SERVICE MANUAL

MITSUBISHI DIESEL ENGINE

S6R-Y1PTA

for Mitsubishi Engine North America, Inc.

March 2004

MITSUBISHI HEAVY INDUSTRIES, LTD.

Foreword

This service manual describes the specifications and the maintenance and adjustment procedures of the S6R-Y1PTA Diesel Engine that has met the exhaust emission regulations of the Environmental Protection Agency (EPA) of the United States.
If the engine is carefully maintained it will deliver a long productive life and efficient performance marked by power and economy.

Before you attempt to inspect, disassemble, or repair the engine, read this manual carefully to learn more about the engine and how to care for it properly. Take due care that the EPA exhaust emission regulations cannot be satisfied unless the engine is repaired by the methods described in this manual and by using the designated parts. All descriptions, illustrations, specifications and serial numbers in this manual are effective as of the date printing of this manual.

The information contained in this manual applies to the engine model produced at the time of publication. It should be noted that specifications and design may change due to improvements made thereafter.

Pub No. 99416-A1100

What This Manual Covers

This service manual covers standard specifications for the S6R-Y1PTA Diesel Engine, and describes

- Specifications
- Maintenance standards
- Adjustments
- Disassembly, inspection and repair
- Reassembly

In addition to the Summary of Manual Contents, a short summary of contents is found on the first page of each section of the manual.

Operation and periodical maintenance are described in the *Operation & Maintenance Manual*, component parts and ordering of service parts are described in the *Parts Catalogue*. Construction and function of the engine are described in the various training manuals.

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Take care that the parts may be partly modified due to improvement, for example.
Work related to the exhaust emission regulations can be conducted only at our designated service factories.

How to Use This Manual

1. Parts in illustrations are numbered to correspond with references to these numbers in text.
2. Items or conditions to be inspected during disassembly are enclosed in a box in the disassembled views:

   Clogged oil hole

3. Maintenance standards for inspection and repair are described in text where they are relevant. For a quick summary of maintenance standards refer to group 2 of this manual.
4. The sequence in which parts are to be reassembled is summarized below each assembled view.

   ⑤→②→④→③→①

5. Tightening torque under *wet* conditions is indicated as "(wet)" in text, drawings, and tables. When so indicated as (wet), apply engine oil to the threaded portion of the fastener. Unless indicated as such, the tightening torque is to be assumed in the dry condition.
6. Pay attention to the special notes, cautions, and warnings.

Notes, Cautions, and Warnings

Notes, cautions, and warnings are used in this manual to emphasize important or critical instructions or advice.

⚠WARNING ..... Operating procedures or practices which if ignored could result in injury or loss of life.

⚠CAUTION ..... Operating procedures or practices which if ignored could result in damage to the engine.

NOTE ..... An operating procedure, condition, etc. that will help you work more efficiently.

Terms Used in This Manual ..... Before you read this manual, note that the following special terms are used in dimensional and other specifications.

Assembly Standard ..... Indicates the dimension of a part, the dimension to be attained at the time of reassembly or the standard performance. The value is rounded to the nearest whole number needed for inspection and is different from the design value.

Nominal Value ..... Indicates the standard dimension of a part.

Repair Limit ..... A part which has reached this limit must be repaired.

Service Limit ..... A part which has reached this limit must be replaced.

Standard Clearance ..... Indicates the clearance to be obtained between mating parts at reassembly.

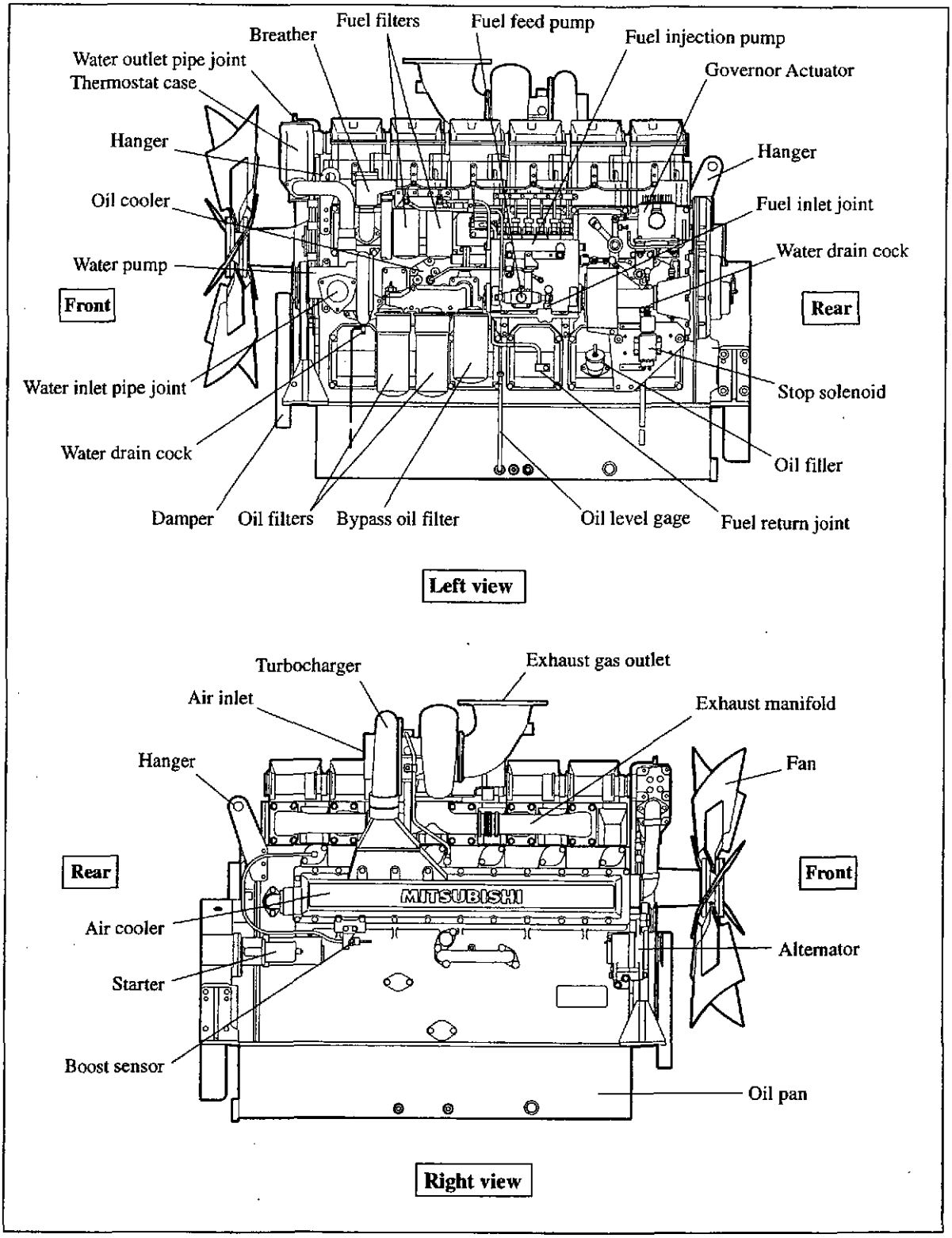
Summary of Manual Contents

Group	Contents
1. General	External views, engine serial number location, engine model and application codes, specifications, tips on disassembly and reassembly.
2. Maintenance Standards	Maintenance standards, tightening torque, sealants and lubricants.
3. Special and Basic Tools	A list of special tools and basic tools required.
4. Overhaul Instructions	Determining when to overhaul the engine, testing compression pressure.
5. Adjustments, Bench Testing, and Performance Tests	Adjustment of valve clearance and fuel system priming, fuel injection timing adjustment, bench testing and performance tests.
6. Engine Auxiliaries Removal and Installation	Removal and installation of turbochargers, air coolers, fuel injection pumps, alternator, starters, etc.
7. Engine Main Parts	Disassembly, inspection and reassembly of the engine proper, to include cylinder heads, valve mechanisms, pistons, flywheel, timing gears, camshaft, viscous damper, crankshaft.
8. Inlet and Exhaust Systems	Disassembly, inspection and reassembly of inlet and exhaust systems, to include air coolers, exhaust manifolds, and turbocharger.
9. Lubrication System	Disassembly, inspection and reassembly of lubrication system, to include the oil pump, relief valve, oil cooler, oil thermostats, oil filters, safety valve and oil filter alarm.
10. Cooling System	Disassembly, inspection and reassembly of cooling system, to include water pump, thermostats, and fan-drive.
11. Fuel System	Disassembly, inspection and reassembly of the fuel system, to include fuel filters, fuel injection nozzles, fuel injection pump and fuel feed pump.
12. Electrical System	Disassembly, inspection and reassembly of electrical system, to include starters and the alternator.
13. Workshop Tips	General precautions for disassembly and reassembly of parts: oil seals, O-rings, bearings, lock plates and pins.

GENERAL

1. Outline

1.1 External View



Engine Type			S6R-Y1PTA
Lubrication system	Type		Forced circulation type (pressure feed by gear pump)
	Engine oil	Standard	Class CD oil or class CF oil (API service classification)
		Capacity (engine) liter [U.S.gal]	92 [24.3], approx.
	Oil pump	Type	Gear pump
		Delivery capacity liter [U.S.gal] min	140 [83.2] (at 800 min^{-1} engine)
	Relief valve	Type	Piston valve type
		Valve opening pressure MPa (kgf/cm^2) [psi]	0.46 (4.7) [67]
	Oil cooler	Type	Water-cooled multi-plate type (housed in the crankcase)
	Full-flow oil filter	Type	Cartridge type with paper element
	Bypass oil filter	Type	Cartridge type with paper element
	Oil filter alarm	Type	Piston valve type, built-in electric contact points
		Lamp lighting and valve opening pressure (differential pressure) MPa (kgf/cm^2) [psi]	$0.15\,^{+0.03}_{0}$ ($1.5\,^{+0.3}_{0}$) [$21\,^{+4}_{0}$]
	Oil thermostat	Type	Wax type
		Valve opening temperature °C [°F]	80 to 84 [176 to 183]
Cooling system	Type		Water cooled
	Capacity (Engine)	liter [U.S.gal]	50 [13.2], approx.
	Water pump	Type	Centrifugal
		Delivery capacity liter [U.S.gal]	800 [211.2] (at 1800 min^{-1} engine)
	Water pump and alternator drive belts	Type-No. of belts	Low-edge cog "C" –2
		Outer circumference mm [in.]	1535 [60.4]
	Thermostats	Type	Wax type
		Valve opening temperature °C [°F]	71±2 [159.8±3.6]
	Cooling fan	Type	Steel-blade, circular arc type
		No. of blades	6
		Outside diameter mm [in.]	1010 [39.8]

