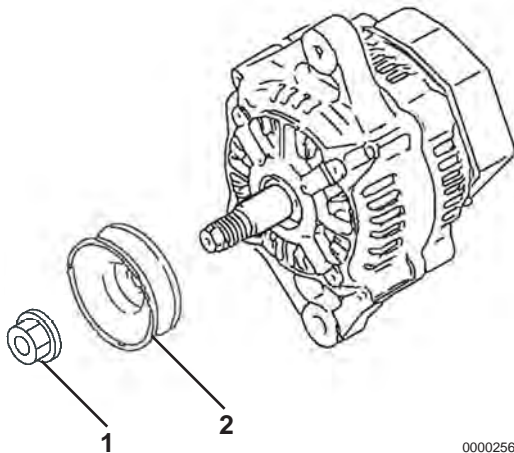


Figure 11-18

11. Reassemble the pulley (**Figure 11-18, (2)**) and nut (**Figure 11-18, (1)**) to the shaft of the rotor assembly. Tighten the nut.

Installation of Alternator

1. Position the alternator on the gear case. Loosely reinstall the nut (**Figure 11-19, (2)**) on the gear case stud and the V-belt adjuster bolt (**Figure 11-19, (1)**).

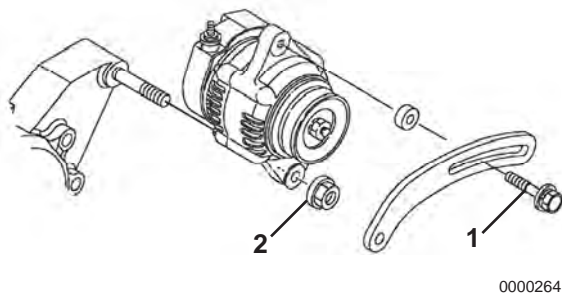


Figure 11-19

2. Reconnect the electrical wires to the alternator. Tighten the nuts to 15 to 20 in.-lb (1.7 to 2.3 N·m; 17 to 23 kgf·m).
3. Reinstall the V-belt. Tighten the V-belt to the proper tension. *See Check and Adjust Cooling Fan V-Belt on page 5-13. NOTICE: Using a non-specified V-belt will cause inadequate charging and shorten the belt life. Use the specified belt.*

4. Start the engine. Listen for any unusual sounds from the alternator. **NOTICE: Do not operate the engine if the alternator is producing unusual sounds.**
5. Verify that the charge indicator is on while the engine is operating. If the charge indicator is not on, repair the problem before operating the engine.

Section 1&

TROUBLESHOOTING

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Safety Precautions	12-3
Special Service Tools	12-3
Troubleshooting By Measuring Compression Pressure	12-4
Compression Pressure Measurement Method	12-4
Standard Compression Pressure	12-5
Measured Value and Troubleshooting.....	12-5
Quick Reference Table for Troubleshooting.....	12-5
Troubleshooting Charts	12-7

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SAFETY PRECAUTIONS

Before performing any troubleshooting procedures, review the *Safety section on page 3-1*.

SPECIAL SERVICE TOOLS

Compression Gauge Kit		
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TROUBLESHOOTING BY MEASURING COMPRESSION PRESSURE

Compression pressure drop is one of major causes of increasing blow-by gas (engine oil contamination or increased engine oil consumption as a resultant phenomenon) or starting failure. The compression pressure is affected by the following factors:

- Degree of clearance between piston and cylinder
- Degree of clearance at intake / exhaust valve seat
- Gas leak from nozzle gasket or cylinder head gasket

The pressure will drop due to increased parts wear. Pressure drop reduces the durability of the engine.

A pressure drop may also be caused by scratched cylinder or piston by dust entrance from the dirty air cleaner element or worn or broken piston ring. Measure the compression pressure to determine the condition of the engine.

Compression Pressure Measurement Method

1. Warm up the engine.
2. Stop the engine. Remove the high-pressure fuel injection lines as an assembly from the engine. See *Removal of High-Pressure Fuel Injection Lines* on page 7-10. Remove the fuel injector from the cylinder to be measured. See *Removal of Fuel Injectors* on page 7-21.

