

51. ENGINE

PREFACE

51

This service manual explains the single engine. Note that this manual is edited without modification by based on the service manual of MITSUBISHI HEAVY INDUSTRIES, Ltd.

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Be Careful When Handling Fuel, Engine Oil or Coolant

WARNING

Use Specified Fuel, Engine Oil and Coolant Only

Use the fuel, oil and coolant specified in this manual only, and handle them carefully. Use of material other than specified one, or improper handling may cause various engine defects and malfunctions. Get the MSDS issued from the fuel, oil and coolant suppliers, and follow the directions in the MSDS for proper handling.

Be Careful with Coolant

When handling coolant, wear rubber gloves and a protective face mask. If the coolant contacts your skin, or get into your eyes or mouth, it may cause injury of skin or eyes, or poisoning. If coolant is accidentally swallowed, induce vomiting immediately and seek medical attention. If coolant enters your eyes, flush them immediately with plenty of water and seek medical attention. If coolant contacts your skin or clothing, wash it away immediately with plenty of water. Keep flames away from coolant. Coolant can catch flames and cause a fire. Drained coolant is a hazardous material. Do not discard it in an unauthorized procedure. Practice the applicable law and regulations when discard drained coolant.

Proper procedure to discard waste oil and coolant

Do not discard waste engine oil or coolant in an unauthorized procedure. Such a way of disposal is strictly prohibited by laws and regulations. Discard waste oil, coolant and other environmentally hazardous waste in accordance with the applicable laws and regulations.

Be Careful of Burns

WARNING

Do Not Touch the Engine During or Immediately After Operation

Do not touch any parts of the engine during or immediately after operation.

You can get burned. Before starting the maintenance and inspection work,

check the water temperature meter to make sure that the engine is cooled down.



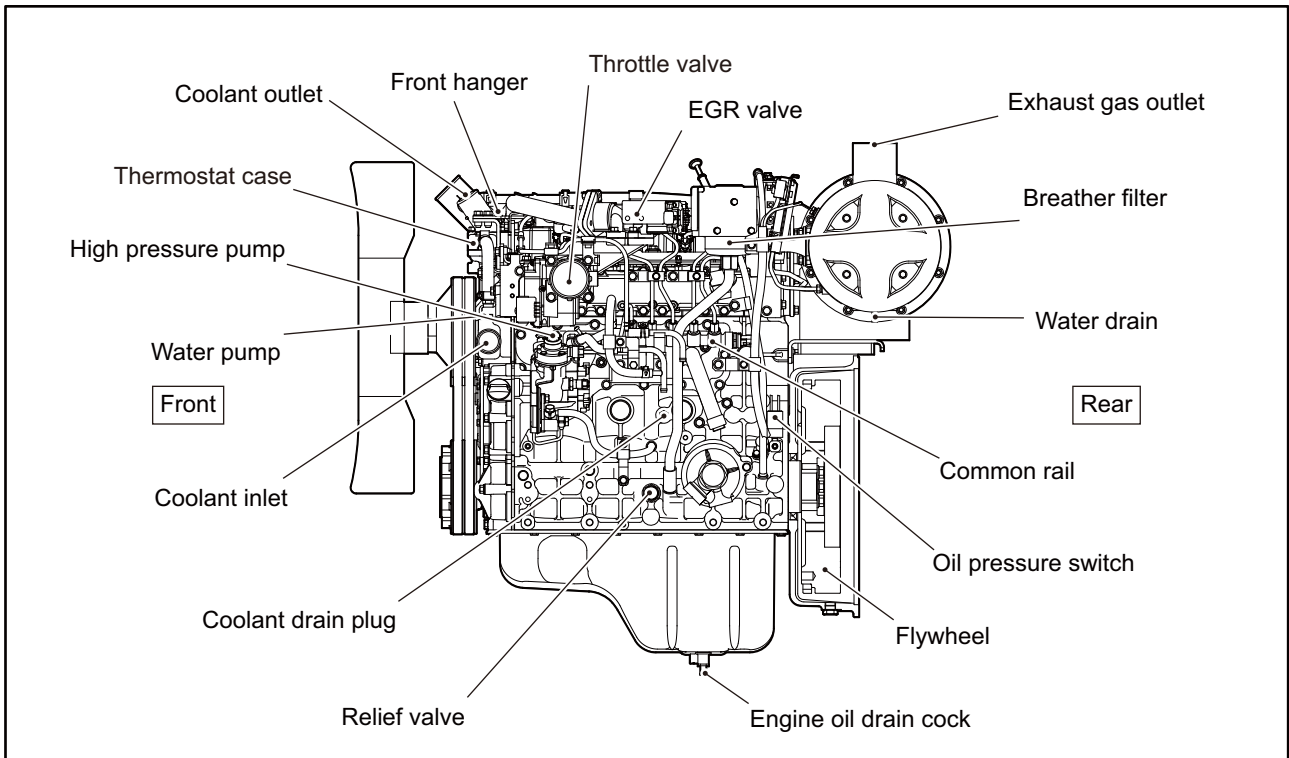
Be Careful to Open and Close the Radiator Cap

Never open the radiator cap while the engine is running or immediately after the engine stops. Stop the engine and give a sufficient time to allow the coolant to cool down before opening the cap. When opening the radiator cap, slowly open the cap so as to release internal pressure. To prevent hot steam scalds, wear thick rubber gloves or, cover the cap with a cloth. When closing the radiator cap, tightly close the cap. Do not open the radiator cap during engine running or immediately after engine stop. Otherwise hot steam and coolant gush out and can cause burns.