Engine Type			S6R-Y1PTA
Fuel system	Injection pump	Model	PS 6 type
		Manufacturer	Mitsubishi Heavy Industry
		Plunger outside diameter mm [in.]	17 [0.67]
		Plunger lead mm [in.]	Both-side 35 lead [1.38]
		Cam lift mm [in.]	15 [0.59]
	Feed pump	Model	Bosch KD 22Z type
		Manufacturer	Bosch Automotive Systems Corporation
		Cam lift	12 [0.47]
	Governor	Type	Electric governor actuator ProAct Model II
		Manufacturer	Woodward Governor Company
	Injection nozzles	Type	Hole type
		Manufacturer	Bosch Automotive Systems Corporation
		No. of spray orifice	10
		Spray orifice inside diameter, mm [in.]	ø0.29 [0.0114]
		Spray angle	160°
		Injection pressure MPa (kgf/cm^2) [psi]	34.32 to 34.81 (350 to 355) [4978 to 5049]
	Fuel filter	Type	Cartridge type with paper element

Engine Type			S6R-Y1PTA
Electrical system	Voltage polarity		24V- Negative (–) ground
	Starter	Model	8-23000-6642
		Manufacturer	Nikko Electric Industry
		Pinion mesh type	Pinion shift (Reduction type)
		Out put V-kW	24-7.5
		No. of starters	1
		Pinion/ring gear ratio	11/182
	Alternator	Type	3-Phase with built-in IC regulator
		Manufacturer	Mitsubishi Electric
		Output V-A	24-30
		Rated output Generated min^{-1}	5000 (at 27V, 30A)
		Maximum speed min^{-1}	8000
		Regulator adjusting voltage V	28.5±0.5
	Safety relay (for starter chattering)	Model	0–25000–5340
		Manufacturer	Nikko Electric Industry
		Nominal voltage V	24
		Allowable temperature °C [°F]	-30 to 40 [-22 to 104.0]
		Rating Seconds	30
		Allowed contact current A	330 (momentary)
			50 (30 seconds)
		Ground	2-wire system

3. Tips on Disassembly and Reassembly

This service manual covers recommended procedures to be followed when servicing Mitsubishi diesel engines. It also contains information on special tools required and basic safety precautions.

It is the responsibility of service personnel to be familiar with these requirements, precautions and potential hazards and to discuss these points with their foreman or supervisor.

Study this manual carefully and observe the following general precautions to prevent serious personal injury and to avoid damage to the engine, equipment and parts.

⚠CAUTION

Work related to the exhaust emission regulations can be conducted only at our designated service factories.

3.1 Disassembly

(1) Use the correct tools and instruments. Serious injury or damage to the engine can result from using the wrong tools and instruments.

(2) Use an overhaul stand or work bench if necessary. Also, use assembly bins to keep the engine parts in order of removal.

(3) Lay down disassembled or cleaned parts in the order in which they were removed. This will save you time at reassembly.

(4) Pay attention to the marks on assemblies, components and parts for positions or directions. Put on your own marks, if necessary, to aid reassembly.

(5) Carefully check each part for faults during removal or cleaning. Signs of abnormal wear will tell if parts or assemblies are functioning improperly.

(6) When lifting or carrying heavy parts, get someone to help you if the part is too awkward for one person to handle. Use jacks and chain blocks when necessary.

3.2 Reassembly

(1) Wash all engine parts, except oil seals, O-rings, rubber seals, etc. in cleaning solvent and dry them with compressed air.

(2) Use only the correct tools and instruments.

(3) Use only good quality lubricating oils and greases. Be sure to apply a coat of oil, grease, or sealant to parts as specified. (Refer to 3, Group No. 2)

(4) Use a torque wrench to tighten parts when specified tightening torques are required. (Refer to 2, Group No.2)

(5) Replace all gaskets and packing. Apply only the proper amount of quick-drying cement to gaskets or packets when required.

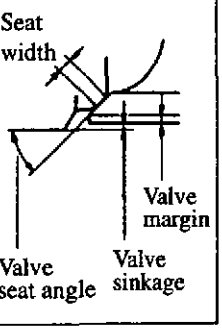
⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Work related to the exhaust emission regulations can be conducted only at our designated service factories.

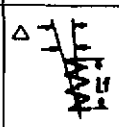
MAINTENANCE STANDARDS

1. Maintenance Standards Table

Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
General	Maximum min^{-1}		5 to 10% higher than rated min^{-1}		Faulty if lower or 15% higher than rated min^{-1}		Check governor setting.
	Minimum min^{-1}		600 to 650 min^{-1}				
	Compression pressure MPa (kgf/cm^2) [psi]		1.81 (18.5) [263] minimum (at 120 min^{-1})		Faulty if 1.27 (13) [185] or less		Oil and water temp. 20 to 30°C [68 to 86°F]
	Lube oil pressure MPa (kgf/cm^2) [psi]		[0.49 to 0.59 (5 to 6) [71 to 85.4] (at rated min^{-1}) 0.20 to 0.29 (2 to 3) [28.5 to 42.7] or more (at idling)		Faulty if 0.49 (5) [71] or less Faulty if 0.10 (1) [14] or less		Oil temp. 60 to 70°C [140 to 158°F]
	Valve timing (with 2mm [0.08 in] clearance on valve side, cold)		Inlet valve opens Inlet valve closes Exhaust valve opens Exhaust valve closes		BTDC 14° ABDC 12.5° BBDC 25.5° BTDC 5.5°AT ±2° (crank angle)		Valves are only for checking valve timing and are different from the actual ones.
	Valve clearance (cold)	Inlet valves		0.6 [0.024]			
		Exhaust valves		0.8 [0.031]			
	Injection timing		BTDC	±1° (crank angle)			Varies according to specifications. Refer to caution plate on No.1 rocker cover.
Engine main parts	Rockers	Rocker bushing inside diameter	ø36 [1.42]	36.000 to 36.040 [1.4173 to 1.4189]		36.090 [1.4209]	
		Rocker diameter	ø36 [1.42]	35.966 to 35.991 [1.4160 to 1.4170]		35.940 [1.4150]	
	Valves	Valve stem diameter	ø10 [0.39]	9.940 to 9.960 [0.3913 to 0.3921]		9.910 [0.3902]	The same for both inlet and exhaust valves.
		Valve guide inside diameter	ø10 [0.39]	10.000 to 10.015 [0.3937 to 0.3943]		10.060 [0.3961]	The same for both inlet and exhaust valves.
	Valve seats and valves	Valve seat angle	30°				
		Valve sinkage	0	–0.2 to 0.2 [–0.0079 to 0.0079]	1.0 [0.039]		
		Seat width	2.3 [0.091]	2.15 to 2.45 [0.0840 to 0.0965]	2.8 [0.110]		
		Valve margin	3.0 [0.12]	2.8 to 3.2 [0.110 to 0.126]	Refacing permissible up to 2.5 [0.098]		

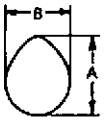
Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Engine main parts	Valve seats and valves	Cylinder head bore inside diameter and valve seat diameter	ø60 [2.36]	(–0.070 to –0.130) ([–0.0028 to –0.0051])			– (minus) indicates the valve is closed.
	Valve springs	Free length		73 [2.87]		71 [2.80]	
		Squareness	 θ=1.5° Δ= 1.9 [0.075] Lf=73 [2.874]			Δ =2.2 [0.087] over the length	
		Set length/ Set force		66.0[2.598]/ 289 to 319 N (29.45 to 32.55 kgf) [64.9 to 71.8 lbf]			
	Valve push rods	Deflection		0.5 [0.020] or less			
	Cylinder heads	Flatness of gasketed surface		0.03 [0.0012] or less	0.07 [0.0028]	0.50 [0.0197]	Reface if necessary.
	Cylinder liners	Inside diameter	ø170 [6.69]	170.000 to 170.040 [6.6929 to 6.6945]	170.200 [6.7008]	170.500 [6.7126]	
		Roundness		0.02 [0.0008] or less			
		Cylindricity		0.02 [0.0008] or less			
		Perpendicularity of flange lower face to linear axle		0.03 [0.0012] or less			
		Protrusion of cylinder liner flange above gasketed surface		0.11 to 0.20 [0.0043 to 0.0078]			
	Pistons	Outside diameter	ø170 [6.69]	169.76 to 169.80 [6.6835 to 6.6850]		169.66 [6.6795]	Measure diameter in the direction transverse to pin at piston skirt.
		Variance in weight among pistons per engine		±10 g [±0.35 oz] or less			
		Pin bore diameter	ø70 [2.76]	70.002 to 70.015 [2.7560 to 2.7565]		70.040 [2.7575]	
		Protrusion		0.14 to 0.65 [0.0055 to 0.0256]			
	Cylinder head gasket	As-installed thickness	1.8 [0.071]	1.77 to 1.83 [0.0697 to 0.0720]			

Unit: mm [in.]