NOTICE: Remove and install the high-pressure fuel injection lines as an assembly whenever possible. Disassembling the high-pressure fuel injection lines from the retainers or bending any of the fuel lines will make it difficult to reinstall the fuel lines.

3. Turn off the fuel supply valve in the fuel supply line. Disconnect the fuel injection stop solenoid at the connector. Crank the engine for a few seconds with the stop solenoid disconnected (no injection state) before installing the compression gauge adapter (**Figure 13-1, (1)**), **this will expel any residual fuel from the cylinder.**
4. Install one injector gasket at the tip end of the compression gauge adapter. Install the compression gauge and the compression gauge adapter at the cylinder to be measured.
5. Crank the engine until the compression gauge reading is stabilized.

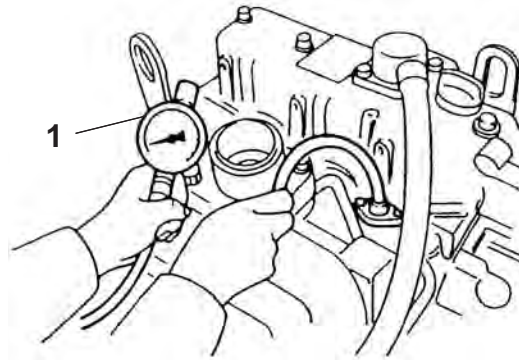
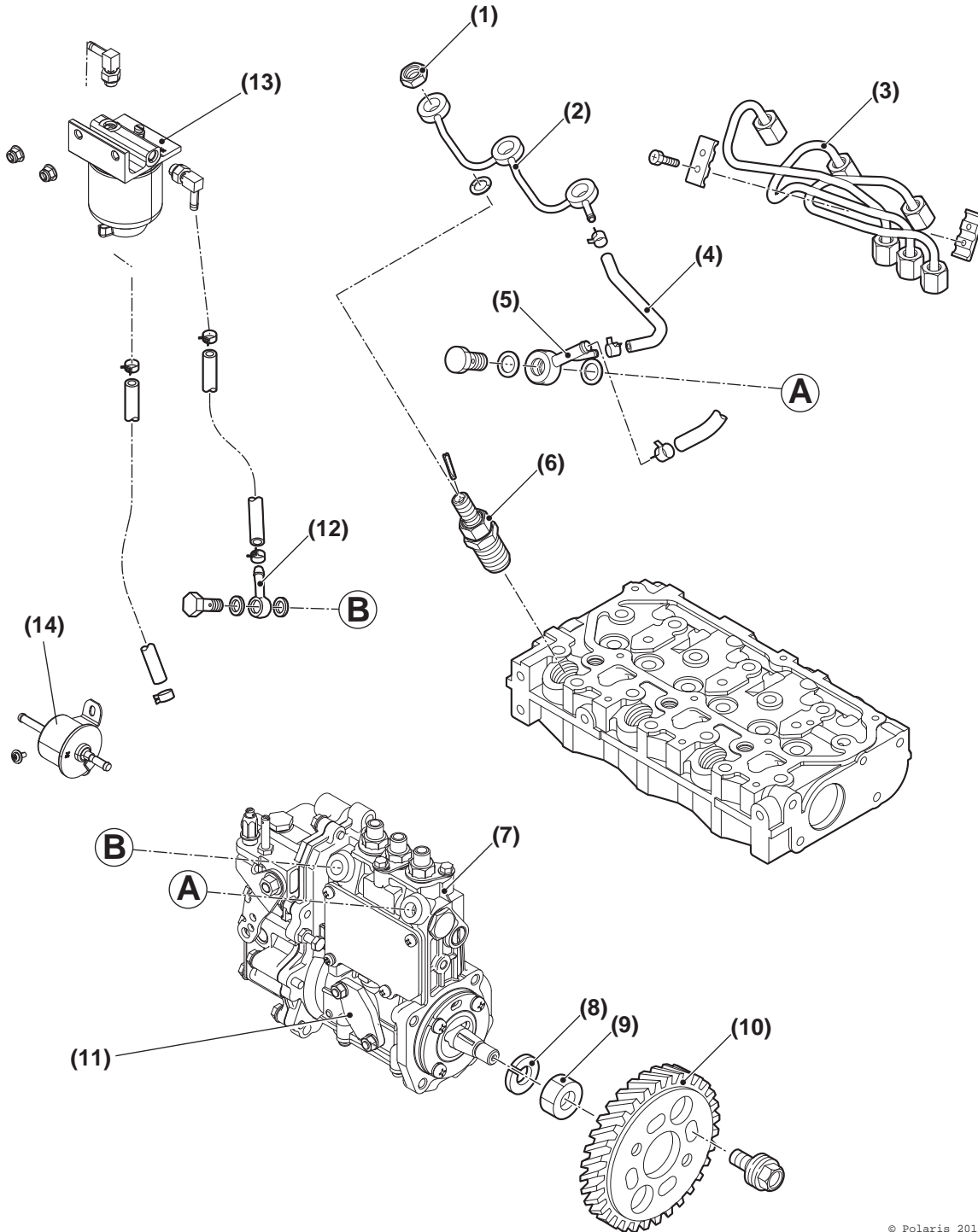


