YANMAR

SERVICE MANUAL

INDUSTRIAL ENGINES

3TNV88F

YANMAR limited warranty - continued

Warranty Limitations:

The foregoing is YANMAR's only obligation to you and your exclusive remedy for breach of warranty. Failure to follow the requirements for submitting a claim under this warranty may result in a waiver of all claims for damages and other relief. **In no event shall YANMAR or any authorized industrial engine dealer or distributor be liable for incidental, special or consequential damages.** Such consequential damages may include, but not be limited to, loss of revenue, loan payments, cost of rental of substitute equipment, insurance coverage, storage, lodging, transportation, fuel, mileage, and telephone costs. The limitations in this warranty apply regardless of whether your claims are based on breach of contract, tort (including negligence and strict liability) or any other theory. Any action arising hereunder must be brought within one (1) year after the cause of action accrues or it shall be barred. Some states and countries do not allow certain limitations on warranties or for breach of warranties. **This warranty gives you specific legal rights, and you may also have other rights which vary from state to state and country to country.** Limitations set forth in this paragraph shall not apply to the extent that they are prohibited by law.

Warranty Modifications:

Except as modified in writing and signed by the parties, this warranty is and shall remain the complete and exclusive agreement between the parties with respect to warranties, superseding all prior agreements, written and oral, and all other communications between the parties relating to warranties. **No person or entity is authorized to give any other warranty or to assume any other obligation on behalf of YANMAR, either orally or in writing.**

Questions:

If you have any questions or concerns regarding this warranty, please call or write to the nearest authorized YANMAR industrial engine dealer or distributor or other authorized facility.

⚠ WARNING

Burn Hazard!

- Batteries contain sulfuric acid. Never allow battery fluid to come in contact with clothing, skin or eyes. Severe burns could result. Always wear safety goggles and protective clothing when servicing the battery. If battery fluid contacts the eyes and/or skin, immediately flush the affected area with a large amount of clean water and obtain prompt medical treatment.
- Failure to comply could result in death or serious injury.

⚠ WARNING

High-Pressure Hazard!

- Avoid skin contact with the high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.
- Never check for a fuel leak with your hands. Always use a piece of wood or cardboard. Have your authorized YANMAR industrial engine dealer or distributor repair the damage.
- Failure to comply could result in death or serious injury.

⚠ 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.
- Failure to comply could result in death or serious injury.

⚠ WARNING

Entanglement Hazard!

- Stop the engine before you begin to service it.
- Never leave the key in the key switch when you are servicing the engine. Someone may accidentally start the engine and not realize you are servicing it. This could result in a serious injury.
- If you must service the engine while it is operating, remove all jewelry, tie back long hair, and keep your hands, other body parts and clothing away from moving/rotating parts.
- Failure to comply could result in death or serious injury.

⚠ WARNING

Sudden Movement Hazard!

- Engaging the transmission or PTO at an elevated engine speed could result in unexpected movement of the equipment.
- Failure to comply could result in death or serious injury.

NOTICE

- Do not plug or unplug the E-ECU for a period of at least 6 seconds after power to the unit has been turned on or off.
- Do not touch connector pins of the E-ECU with bare hands.
  Doing so may result in corrosion of the connector pins and/or damage to the internal circuits of the E-ECU due to static electricity.
- Do not force a measuring probe into the female coupler.
  Doing so may cause contact failure of the connector pins, resulting in malfunction of the E-ECU.
- Take care to prevent water from entering the couplers when plugging or unplugging the connector.
  Water inside the couplers may cause corrosion, resulting in malfunction of the E-ECU.
- Avoid plugging/unplugging the connector more than approx. 10 times.
  Frequent plugging/unplugging of the connector may cause contact failure of the connector pins, resulting in malfunction of the E-ECU.
- Do not use the E-ECU that has ever suffered drop impact.

NOTICE

- Never permit anyone to operate the engine or driven machine without proper training.
- Read and understand this Operation Manual before you operate or service the machine to ensure that you follow safe operating practices and maintenance procedures.
- Machine safety signs and labels are additional reminders for safe operating and maintenance techniques.
- See your authorized YANMAR industrial engine dealer or distributor for additional training.

Component/feature		Description
Droop control	Standard with VM series	Reduces the engine speed by a certain percentage from no load to full (rated) load in steady state operation. The same percentage droop is maintained even when the load increases at any no-load speed.
Isochronous control	Standard with CL series Optional with VM series	Offers a constant engine speed from no load to full load. The engine speed does not decrease even when the load increases at any no-load speed.
Low-idling speed up		Increases the low-idling speed to up to 1000 min^{-1} (rpm) depending on the engine coolant temperature. When the coolant temperature reaches a predetermined value, this feature returns the engine speed to the normal low idle setting, thus reducing the warm-up time.
High-idling speed down	Optional	Decreases the high-idling speed depending on the engine coolant temperature. When the coolant temperature falls to a predetermined value, this feature returns the engine speed to the normal high idle setting, thus minimizing the emission of white smoke at low temperatures.
Auto deceleration	Optional	Brings the running engine in low idle mode automatically when the accelerator pedal is not operated for a predetermined period of time. When the pedal is operated, i.e., the accelerator sensor is activated, the low idle mode is cancelled.

ENGINE COOLANT

⚠ DANGER

Scald Hazard!