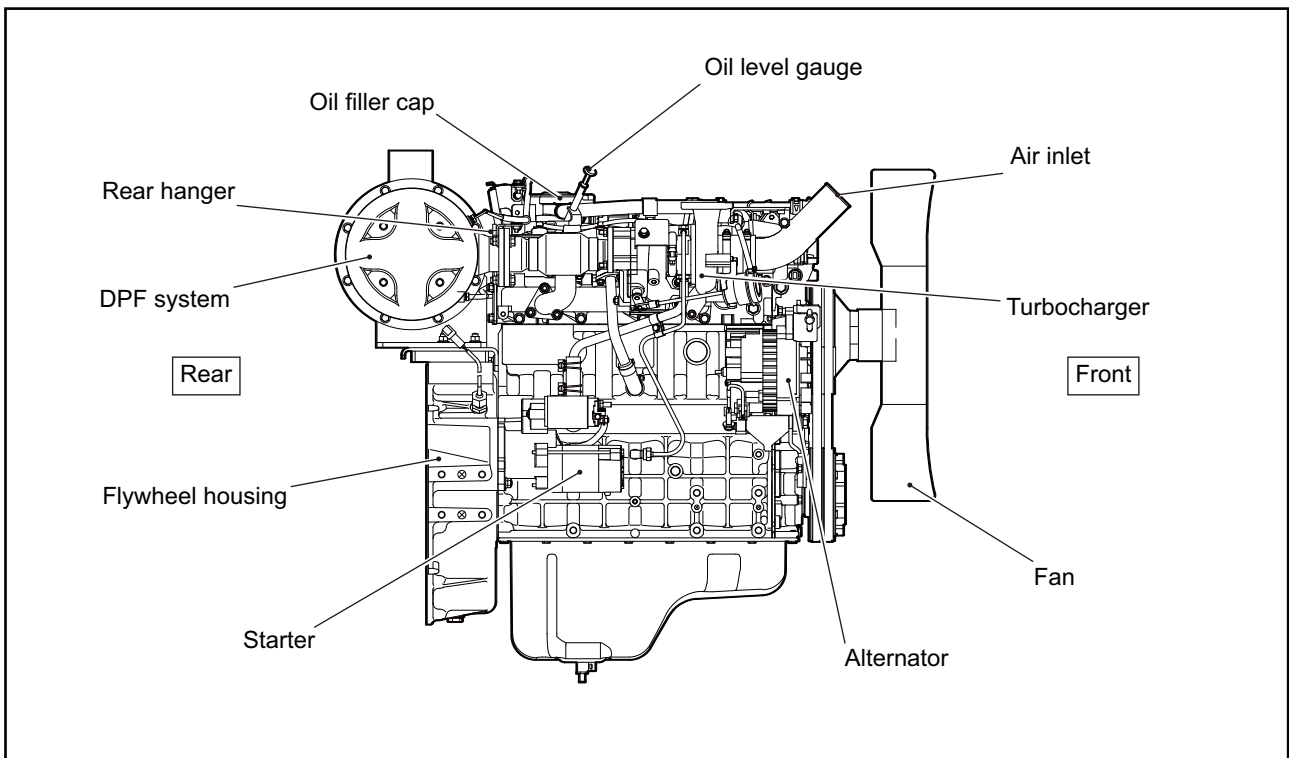
Refill Coolant Only After the Coolant Temperature Dropped

Refill the coolant after the coolant temperature drops to a room temperature. Replacement job immediately after the engine stop may cause burns.

1. External View

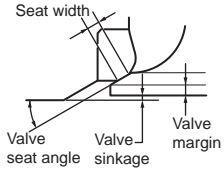
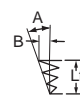


Left Side View



Right Side View

Unit: mm [in.]

Item		Nominal value	Standard value	Limit value	Remarks	
Valve seat ring	Valve seat angle	Inlet	30°			
		Exhaust				
	Valve sinkage	Inlet	0.4 [0.016]	0.3 to 0.5 [0.012 to 0.020]		1.0 [0.039]
		Exhaust	0.5 [0.020]	0.4 to 0.6 [0.016 to 0.024]		1.0 [0.039]
	Seat width	Inlet	1.4 [0.055]	1.26 to 1.54 [0.0496 to 0.0606]		1.8 [0.071]
		Exhaust				
Valve margin		2.13 [0.0839]	2.13 [0.0839]	1.83 [0.0720] or less after refacing		
Valve spring	Free length			48.85 [1.9232]	47.60 [1.8740]	
	Squareness			A = 1.5° or less B=1.3 [0.051] or less Lf = 48.85 [1.9232]	Total length B = 1.5 [0.059]	
	Set length / load			43 mm [1.69 in.]/ 176 to 196 N {18 to 20 kgf} [39.57 to 44.06 lbf]	43 mm [1.69 in.]/147 N {15 kgf} [33.05 lbf]	
Rocker arm	Rocker bushing inside diameter		∅ 19 [0.75]	19.010 to 19.030 [0.7484 to 0.7492]		
	Rocker shaft outside diameter		∅ 19 [0.75]	18.980 to 19.000 [0.7472 to 0.7480]		
	Clearance between rocker shaft and rocker bushing			0.010 to 0.050 [0.0004 to 0.0020]	0.070 [0.0028]	
Push rod	Runout			0.6 [0.024]	TIR	
Crankshaft	Runout			0.04 or [0.0016] or less	0.10 [0.0039]	Sgtraightness ∅ 0.02 [0.0008]
	Crankshaft main journal outside diameter		∅ 80 [3.15]	79.955 to 79.970 [3.1478 to 3.1484]	79.850 [3.1437]	If the specified limit is exceeded when changing the standard size of main bearing, change it into the undersize main bearing. Service limit: 79.10 [3.1142]
	Crankpin outside diameter		∅ 60 [2.36]	59.955 to 59.970 [2.3604 to 2.3610]	59.800 [2.3543]	
	Distance between centers of journal and crankpin		60 [2.36]	60 [2.36]		
	Parallelism of journal and crankpin			Over entire pin length Max runout 0.01 or less		
	Circularity of journal and crankpin			0.01 [0.0004] or less	0.03 [0.0012]	
	Cylindricity of journal and crankpin			0.01 [0.0004] or less	0.03 [0.0012]	
	Fillet radius of journal		R4	± 0.2 [0.008]		
	Fillet radius of pin		R4	± 0.2 [0.008]		
	End play			0.100 to 0.258 [0.0039 to 0.0102]	0.300 [0.0118]	Use connecting rod with replacing thrust plate until reaching the limit. When the limit is exceeded, replace it to the oversize thrust plate.

Chapter 3 SERVICE TOOLS

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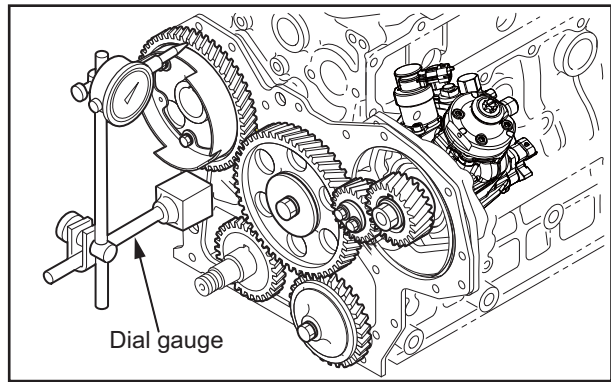
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3.4 Idler Gear and Camshaft End Play - Measure

Measure the idler gear and camshaft end play, and recognize the current condition.

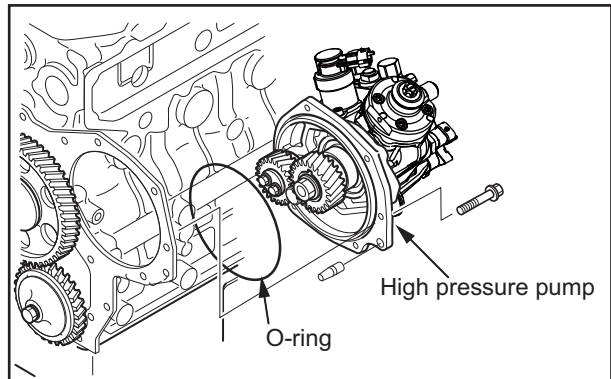
For the inspection procedure, refer to "Idler Gear and Camshaft End Play - Measure" of "ASSEMBLY OF BASIC ENGINE".