Group	Inspection Point			Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Engine main parts	Piston and cylinder head	Clearance between piston top and cylinder head			(1.24 to 1.99) ([0.0488 to 0.0783])			
	Piston rings	Gaps	Top		(0.6 to 0.8) ([0.024 to 0.031])		(2.0) ([0.079])	If gage is not available, the general value can be obtained at the cylinder bore.
			Second		(0.6 to 0.8) ([0.024 to 0.031])		(2.0) ([0.079])	
			Oil		(0.3 to 0.45) ([0.012 to 0.018])		(2.0) ([0.079])	
	Piston pins	Diameter		ø70 [2.76]	69.987 to 70.000 [2.7554 to 0.7559]		69.970 [2.7547]	
	Connecting rods	Bushing inside diameter		ø70 [2.76]	70.020 to 70.040 [2.7567 to 2.7575]		70.070 [2.7587]	
		Bend and twist			0.05/100 [0.0020/3.9] or less			
		End play (crankpin and big-end widths)		67 [2.64]	(0.4 to 0.6) ([0.016 to 0.024])		(1.0) ([0.0394])	
		Variance in weight among connecting rods per engine			±30g [±1.06 oz] or less			
		Big-end bore diameter		ø131 [5.16]	131.000 to 131.025 [5.1547 to 5.1585]		131.050 [5.1594]	If gage is not available, the general value can be obtained at the cylinder
	Connecting rod bearing	Thickness of center	STD	3.000 [0.1181]	2.957 to 2.970 [0.1164 to 0.1169]		2.930 [0.1154]	Replace bearings if worn down to service limit. Regrind crankpins and use undersize beyond service limit.
			– 0.25 [–0.0098]	3.125 [0.1230]	3.082 to 3.095 [0.1213 to 0.1219]		3.055 [0.1203]	
			– 0.50 [–0.0197]	3.250 [0.1280]	3.207 to 3.220 [0.1263 to 0.1268]		3.180 [0.1252]	
			– 0.75 [–0.0295]	3.375 [0.1329]	3.332 to 3.345 [0.1312 to 0.1317]		3.305 [0.1301]	
			– 1.00 [–0.0394]	3.500 [0.1378]	3.457 to 3.470 [0.1361 to 0.1366]		3.430 [0.1350]	
	Flywheel	Face deflection			0.285 [0.0112] or less			
		Circular deflection			0.127 [0.0050] or less			
	Injection pump Accessory drive	Drive case bearing journal inside diameter		ø90 [3.54]	89.987 to 90.022 [3.5428 to 3.5442]			
				ø100 [3.94]	99.987 to 100.022 [3.9365 to 3.9379]			
		Bearing Outside diameter		ø90 [3.94]	89.985 to 90.000 [3.5427 to 3.5433]			
				ø100 [3.94]	99.985 to 100.000 [3.9364 to 3.9370]			

Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Engine main parts	Injection pump Accessory drive	Bearing Inside diameter	ø45 [1.77]	44.988 to 45.000 [1.7712 to 1.7717]			
			ø50 [1.97]	49.988 to 50.000 [1.9680 to 1.9685]			
		Drive shaft bearing journal outside diameter	ø45 [1.77]	45.002 to 45.013 [1.7717 to 1.7722]			
			ø50 [1.97]	50.002 to 50.013 [1.9680 to 1.9690]			
	Damper	Radial deflection (at periphery)		0.5 [0.020] or less		1.5 [0.059]	Replace every 8000 service hours.
		Face deflection		0.5 [0.020] or less		1.5 [0.059]	
	Timing and front gears	Backlash		(0.12 to 0.18) ([0.0047 to 0.0071])	(0.30) ([0.0118])	(0.50) ([0.0197])	Replace gears, if necessary.
		Idle gear shaft bushing inside diameter	ø50 [1.97]	50.000 to 50.025 [1.9685 to 1.9695]		50.060 [1.9709]	Same as the front oil drive idler, front fan drive idler.
		Idle gear shaft diameter	ø50 [1.97]	49.950 to 49.975 [1.9665 to 1.9675]		49.900 [1.9646]	
		Idle gear end play		(0.2 to 0.4) ([0.008 to 0.016])		(0.6) ([0.024])	
	Camshaft	Cam lift (A-B)	9.247 [0.3641]	9.197 to 9.297 [0.3621 to 0.3660]		8.45 [0.3327]	
		Deflection		0.05 [0.002] or less	0.08 [0.0031]		Deflection at center bushing measured with both ends supported. Repair or replace, if necessary.

Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Engine main parts	Camshaft	Journal diameter	ø84 [3.31]	83.92 to 83.94 [3.3039 to 3.3047]		83.87 [3.3020]	
		Camshaft bushing inside diameter (as installed in crankcase)	ø84 [3.31]	84.000 to 84.035 [3.3071 to 3.3085]		84.10 [3.3110]	Replace bushings and ream them, if necessary.
		End play	8 [0.3]	(0.10 to 0.25) ([0.0039 to 0.0098])		(0.40) ([0.016])	Replace thrust plate, if necessary.
	Crankshaft	Crankpin diameter	ø125 [4.92]	124.930 to 124.950 [4.9185 to 4.9193]	124.890 [4.9169]		
		Crankpin journal diameter	ø140 [5.51]	139.930 to 139.950 [5.5091 to 5.5098]	139.890 [5.5075]		
		Center to center distance between journal and crankpin	90 [3.54]	89.90 to 90.10 [3.539 to 3.547]			
		Parallelism between journals and crankpins		0.01 [0.0004] or less at pin length	0.03 [0.0012]		
		Roundness between journals and crankpins		0.01 [0.0004] or less	0.03 [0.0012]		
		Cylindricity of journals and crankpins		0.02 [0.0008] or less	0.03 [0.0012]		
		Fillet radius of journals	7R [0.28]	6.8 to 7.0 [0.268 to 0.276]			
		Hardness of journals and crankpins		Hv>620			
		Angularity		±0°20'			
		Deflection		0.04 [0.0016] or less	0.10 [0.0039]		Repair or replace, if necessary.
		End play (Width between web and thrust bearings)	66 [2.60]	(0.30 to 0.50) ([0.0118 to 0.0197])		(0.50) ([0.0197]) +1.18 [+0.0465]	Replace thrust bearings if worn down to repair limit. Use oversize thrust plate if worn beyond repair limit. +0.25 [+0.0098], +0.50 [+0.0197], +0.75 [+0.0295]

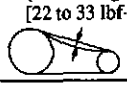
Unit: mm [in.]

Group	Inspection Point			Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Engine main parts	Main bearing	Thickness of center	STD –0.25 [–0.0098] –0.50 [0.0197] –0.75 [–0.0295] –1.00 [–0.0394]	3.500 [0.138] 3.625 [0.1427] 3.750 [0.1476] 3.875 [0.1526] 4.000 [0.1575]	3.467 to 3.480 [0.1365 to 0.1370] 3.592 to 3.605 [0.1414 to 0.1419] 3.717 to 3.730 [0.1463 to 0.1469] 3.842 to 3.855 [0.1513 to 0.1518] 3.967 to 3.980 [0.1562 to 0.1567]		3.425 [0.1348] 3.550 [0.1398] 3.675 [0.1447] 3.800 [0.1496] 3.925 [(0.1545]	Replace bearings if worn down to service limit. Regrind crankpins and use undersize bearings if worn beyond service limit.
	Crankcase	Flatness of gasketed surface			0.1 [0.004] or less		0.2 [0.008]	Reface if necessary.
		Main bearing bore diameter		ø147 [5.79]	147.000 to 147.025 [5.7874 to 5.7884]		147.035 [5.7888]	
Turbocharger	Inside diameter of bearing-fitted housing section			ø36 [1.4173]			36.014 [1.4179]	
	Bearing	Outside diameter		ø36 [1.4173]			35.847 [1.4113]	
		Inside diameter		ø24 [0.9449]			24.0335 [0.9462]	
		Length		23.5 [0.9252]			23.440 [0.9228]	
	Shaft and turbine wheel	Journal outside diameter		ø24 [0.9449]			23.996 [0.9447]	
		Shaft deflection					0.015 [0.0006]	
	Piston ring gap clearance				0.05 to 0.20 [0.0020 to 0.0079]			When piston ring is installed to the insert.
	Clearance between shaft & turbine wheel and turbine housing				(0.58 to 1.32) ([0.0228 to 0.0520])			
	Shaft end play				0.075 to 0.135 [0.0030 to 0.0053]			
	Clearance between turbine backplate and turbine wheel				(0.78 to 1.22) ([0.0307 to 0.0480])			

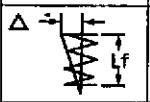
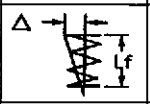
Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Lubrication system	Oil pump	Oil pump gear - to - idler gear backlash		(0.087 to 0.316) ([0.0034 to 0.0124])		(0.4) ([0.016])	
		Drive and driven gear backlash		(0.11 to 0.23) ([0.0043 to 0.0091])		(0.4) ([0.016])	
		Radical clearance of gear in case	ø60 [2.36]	(0.100 to 0.196) ([0.0039 to 0.0077])		Tip clearance (0.35) ([0.0138])	
		End clearance of gears in case	34 [1.34]	(0.050 to 0.114) ([0.0020 to 0.0045])		(0.25) ([0.0098])	
		Drive, driven and shaft diameter	ø25 [0.98]	24.947 to 24.960 [0.9822 to 0.9827]		24.900 [0.9803]	
		Bushing inside diameter		25.000 to 25.021 [0.9843 to 0.9850]		25.100 [0.9882]	
	Safety valve	Valve opening pressure		1.37±0.10 MPa (14.0±1.0 kgf/cm²) [199±14 psi]			
		Spring installation length/ weight		67.2/384 N (39.2 kgf) [86.4 lbf]			
	Pump idler gear-to-crank-shaft gear backlash			(0.12 to 0.18) ([0.0047 to 0.0071])			
	Relief valve	Opening pressure		0.46 MPa (4.7 kgf/cm²) [66.86 psi]			
	Oil thermostat	Temperature at which valve starts opening		80 to 84°C [176 to 183°F]			
		Temperature at which valve lift is more than 11 mm [0.43 in.]		95°C [203°F]			
	Bypass alarm	Lamp lighting and valve opening pressure (differential pressure)		$0.15^{+0.03}_{0}$ MPa ($1.5^{+0.3}_{0}$ kgf/cm²) [21^{+4}_{0} psi]			1 mm [0.04 in.] shim changes [0.007 MPa] (0.07 kgf/cm²) [1 psi].
	Piston cooling nozzle	Opening pressure		0.26 to 0.32 MPa (2.7 to 3.3 kgf/cm²) [38.4 to 45 psi]			

Unit: mm [in.]