- **Never remove the radiator cap if the engine is hot. Steam and hot engine coolant will spurt out and seriously burn you. Allow the engine to cool down before you attempt to remove the radiator cap.**
- **Tighten the radiator cap securely after you check the radiator. Steam can spurt out during engine operation if the cap is loose.**
- **Always check the level of the engine coolant by observing the reserve tank.**
- **Failure to comply will result in death or serious injury.**

⚠ WARNING

Burn Hazard!

- **Wait until the engine cools before you drain the engine coolant. Hot engine coolant may splash and burn you.**
- **Failure to comply could result in death or serious injury.**

⚠ CAUTION

Coolant Hazard!

- **Wear eye protection and rubber gloves when you handle long life or extended life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.**
- **Failure to comply may result in minor or moderate injury.**

NOTICE

- Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and/or shorten engine life.
- Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.
- Never mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

Section 5

PERIODIC MAINTENANCE

Page

Every 50 Hours of Operation

After you complete the initial 50 hour maintenance procedures, perform the following procedures every 50 hours thereafter.

- **Drain fuel filter/water separator**
- **Check battery**

■ Drain fuel filter/water separator

⚠ DANGER

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) place 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.**
- **Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.**
- **Failure to comply will result in death or serious injury.**

NOTICE

If the fuel filter/water separator is positioned higher than the fuel level in the fuel tank, water may not drip out when the fuel filter/water separator drain cock is opened. If this happens, turn the air vent screw on the top of the fuel filter/water separator 2 - 3 turns counterclockwise.

Be sure to tighten the air vent screw after the water has drained out.

NOTICE

- Always be environmentally responsible.

- Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.
- Never dispose of hazardous materials irresponsibly by dumping them into a sewer, on the ground, or into ground water or waterways.
- Failure to follow these procedures may seriously harm the environment.

Drain the fuel filter/water separator whenever there are contaminants, such as water, collected in the bottom of the cup. Never wait until the scheduled periodic maintenance if contaminants are discovered.

The cup of the separator is made from semi-transparent material. In the cup is a red colored float ring. The float ring will rise to the surface of the water to show how much needs to be drained. Also, some optional fuel filter/water separators are equipped with a sensor to detect the amount of contaminants. This sensor sends a signal to an indicator to alert the operator.

3. Remove the drain plug or open the drain cock **(Figure 5-15, (2))** at the lower portion of the radiator and drain the engine coolant.

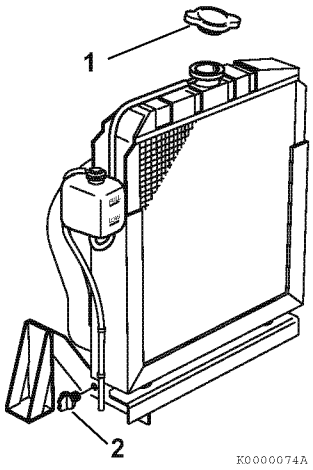


Figure 5-15

4. Drain the coolant from the engine block.
   - On models not equipped with an oil cooler, remove the coolant drain plug **(Figure 5-16, (1))** from the engine block.

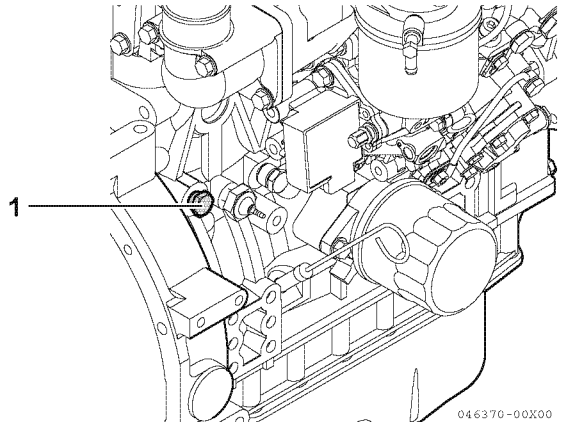


Figure 5-16

5. After draining the engine coolant, flush the radiator and engine block to remove any rust, scale and contaminants. Then reinstall and tighten the drain plug or close the drain cock in the radiator. Reinstall and tighten the cylinder block drain plug.
6. Fill radiator and engine with engine coolant. *See Filling Radiator with Engine Coolant on page 4-20.*

■ Adjust intake/exhaust valve clearance

Proper adjustment is necessary to maintain the correct timing for opening and closing the valves. Improper adjustment will cause the engine to run noisily, resulting in poor engine performance and engine damage. *See Intake/Exhaust Valve and Guide on page 6-4.*

CRANKSHAFT AND PISTON SPECIFICATIONS

Crankshaft

Note: Check appropriate parts catalog for various sizes of replacement main bearing inserts.