Idler Gear and Camshaft End Play - Measure

3.5 High-Pressure Pump - Remove

Remove the high-pressure pump from the front plate.



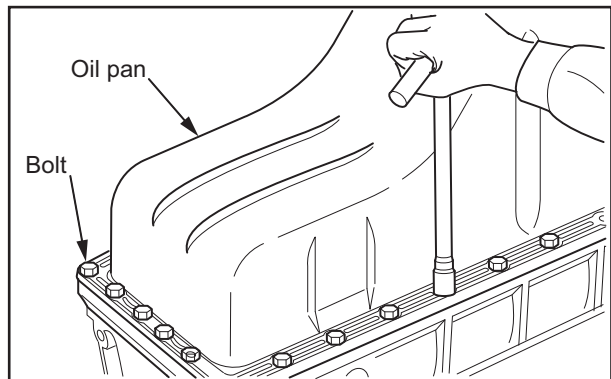
High-Pressure Pump - Remove

3.6 Oil Pan - Remove

CAUTION

Do not remove the oil pan inserting chisel or drive between oil pan and crankcase. When inserting chisel or driver, oil pan flange will deform.

- (1) Turn over the engine.
- (2) Remove the bolts, tap bottom corners of the oil pan with a plastic hammer and remove the oil pan from the crankcase.



Oil Pan - Remove

3.7 Oil Strainer - Remove

Remove the oil strainer from the crankcase.



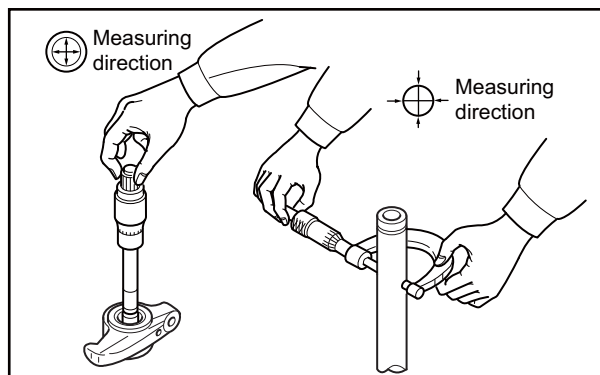
Oil Strainer - Remove

1. Cylinder Head and Valve Mechanism - Inspect and Repair

1.1 Clearance Between Rocker Bushing and Rocker Shaft - Measure

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

Item	Nominal value	Standard value	Limit value
Rocker bushing inside diameter	ø19 mm [0.75 in.]	19.010 to 19.030 mm [0.7484 to 0.7492 in.]	-
Rocker shaft outside diameter	ø19 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.]



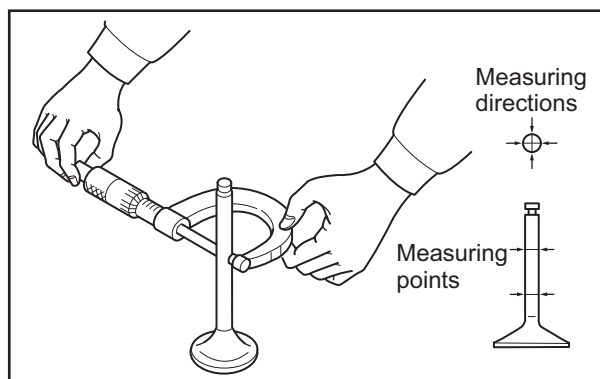
Clearance Between Rocker Bushing and Rocker Shaft - Measure

1.2 Valve Stem Outside Diameter and Valve Guide Inside Diameter - Measure

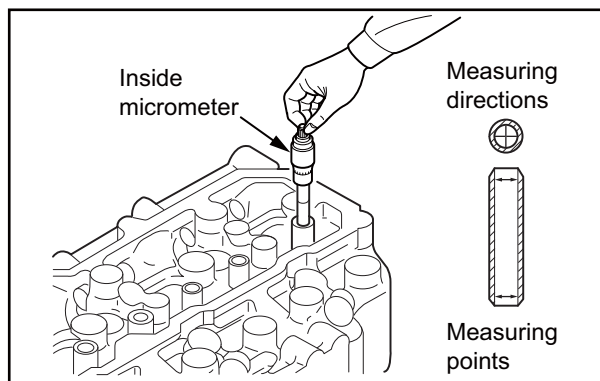
Measure the outside diameter of valve stem and the inside diameter of valve guide at the top and bottom sliding ends in mutually right-angle directions as shown, as the sliding surfaces tend to wear at the top and bottom ends. If the outside diameter is less than the limit, or the clearance exceeds the limit, replace either the valve or the valve guide with a new one.

Note: Lap the valve and valve seat whenever a new valve is installed.

Item		Nominal value	Standard value	Limit value
Valve stem outside diameter	Inlet	ø8 mm [0.32 in.]	7.940 to 7.955 mm [0.3126 to 0.3132 in.]	7.900 mm [0.3110 in.]
	Exhaust	ø8 mm [0.32 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 installed length		14 mm [0.55 in.]	13.9 to 14.1 mm [0.547 to 0.555 in.]	-



Valve Stem Outside Diameter - Measure

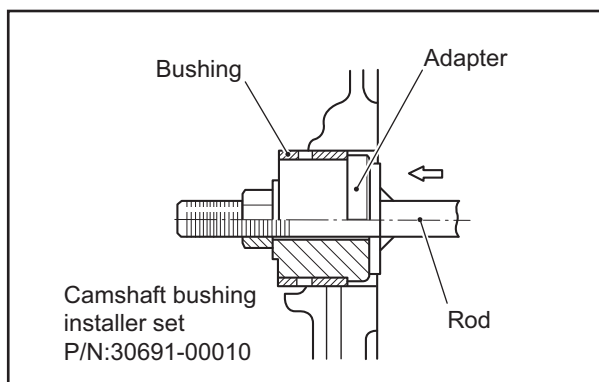


Valve Guide Inside Diameter - Measure

3.7 Camshaft Bushing - Replace

3.7.1 Camshaft bushing - Remove

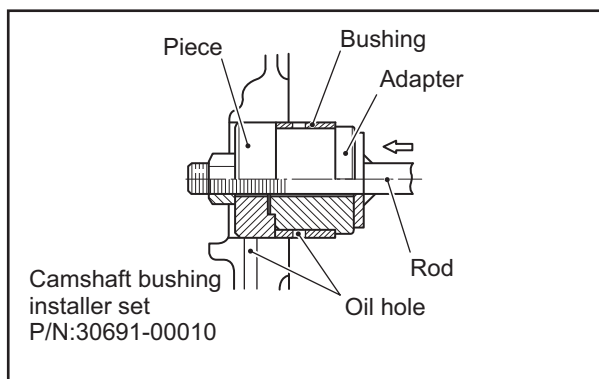
- (1) Install a camshaft bushing installer set to the camshaft bushing.
- (2) Remove the camshaft bushing by tapping the end of the rod of camshaft bushing installer set.