Group	Inspection Point			Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Cooling system	Water pump	Bearing bore inside diameter		ø 80 [3.15]	79.988 to 80.018 [3.1491 to 3.1503]		80.025 [3.1506]	
				ø 90 [3.54]	89.987 to 90.022 [3.5428 to 3.5442]		90.025 [3.5443]	Same as the bearing cover
		Bearing	Outside diameters	ø 80 [3.15]	79.987 to 80.000 [3.1491 to 3.1496]			
				ø 90 [3.54]	89.985 to 90.000 [3.5427 to 3.5433]			
			Inside diameters	ø 40 [1.57]	39.988 to 40.000 [1.5743 to 1.5748]			
		Diameter of shaft on which bearing inner race is fitted		ø 40 [1.57]	40.002 to 40.013 [1.5749 to 1.5753]		39.995 [1.5749]	
		Vane front face clearance		0.72 [0.028]	(0.14 to 1.3) ([0.0060 to 0.051])			
	Thermostat	Temperature valve opening			71±2°C [159.8±3.6°F]			
		Temperature at which valve lift is 11 mm [0.43 in.] or more			85°C [185°F]			Check at atmospheric pressure.
	Fan drive	Bearing bore inside diameter		ø 100 [3.94]	99.987 to 100.022 [3.9365 to 3.9379]			
				ø 110 [4.33]	109.987 to 110.022 [4.3302 to 4.3316]			
		Bearing	Outside diameters	ø 100 [3.94]	99.985 to 100.000 [3.9364 to 3.9370]			
				ø 110 [4.33]	109.985 to 110.000 [4.3301 to 4.3307]			
			Inside diameters	ø 45 [1.77]	44.988 to 45.000 [1.7712 to 1.7717]			
				ø 50 [1.97]	49.985 to 50.000 [1.9679 to 1.9685]			
		Shaft bearing journal diameter		ø 45 [1.77]	45.002 to 45.013 [1.7717 to 1.7722]			
				ø 50 [1.97]	50.002 to 50.013 [1.9686 to 1.9690]			
	Tension of water pump and alternator drive belt				10 to 15 [0.39 to 0.59]			Measure deflection by pushing belt midway between pulleys. Approx. 98 to 147 N·m (10 to 15 kgf·m) [22 to 33 lbf·ft] 

Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Fuel system	Fuel injection nozzle	Valve opening pressure MPa(kgf/cm²)[psi]	34.32 (350) [4977]	34.32 to 34.81 (350 to 355) [4997 to 5050]			
		Spray cone angle	160°				Check nozzle with a hand tester (at fuel oil temperature 20°C. [68°F]). Replace the nozzle tip if the spray pattern is still defective after washing in clean fuel oil.
	Fuel injestion pump	Tappet roller overall clearance				0.2 [0.008]	
		Wear of plunger contacting surface of tappet				0.2 [0.008]	
		Camshaft deflection		0.05 [0.0020]		0.15 [0.0059]	Repair bent camshaft or replace.
		Diameter of camshaft at oil seal contacting surface	ø35 [1.38]	34.938 to 34.963 [1.37551 to 1.37649]		34.800 [1.3701]	Insert oversized sleeve if service limit is exceeded.
		Camshaft thrust clearance		0.02 to 0.06 [0.0008 to 0.024]			
		Plunger spring perpendicularity				Δ =1.8 [0.071] at the end	Lf=70.8 [2.79]
		CPV spring perpendicularity				Δ =0.6 [0.024] at the end	Lf=18 [0.71]
		Control rack total stroke		36 [1.42]			
		Control rack sliding resistance		4.9 N (500 gf) [1.10 lbf] or less			
		Clearance between plunger and barrel	Replace plunger assembly if injection characteristics value exceeds -5% at 17 [0.67] rack position.				

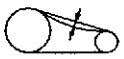
Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Fuel system	Fuel feed pump	Airtightness	There shall be no air leakage (air bubbles) from test assembly.				Plug discharge port, apply air pressure of 0.20 MPa (2.0 kgf/cm^2) [28.5 psi] to suction port, and immerse in diesel fuel.
		Feed pressure	Discharge start time: 20 seconds or less				Operate pump at 100 min^{-1} and measure discharge start time.
		Priming pump suction capacity	Discharge start: 30 strokes or less				Operate pump at 60 to 100 st/min^{-1} and count the number of pumping operations required for fuel to reach the pump.
		Feed rate	Feed rate: 1100 cm^3 [67 cu.in.]/15 sec. or more				Open valve on discharge side, operate pump at 500 min^{-1} and measure the amount of fuel fed in 15 seconds.

Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Electrical system	Starter	Commutator outside diameter	ø43 [1.69]			ø42 [1.65]	
		Deflection of commutator		0.06 [0.0024] or less		0.10 [0.0039]	
		Mica depth in commutator		0.7 to 0.9 [0.0276 to 0.0354]	0.2 [0.008]		
		Height of brushes		22 to 23 [0.87 to 0.91]		13 [0.51]	
		Tension of brush springs N (kgf) [lbf]	44.13 (4.5) [64.10]	39.23 to 49.03 (4.0 to 5.0) [9 to 11]		39.23 (4.0) [9]	
		Diameter of armature shaft rear side	ø14 [0.55]	14.15 to 14.25 [0.55709 to 0.56102]			
		Diameter of armature shaft front side	ø20 [0.79]	20.15 to 20.25 [0.79330 to 0.79724]			
		Diameter of pinion shaft rear side	ø30 [1.18]	30.002 to 30.011 [1.18118 to 1.18153]			
		Diameter of pinion shaft front side and inside diameter of metal	ø19 [0.75]	(18.900 to 18.940) ([0.7441 to 0.74567])			
		Front metal	ø19 [0.75]	19.000 to 19.033 [0.7480 to 0.7493]		0.25 [0.0098]	Clearance between shaft and metal
		Pinion	ø19 [0.75]	19.000 to 19.033 [0.7480 to 0.7493]		0.25 [0.0098]	Clearance between shaft and metal
		Rear metal		14.000 to 14.027 [0.5512 to 0.5522]		0.25 [0.0098]	Clearance between shaft and metal
		Armature end play		0.3 to 0.7 [0.012 to 0.028]			
		Pinion shaft end play		0.2 to 0.8 [0.008 to 0.031]			

Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Electrical system	Alternator	Slip ring outside diameter	33[1.30]	32.8 to 33.2 [1.291 to 1.307]		32.4 [1.276]	
		Brush height	21.5 [0.85]			8.0 [0.31]	Up to wear limit
		Brush spring tension N (gf) [lbf]	3.7 (380) [0.84]	3.1 to 4.3 (320 to 440) [0.70 to 0.97]		1.8 (180) [0.40]	
	Alternator drive belt tension			10 to 15 [0.4 to 0.6]			Deflection when pressed with thumb: 98 to 147 N (10 to 15 kgf) [22 to 33 lbf] 

2. Tightening Torque Table

2.1 Important Bolts and Nuts

Description	Thread Diameter × Pitch (M-thread) mm [in.]	Torque			Remarks
		N·m	kgf·m	lbf·ft	
Cylinder head	22 × 2.5 [0.866 × 0.0984]	539	55	398	[Wet] 2-step tightening method Note (a)
Cylinder head nozzle glands (studs)	14 × 2.0 [0.551 × 0.0787]	69 to 78	7 to 8	51 to 58	
Rocker case	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Rocker shaft	14 × 2.0 [0.551 × 0.0787]	147	15	108	
Rocker arm lock nuts	12 × 1.25 [0.472 × 0.0492]	64	6.5	47	
Bridge lock nuts	10 × 1.25 [0.394 × 0.0492]	55	5.6	40	
Camshaft gear (rear)	12 × 1.25 [0.472 × 0.0492]	176	17.9	129	
Camshaft thrust plate	12 × 1.25 [0.472 × 0.0492]	59	6	43	
Main bearing caps	24 × 3.0 [0.945 × 0.118]	490	50	362	[Wet]
Hanger	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Piston cooling nozzle	12 × 1.75 [0.472 × 0.0689]	34	3.5	25	Note (b)
Timing gear case	16 × 1.5 [0.63 × 0.0591]	255	26	188	With hand washer
Rear plate	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Oil pan	12 × 1.25 [0.472 × 0.0492]	59	6	43	
Front mounting bracket	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Rear mounting bracket	16 × 1.5 [0.63 × 0.0591]	216	22	159	
Connecting rod bearing caps	22 × 1.5 [0.866 × 0.0591]	539	55	398	[Wet] 2-step tightening method Note (c)
Flywheel	22 × 1.5 [0.866 × 0.0591]	539	55	398	[Wet]
Damper	22 × 1.5 [0.866 × 0.0591]	490	50	362	
Rear idle shaft	12× 1.25 [0.472 × 0.0492]	108	11	80	
Rear idle shaft thrust plate	10 × 1.25 [0.394 × 0.0492]	29	3	22	
Exhaust manifold V-clamp nuts	6 × 1.0 [0.236 × 0.0394]	9	0.9	7	
Injection pump drive case	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Injection pump gears (nuts)	30 × 1.5 [1.18 × 0.0591]	392	40	289	
Oil pump	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Oil pump idler gear (nuts)	12 × 1.25 [0.472 × 0.0492]	69	7	51	Apply Loctite 262 to screw threads
Water pump	12 × 1.25 [0.472 × 0.0492]	59	6	43	
Water pump shaft pulley (nut)	24 × 1.5 [0.0945 × 0.0591]	245	25	181	
Fan drive camshaft gear (front)	14 × 1.5 [0.0551 × 0.0591]	176	17.9	129	
Fan drive shaft gear (nut)	30 × 1.5 [1.18 × 0.0591]	392	40	289	
Fan plate	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Air cooler	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Injection pump brackets	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Injection pump	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Injection nozzle gland (nuts)	14 × 1.5 [0.551 × 0.0591]	98	10	72	
Injection nozzle chip (nuts)	28 × 1.5 [1.1 × 0.0591]	177 to 196	18 to 20	130 to 145	

Description	Thread Diameter × Pitch (M-thread) mm [in.]	Torque			Remarks
		N·m	kgf·m	lbf·ft	
Nozzle holder cap nuts	14 × 1.5 [0.551 × 0.0591]	69 to 78	7 to 8	51 to 58	
Injection nozzle set screw	14 × 1.5 [0.551 × 0.0591]	34 to 44	3.5 to 4.5	25 to 32	
Injection nozzle inlet connector	16 × 1.5 [0.63 × 0.0591]	64 to 74	6.5 to 7.5	47 to 54	
Injection pipes	18 × 1.5 [0.709 × 0.0591]	49 to 69	5 to 7	36 to 51	
Fuel rack control lever	8 × 1.25 [0.315 × 0.0492]	25	2.5	18	2-step tightening method
Fuel filter air vent plug	8 × 1.25 [0.315 × 0.0492]	8 to 10	0.8 to 1.0	6 to 7	
Starter	12 × 1.25 [0.472 × 0.0492]	59	6	43	
Turbocharger compressor wheel (nut) (Left-handed thread)	1/2-20 UNF	—	—	—	Apply Loctite No.962T to thread. Note (f)
Turbocharger V-clamp	—	9.8 to 10.8	1.0 to 1.1	7.2 to 8.0	Apply Moly Disulfide to thread.

Note: (a) Tighten the cylinder head bolts by the angle method in the following order:
(1) Tighten snug torque to 294 N·m (30 kgf·m) [217 lbf·ft].
(2) Turn by 30°.
(3) Turn by another 30°.
(4) Loosen all bolts, and then retighten them by the angle method. (2-step tightening)

(b) To tighten piston cooling nozzle, check valves, be sure to use a torque wrench. Tightening without the use of a torque wrench can result in excessive tightening force, and this can cause valve malfunctions and lead to seizing of pistons due to insufficient lubricating oil during engine operation.