Inspection item		Standard	Limit	Reference page
Bend (1/2 the dial gauge reading)		–	0.0008 in. (0.02 mm)	*See Inspection of crankshaft on page 6-44.*
Connecting rod journals	Journal outside diameter	1.8879 - 1.8883 in. (47.952 - 47.962 mm)	1.8859 in. (47.902 mm)	
	Bearing inside diameter	1.8898 - 1.8909 in. (48.000 - 48.026 mm)	–	
	Bearing insert thickness	0.0587 - 0.0591 in. (1.492 - 1.500 mm)	–	
	Oil clearance	0.0015 - 0.0029 in. (0.038 - 0.074 mm)	0.0059 in. (0.150 mm)	
Main bearing journal	Journal outside diameter	1.9666-1.9670 in. (49.952-49.962 mm)	1.9646 in. (49.902 mm)	*See Inspection of crankshaft on page 6-44.*
	Bearing inside diameter	1.9685 - 1.9693 in. (50.000 - 50.020 mm)	–	
	Bearing insert thickness	0.0785 - 0.0791 in. (1.995 - 2.010 mm)	–	
	Oil clearance	0.0015 - 0.0027 in. (0.038 - 0.068 mm)	0.0059 in. (0.150 mm)	

Thrust Bearing

Inspection item	Standard	Limit	Reference page
Crankshaft end play	0.0051 - 0.0091 in. (0.13 - 0.23 mm)	0.0110 in. (0.28 mm)	*See Removal of crankshaft on page 6-39.*

Piston

Inspection item		Standard	Limit	Reference page
Piston outside diameter (Measure at 90° to the piston pin.)		3.4622 - 3.4634 in. (87.940 - 87.970 mm)	3.4604 in. (87.895 mm)	*See Inspection of pistons, piston rings and wrist pin on page 6-41.*
Piston diameter measure location (Upward from the bottom of the piston.)		0.9449 in. (24 mm)	–	
Piston pin	Hole inside diameter	1.0236 - 1.0240 in. (26.000 - 26.009 mm)	1.0252 in. (26.039 mm)	*See Inspection of pistons, piston rings and wrist pin on page 6-41.*
	Pin outside diameter	1.0234 - 1.0236 in. (25.995 - 26.000 mm)	1.0222 in. (25.965 mm)	
	Oil clearance	0.0000 - 0.0006 in. (0.000 - 0.014 mm)	0.0029 in. (0.074 mm)	

Disassembly of Cylinder Head

Prepare a clean, flat working surface on a workbench large enough to accommodate the cylinder head assembly. Discard all gaskets, O-rings and seals. Use new gaskets, O-rings and seals on reassembly of the cylinder head.

1. Drain the coolant from the engine into a suitable container. *See Drain, flush and refill cooling system with new coolant on page 5-20.*

NOTICE

Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

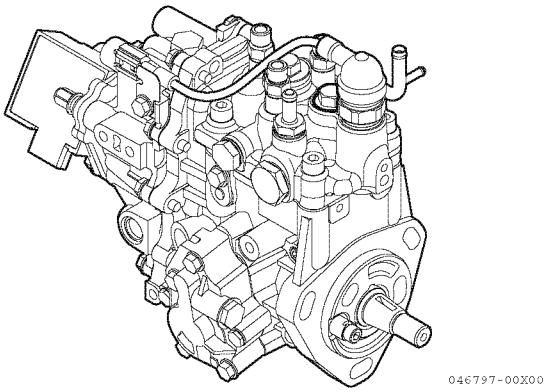


Figure 6-3

2. Remove the intake manifold bolts **(Figure 6-4, (1))**. Remove the intake manifold **(Figure 6-4, (2))**. Discard the intake manifold gasket **(Figure 6-4, (3))**.

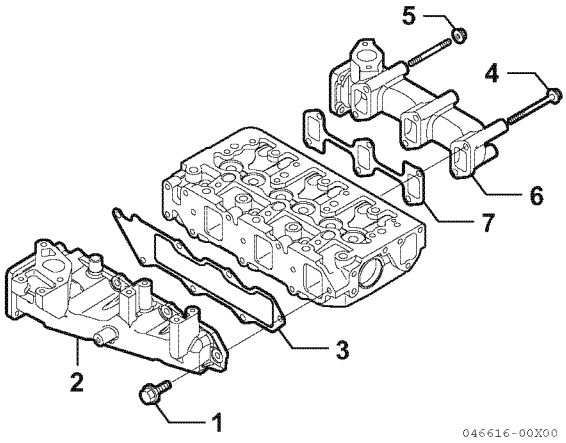


Figure 6-4

3. Remove the exhaust manifold bolts **(Figure 6-4, (4))** and nuts **(Figure 6-4, (5))**. Remove the exhaust manifold **(Figure 6-4, (6))** and the exhaust manifold gasket **(Figure 6-4, (7))**.
4. Remove the coolant pump. *See Disassembly of Engine Coolant Pump on page 8-8.*
5. Remove the high-pressure lines and fuel injectors from the cylinder head. *See Removal of Fuel Injectors on page 7-25.*

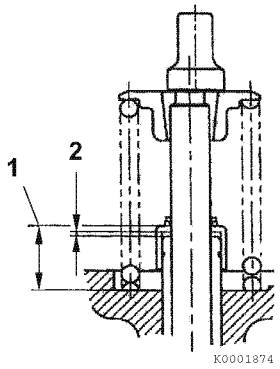


Figure 6-30

3. Place the cylinder head assembly on its exhaust port side.
4. Place all the valves **(Figure 6-31, (6))** in their proper location in the cylinder head.