Camshaft bushing - Remove

3.7.2 Camshaft bushing - Install

- (1) Install the camshaft bushing to a camshaft bushing installer set.
- (2) When driving in a bushing, tap the end of rod of camshaft bushing installer set so that the oil hole in the bushing aligns with the oil hole to the oil gallery.

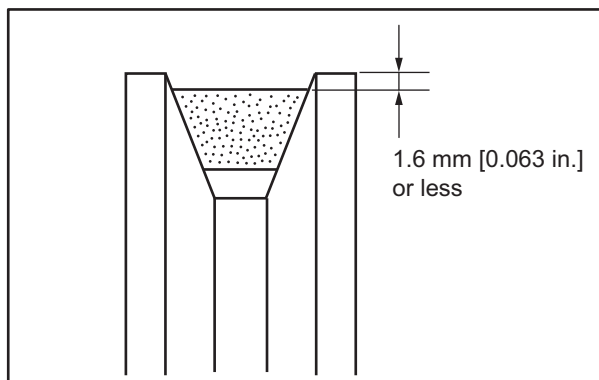


Camshaft bushing - Install

3.8 Belt Groove Wear - Inspect

Check the belt groove of pulley for wear. Attach a new belt around the pulley, apply high tension and measure the sinkage of belt.

If the wear appears excessive, and the belt top surface sinks 1.6 mm [0.063 in.] or more down from the top edge of groove, replace the pulley with a new one. If the pulley has two or more grooves for belt, and the difference of the wear amount between grooves is significant, replace the pulley with a new one.



Belt Groove Wear - Inspect

5.5 Crankshaft - Grind

The crankshaft should be grinded to the values of grinding dimension shown as the right table, and assemble it with same rank of undersize main bearing, undersize connecting rod bearing or oversize thrust plate.

When grinding, be careful not to change the fillet radius and width. When grinding the outer surface of shaft, be careful not to change the width.

If a remarkable decrease in hardness is found, quench the crankshaft again and inspect it with the magnetic particle inspection. If the surface hardness is considered to have been reduced, re-harden the crankshaft and check for flaws by means of magnetic particle inspection. Ensure that the surface finish accuracy of the crankpins and crank journals is kept within the standard even after the correction by grinding.

After the grinding, measure the width of crankpins and rear-most crank main journal.

Item	Under size	Finishing dimension
Crank journal	0.25 mm [0.0098 in.]	77.705 to 77.720 mm [3.0592 to 3.0598 in.]
	0.50 mm [0.0197 in.]	77.455 to 77.470 mm [3.0494 to 3.0500 in.]
	0.75 mm [0.0295 in.]	77.205 to 77.220 mm [3.0396 to 3.0402 in.]
Crankpin	0.25 mm [0.0098 in.]	57.705 to 57.720 mm [2.2718 to 2.2724 in.]
	0.50 mm [0.0197 in.]	57.455 to 57.470 mm [2.2620 to 2.2626 in.]
	0.75 mm [0.0295 in.]	57.205 to 57.220 mm [2.2522 to 2.2528 in.]

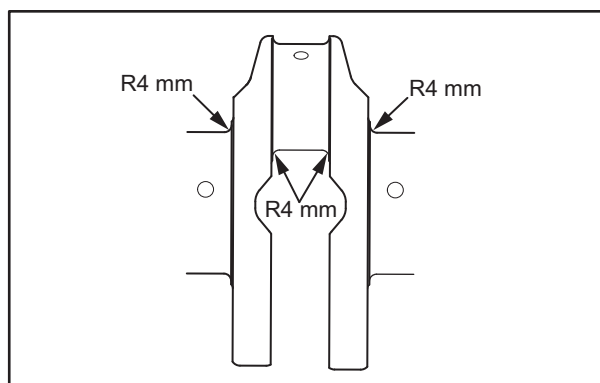
5.6 Crankshaft Runout - Measure

Support the crankshaft at the front and rear main journals with V-blocks, and measure the crankshaft runout at the center journal with a dial gauge. If the runout deviates slightly outside the standard values, correct the crankshaft by grinding. If the value exceeds the standard value considerably, straighten the crankshaft with a pressing machine.

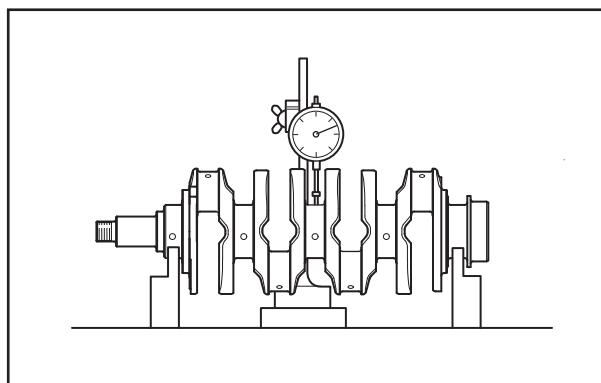
If the value exceeds the limit, replace the crankshaft with a new one.

If the crankshaft is repaired by grinding or pressing, inspect the crankshaft for cracks and other harmful damages with the magnetic particle inspection.

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



Crankshaft - Grind



Crankshaft Runout - Measure

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1.7 Main Bearing Cap - Install

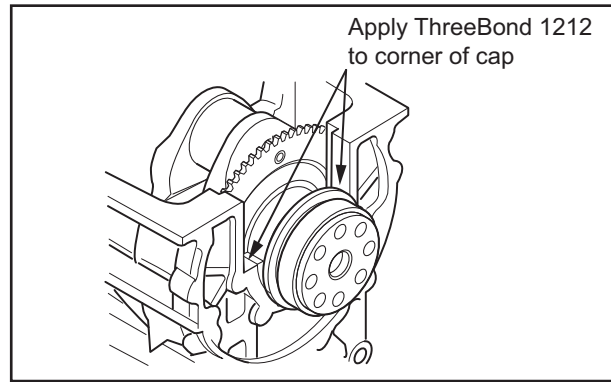
CAUTION

Be sure to tighten the bolts in the specified sequence when installing the main bearing cap bolts.

