

Safety Cautions

WARNING

Fire and explosion

Keep flames away

Store fuel and engine oil in a well ventilated designated area.

Make sure that the caps of fuel and engine oil containers are tightly closed.



Do not use flames, do not smoke, and do not work near a heater or other fire hazard where fuel or oil is handled or when cleaning solvent is being used for washing parts.

Wipe off spilled fuel, oil and LLC immediately and thoroughly. Spilled fuel, oil and LLC may ignite and cause a fire.

Keep surrounding area tidy and clean

Do not leave combustible or explosive materials, such as fuel, engine oil and LLC, near the engine. Such substances can cause fire or explosion.

Remove dust, dirt and other foreign materials accumulated on the engine and surrounding parts thoroughly. Such materials can cause fire or the engine to overheat. In particular, clean the top surface of the battery thoroughly. Dust can cause a short-circuit.

Always operate the engine at a position at least 1 m [3.28 ft.] away from buildings and other equipment to prevent possible fire caused by engine heat.

Avoid accessing crankcase until engine cools

Do not attempt to open the side cover of the crankcase before the engine cools down. Wait at least 10 minutes after stopping the engine.

Opening the cover when the engine is hot allows fresh air to flow into the crankcase, which can cause oil mist to ignite and explode.

Care about fuel, oil and exhaust gas leakage

If any fuel, oil or exhaust gas leakage is found, immediately take corrective measures to stop it.

Such leakages, if left uncorrected, can cause fuel or engine oil to reach hot engine surfaces or hot exhaust gas to contact flammable materials, possibly leading to personal injury and/or damage to equipment.

Use explosion-proof lighting apparatus

When inspecting fuel, engine oil, coolant, battery electrolyte, etc., use a flameproof light. An ordinary light, if accidentally broken, may ignite and cause an explosion.

Prevent electrical wires from short-circuiting

Avoid inspecting or servicing the electrical system with the ground cable connected to the battery. Otherwise, a fire could result from short-circuiting. Be sure to disconnect the battery cable from the negative (-) terminal before beginning with the work procedure.

Short-circuits, possibly resulting in fire, may be caused by a loose terminal or damaged cable/wire. Inspect the terminals, cables and wires, and repair or replace the faulty parts before beginning with the service procedure.

Keep fire extinguishers and first-aid kit handy

Keep fire extinguishers handy, and become familiar with their usage.

Keep a first-aid kit at the designated place where it is easily accessible by anyone at any time.



Establish response procedures to follow in the event of fire or accident. Provide an emergency evacuation route, contact points, and means of communication in case of emergency.

⚠ CAUTION

About warning labels

Maintenance of warning labels

Make sure all warning/caution labels are legible.

Clean or replace the warning/caution labels when the description and/or illustration are not clear to read.

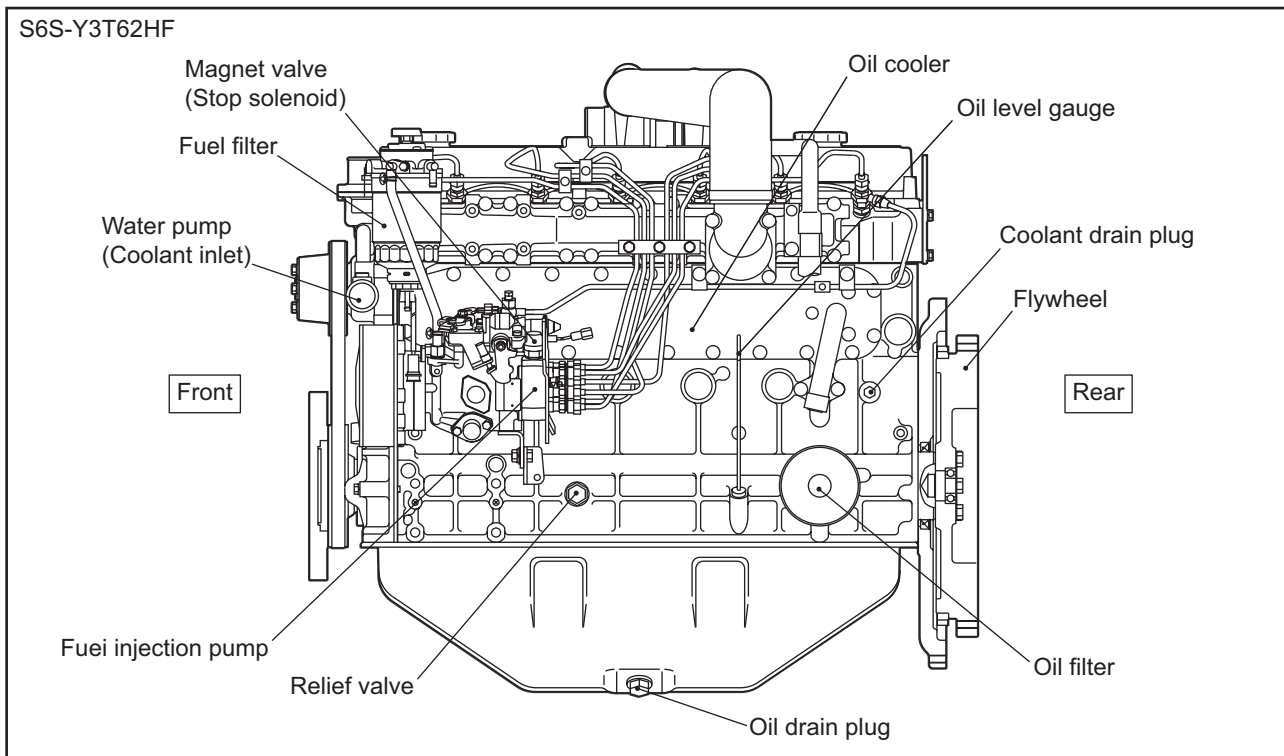
For cleaning the warning/caution labels, use a cloth, water and soap. Do not use cleaning solvents, gasoline or other chemicals to prevent the letters from getting blurred or the adhesion from being weakened.

Replace damaged or fractured labels with new ones.