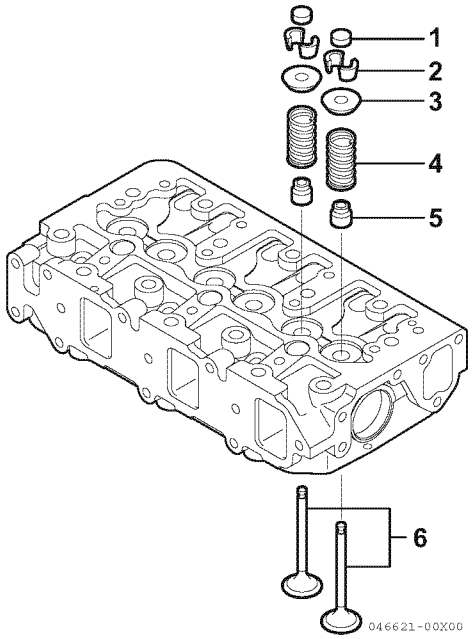


Figure 6-31

5. Place the cylinder head on the workbench with the combustion side down to install the valve springs. Install the valve spring **(Figure 6-31, (4))** and the spring retainer **(Figure 6-31, (5))**.
6. Using the valve spring compressor tool, compress the valve spring.
7. Insert the valve keepers **(Figure 6-31, (2))** and slowly release the tension on the valve spring. Install the valve cap **(Figure 6-31, (1)).** Repeat the steps on all the remaining valves.

■ Reassembly of cylinder head

1. Carefully clean both the combustion surface of the cylinder head and the top surface of the cylinder block. Then place a new cylinder head gasket **(Figure 6-32, (2))** on the cylinder block.
2. Position the cylinder head on the cylinder head gasket.

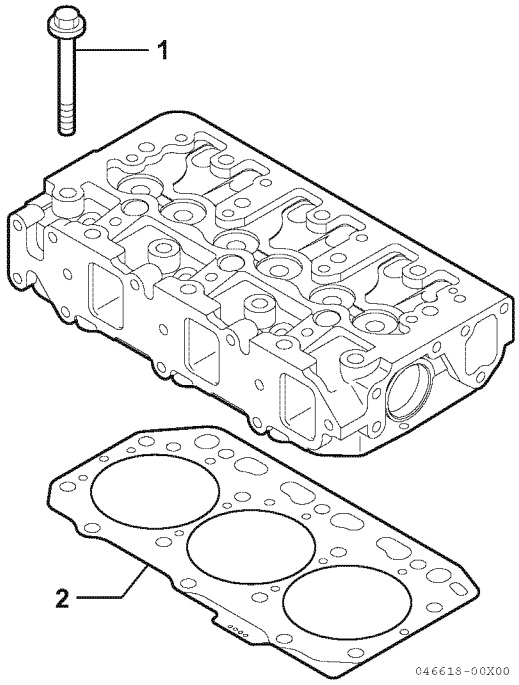


Figure 6-32

3. Lightly oil the threads of the cylinder head bolts **(Figure 6-32, (1))**. Tighten the bolts to the specified torque in two steps as shown in the chart below. Tighten in the sequence shown in **(Figure 6-33)**. *See Special Torque Chart on page 6-10 for specification.*

First step	1/2 of final torque
Second step	Final torque

4. Insert the push rods in their respective positions.

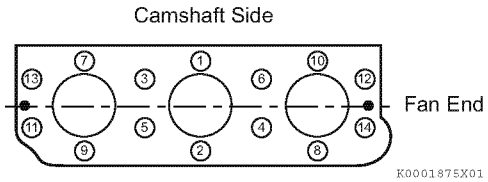


Figure 6-33

■ Removal of gear case or front plate

Note: The camshaft must be removed before the gear case/front plate can be removed. See Inspection of camshaft on page 6-45.

1. Remove the oil pump.
   Note: It is not necessary to remove the fuel injection pump from the gear case/front plate to remove the gear case/front plate. If the fuel injection pump does not need to be repaired, leaving it mounted to the timing gear case/front plate will eliminate the need to re-time it during assembly. See Fuel Injection Pump on page 7-11.
2. Remove the bolts.
3. Remove the gear case or front plate from the cylinder block. Thoroughly clean all old sealant from the mating surfaces.
4. Inspect and measure the camshaft bushing. *See Camshaft on page 6-6 for the service limit.* If damaged or worn beyond service limits, remove the camshaft bushing.
5. Remove two O-rings.
6. Remove the O-ring **(Figure 6-51, (2))** and dowels **(Figure 6-51, (5))**.

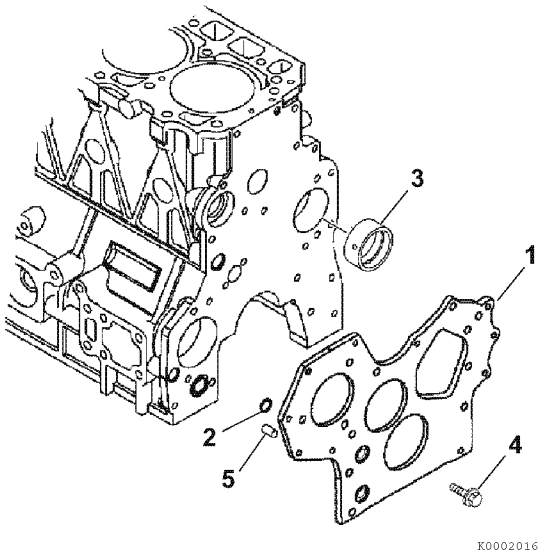


Figure 6-51

Disassembly of Crankshaft and Piston Components

■ Removal of pistons

NOTICE

Keep the piston pin parts, piston assemblies, and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.

NOTICE

Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing the pistons.

Note: Pistons can fall from cylinder block if the engine is inverted. Rotate the engine so the connecting rods are horizontal before removing the connecting rod caps.