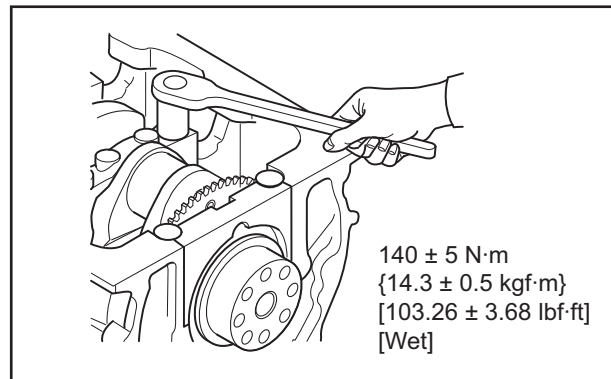
- (1) Make sure that the main bearings and the thrust plates installed on the main bearing caps are evenly coated with clean engine oil.
- (2) Install the main bearing cap from the front side to the rear side of the engine with the arrow on the bottom of the main bearing cap facing the front side of the engine. All of the lug grooves on the main bearing cap should be in the same position.
- (3) Coat the main bearing cap bolt and washer with engine oil, and install the bolts and washer temporarily.
- (4) Tap the main bearing caps with a soft-head hammer evenly to install them in position.

Note: The foremost and rearmost main bearing caps should be flat with the end face of the crankcase.

- (5) Apply engine oil to the threads and bolt seat surface.
- (6) Tighten the main bearing cap bolts alternately and progressively to the specified torque.
- (7) Tighten the rearmost main bearing cap bolt until its seat surface contacts lightly with the main bearing cap. Measure the crankshaft end play in this condition.



Main Bearing Cap - Install

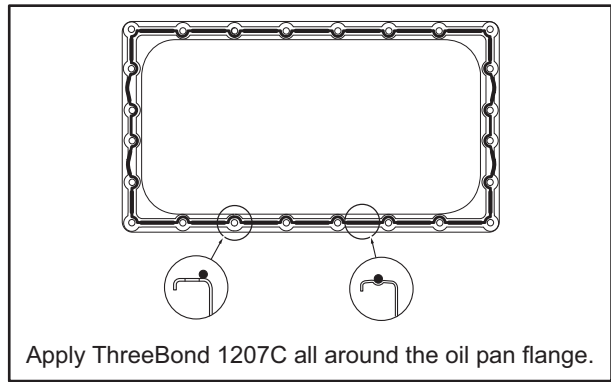


Main Bearing Cap Bolts - Install

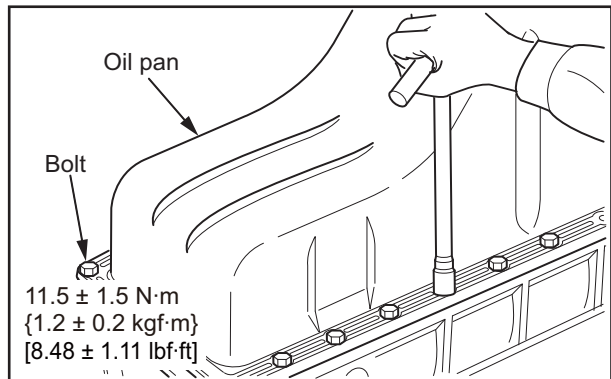
2.13 Oil Pan - Install

- (1) Clean the mount surfaces of the crankcase, timing gear case, and oil pan.
- (2) Squeeze ThreeBond 1207C (32A91-05100: liquid gasket) in a 4 mm [0.16 in.] diameter bead all around the oil pan flange periphery, and spread it evenly.
- (3) Install the oil pan to the crankcase within five minutes of applying the liquid gasket.
- (4) Tighten the bolts to the specified torque.

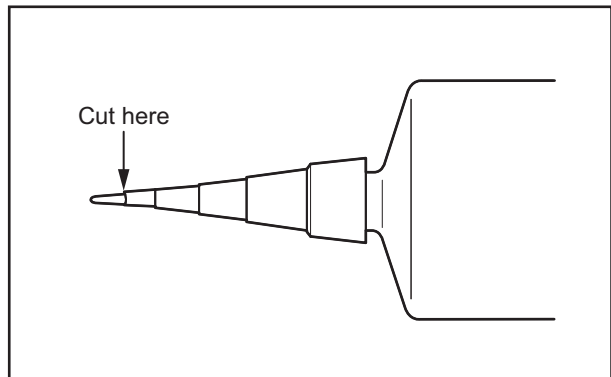
Note: Cutting the top of the sealant tube at the point shown in the illustration will provide a 4 mm [0.16 in.] bead.



Liquid Gasket Application Position



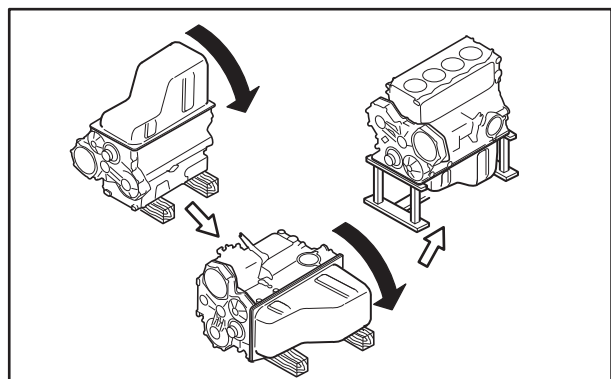
Oil Pan - Install



Cutting Point of the Liquid Gasket Tube Nozzle

2.14 Crankcase - Turn Over

Using a turnover machine, turn over the crankcase. When the turnover machine is not available, hitch slings to the crankcase using wood pieces and cloth pads, and raise the crankcase with a hoist or crane. Then lay it on the wooden block with its side face downward. Then, change the sling positions. Turn over the crankcase on the wooden blocks to turn it to the normal position.