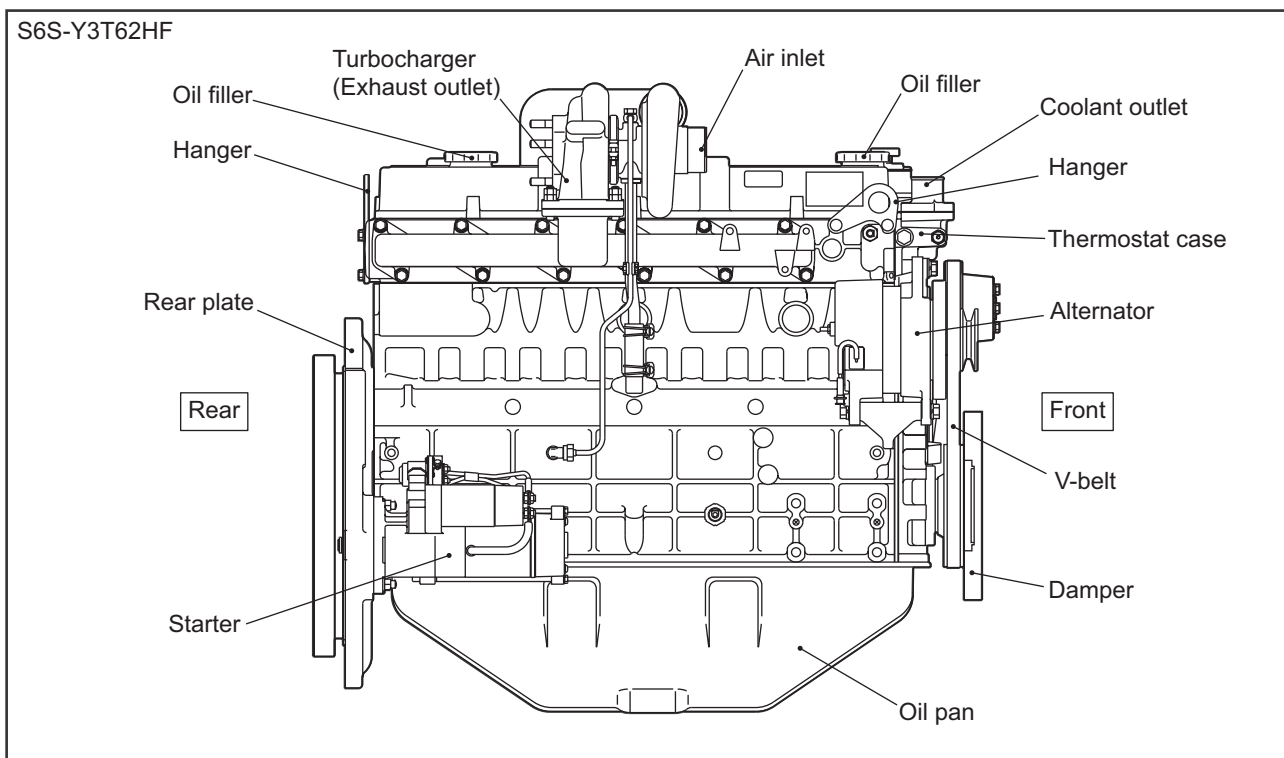
If any engine part on which a warning label is attached is replaced with a new one, attach a new identical warning label to the new part.



Warning labels



Engine left view



Engine right view

SERVICE DATA

Table 2-2 Maintenance service data table - Basic engine (4 / 4)

Unit: mm [in.]

Inspection point		Nominal	Standard	Limit	Remark
Main bearing	Clearance between main bearing and crankshaft journal		0.050 to 0.110 [0.0020 to 0.0043]	0.200 [0.0079] crank journal outside diameter (ϕ 78 [3.0709]) -0.9 [-0.0354]	Replace bearings before limit is reached. Regrind crank journal and use next undersize bearings if limit is exceeded; -0.25 [-0.0098], -0.50 [-0.0197], -0.75 [-0.0295]
Crankcase	Flatness of top surface		0.05 [0.0020] or less	0.20 [0.0079]	Reface minimum thickness.
	Tappet guide hole inside diameter		14.000 to 14.018 [0.5512 to 0.5519]	14.100 [0.5551]	
	Clearance between tappet and tappet guide hole		0.016 to 0.052 [0.0006 to 0.0020]	0.08 [0.0031]	If the diameter is the limit or more, replace tappet.

1.3 Fuel system

Table 2-3 Maintenance service data table - Fuel system

Unit: mm [in.]

Inspection point		Nominal	Standard	Limit	Remark
Fuel injection nozzle	Valve opening pressure	11.77 MPa {120 kgf/cm ² } [1707 psi]	11.77 to 12.75 MPa {120 to 130 kgf/cm ² } [1707 to 1849 psi]		Make shim adjustment. Pressure varies by 1 MPa {10 kgf/cm ² } [142 psi] per 0.1 [0.004] thickness of shim.
	Spray cone angle	0°			Check nozzle with a hand tester (at fuel oil temperature 20°C [68°F]). Replace the nozzle tip if the spray pattern is still bad after washing in clean fuel oil.
	Nozzle valve seat oil sealing	Seat shall hold a test pressure lower than valve opening pressure by 2 MPa {20 kgf/cm ² } [285 psi] for 10 seconds.			Wash in clean fuel oil or replace nozzle tip.

1.4 Lubrication system

Table 2-4 Maintenance service data table - Lubrication system

Unit: mm [in.]

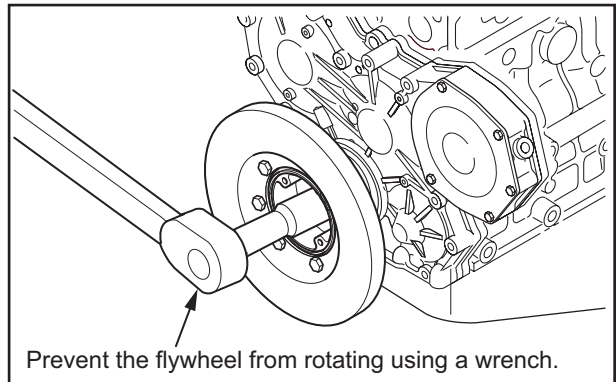
Inspection point		Nominal	Standard	Limit	Remark
Oil pump	Clearance between outer rotor and case		0.20 to 0.30 [0.0079 to 0.0118]	0.50 [0.0197]	Replace pump assembly.
	Main shaft outside diameter (between case)	ϕ 16 [0.63]	15.985 to 16.000 [0.6293 to 0.6299]		
	Main shaft outside diameter (between oil pump bushing)	ϕ 14 [0.55]	13.957 to 13.975 [0.5495 to 0.5502]		
	Clearance between main shaft and pump case		0.032 to 0.074 [0.0013 to 0.0029]	0.150 [0.0059]	Replace pump case or replace pump assembly.
	Clearance between main shaft and oil pump bushing		0.025 to 0.111 [0.0010 to 0.0044]	0.200 [0.0079]	Replace oil pump bushing or replace pump assembly.
	Clearance between inner rotor and outer rotor		0.13 to 0.15 [0.0051 to 0.0059]	0.20 [0.0079]	Replace outer rotor and shaft assembly.
	Rotor and case end play		0.04 to 0.09 [0.0016 to 0.0035]	0.15 [0.0059]	Replace pump assembly.
Relief valve	Valve opening pressure	0.35 MPa {3.6 kgf/cm ² } [51.20 psi]	0.35 ± 0.05 MPa {3.5 ± 0.5 kgf/cm ² } [49.78 ± 7.11 psi]		
Safety valve	Valve opening pressure		1.1 MPa {11 kgf/cm ² } [157 psi]		

2.1 Removing flywheel

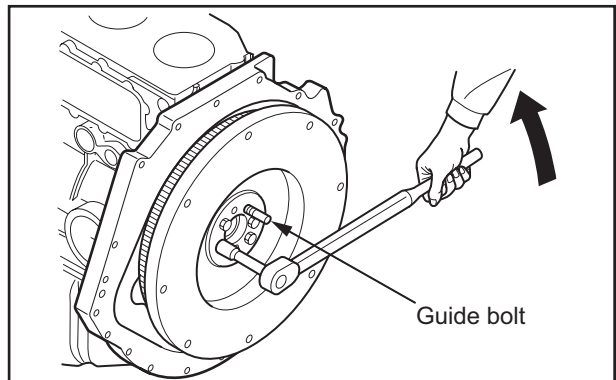
CAUTION

- (a) Be careful not to cut yourself with the ring gear when pulling out the flywheel.
Be careful not to drop or hit the flywheel when removing.
- (b) The person who holds the pulley must be very careful to assure safety by communicating with the person who is removing the flywheel.