1. Using a feeler gauge, measure the connecting rod side clearance as shown **(Figure 6-52)**. *See Connecting Rod on page 6-8 for the standard limit.* If the measurement is out of specification, replace the crankshaft, connecting rod, or both.

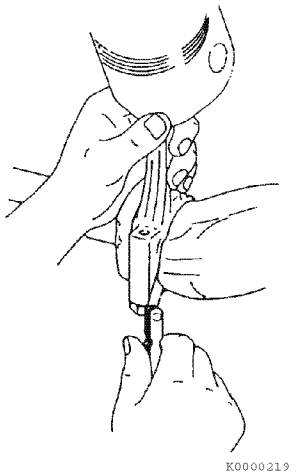


Figure 6-52

NOTICE

Do not allow the honing tool to operate in one position for any length of time. Damage to the cylinder wall will occur. Keep the tool in constant up-and-down motion.

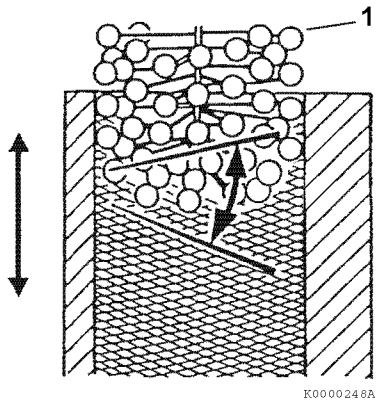


Figure 6-80

- Use a 50:50 mixture of diesel fuel and engine oil as a honing fluid.
- Use a 300-grit hone at 300 - 1200 min^{-1} (rpm) **(Figure 6-81)**.

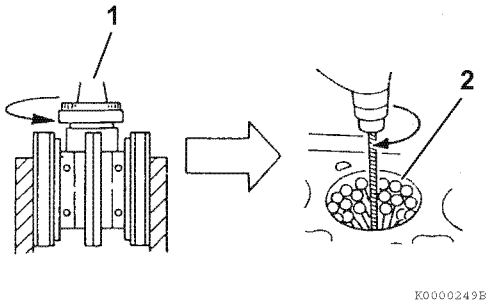


Figure 6-81

NOTICE

Solvents will not adequately remove honing residue, resulting in premature piston and ring wear. Always wash cylinders using hot, soapy water.

- When honing is completed, wash the cylinder block with hot water and soap. The cylinder wall is adequately cleaned when a white rag wiped in cylinder comes out clean. Use brushes to clean all passages and crevices. Rinse with hot water and dry with compressed air. Apply clean engine oil to all steel surfaces to prevent rusting.

Reassembly of Crankshaft and Piston Components

Note:

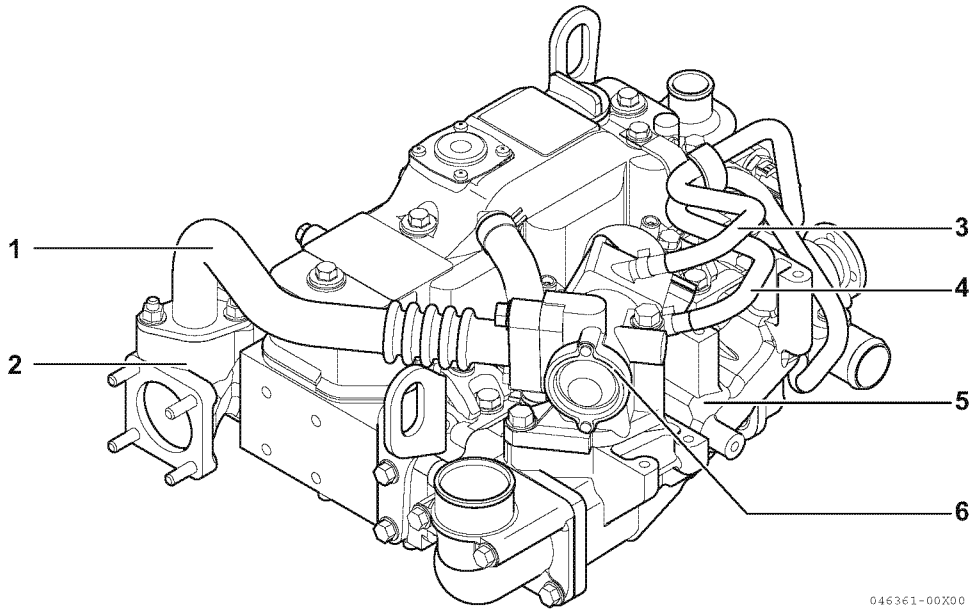
- *Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.*
- *Use new gaskets, seals and O-rings during assembly.*
- *Liberally apply clean engine oil to all internal parts during assembly.*
- *All fasteners should be tightened to a given torque. If a special torque is not provided in the Special Torque Chart on page 6-10, tighten to standard torque specifications. See Tightening Torques for Standard Bolts and Nuts on page 4-25.*

■ Reassembly of pistons

1. Select the parts needed to reassemble the piston and connecting rod for one cylinder.
2. If removed, install a new wrist pin bushing **(Figure 6-82, (7))** using a press and the appropriate service tool. Be sure to align the oil holes.