Figure 13-1

6. After performing the compression check, remove the compression gauge and compression gauge adapter from the cylinder. Reinstall the fuel injector, high-pressure fuel injection lines and reconnect the stop solenoid. See *Installation of the Fuel Injectors* on page 7-26 and *Installation of High-Pressure Fuel Injection Lines* on page 7-11.
7. Turn on the fuel supply valve and reconnect the injection pump stop solenoid.
8. Prime the fuel system. Check for leaks. Test the engine.

FUEL SYSTEM COMPONENTS



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Figure 7-3

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Troubleshooting Charts

Cause	Trouble Symptom	Starting Problem			Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging			Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Engine Coolant		Air Intake		Exhaust Temperature Rise	Corrective Action	Reference Page	
		Engine Does Not Start	Engine Starts But Stops Soon		Exhaust Color			During Work					During Idling	During Work Operation	Excessive Engine Vibration			Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Water	Low Oil Pressure	Excessive Blow-by Gas	Overheat	Low Coolant Temperature	Pressure Drop				Pressure Rise
			None	Little	Much	Ordinary	White	Black	White																				
Engine System	Improper Intake / Exhaust Valve Clearance	○	○		○					○													○		○	Adjust the Valve Clearance.	See Measuring and Adjusting Valve Clearance on page 6-30		
	Compression Leakage from Valve Seat				○		○		○						○			○						○		○	Lap the Valve Seat.	See Valve Face and Valve Seat on page 6-24	
	Intake / Exhaust Valve Seizure	○			○		○		○				○	○				○						○			Correct or Replace Intake / Exhaust Valve.	See Inspection of Intake and Exhaust Valves on page 6-23	
	Cylinder Head Gasket Blowout				○													○			○						Replace the Gasket.	See Disassembly of Cylinder Head on page 6-17	
	Seized or Broken Piston Ring	○			○		○			○		○		○				○	○		○					○	Replace the Piston Ring.	See Reassembly of Cylinder Head on page 6-27	
	Worn Piston Ring, Piston or Cylinder	○			○		○											○	○		○						Perform Honing and Use Oversize Parts.	See Honing and Boring on page 6-48	
	Seized Crankpin Metal or Bearing	○	○								○		○	○	○						○							Repair or Replace.	See Inspection of Crankshaft and Camshaft Components on page 6-42
Improper Arrangement of Piston Ring Gaps		○				○											○			○							Correct the Ring Joint Positions.	See Reassembly of Pistons on page 6-50	