- (1) One personnel must firmly hold the pulley with a wrench to prevent the flywheel from turning.
 - (2) Remove one bolt from the flywheel.
 - (3) Screw a guide bolt into the threaded hole of the bolt that has been removed.
 - (4) Remove remaining bolts from the flywheel.
 - (5) Hold the flywheel firmly with both hands, and while moving it back and forth, pull it out straight.
- Note: The ring gear is shrink fitted to the flywheel. Do not remove the ring gear unless it is defective.



Locking the flywheel



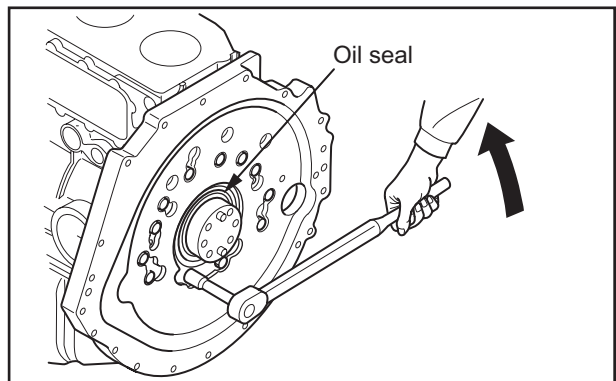
Removing flywheel

2.2 Removing rear plate

CAUTION

Be very careful not to damage the oil seal.

Remove the rear plate mounting bolts, and remove the rear plate using a guide bolt.

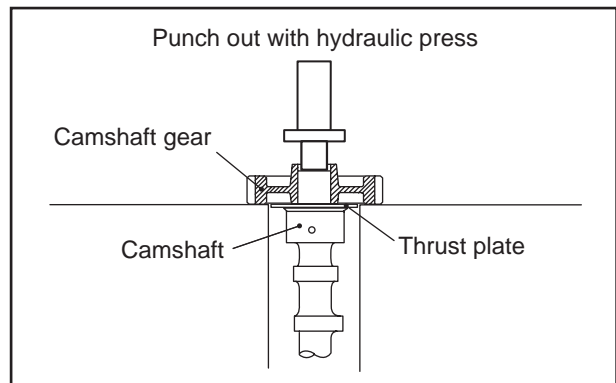


Removing rear plate

3.13 Separating camshaft gear

Using hydraulic press, remove the camshaft gear and thrust plate from the camshaft.

Note: Do not remove the camshaft gear from the camshaft unless the camshaft gear or the thrust plate is defective.



Separating gear from camshaft

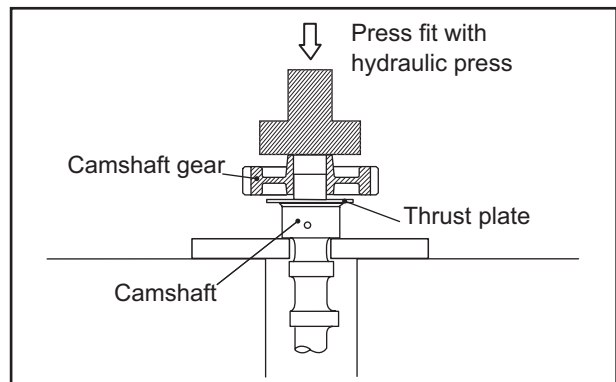
3.14 Installing camshaft gear and thrust plate

(1) Install the woodruff key and the thrust plate on the camshaft.

Note: Be sure to install the thrust plate before installing the camshaft gear.

(2) Heat the camshaft gear with a gear heater to a temperature of about 150°C [302°F].

(3) Press fit the camshaft gear with press.



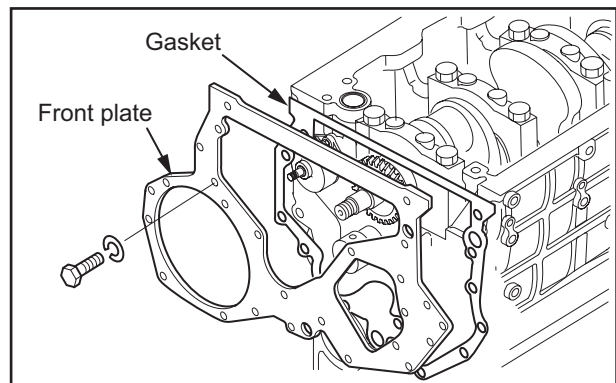
Installing camshaft gear and thrust plate

3.15 Removing front plate

(1) Remove the front plate bolts.

(2) Remove the front plate from the crankcase.

Note: If it is difficult to remove the front plate, lightly tap it with a plastic hammer.

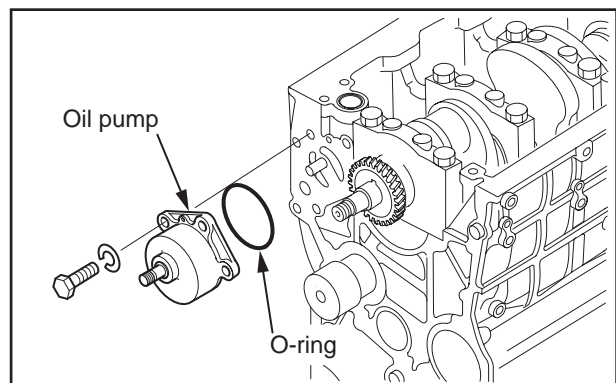


Removing front plate

3.16 Removing oil pump

(1) Remove the oil pump mounting bolts.

(2) Remove the oil pump.



Removing oil pump

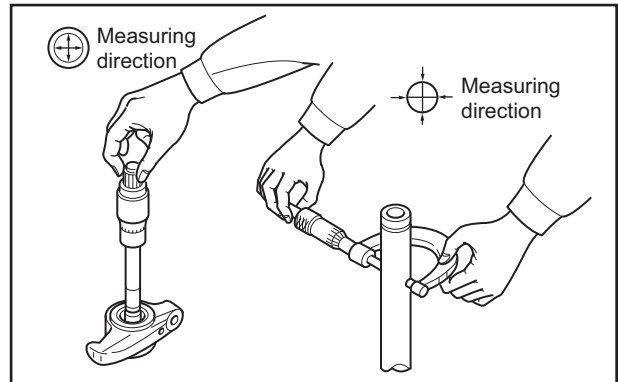
1. Inspecting and repairing cylinder head and valve mechanism

1.1 Measuring clearance between rocker

bushing and rocker shaft

Measure the rocker assembly inside diameter and the rocker shaft diameter. If the clearance exceeds the limit, replace either rocker assembly or rocker shaft with a new one.