EGR SYSTEM

EGR System



1 – EGR pipe
2 – Exhaust manifold
3 – Cooling water hose, EGR valve inlet
4 – Cooling water hose, EGR valve outlet
5 – Intake manifold
6 – EGR valve

Figure 6-103

FUEL SYSTEM SPECIFICATIONS

Special Torque Chart

Component	Tightening torque	Lubricating oil application (Thread portion and seat surface)
Fuel injector retainer bolt	29 ft·lb (39.2 N·m; 4 kgf·m)	Not applied
Fuel pump drive gear nut	58 - 65 ft·lb (78 - 88 N·m; 8 - 9 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 bolts	69 - 87 in·lb (7.8 - 9.8 N·m; 0.8 - 1.0 kgf·m)	Not applied
Fuel injection pump mounting nuts	17 - 21 ft·lb (23 - 28 N·m; 2.3 - 2.9 kgf·m)	Not applied
Fuel injector nozzle case nut	30 - 33 ft·lb (39.2 - 44.1 N·m; 4 - 4.5 kgf·m)	Not applied
Fuel injection pump plunger plug	22 - 26 ft·lb (30 - 35 N·m; 3.1 - 3.6 kgf·m)	Not applied

21. If required, remove the intake manifold and fuel pump insulator to access the fuel injection pump mounting nuts.

    Note: The MP2 fuel injection pump is fastened to the gear case with three (3) studs and nuts.

22. Remove the fuel injection pump **(Figure 7-16, (1))**. For purposes of future injection timing purposes, record the fuel injection pump timing index number located on the boss on the engine side (back) of the of the fuel injection pump **(Figure 7-17, (1))**.

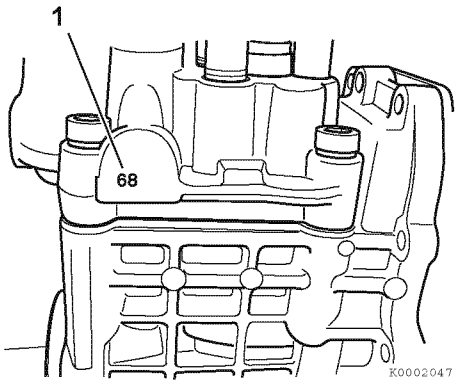


Figure 7-17

NOTICE

Do not rotate the crankshaft with the injection pump removed.

23. 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.

Installation of Fuel Injection Pump

For electronically controlled engine

⚠ WARNING

- **Replacing the fuel injection pump involves rewriting the fuel injection data in the E-ECU. Be sure to contact your local YANMAR dealer before replacing the fuel injection pump. Failure to rewrite the fuel injection data before replacing the fuel injection pump will void the engine warranty.**
- **Improper use or misuse of the E-ECU may result in death or serious injury due to an abrupt and unexpected increase in engine speed.**

NOTICE

If installing a new or recalibrated fuel injection pump, locate and record the timing index number located on the pump housing boss on the engine side of the new or recalibrated fuel injection pump **(Figure 7-18, (1))**. This number will be used to calculate and adjust the final fuel injection timing.

Note: If either or both of the fuel injection pumps do not have a timing index number, note the injection pump ID (example: XK42) on the injection pump ID label.

To locate the timing index number for the engine being serviced use the Timing Index Chart under "FIE Specs" on the YANMAR Distributor Website (http://distributor.yanmar.co.jp).

If additional assistance is needed in locating the engine timing index number *See To Locate an Authorized YANMAR Industrial Engine Dealer or Distributor: on page 2-4* and follow the instructions to locate an authorized YANMAR industrial engine dealer or distributor for assistance.

Note: Treat the timing index number as if it has a decimal point (68 = 6.8).

3. Note the reading on the dial indicator **(Figure 7-42, (1))**. If the reading is less than 2.5 mm (0.098 in.), the fuel injection timing is "retarded". If the dial indicator reading is greater than 2.5 mm (0.098 in.), the fuel injection timing is "advanced."

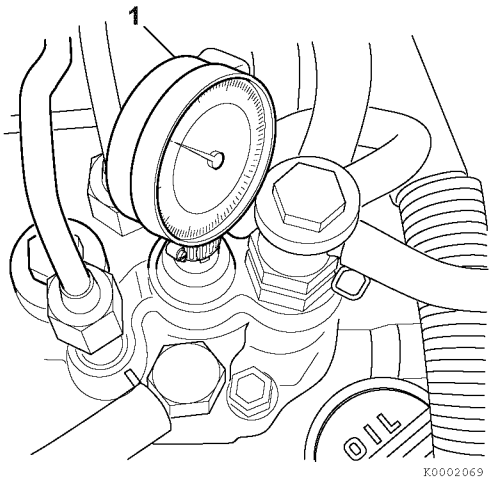


Figure 7-42

Note: Some model engines require the intake manifold and fuel injection pump insulator be removed to access the inner fuel injection pump retaining nuts.

4. Loosen the nuts fastening the fuel injection pump to the gear case or front plate. Loosen the rear bracket(s) on the fuel injection pump.

   Note: Loosening the high-pressure injection line nuts on the fuel injection pump may make rotating the pump easier.

5. Rotate the fuel injection pump until the dial indicator reads 2.5 mm (0.098 in.).
6. To "advance" the injection timing, rotate the top of the fuel injection pump away from the engine.
7. To "retard" the injection timing, rotate the top of the fuel injection pump toward the engine.
8. When the dial indicator reads 2.5 mm (0.098 in.) of pump plunger lift and the target timing mark on the flywheel aligns with the reference mark on the flywheel housing or engine back plate, the injection timing is correct.
9. Tighten the fuel injection pump mounting nuts and rear bracket(s).
10. Remove the dial indicator and adapter. Replace the plug in the pump plunger opening and tighten it to specification. If removed, install the intake manifold and pump insulator. Tighten the high-pressure injection line nuts to specification. Open the fuel supply valve, remove the clamp from the fuel return line and prime the fuel system. Operate the engine and check it for leaks.