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Cause	Trouble Symptom	Starting Problem			Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Engine Coolant		Air Intake		Exhaust Temperature Rise	Corrective Action	Reference Page		
		Engine Does Not Start	Engine Starts But Stops Soon		Exhaust Color			During Work					During Idling	During Work Operation			Excessive Engine Vibration	Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Water	Low Oil Pressure	Excessive Blow-by Gas	Overheat	Low Coolant Temperature				Pressure Drop	Pressure Rise
			None	Little	Much	Ordinary	White	Black	White																				
Engine System - Continued	Reverse Assembly of Piston Rings					○		○								○				○					Reassemble Correctly.	See Reassembly of Pistons on page 6-50			
	Worn Crankpin and Journal Bearing				○					○		○	○					○								Measure and Replace.	See Inspection of Crankshaft and Camshaft Components on page 6-42		
	Loose Connecting Rod Bolt									○			○							○						Tighten to the Specified Torque.	See Special Torque Chart on page 6-11		
	Foreign Matter Trapped in Combustion Chamber	○								○						○				○						Disassemble and Repair.	See Disassembly of Cylinder Block Components on page 6-33		
	Excessive Gear Backlash									○																Adjust Gear Meshing.	See Checking Timing Gear Backlash on page 6-34		
	Worn Intake / Exhaust Valve Guide					○										○				○						Measure and Replace.	See Inspection of Valve Guides on page 6-22		
	Governor Adjusted Incorrectly		○										○	○	○	○										Make Adjustment.	See Check and Adjust the Governor Lever and Engine Speed Control on page 5-13		
	Improper Open / Close Timing of Intake / Exhaust Valves	○					○	○	○	○	○															Adjust the Valve Clearance.	See Measuring and Adjusting Valve Clearance on page 6-30		

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Cause	Trouble Symptom	Starting Problem			Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging			Difficulty in Returning to Low Speed	Engine Oil					Engine Coolant		Air Intake		Corrective Action	Reference Page	
		Engine Does Not Start	Engine Starts but Stops Soon		Exhaust Color			During Work					Excessive Fuel Consumption	Excessive Oil Consumption	Dilution by Diesel Fuel		Oil with Water	Low Oil Pressure	Excessive Blow-by Gas	Overheat	Low Coolant Temperature	Pressure Drop	Pressure Rise	Exhaust Temperature Rise				
			Exhaust Smoke		Ordinary	White	Black	White	Black																			
			None	Little																					Much			
Engine Coolant System	Excessive Radiator Cooling																							Replace Thermostat.	See Disassembly of Engine Coolant Pump on page 8-6			
	Insufficient Radiator Cooling																								Replace Thermostat or Check for Loose Coolant Pump Belt.	See Disassembly of Engine Coolant Pump on page 8-6 or Check and Adjust Cooling Pump V-Belt on page 5-13		
	Insufficient Engine Coolant Level																								Check Coolant Leakage from Engine Coolant System.	See Engine Coolant System Check on page 8-6		
	Cracked Coolant Jacket																									Repair or Replace.	See Disassembly of Engine Coolant Pump on page 8-6	
	Stretched Coolant Pump V-Belt																									Adjust the Belt Tension.	See Check and Adjust Cooling Pump V-Belt on page 5-7	
	Defective Thermostat																										Check or Replace.	See Disassembly of Engine Coolant Pump on page 8-6
Engine Oil System	Incorrect Engine Oil																									Use Correct Engine Oil.	See Engine Oil Specifications on page 4-14	
	Engine Oil System Leakage																										Repair.	See Disassembly of Oil Pump on page 9-5
	Insufficient Delivery Capacity of Trochoid Pump																										Check and Repair.	See Disassembly of Oil Pump on page 9-5
	Clogged Engine Oil Filter																										Clean or Replace.	See Replace Engine Oil and Engine Oil Filter on page 5-12
	Defective Pressure Regulating Valve																										Clean, Adjust or Replace.	See Disassembly of Oil Pump on page 9-5
	Insufficient Engine Oil Level																										Add Correct Engine Oil.	See Adding Engine Oil on page 4-15
	Overfilled Engine Crankcase																										Check Engine Oil	See Checking Engine Oil on page 4-15

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Cause	Trouble Symptom	Starting Problem			Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil			Excessive Blow-by Gas	Engine Coolant		Air Intake		Exhaust Temperature Rise	Corrective Action	Reference Page		
		Engine Does Not Start	Engine Starts but Stops Soon		Exhaust Color			During Work					During Idling	During Work Operation			Excessive Engine Vibration	Excessive Oil Consumption	Dilution by Diesel Fuel		Oil with Water	Low Oil Pressure	Overheat	Low Coolant Temperature				Pressure Drop	Pressure Rise
			None	Little	Much	Ordinary	White	Black	White																				
Fuel System	Too Early Timing of Fuel Injection Pump								○	○														Check and Adjust.	See Checking and Adjusting Fuel Injection Timing on page 7-16				
	Too Late Timing of Fuel Injection Pump					○		○							○								○	Check and Adjust.	See Checking and Adjusting Fuel Injection Timing on page 7-16				
	Incorrect Diesel Fuel				○	○	○	○	○		○													Use Correct Fuel Oil.	See Diesel Fuel Specifications on page 4-10				
	Water in Fuel System	○			○	○		○			○	○	○												Drain the Fuel Filter.	See Drain Fuel Filter / Water Separator on page 5-9			
	Clogged Fuel Filter	○	○		○																				Clean or Replace.	See Drain Fuel Filter / Water Separator on page 5-9			