(c) To tighten connecting rod caps according to the angle method, tighten to 245 N·m (25 kgf·m) [181 lbf·ft], then turn each bolt by 30°. After tightening all the bolts, turn each bolt again by 30° (total of 60° turn).

(d) [Wet] indicates apply engine oil to the threads of the nuts and bolts.

(e) [2-step tightening method] indicates tightening to specified torque, loosen the bolts completely and retighten again to the specified torque.

(f) Tighten the lock nut to torque of 69 N·m (7 kgf·m) [51 lbf·ft] first, then loosen it completely. Retighten the nut to a snug torque of 9.8 N·m (1 kgf·m) [7.2 lbf·ft], then turn further by 90 ± 3°.

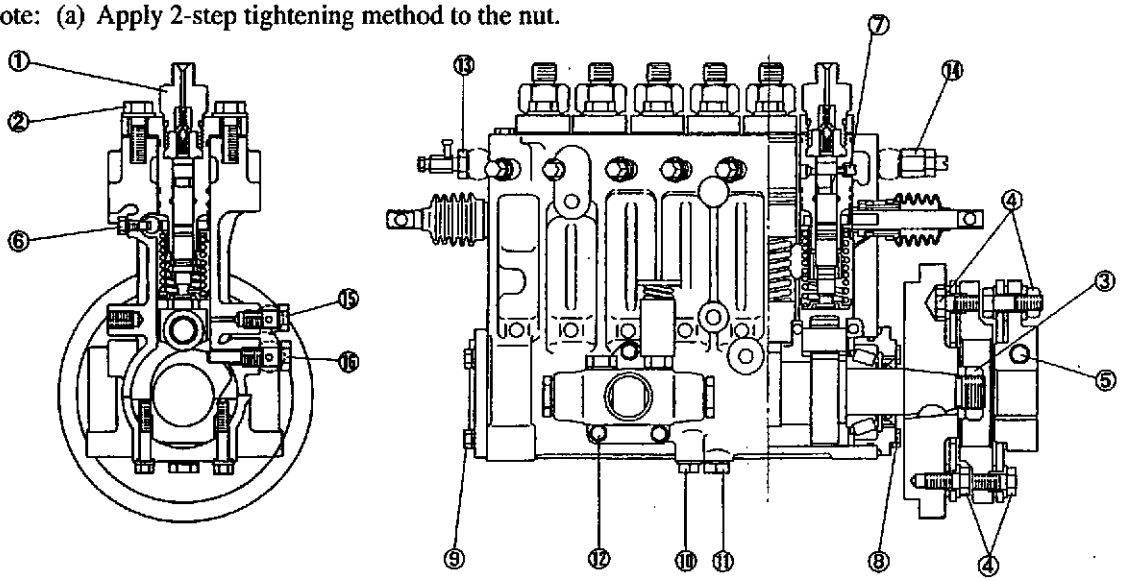
⚠CAUTION

Absolutely avoid Moly Disulfide sticking to the contact surface of the compressor wheel rear face and sleeve.

2.2 Fuel Injection Pump

Mounted part	Thread Diameter × Pitch (M-thread) mm [in.]	Width across flats mm [in.]	Tightening torque			Remarks
			N·m	kgf·m	lbf·ft	
Valve holder ①	M30 × 1.5 [1.18 × 0.059]	32 [1.26]	235 to 255	24 to 26	174 to 188	Tighten in two steps.
Barrel bolt ②	M12 × 1.25 [0.55 × 0.049]	19 [0.79]	78 to 83	8.0 to 8.5	58 to 61	
Flywheel mounting nut ③	M24 × 1.5 [0.94 × 0.059]	36 [1.42]	392	40	289	Note (a)
Laminated plate connecting bolt ④	M12 × 1.25 [0.55 × 0.049]	17 [0.67]	103 to 113	10.5 to 11.5	76 to 83	
Coupling shaft tightening bolt ⑤	M14 × 1.5 [0.55 × 0.059]	22 [0.87]	167 to 177	17 to 18	123 to 130	
Rack set screw ⑥	M8 × 1.25 [0.31 × 0.049]	12 [0.47]	21	2.1	15	
Deflector bolt ⑦	M10 × 1.25 [0.39 × 0.049]	12 [0.47]	41	4.2	30	
Rear cover mounting bolt ⑧	M8 × 1.25 [0.31 × 0.049]	12 [0.47]	21	2.1	15	
Front cover mounting bolt ⑨	M8 × 1.25 [0.31 × 0.049]	12 [0.47]	21	2.1	15	
Center bearing mounting bolt ⑩	M8 × 1.25 [0.31 × 0.049]	12 [0.47]	19.6 to 21.6	2.0 to 2.2	14.5 to 15.9	
Drain plug ⑪	M12 × 1.25 [0.47 × 0.049]	19 [0.75]	21	2.1	15	
Feed pump mounting bolt ⑫	M6 × 1.0 [0.24 × 0.039]	10 [0.39]	8.8	0.9	6.5	
Fuel inlet eyebolt ⑬	M14 × 1.5 [0.55 × 0.059]	19 [0.75]	34 ± 4	3.5 ± 0.4	25 ± 3	
Fuel outlet check valve bolt ⑭	M12 × 1.25 [0.47 × 0.049]	19 [0.75]	34 ± 4	3.5 ± 0.4	25 ± 3	
Lubricating oil inlet eyebolt ⑮	M12 × 1.25 [0.47 × 0.049]	17 [0.67]	34 ± 4	3.5 ± 0.4	25 ± 3	
Lubricating oil return port eyebolt ⑯	M14 × 1.25 [0.55 × 0.049]	19 [0.75]	34 ± 4	3.5 ± 0.4	25 ± 3	

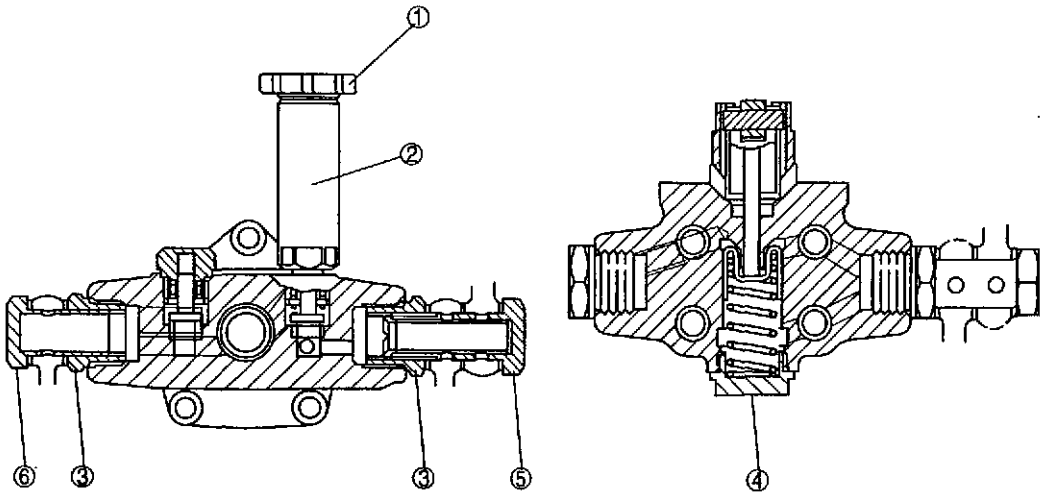
Note: (a) Apply 2-step tightening method to the nut.



2.3 Fuel Feed Pump

Mounted part	Thread Diameter × Pitch (M-thread) mm [in.]	Width across flats mm [in.]	Tightening torque			Remarks
			N·m	kgf·m	lbf·ft	
Priming pump cap ①	—	—	—	—	—	Note (a)
Priming pump ②	M16 × 1.5 [0.63 × 0.059]	24 [0.94]	39 to 44	4.0 to 4.5	29 to 33	
Adaptor ③	M24 × 1.5 [0.94 × 0.059]	26 [1.42]	49 to 59	5 to 6	36 to 43	
Plug ④	M26 × 1.5 [1.02 × 0.059]	27 [1.06]	78 to 88	8 to 9	58 to 65	
Fuel inlet eyebolt ⑤	M14 × 1.5 [0.55 × 0.059]	19 [0.79]	1.5 to 2.9	0.15 to 0.3	1.1 to 2.2	
Rack set screw ⑥	M14 × 1.5 [0.55 × 0.059]	19 [0.79]	1.5 to 2.9	0.15 to 0.3	1.1 to 2.2	

Note: (a) Refer to page 5-5 when retightening priming pump cap. Do not apply excessive tightening force to prevent damage and overtightening.



2.4 Turbocharger

Mounted part	Thread Diameter × Pitch (M-thread) mm [in.]	Width across flats mm [in.]	Tightening torque			Remarks
			N·m	kgf·m	lbf·ft	
Turbine housing mounting bolts	10 × 1.5 [0.394 × 0.059]	14 [0.551]	21.6 to 25.5	2.2 to 2.6	15.93 to 18.81	Apply Moly Disulfide to thread
V-clamp mounting nut			9.8 to 10.8	1.0 to 1.1	7.2 to 8.0	Apply Moly Disulfide to thread
Compressor wheel tightening nut	Left1/2UNF-20	24 [0.945]	* Angle-of-turn method (refer to the explanation below) * If not possible to use angle-of-turn method, use torque method.			Apply Loctite to thread.
			86.3 to 90.2	8.8 to 9.2	63.65 to 66.56	

Note: Left-handed threads.

Angle-of-turn tightening method for compressor wheel nut (note: left-handed thread)

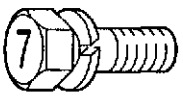
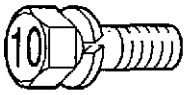
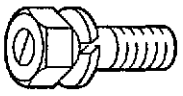
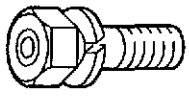
(1) Clean the threads of the lock nut and shaft to remove oil and grease.
(2) Tighten the lock nut to torque T1, then loosen the nut.
(3) Apply Loctite No. 962T to the threads of the lock nut or shaft.
(4) Tighten the lock nut to torque T2.
(5) Further tighten the nut by angle θ.

T1=69 N·m (7 kgf·m) [51 lbf·ft]
T2=9.8 N·m (1kgf·m) [7.2 lbf·ft]
θ=90 ± 3°

⚠CAUTION

(1) When loosening or tightening the nut, do not apply bending or pressing force on the shaft.
(2) Do not repeat the above tightening procedure more than 10 times with the same nut.
(3) Do not use the nut if it has dints or burrs on the seating surface.