FUEL INJECTORS

Removal of Fuel Injectors

1. Close any fuel valves in the fuel supply line.
2. Remove the high-pressure fuel injection lines as an assembly **(Figure 7-43, (1))**.

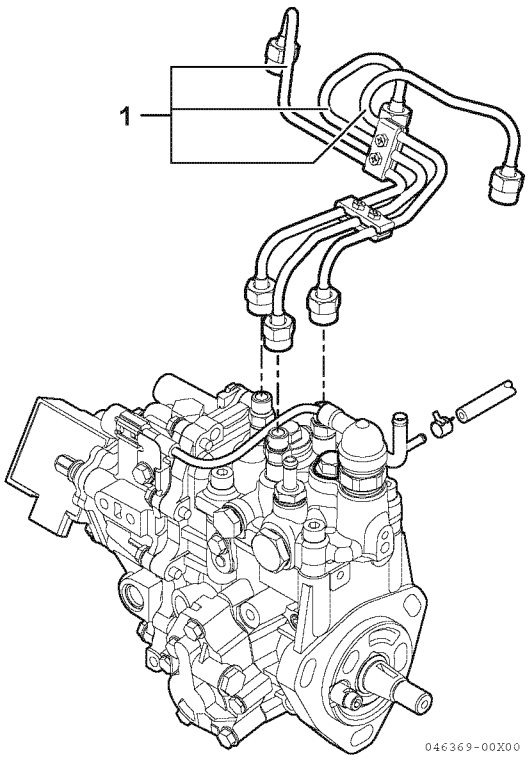


Figure 7-43

BEFORE YOU BEGIN SERVICING

Before performing any service procedures within this section, read the following safety information and review the *Safety* section on page *3-1*.

Section 9

LUBRICATION SYSTEM

Section 10

STARTER MOTOR

20. E-ring

Use a special tool and hit with a hammer to pull out the E-ring from the pinion shaft groove.

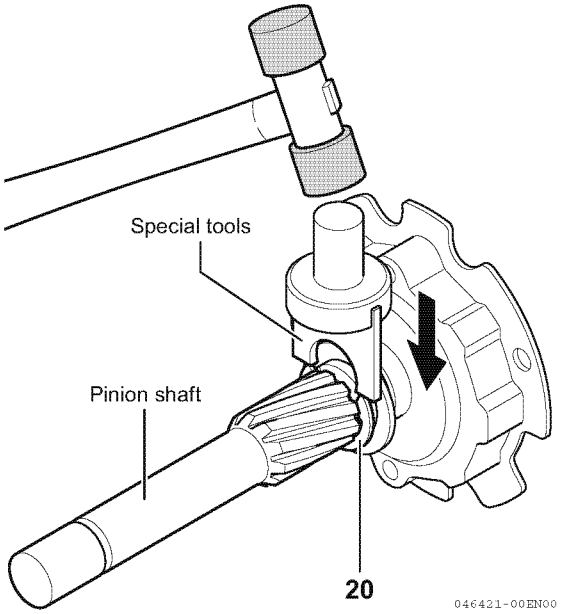


Figure 10-13

21. Washer (2)
22. Center bracket P
23. Pinion shaft

Remove the E-ring, and then pull out the center bracket P and the washers from the pinion shaft.

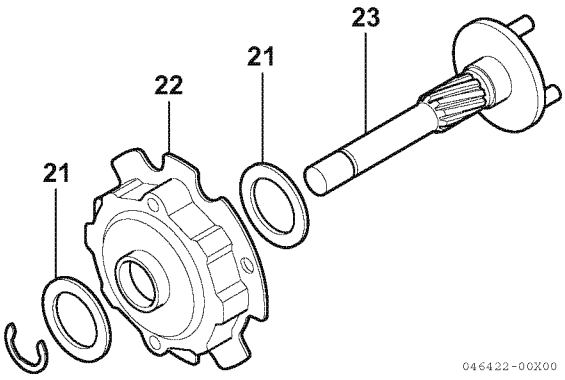


Figure 10-14

Inspection and Maintenance

1. Armature

1- Outer diameter of commutator

Measure the outer diameter of the commutator. If it is below the limit, replace it with a non-defective.

Standard	Limit
ø29 mm	ø28 mm

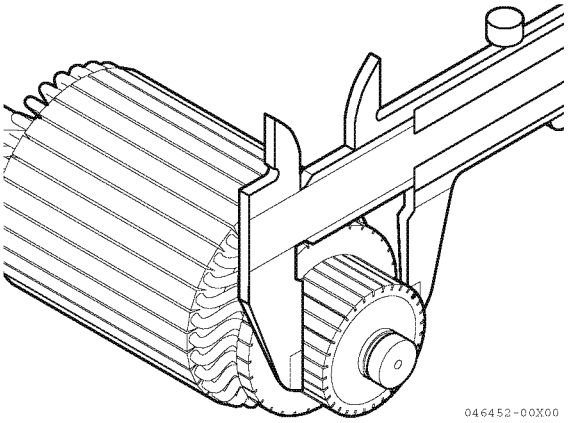


Figure 10-15

2- Conduction test for armature coil

Check between the commutator bars with a tester.
If there is conduction, it is a non-defective.