Item	Nominal	Standard	Limit
Rocker bushing inside diameter	ø 19 mm [0.75 in.]	19.010 to 19.030 mm [0.7484 to 0.7492 in.]	-
Rocker shaft outside diameter	ø 19 mm [0.75 in.]	18.980 to 19.000 mm [0.7472 to 0.7480 in.]	-
Clearance between rocker bushing and shaft	-	0.010 to 0.050 mm [0.0004 to 0.0020 in.]	0.070 mm [0.0028 in.]

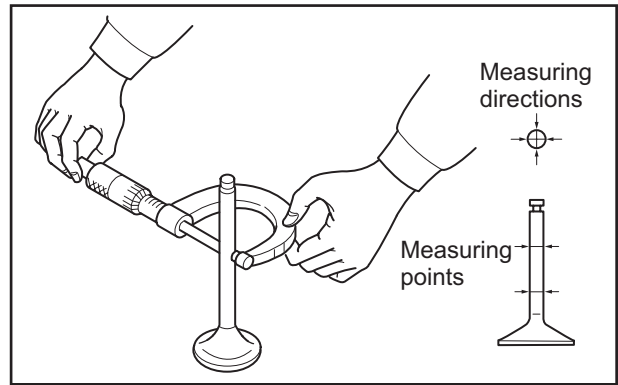


Measuring clearance between rocker bushing and rocker shaft

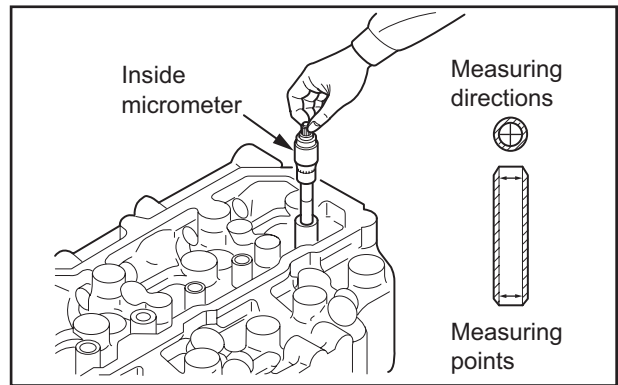
1.2 Measuring valve stem outside diameter and valve guide inside diameter

Measure the diameter at the top and bottom ends at right angles to the outer and inner surfaces, since valve stems and valve guides are more likely to wear at both ends. If the outside diameter is less than the limit, or the clearance exceeds the limit, replace either the valve or the valve guide with a new one.

Item	Nominal	Standard	Limit	
Valve stem outside diameter	Inlet	ø 8 mm [0.31 in.]	7.940 to 7.955 mm [0.3126 to 0.3132 in.]	7.900 mm [0.3110 in.]
	Exhaust	ø 8 mm [0.31 in.]	7.920 to 7.940 mm [0.3118 to 0.3126 in.]	7.850 mm [0.3091 in.]
Clearance between valve stem and valve guide	Inlet	-	0.065 to 0.095 mm [0.0026 to 0.0037 in.]	0.150 mm [0.0059 in.]
	Exhaust	-	0.080 to 0.115 mm [0.0031 to 0.0045 in.]	0.200 mm [0.0079 in.]
Valve guide mounting dimension	14 mm [0.55 in.]	13.9 to 14.1 mm [0.547 to 0.555 in.]	-	



Measuring valve stem outside diameter



Measuring valve guide inside diameter

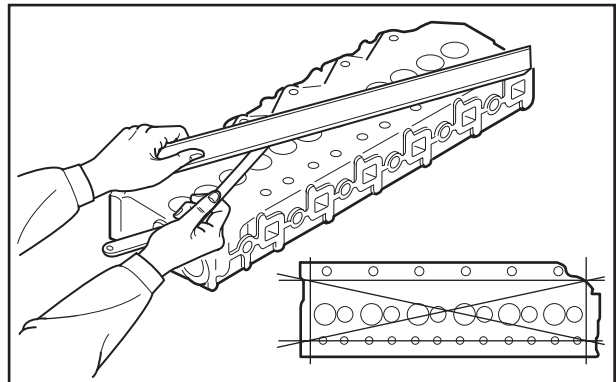
1.10 Measuring distortion of the bottom surface of the cylinder head

CAUTION

Refacing of cylinder head should be kept to an absolute minimum.

Excessive grinding of the cylinder head may result in defects such as defective combustion and stamping (contact between piston and valve).

With a straight edge placed on the bottom face of the cylinder head, measure the bottom face distortion using a feeler gauge. If the measurement exceeds the limit, grind the bottom face using a surface grinder.



Measuring distortion of the bottom surface of the cylinder head

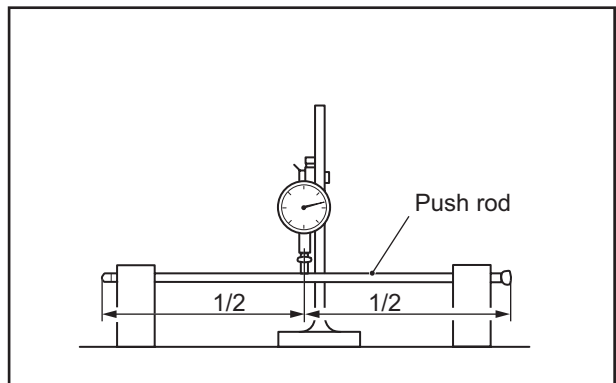
Item	Standard	Limit
Distortion of bottom face	0.05 mm [0.0020 in.] or less	0.20 mm [0.0079 in.]

Note: Do not grind the surfaces more than 0.2 mm [0.008 in.] in total (cylinder head bottom surface plus crankcase top surface).

1.11 Measuring push rod runout

Measure the runout of each push rod. Replace if the limit is exceeded.

Item	Standard	Limit	Remark
Push rod runout	0.6 mm [0.024 in.] or less	0.6 mm [0.024 in.]	Total indicated reading (TIR)



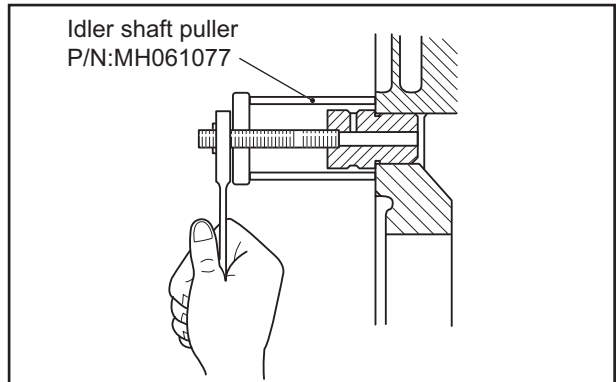
Measuring push rod runout

3.9 Replacing idler shaft

To remove the idler shaft, use the idler shaft puller.