2.5 Standard Bolts and Nuts

	Thread Diameter × Pitch, mm [in.]	Width across flats, mm [in.]	Strength classification					
			7T			10.9		
			N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
Metric automobile screw thread								
	M8 × 1.25 [0.31 × 0.049]	12 [0.47]	17	1.7	12	30	3.1	22
	M10× 1.25 [0.39 × 0.049]	14 [0.55]	33	3.4	25	60	6.1	44
	M12× 1.25 [0.47 × 0.049]	17 [0.67]	60	6.1	44	108	11.0	80
	M14× 1.5 [0.55 × 0.059]	22 [0.87]	97	9.9	72	176	17.9	129
	M16× 1.5 [0.63 × 0.059]	24 [0.94]	145	14.8	107	262	26.7	193
	M18× 1.5 [0.71 × 0.059]	27 [1.06]	210	21.4	155	378	38.5	278
	M20× 1.5 [0.79 × 0.059]	30 [1.18]	291	29.7	215	524	53.4	386
	M22× 1.5 [0.87 × 0.059]	32 [1.26]	385	39.3	284	694	70.8	512
	M24× 1.5 [0.94 × 0.059]	36 [1.42]	487	49.7	359	878	89.5	647
	M27× 1.5 [1.06 × 0.059]	—	738	75.3	544	1328	135.5	980
Metric course screw threads								
	M10× 1.5 [0.39 × 0.059]	14 [0.55]	32	3.3	24	58	5.9	43
	M12× 1.75 [0.47 × 0.069]	17 [0.67]	57	5.8	42	102	10.4	75
	M14× 2 [0.55 × 0.079]	22 [0.87]	93	9.5	69	167	17.0	123
	M16× 2 [0.63 × 0.079]	24 [0.94]	139	14.2	103	251	25.6	185
	M18× 2.5 [0.71 × 0.098]	27 [1.06]	194	19.8	143	350	35.7	258
	M20× 2.5 [0.79 × 0.098]	30 [1.18]	272	27.7	200	489	49.9	361
	M22× 2.5 [0.87 × 0.098]	32 [1.26]	363	37.0	268	653	66.6	482
	M24× 3 [0.94 × 0.12]	36 [1.42]	468	47.7	345	843	86.0	622
	M27× 3 [1.06 × 0.12]	—	686	70.0	506	1236	126.0	911

Remarks: (a) This table lists the tightening torque for the standard nuts and bolts.
(b) The numerical values in this table are for when using spring washers.
(c) This table shows the standard values with a maximum tolerance value of ±10%.
(d) Except for special tables, tightening torque should be done using this table.
(e) Don't apply oil to screws (Dry).

2.6 Standard Eyebolts

Threads Diameter × Pitch, mm [in.]	Width across flats, mm [in.]	Strength classification		
		4T		
		N·m	kgf·m	lbf·ft
M8 ×1.25 [0.31 × 0.049]	12 [0.47]	8±1	0.8±0.1	5.8±0.72
M10 × 1.25 [0.39 × 0.049]	14 [0.55]	15±2	1.5±0.2	10.8±1.45
M12 × 1.25 [0.47 × 0.049]	17 [0.67]	25±3	2.5±0.3	18.1±2.17
M14 × 1.5 [0.55 × 0.059]	19 [0.75]	34±4	3.5±0.4	25.3±2.89
M16 × 1.5 [0.63 × 0.059]	22 [0.87]	44±5	4.5±0.5	32.5±3.62
M18 × 1.5 [0.71 × 0.059]	—	74±5	7.5±0.5	54.2±3.62
M20 × 1.5 0.79 × 0.059]	27 [1.06]	98±10	10.0±1.0	72.3±7.23
M22 × 1.5 [(0.87 × 0.059]	32 [1.26]	147±15	15.0±1.5	108.5±10.8
M24 ×1.5 [0.94 × 0.059]	—	226±20	23.0±2.0	166.3±14.5

(Dry)

2.7 Standard Union Nuts

Nominal Diameter	Cap nut size mm [in.]	Width across flats mm [in.]	N·m	kgf·m	lbf·ft
63	M14 × 1.5 [0.55 × 0.059]	19 [0.75]	39	4	29
80	M16 × 1.5 [0.63 × 0.059]	22 [0.87]	49	5	36
100	M20 × 1.5 [0.79 × 0.059]	27 [1.06]	78	8	58
120	M22 × 1.5 [0.87 × 0.059]	30 [1.18]	98	10	72
150	M27 × 1.5 [1.06 × 0.059]	32 [1.26]	157	16	116
180	M30 × 1.5 [1.18 × 0.059]	36 [1.42]	196	20	145
200	M30 × 1.5 [1.18 × 0.059]	36 [1.42]	196	20	145
220	M33 × 1.5 [1.30 × 0.059]	41 [1.61]	245	25	181
254	M36 × 1.5 [1.42 × 0.059]	41 [1.61]	294	30	217

(Dry; maximum tolerance value of ± 10%)

2.8 High-pressure Fuel Injection Pipes

Cap nut size mm [in.]	N·m	kgf·m	lbf·ft
M12 × 1.5 [0.49 × 0.059]	39±5	4±0.5	29±3.6
M14 × 1.5 [0.55 × 0.059]	49±5	5±0.5	36±3.6
M18 × 1.5 [0.71 × 0.059]	59±1	6±1.0	43±7.2

(Dry)

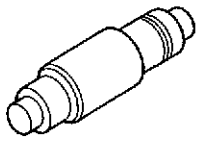
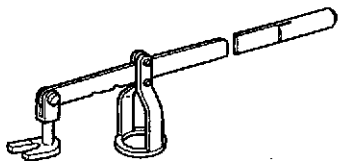
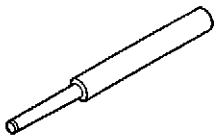
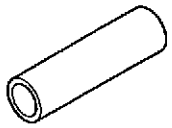
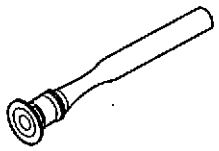
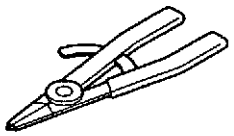
3. Sealants and Lubricants Table

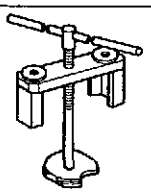
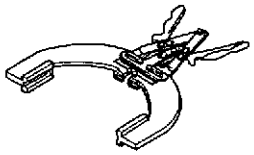
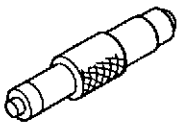
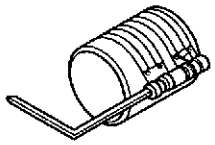
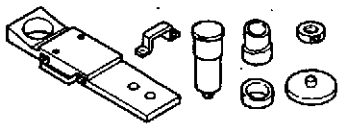
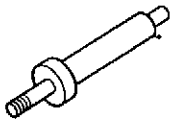
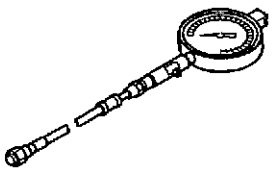
Group	Application point		Sealant or lubricant	How to use
Engine main parts	Cylinder head sealing caps		Hermeseal S-2 or Hermelock 510	Coat holes in crankcase, Note (a)
	Water outlet connectors (Rocker case)		Grease	Grease O-ring joint
	Cylinder liners		Engine oil	Grease O-ring joint
	Front cover, oil pan, and crankcase		Herdite	Coat three-face-mating portions
	Rear plate, gear case, oil pan, and crankcase		Herdite	Coat three-face-mating portions
	Crankcase taper plugs		Seal-lock, Loctite (made by Three Bond)	Apply to threads
	Crankcase sealing cap		Three Bond 1211	Coat holes in crankcase
	Oil pan and crankcase		Herdite	Coat joint portions only on both sides of packing
	Oil seals		Engine oil	Coat lip of each oil seal
	Rear plate, timing gear case and crankcase		Three Bond 1211	Coat both sides of packing, Note (b)
	Front cover and crankcase		Three Bond 1211	Coat both sides of packing, Note (b)
	Fan drive case and fan plate		Three Bond 1211	Coat both sides of packing, Note (b)
	Cylinder head gasket		Three Bond 1211	Apply to areas around tappet chambers, Note (b), (c)
Cooling system	Water pump	Oil seal	Engine oil	Coat lip of inner seal
		Unit seal	LLC solution (antifreeze)	Coat floating seat
	Fan drive	Oil seal	Engine oil	Coat lip of each oil seal
Inlet system	Air cooler	Between the element and the both side of plate	Shin-Etsu Chemical Co., Ltd KE45-W or a similar sealant or lubricant.	Fill the gap between the element and the plate.
Others	Taper plugs and cocks not precoated with Three Bond thread sealants.		Seal tape	Wrap threads with 2 rounds of tape. Do not seal tape on hot exhaust parts.

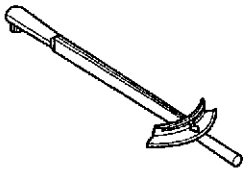
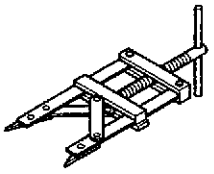
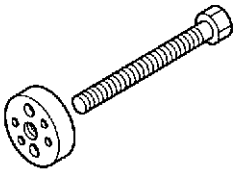
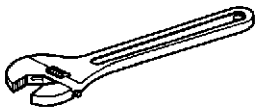
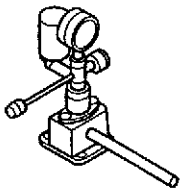
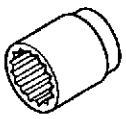
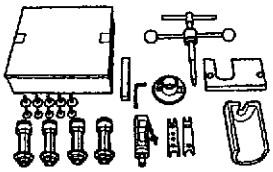
Note: (a) When the use of Hermeseal S-2 or Hermelock 510 is specified, be sure to use the designated liquid sealant manufactured by Japan Hermetic Co., Ltd.
(b) Never use ThreeBond 1121 at locations where the use of ThreeBond 1211 is specified.
(c) For the method of applying a sealer to cylinder gaskets, refer to page 7-13.
(d) Seal-lock is a coating agent that also provides a sealing function. Mec-coat is a coating sealer with sealing and locking functions. (manufacturer: ThreeBond)
(e) ThreeBond 1211 or 1121 may be used to hold O-rings in place (fall prevention).