No conduction (Coil burnout)	Replace the armature

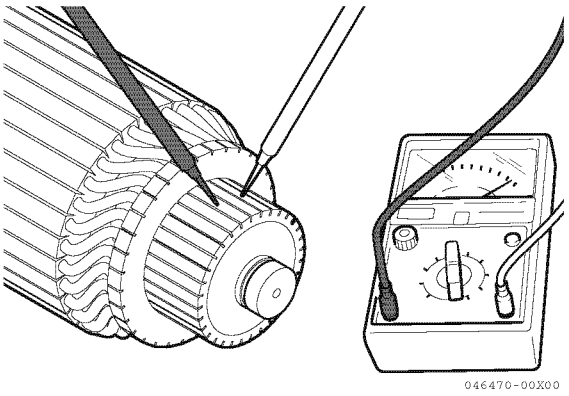


Figure 10-16

BEFORE YOU BEGIN SERVICING

Before performing any service procedures within this section, read the following safety information and review the *Safety* section on page *3-1*.

2. 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))**.

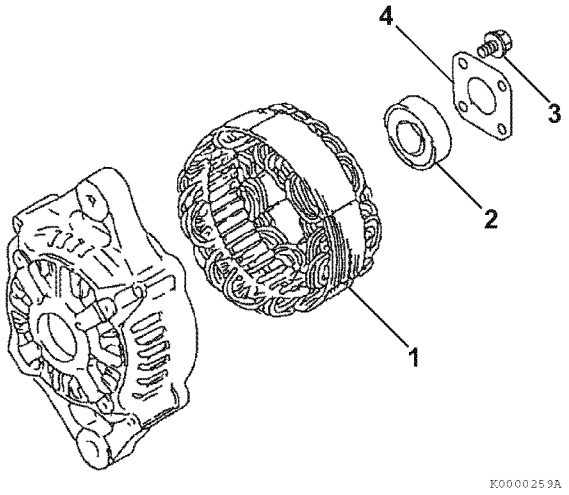


Figure 11-13

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))**.

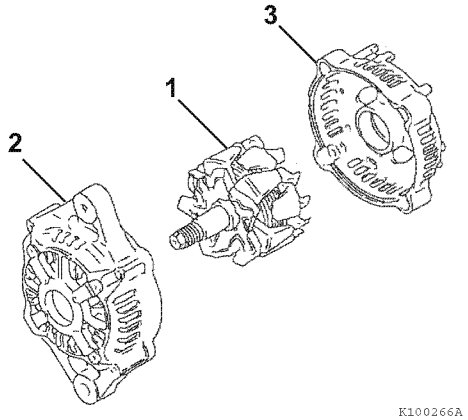


Figure 11-14

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))**.

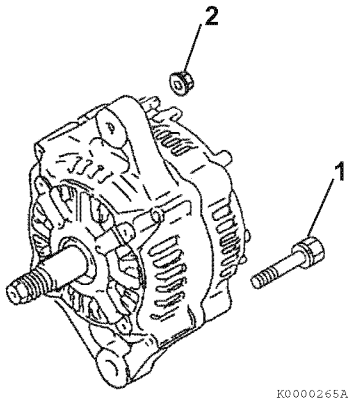


Figure 11-15

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

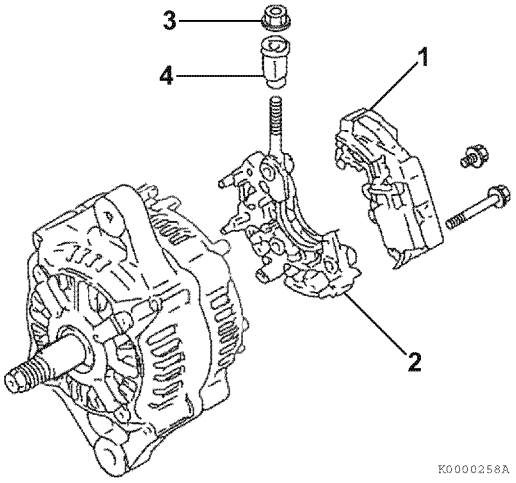


Figure 11-16

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))**.

BEFORE YOU BEGIN SERVICING

Before performing any service procedures within this section, read the following safety information and review the *Safety* section on page *3-1*.

CONVERSION OF AWG TO EUROPEAN STANDARDS

Conductor size (AWG)	Conductor diameter (mm)	Conductor cross-sectional area (mm^2)
25	0.455	0.163
24	0.511	0.205
23	0.573	0.259
22	0.644	0.325
21	0.723	0.412
20	0.812	0.519
19	0.992	0.653
18	1.024	0.823
17	1.15	1.04
16	1.29	1.31
15	1.45	1.65
14	1.63	2.08
13	1.83	2.63
12	2.05	3.31
11	2.30	4.15
10	2.59	5.27
9	2.91	6.62
8	3.26	8.35
7	3.67	10.6
6	4.11	13.3
5	4.62	16.8
4	5.19	21.2
3	5.83	26.7
2	6.54	33.6
1	7.35	42.4
0 (1/0)	8.25	53.4
00 (2/0)	9.27	67.5
000(3/0)	10.40	85.0
0000 (4/0)	11.68	107.2
00000 (5/0)	13.12	135.1
000000 (6/0)	14.73	170.3
1.1 circular mil (CM) @ 0.0005067 mm^2		