Note: When installing the idler shaft into the crankcase, orient the idler shaft so that its oil hole faces the upper crankcase.

Item	Nominal	Standard
Interference between shaft and crankcase hole	∅ 35 mm [1.38 in.]	0.035T to 0.076T mm [0.0014 to 0.0030 in.]



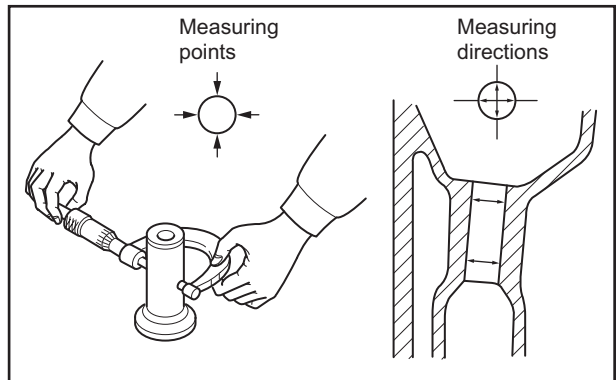
Replacing idler shaft

3.10 Measuring clearance between tappet and tappet guide hole

Measure clearance between the tappet and tappet hole.

Replace the tappet with a new one if the limit is exceeded.

Item	Standard	Limit
Tappet guide hole inside diameter	14.000 to 14.018 mm [0.5512 to 0.5519 in.]	14.100 mm [0.5551 in.]
Clearance between tappet and tappet guide hole	0.016 to 0.052 mm [0.0006 to 0.0020 in.]	0.08 mm [0.0031 in.]

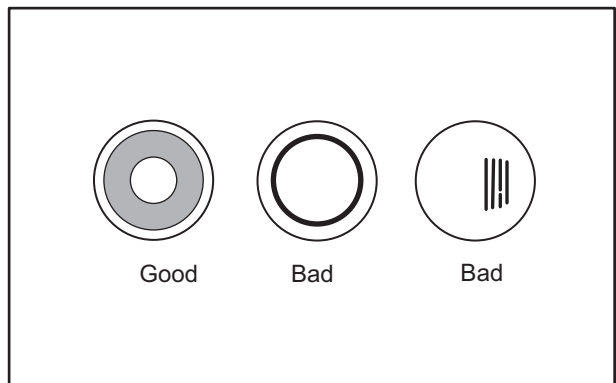


Measuring clearance between tappet and tappet guide hole

3.11 Inspecting tappet

3.11.1 Contact surface of camshaft

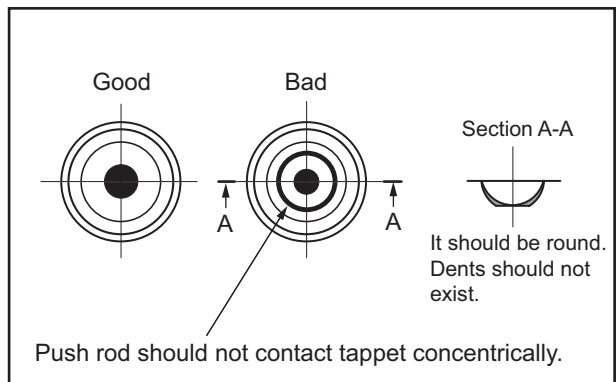
Inspect the cam contact surface of the tappets. Fit new tappets if the surface is excessively worn or damaged.



Contact surface of camshaft

3.11.2 Contact surface of push rod

- (1) Apply a lead-free coloring paste on the push rods, and check the contact surface.
- (2) Check that the push rod contacts the tappet concentrically. If it does, replace the tappet and push rod with new one.



Contact surface of push rod

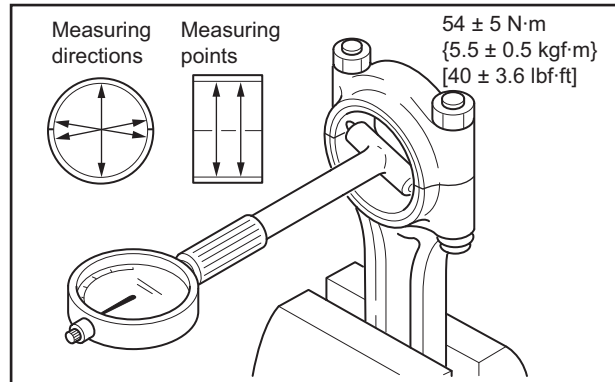
4.8 Measuring clearance between connecting rod bearing and crankpin

CAUTION

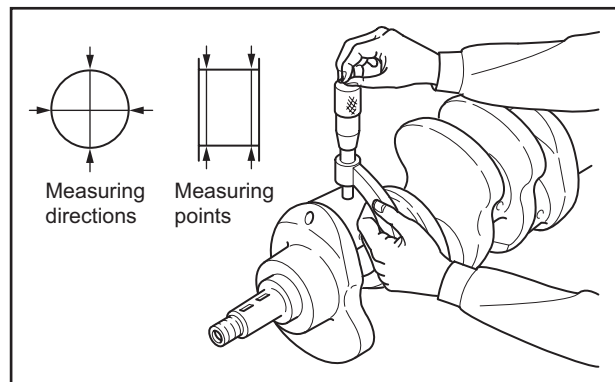
When grinding crankpins, be sure to grind all the pins to the same size.

Finish the fillet radius to the specified dimension.

- (1) Reassemble the bearing into the big end of the connecting rod.
- (2) Tighten the connecting rod cap bolts to the specified torque.
- (3) Measure the inside diameter of the connecting rod bearing.
- (4) Measure the outside diameter of the crankpin.
- (5) Calculate the clearance from the difference between the inside diameter of the connecting rod bearing and outside diameter of the crankpin.
- (6) Replace the connecting rod bearing if the clearance exceeds the limit.
- (7) Measure the clearance between the connecting rod bearing and the crankpin again. Use the undersize bearing if the limit is exceeded.
- (8) If an undersize bearing is used, grind the crankpin to the specified undersize.



Measuring connecting rod bearing inside diameter



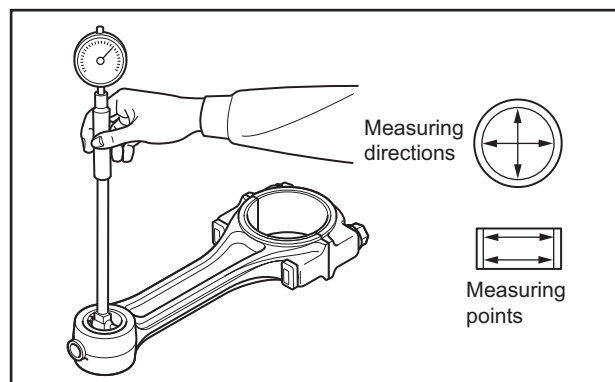
Measuring crankpin diameter

Item	Nominal	Standard	Limit
Crankpin outside diameter	ø 58 mm [2.28 in.]	57.955 to 57.970 mm [2.2817 to 2.2823 in.]	57.800 mm [2.2756 in.]
Clearance between crankpin and connecting rod bearing (oil clearance)	-	0.030 to 0.090 mm [0.0012 to 0.0035 in.]	0.200 mm [0.0079 in.]