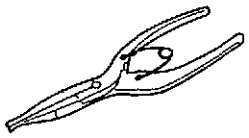
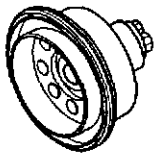
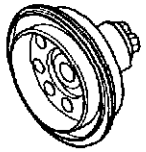
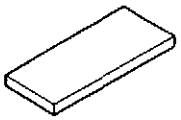
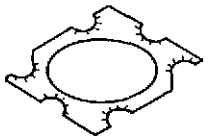
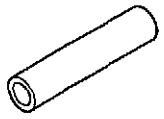
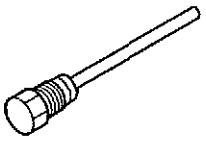
SPECIAL AND BASIC TOOLS

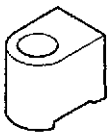
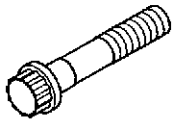
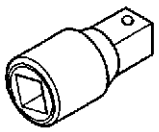
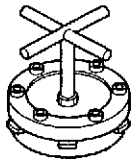
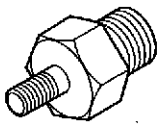
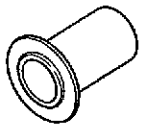
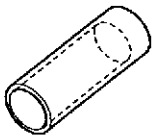
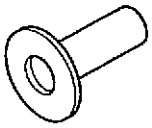
1. Special Tool List

Tool name	Part No.	Shape	Use
Rocker bushing tool	37591-02600		Rocker bushing installation/ removal
Eye nut	37591-02400		Cylinder head lifting
Valve spring pusher	33591-04500		Valve spring removal/ installation
Valve guide remover	33591-04300		Valve guide removal
Valve guide and seal installer	37191-01500		Valve guide and valve stem seal installation
Valve lapper	30091-08800		Valve lapping
Ring pliers	45191-08400		Snap ring removal/ installation

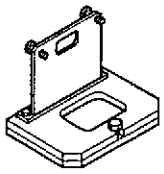
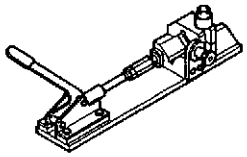
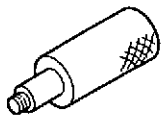
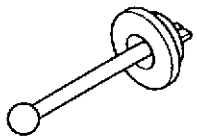
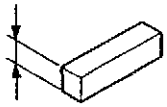
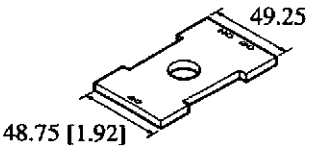
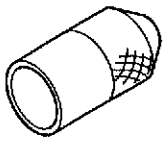
Tool name	Part No.	Shape	Use
Cylinder liner remover	37591-04100		Cylinder liner removal
Piston ring tool	37191-03200		Piston ring removal/installation
Idler bushing puller	32591-02500		Front idle bushing removal/ installation
Piston installer	37191-07100		Piston installation
Connecting rod bushing installer	37591-01010		Connecting rod bushing removal/installation
Gage adaptor	37591- 02200		Compression pressure measurement
Compression gage	33391-02100		Compression pressure measurement
Socket	58309-73100		For removal/installation of fandrive shaft gear, coupling, injection pump gear, and water pump shaft pulley nut.

Tool name	Part No.	Shape	Use
Torque wrench	32191-03100		Measuring range, 0 to 539 N·m (0 to 55 kgf·m) [0 to 398 lbf·ft]
Piston remover	MM321420		Piston lifting
Water pump pliers	37591-03100		For water pump cover snap ring
Impeller remover	37591-03200		Water pump impeller removal
Adjustable wrench	F9611-15000		Width across flats 20 mm [0.79 in.] or less
Nozzle tester	83091-03301		Nozzle opening pressure measurement
Socket	37591-03500		Square 19 × 27 mm [0.75 × 1.06 in.] width across flats
Valve seat puller	32591-04200		Valve seat removal

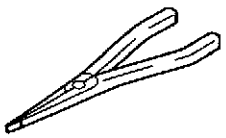
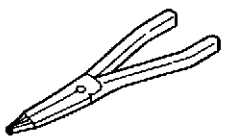
Tool name	Part No.	Shape	Use
Pliers	49160-90301		Snap ring (F3200-04500) removal/installation
Tool box	49160-90501		75×203×360 mm [2.95×7.99×14.17 in.]
Front seal installer assembly	37591-05010		Front oil seal installation
Rear seal installer assembly	37791-06010		Rear oil seal installation
Projection plate	37598-09201		Crankcase counter bore depth measurement
Head bolt plate	37598-08900		Head-bolt tightening through an angle
Head bolt spacer	37598-09100		Spacer used for tightening liner pusher with head bolt
Valve seat cutter shaft	37591-06400		Valve seat contact surface adjustment
Valve seat cutter	37591-06430		

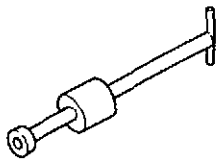
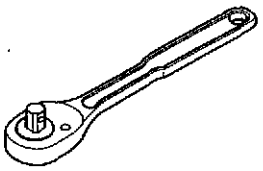
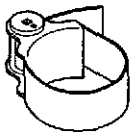
Tool name	Part No.	Shape	Use
Liner pusher	37591-06200		Liner retainment
Bolt	37591-06300		
Extension bar	37591-03600		Male 19 × Female 19 [0.748 × 0.748 in.]
Cylinder grinder	37591-07010		For correction of right/left depth of liner shelf in cranckase
Adapter	37591-04300		For removal of main bearing cap M20 × M10 [0.787 × 0.394 in.]
Oil seal installer	32591-03100		For installation of fan drive oil seal
Bearing installer	32691-04200		For press-fitting of fan drive bearing
Bearing installer	32691-04300		

Fuel injection pump

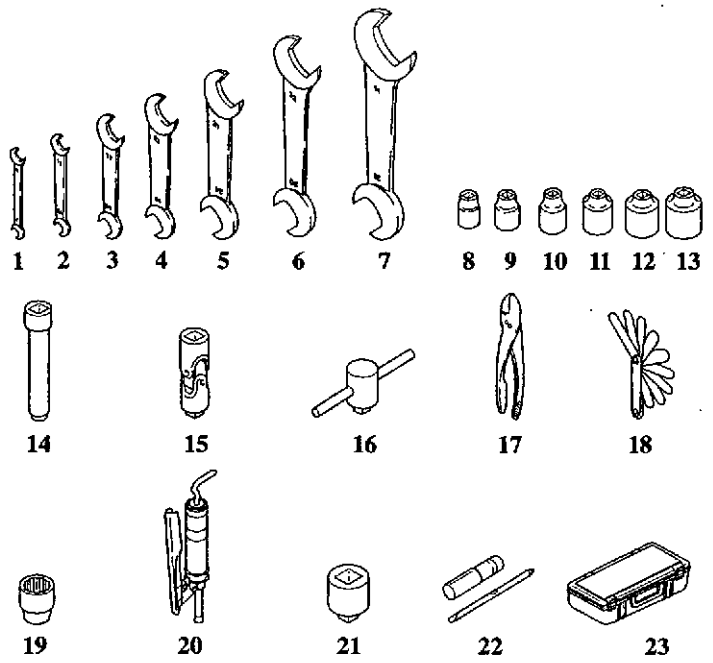
Tool name	Part No.	Shape	Use
Pump assembly stand	48291-00100		For disassembly and reassembly of pump
Plunger spring compression jig	48291-00200		For removal of plunger spring
Plunger holder	48291-00301		For removal of plunger spring (6 holders required for PS6, and 8 holders of PS8)
Cam thrust ejector	48291-00400		For measurement of camshaft thrust clearance
Stopper plate	48291-00500	Square = 11 mm [0.43 in.] 	For prevention of damage to pinion and rack during barrel installation
Injection coupling gage	37591-06100		Injection pump coupling connection
Sleeve installer	48202-09301		For installation of oversized sleeve on camshaft

Turbocharger

Tool name	Part No.	Shape	Use
Pliers	49160-90101		Snap ring (49162-23200) removal/installation
Pliers	49160-90110		Snap ring (49129-23100) removal/installation

Tool name	Part No.	Shape	Use
Nozzle remover	33591-10101		Injection nozzle removal
Rachet handle	37191-03300		For socket
Oil filter wrench	32591-22100		Oil filter and fuel filter installation/removal

2. Basic Tool List



No.	Tool name	Part No.	Remarks
—	Tool set	32591-00012	Includes parts No. 1 through 23
1	Open-end wrench	F9600-07008	Width across flats: 7 × 8 mm [0.28 × 0.31 in.]
2	Open-end wrench	F9600-10012	Width across flats: 10 × 12 mm [0.39 × 0.47 in.]
3	Open-end wrench	F9600-14017	Width across flats: 14 × 17 mm [0.55 × 0.67 in.]
4	Open-end wrench	F9600-19022	Width across flats: 19 × 22 mm [0.75 × 0.87 in.]
5	Open-end wrench	F9600-24027	Width across flats: 24 × 27 mm [0.9 × 1.06 in.]
6	Open-end wrench	F9600-30032	Width across flats: 30 × 32 mm [1.18 × 1.26 in.]
7	Open-end wrench	F9600-36041	Width across flats: 36 × 41 mm [1.42 × 1.61 in.]
8	Socket	F9614-17000	Width across flats: 17 mm [0.67 in.]
9	Socket	F9614-22000	Width across flats: 22 mm [0.87 in.]
10	Socket	F9614-24000	Width across flats: 24 mm [0.95 in.]
11	Socket	F9614-27000	Width across flats: 27 mm [1.06 in.]
12	Socket	F9614-30000	Width across flats: 30 mm [1.18 in.]
13	Socket	F9614-32000	Width across flats: 32 mm [1.26 in.]
14	Extension bar	F9615-25000	12.7 [0.50 in]- square drive, L=250 mm [9.84 in.]
15	Universal joint	F9617-10000	12.7 [0.50 in.]- square drive, L=75 mm [2.95 in.]
16	Slide handle	F9618-30000	12.7 [0.50 in.]- square drive, L=300 mm [11.81 in.]
17	Pliers	F9630-15000	L=150 mm [5.91 in.]
18	Thickness gages	30091-06501	Set of 9 gages, 0.04 mm [0.002 in.] to 0.30 mm [1.18 in.]
19	Socket	33491-13500	Width across flats: 36 mm [1.42 in.]
20	Grease pump	64309-15300	Capacity: 0.08 ℓ [0.0211 U.S. gallons]
21	Adapter	33491-03600	19.15 × 12.7 mm [0.75 × 0.500 in.] square drive
22	Screwdriver	91267-00201	Slotted and Phillips ends
23	Tool box	MC420083	352 mm [13.9 in.] (L) 146 [5.75 in.](W) 82 mm [3.23 in.] (H),weight capacity: 7 kg [15.4 lb.] or less

OVERHAUL INSTRUCTIONS

1. Determination of Overhaul Timing

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Work related to the exhaust emission regulations can be conducted only at our designated service factories.