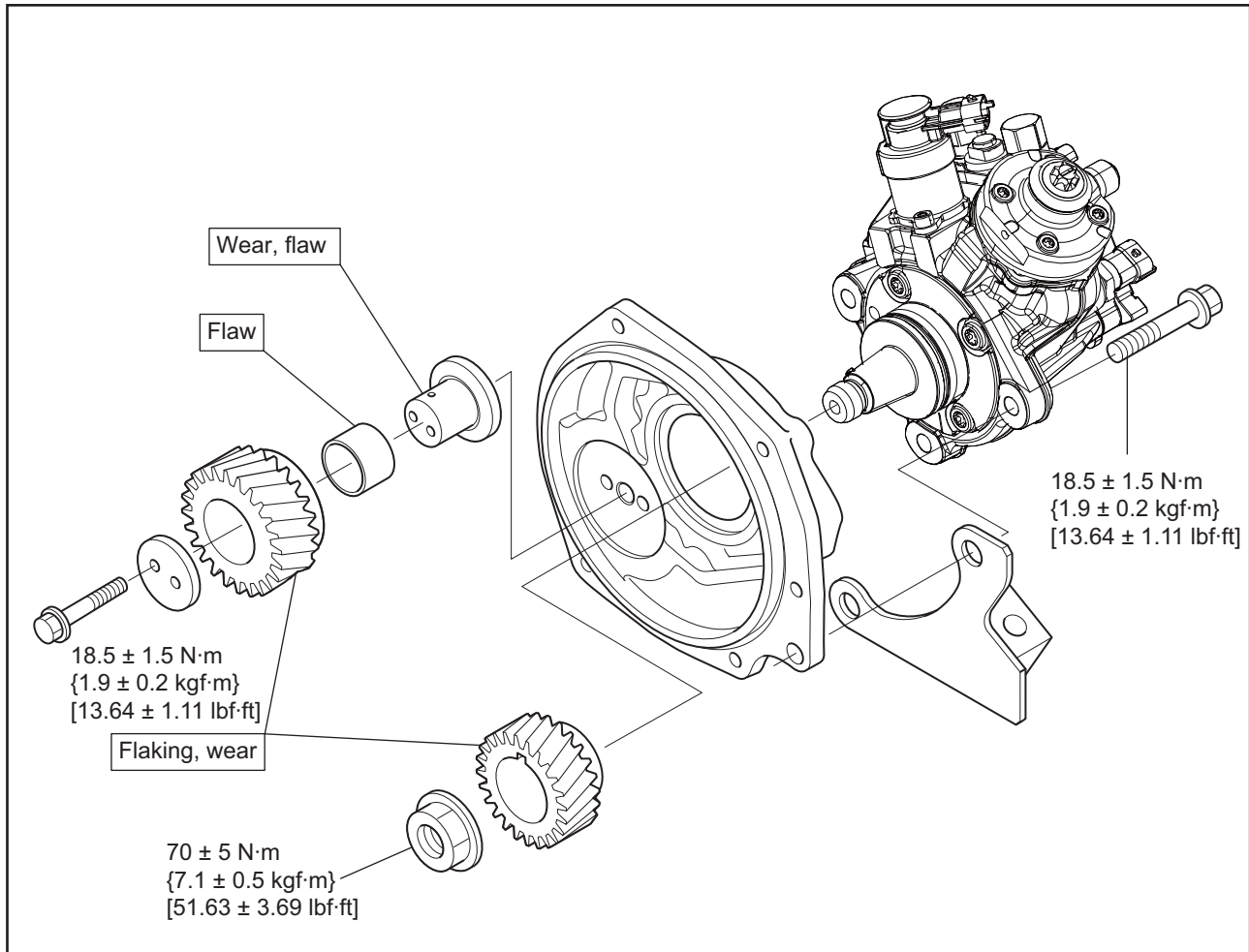
Crankcase - Turn Over

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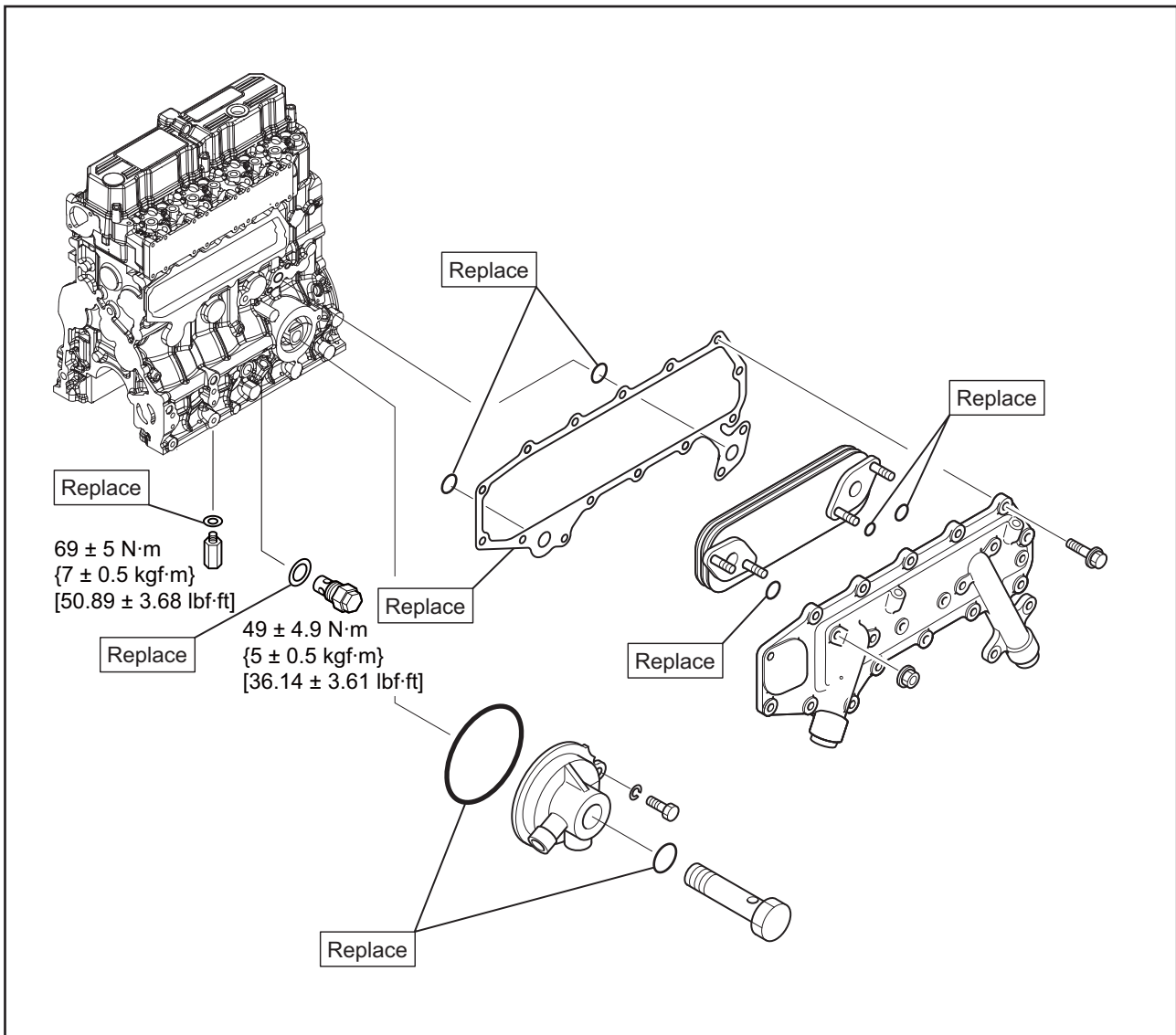
6. Fuel System - Install

6.1 Fuel System - Install (1)



Fuel System - Install (1)