4.9 Measuring clearance between connecting rod bushing and piston pin

Measure the inside diameter of the connecting rod bushing and the outside diameter of the piston pin. Replace if the limit is exceeded.

Item	Nominal	Standard	Limit
Bushing inside diameter	ø 30 mm [1.18 in.]	30.020 to 30.045 mm [1.1819 to 1.1829 in.]	-
Clearance between connecting rod bushing	-	0.020 to 0.091 mm [0.0008 to 0.0036 in.]	0.120 mm [0.0047 in.]



Measuring connecting rod bushing inside diameter

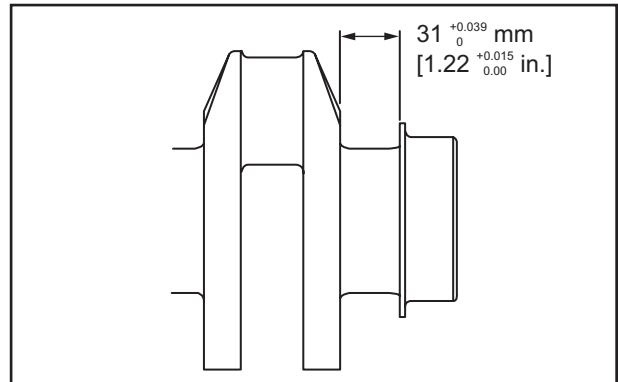
4.18 Measuring crankshaft end play

- (1) Measure the crankshaft end play (clearance between the crank arm at the thrust force receiving journal and the bearing cap with thrust plate attached). If the limit is exceeded, replace the thrust plate with a new one.
- (2) If the limit is still exceeded after a new thrust plate has been installed, use an oversize thrust plate.

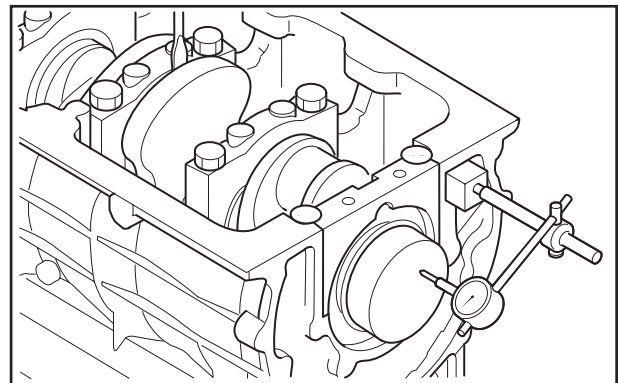
Note: In general, the rear thrust bearing wears faster than the front thrust bearing. Therefore, in most cases, the correction is achieved by replacing the rear thrust plate with the next oversize one.

Item	Standard	Limit
Crankshaft end play	0.100 to 0.264 mm [0.0039 to 0.0104 in.]	0.300 mm [0.0118 in.]

Crankshaft thrust size after grinding			
Item	OS, used on one side	OS, used on both sides	Tolerance
+0.15 mm [+0.0059 in.] OS	31.15 mm [1.2264 in.]	31.30 mm [1.2323 in.]	$\begin{matrix} +0.039 \\ 0 \end{matrix}$ mm $\begin{bmatrix} +0.0015 \\ 0.00 \end{bmatrix}$ in.]
+0.30 mm [+0.0118 in.] OS	31.30 mm [1.2323 in.]	31.45 mm [1.2382 in.]	



Width of crankshaft thrust journal



Measuring crankshaft end play

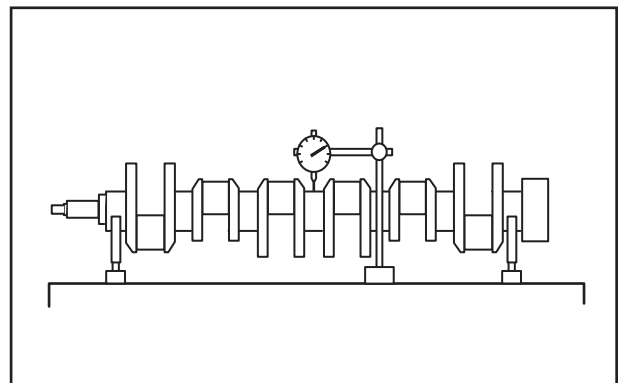
4.19 Measuring crankshaft runout

Support the crankshaft at the front and rear journals with V-blocks, and measure the crankshaft runout at the center journal using a dial gauge. If the runout deviates from the standard only slightly, grind the crankshaft to repair. If the runout exceeds the standard considerably, straighten the crankshaft using a press.

If the limit is exceeded, replace the crankshaft.

If the crankshaft has been repaired by grinding or pressing, inspect the crankshaft for cracks and other harmful damage using a magnetic particle method.

Item	Standard	Limit	Remark
Crankshaft runout	0.04 mm [0.0016 in.] or less	0.10 mm [0.0039 in.]	TIR



Measuring crankshaft runout

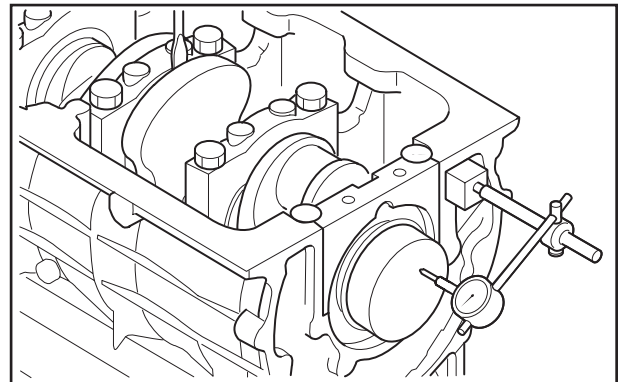
1.8 Measuring crankshaft end play

Attach a dial gauge to the end of the crankshaft to measure the end play.

If the end play deviates from the standard value, loosen the main bearing cap bolts and retighten.

Make sure that the crankshaft turns freely.

Item	Standard	Limit
Crankshaft end play	0.100 to 0.264 mm [0.0039 to 0.0104 in.]	0.300 mm [0.0118 in.]