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Cause	Trouble Symptom	Starting Problem			Insufficient Engine Output		Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Engine Coolant		Air Intake		Corrective Action	Reference Pages			
		Engine Does Not Start	Engine Starts but Stops Soon		Exhaust Color		During Work					During Idling	During Work Operation			Excessive Engine Vibration	Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Water	Low Oil Pressure	Excessive Blow-by Gas	Overheat	Low Coolant Temperature			Pressure Drop	Pressure Rise	Exhaust Temperature Rise
			None	Little	Much	Ordinary	White	Black																				
Fuel System	Air in Fuel System	○	○		○																		Bleed the Air.	See Priming the Fuel System on page 4-13				
	Clogged or Cracked Fuel Line	○	○		○																		Clean or Replace.	See Check and Replace Fuel Hoses and Engine Coolant Hoses on page 5-20				
	Insufficient Fuel Supply to Fuel Injection Pump	○	○		○																		Check the Fuel Tank Cock, Fuel Filter, Fuel Line and Fuel Feed Pump.	See the appropriate procedure in Periodic Maintenance on page 5-1				
	Uneven Injection Volume from Fuel Injection Pump					○	○	○	○		○	○	○	○									○	Check and Adjust.	See Testing of Fuel Injectors on page 7-21			
	Excessive Fuel Injection Volume								○						○	○				○	○		○	○	Check and Adjust.	See Testing of Fuel Injectors on page 7-21		
	Poor Spray Pattern from Fuel Injection Nozzle					○	○	○	○		○	○	○	○											Check and Adjust.	See Testing of Fuel Injectors on page 7-21		
	Priming Failure	○																						Foreign Matter Trapped in the Valve Inside the Priming Pump (Disassemble and Clean).	See Fuel System Components on page 7-9			
Clogged Strainer at Feed Pump Inlet				○																			Clean the Strainer.	See Drain Fuel Tank on page 5-11				

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Cause	Trouble Symptom	Starting Problem			Insufficient Engine Output			Poor Exhaust Color		High Knocking Sound During Combustion	Abnormal Engine Sound	Uneven Combustion Sound	Engine Surging		Difficulty in Returning to Low Speed	Excessive Fuel Consumption	Engine Oil				Engine Coolant		Air Intake		Corrective Action	Reference Pages			
		Engine Does Not Start	Engine Starts but Stops Soon		Exhaust Color			During Work					During Idling	During Work Operation			Excessive Engine Vibration	Excessive Oil Consumption	Dilution by Diesel Fuel	Oil with Water	Low Oil Pressure	Excessive Blow-by Gas	Overheat	Low Coolant Temperature			Pressure Drop	Pressure Rise	Exhaust Temperature Rise
			None	Little	Much	Ordinary	White	Black	White																				
Air/Exhaust Gas System	Clogged Air Filter			○			○		○		○													Clean Air Filter.	See Clean Air Cleaner Element on page 5-13				
	Engine Used at High Temperatures or at High Altitude						○		○					○					○		○				Study Output Drop and Load Matching.	-			
	Clogged Exhaust Pipe						○		○		○												○		Clean Exhaust Pipe.	-			
Electrical System	Starting Motor Defect	○																							Repair or Replace Stater Motor.	See Starter Motor on page 10-8			
	Alternator Defect	○																							Repair or Replace Alternator.	See Removal of Alternator on page 11-10 or Removal of Dynamo on page 11-18			
	Open-Circuit in Wiring	○																							Repair Open Circuit.	-			
	Battery Voltage Drop	○																							Inspect and Change the Battery.	See Check Battery on page 5-10			