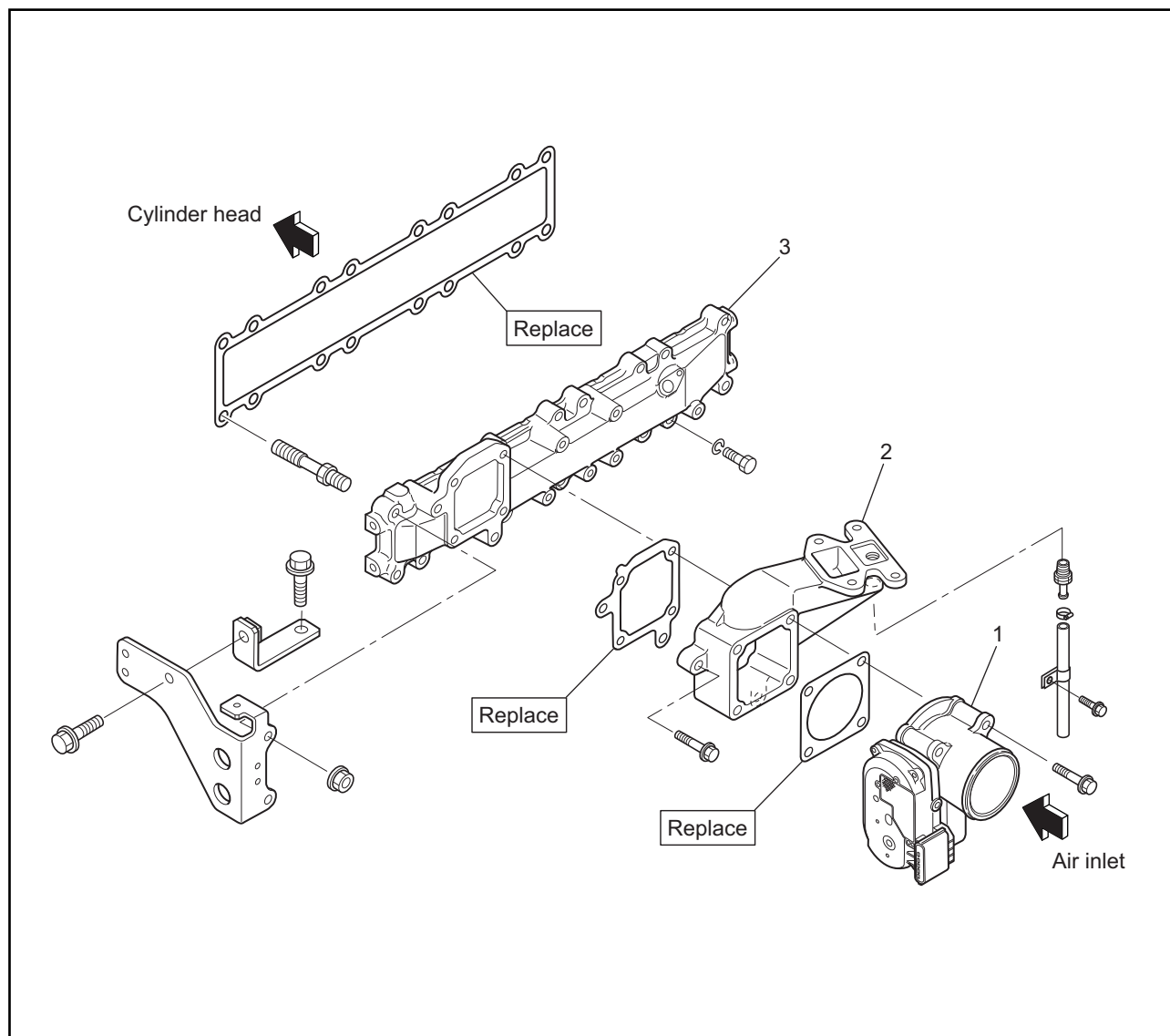
3.2 Oil Cooler, Relief Valve and Safety Valve - Install



Oil Cooler, Relief Valve and Safety Valve - Install

1. Inlet and Exhaust Systems - Remove

1.1 Inlet System - Remove



Inlet System - Remove

Removing sequence

1 Throttle valve

2 Throttle adapter

3 Inlet manifold

2. Electrical System - Disassemble, Inspect and Assemble

2.1 Starter Before Disassembling - Inspect

2.1.1 Magnetic switch - Inspect

Inspect the magnetic switch as described below. If faulty, replace the magnetic switch with a new one.

CAUTION

Do not apply current continuously for longer than 10 seconds.

Pull-in test

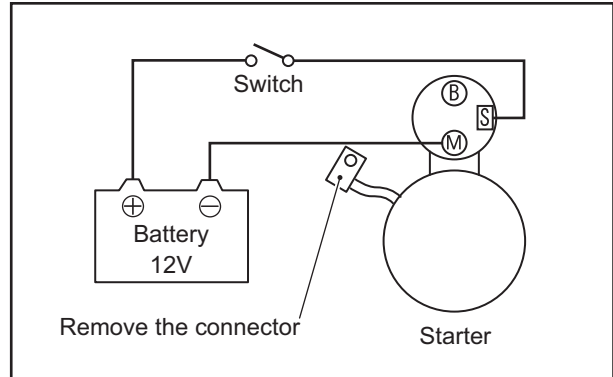
- (1) Disconnect the connector of M terminal.
- (2) Connect the starter to the circuit as shown in the illustration.
- (3) The magnetic switch is normal if the pinion pops out when the switch is turned ON.

Holding test

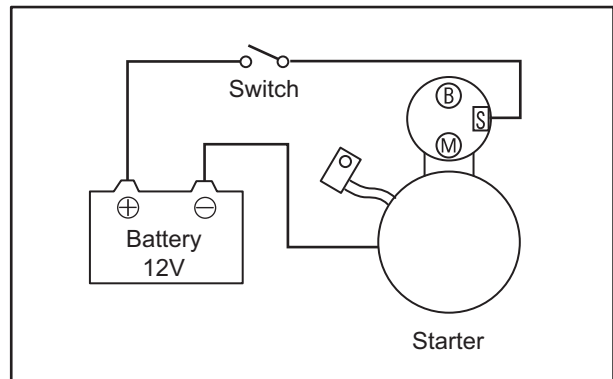
- (1) Disconnect the connector of M terminal.
- (2) Connect the starter to the circuit as shown in the illustration.
- (3) Turn ON the switch and pull out the pinion fully by hand.
The magnetic switch is normal if the pinion does not return when it is released.

Return test

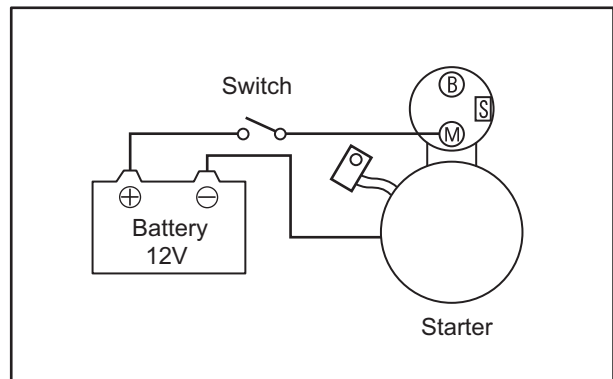
- (1) Disconnect the connector of M terminal.
- (2) Connect the starter to the circuit as shown in the illustration.
- (3) Turn OFF the switch and pull out the pinion fully by hand. The magnetic switch is normal if the pinion returns immediately when it is released.