Measuring crankshaft end play

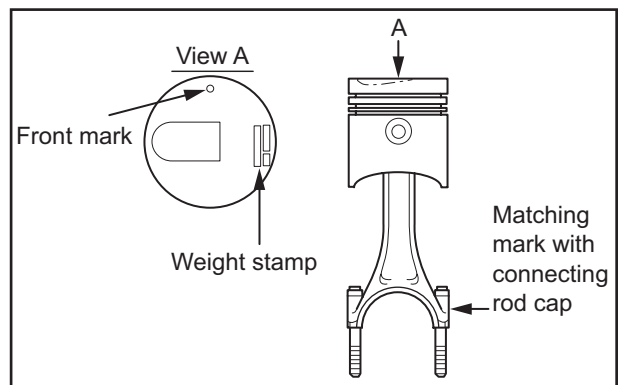
1.9 Reassembling piston and connecting rod

(1) Apply engine oil to the piston pin, and reassemble the piston and the connecting rod by inserting the piston pin, observing the orientation of piston and connecting rod shown in the illustration.

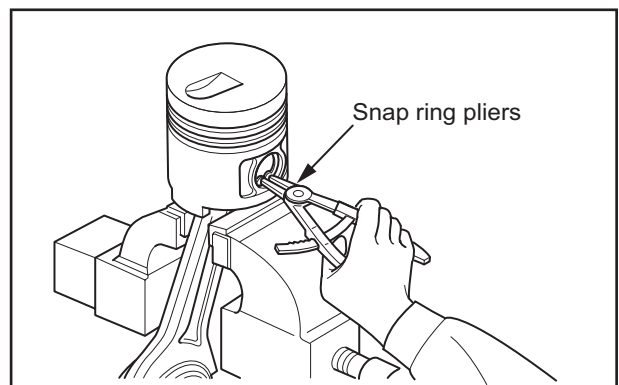
Note: The pistons and piston pins are assembled to each other in clearance fit. However, the piston pins are more easily inserted into the pistons if the pistons are warmed up with a heater or in hot water.

(2) Using ring pliers, install the snap ring. Check the snap ring for its tension, and make sure the ring fits snugly in the groove.

Note: Install all the snap rings so that their end gap faces toward the bottom of the piston.



Reassembling piston and connecting rod



Installing snap ring

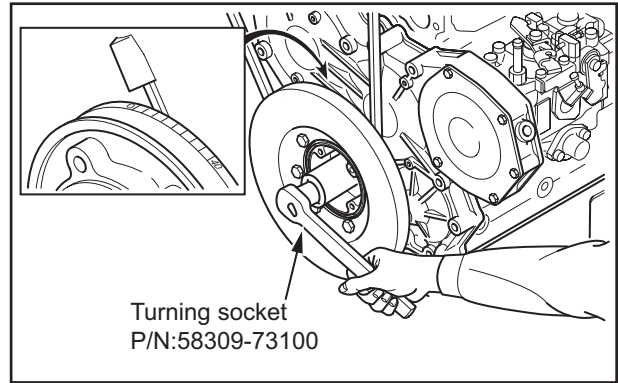
4.10 Determining top dead center of No. 1 cylinder compression stroke

4.10.1 When reusing the damper

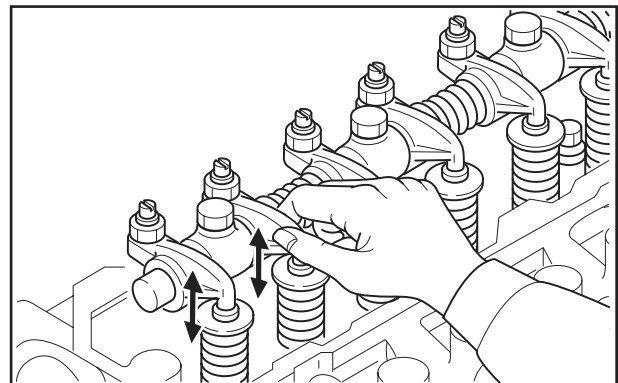
- (1) Attach a socket and ratchet handle to the nut of crankshaft pulley, and rotate the crankshaft in the normal direction (clockwise when viewed from the front of the engine.)
- (2) Stop turning the crankshaft when the notch mark stamped on the damper is aligned with a "0" mark on the pointer.

4.10.2 When replacing the damper with a new one

- (1) Remove the rocker arm, valve cap, valve cotter, valve retainer and valve spring from the No. 1 cylinder inlet side, and make the inlet valve free.
- (2) Attach the dial gauge to the inlet valve and rotate the crankshaft to determine the compression top dead center, when determined, stop rotating the crankshaft.
- (3) With aligning the "0" mark on the timing plate, draw the line to the damper outside periphery.
- (4) Install the valve spring, valve retainer, valve cotter, valve cap and rocker arm to the No. 1 cylinder inlet side.



Determining top dead center of No. 1 cylinder compression stroke (1)

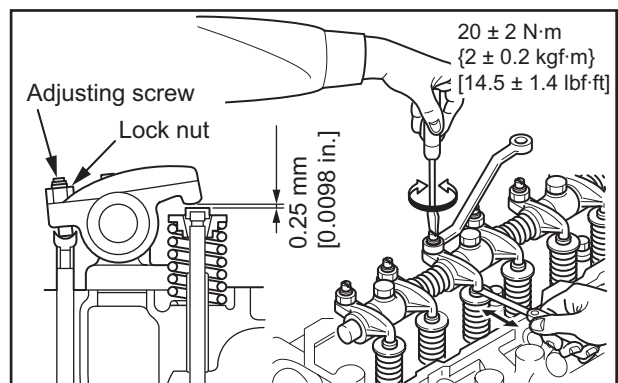


Determining top dead center of No. 1 cylinder compression stroke (2)

4.11 Adjusting valve clearance

Adjust the valve clearance.

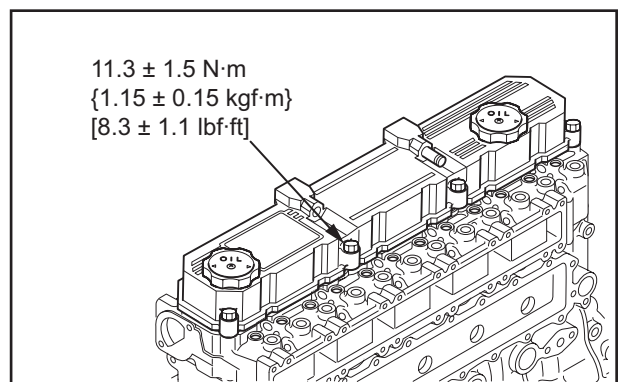
For adjusting procedures, refer to "Adjustment and Operation."



Adjusting valve clearance

4.12 Installing rocker cover

- (1) Make sure that the gasket is firmly installed into the rocker cover.
- (2) Tighten the rocker cover mounting nuts to the specified torque.



Installing rocker cover

2.8 Inspecting and cleaning gauze filter of distribute type fuel injection pump

⚠ WARNING

Keep flames away when handling a diesel fuel. Wipe off any spilled fuel thoroughly.
Spilled fuel could cause a fire.

CAUTION

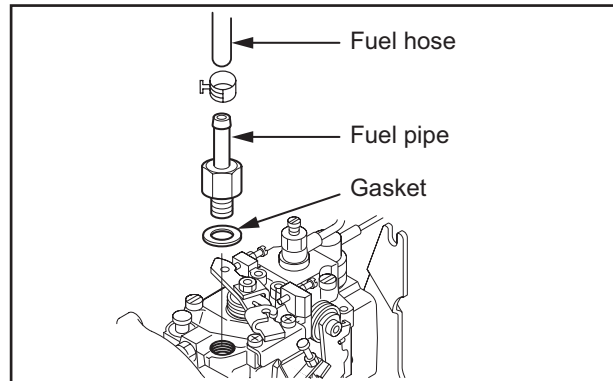
Cover the openings on the fuel injection pump to prevent dust from entering the fuel system.

When output shortage and/or hunting of the engine occurred, the gauze filter may be dirty. Clean the gauze filter accordingly.

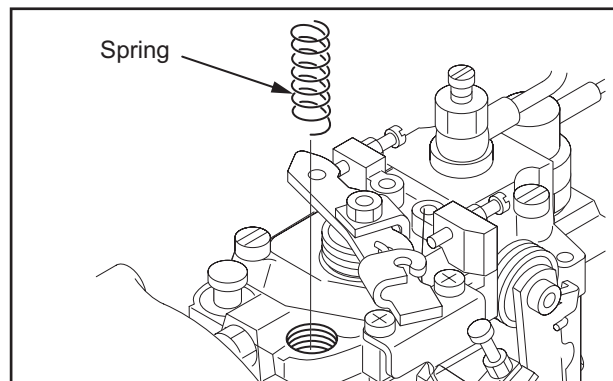
- (1) Clean around the injection pump.
- (2) Drain the fuel in the injection pump, and remove the fuel hose and fuel pipe.
- (3) Remove the spring with a tweezer.
- (4) Remove the gauze filter with a tweezer.

Note: When removing the gauze filter, be careful not to damage the metal mesh of the gauze filter.

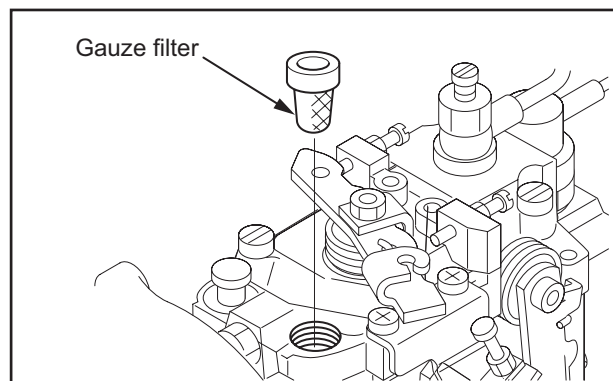
- (5) Remove the dirt and dust from the gauze filter cleaning with compressed air or diesel fuel. When damage is found, or when the gauze filter is still dirty after cleaning, replace the gauze filter with a new one.
- (6) Install the cleaned gauze filter and new gasket, and in reverse order of disassembly, install the fuel pipe and fuel hose.



Removing fuel hose and fuel pipe



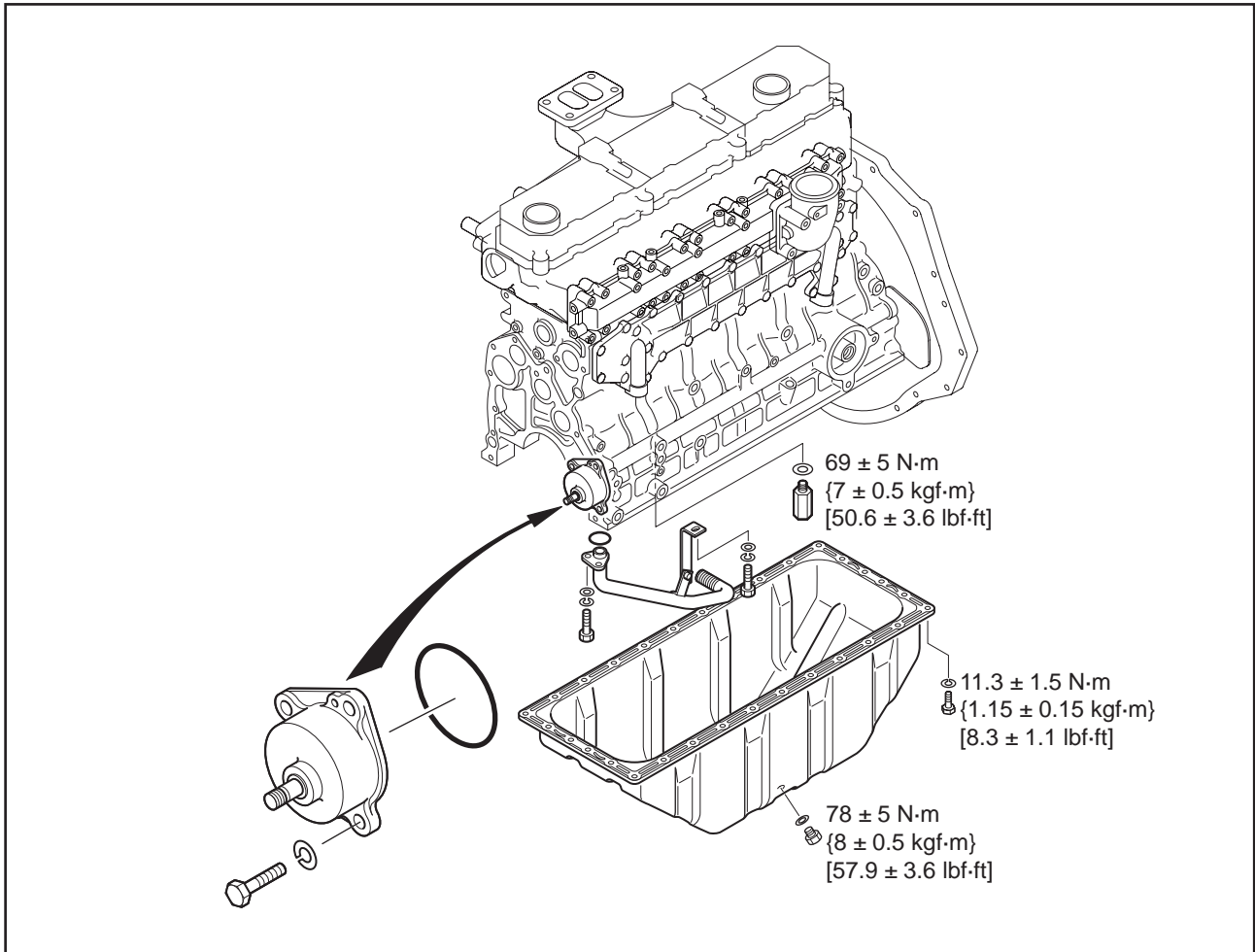
Removing spring



Removing gauze filter

3. Installing lubrication system

3.1 Installing oil pump, oil pan and oil strainer



Installing oil pump, oil pan and oil strainer