Pull-in test



Holding test



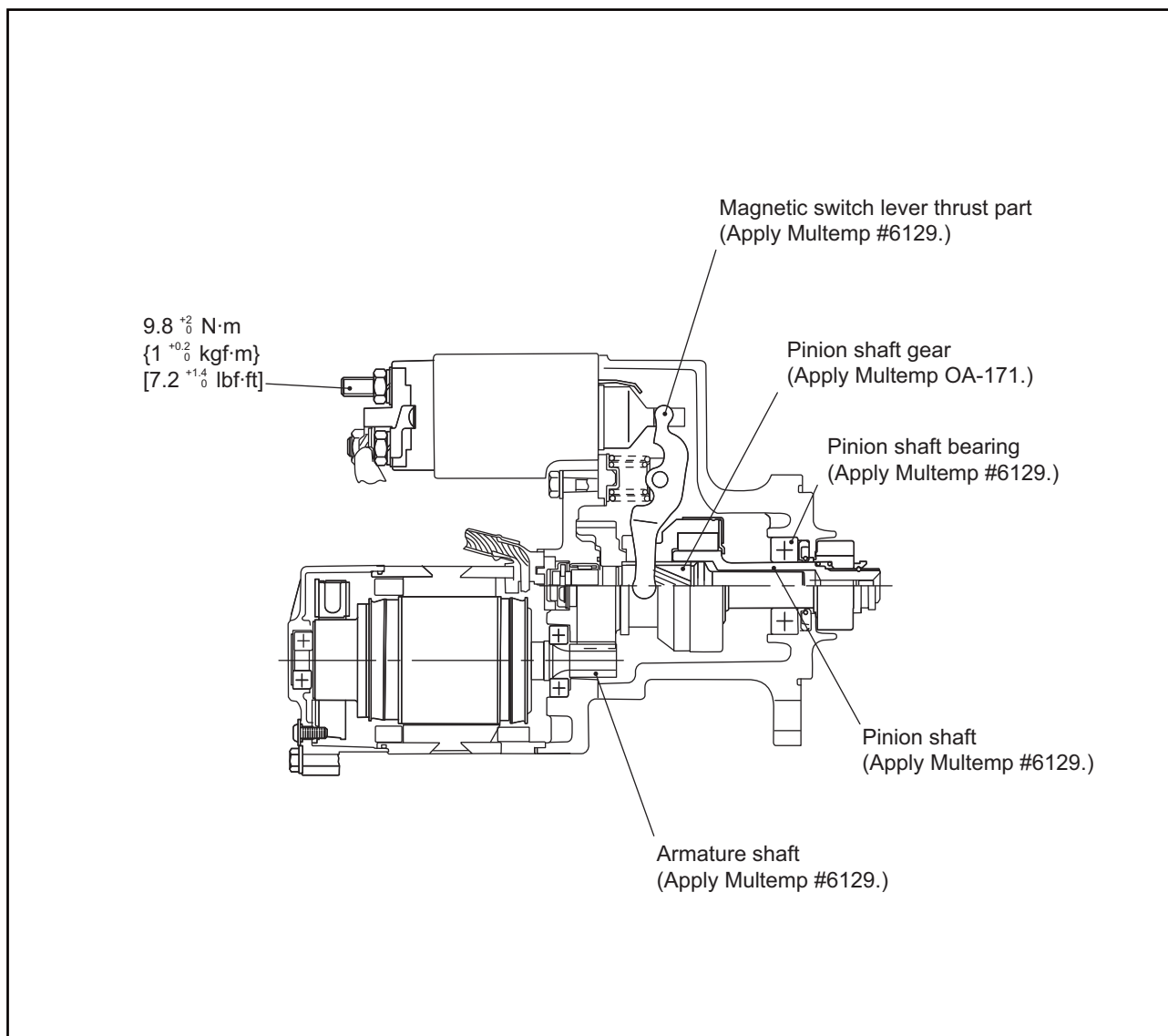
Return test

2.4 Starter - Assemble

To assemble the starter, follow the disassembly sequence in reverse.

CAUTION

- To avoid mixing of different greases, remove old grease before applying new grease.
- Make sure that the starter mounting surface, brushes, commutator and other electric current conducting components are free from grease.



Starter - Assemble

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4. Error Code Table.....	13-11

4. Error Code Table

System	Detected failure item	Detail of detected failure item	Detecting condition	Fail safe action	P Code	KCM code (Reference)	J1939 DTC	
							SPN	FMI
Engin body	Failure of glow relay power stage	Battery short circuit		No reaction	P0380	1	677	3
		GND short circuit		No reaction	P0380	2	677	4
		Wire open circuit		No reaction	P0380	4	677	2
		Over load		No reaction	P0380	8	677	12
	Battery voltage input (Note that this does not mean the battery voltage down.)	High voltage		The final value before the failure is freeze before the failure decision. The substitutional value control after the failure decision The CAN communication information is used for the value in failure	P0563	1	168	3
		Low voltage		The final value before the failure is freeze before the failure decision. The substitutional value control after the failure decision The CAN communication information is used for the value in failure	P0562	2	168	4
	Engine boost low Intake pipe failure (open pipe)	The boost pressure does not rise to the specified value.		Output restriction	P2282	8	102	12
	Engine over speed	The speed exceeds the upper limit.		Injection stop	P0219	1	1614	3
	Starter relay failure	Battery short circuit		Engine can not be started.	P0617	1	2101	3
		GND short circuit		Engine can not be started.	P0616	2	2101	4
Wire open circuit			Engine can not be started.	P0615	4	2101	2	
Over load			Engine can not be started.	P0615	8	2101	12	
ECU	AD converter abnormal	Test pulse conversion failure		(Stop)		4	2008	2
		Long converter processing time		(Stop)		8	2008	12
	EEPROM abnormal	Read abnormal		Output restriction	P062F	2	1235	4
		Write abnormal		Output restriction	P062F	4	1235	2
		Delete impossible		Output restriction	P062F	8	1235	12
	ECU inside abnormal			No reaction		8	2080	12
	ECU inside SPI abnormal	Communication between CPU and IC inside failure		(Stop)		1	1231	3
	Sensor supply voltage (1) abnormal	Supply voltage abnormal		The final value before the failure is freeze before the failure decision. (Intake pressure, analog accelerator) The substitutional value control after the failure decision (Intake pressure, analog accelerator) The CAN communication information is used for the value in failure Output restriction EGR fully closed AFM flow is used for some substitutes. Accelerator opening degree - CAN discrepancy detection stop Accelerator sensor input voltage failure detection stop	P0642	1	3509	3

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