In most cases the engine should be overhauled when the engine's compression pressure is low. Other factors that indicate an engine overhaul is required are as follows:

(a) Reduced power

(b) Increased fuel consumption

(c) Increased engine oil consumption

(d) Increased blow-by gas volume through the breather due to abrasion at the cylinder liner and the piston ring

(e) Gas leakage due to poorly adjusted seating of the suction and the discharge valves

(f) Starting problems

(g) Increased noise from engine parts

(h) Abnormal color of exhaust gas from engine after warm-up

Any one or a combination of these symptoms may indicate that engine overhaul is required; they may also indicate other problems of non-related causes. Of the items listed above some directly relate to deterioration of the engine while others do not. Items (b) and (f) are more likely to be affected substantially by

- Injection volume of the fuel injection pump
- Fuel injection timing
- Abrasion at the plunger
- Fitting of the injection nozzle
- Condition of electrical equipment: battery, starter, or alternator.

Item (d) above, however, requires special consideration because decreased pressure due to abrasion at the cylinder liner and the piston ring is one of the most obvious signs that the engine requires overhauling.
The most effective way to make a determination is by testing the compression pressure; other factors are to be considered secondarily.

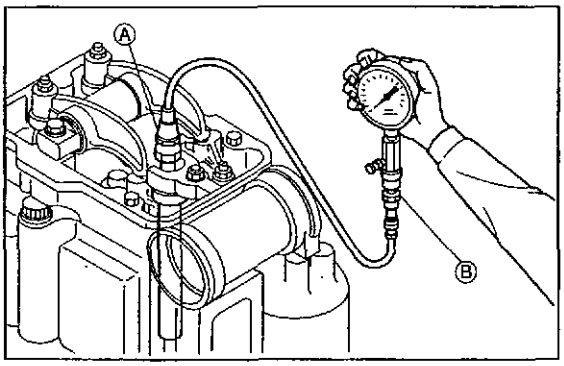
2. Testing the Compression Pressure

(1) Remove the injection nozzle from the cylinder where the compression pressure is to be measured.

(2) Attach the compression gage adapter Ⓐ (3759-02200) to the cylinder and connect compression gage Ⓑ (35A91-03100) to the adaptor.

(3) Crank the engine with the starter, then read the compression gage indication while the engine is running at the specified speed.

(4) If the compression pressure is lower than the repair limit, overhaul the engine.



⚠CAUTION

(a) Measure the compression pressure on all cylinders. It is not a good practice to measure the compression pressure on only two or three cylinders, then make a judgment about the compression on the remaining cylinders.
(b) Compression pressure varies with changes in engine speed.
Check engine speed when measuring compression pressure.
(c) When cranking the engine using starter, cut the fuel.

Unit:MPa (kgf/cm²) [psi]

Item	Assembly Standard	Repair Limit
Compression pressure	1.8 (18.5) [263] or more	1.27 (13.0) [185] or less

NOTE

Measure the compression pressure with the engine running at 120 min^{-1}.

⚠CAUTION

It is important to periodically measure the compression pressure and know its change.
(a) The compression pressure will be slightly higher in a new or overhauled engine.
(b) The compression pressure will decrease to the assembly standard with the run-in of the piston rings and valve seats.
(c) The compression pressure will drop gradually with the wear of these parts.

ADJUSTMENTS, BENCH TESTING, PERFORMANCE TESTS

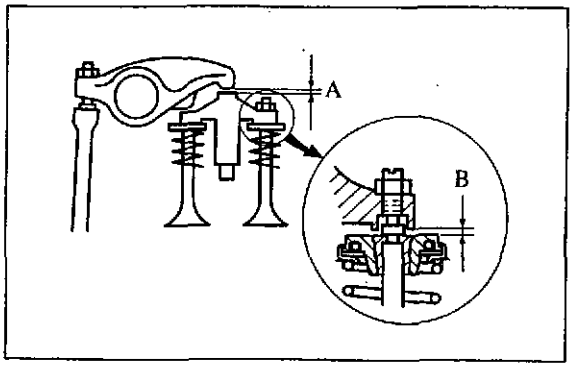
1. Adjustments

1.1 Valve Clearance

Valve clearance should be inspected and adjusted when the engine is cold.

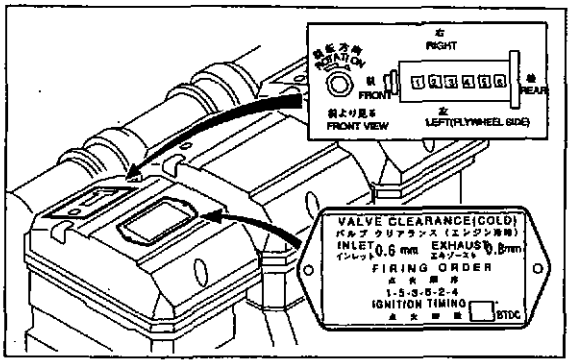
Unit: mm [in.]

Item		Assembly Standard
Valve clearance (A)	Inlet valves	0.6 [0.024]
	Exhaust valves	0.8 [0.031]



NOTE

(a) The bridge-to-valve rotator clearance (B) should be more than 1.5 mm [0.059 in.] after the front and rear valve heights have been adjusted. If the clearance is too small, grind the bridge to obtain the specified clearance.
(b) The inlet valve is on the left and the exhaust valve on the right when you are facing the cylinder head.
(c) The valve clearance standard is also indicated on the caution plate on the rocker cover of cylinder No. 1.

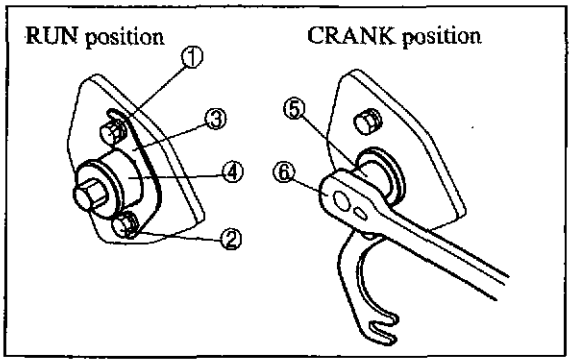


(1) Inspecting valve clearance

(a) Inspect the valve clearance in the firing order by turning the crankshaft (120°) in the direction of normal rotation to bring the piston to top dead center of the compression stroke.

Firing order

Cylinder No.	1-5-3-6-2-4



NOTE

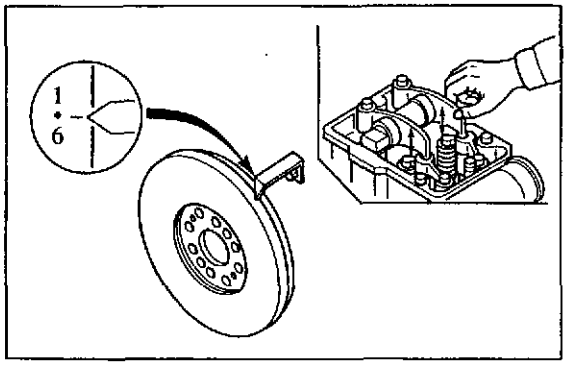
Note these points when using the turning gear
(a) Loosen bolts ① and ②. Remove the plate ③ from the slot of the shaft ④.
Push the shaft ④ until it reaches its limit.
(b) Make the shaft ④ turn by rotating it with the socket ⑤ and the ratchet handle ⑥.
(c) After completing the turn, pull out the shaft ④. Insert the plate ③ into the slot of the shaft ④. Tighten the bolts ① and ②.
Check and be sure the plate ③ is inserted into the slot of the shaft ④.

Injection firing interval	0° -120° -240° -360° -480° - 600°

⚠CAUTION

Set the turning gear at the run time condition before you start the engine.

(b) The top dead center on the compression stroke of the piston is identified by the timing mark (provided on the torsional vibration damper), aligned with the pointer. With the piston so located, the inlet and exhaust valve rocker arms are not pushed up by their push rods.

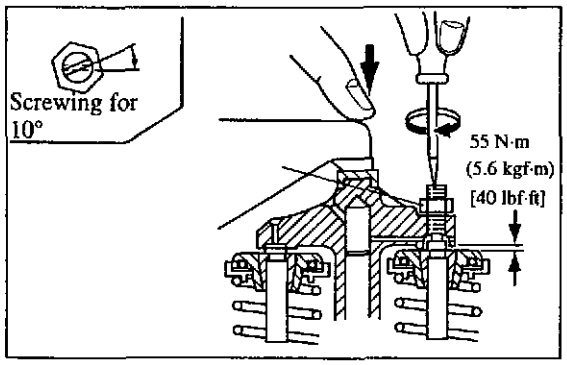


(c) Insert a feeler gage in between the rocker arm and bridge cap, and inspect the valve clearance.

(2) Adjusting front and rear valve heights by the valve bridge

(a) Before adjusting the valve clearance, adjust the front and rear valve heights by means of the bridge (bring the bridge into contact with the valves). If the valve seats are worn, valve heights will differ, causing variations between stem tops and bridges.

(b) To adjust valve height, loosen the lock nut, then back off the adjusting screw.



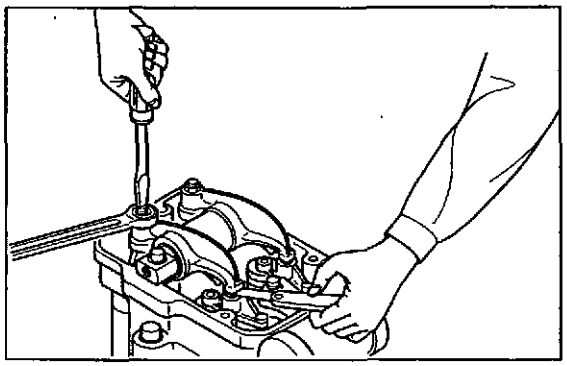
(c) Holding the rocker arm with your fingers, slowly screw in the adjusting screw until it touches the valve stem top. After looking into the hole of the bridge to check that the screw is in contact with the stem top, turn the screw about 10° of one turn, and tighten the lock nut.

NOTE

If the valve clearance between the bridge and valve rotator is less than specified, the valve cotters may come off. Be sure to maintain the clearance of the specified valve or more.

(3) Adjusting valve clearance

(a) Insert a feeler gage between the rocker arm and bridge cap, then adjust the clearance by turning the screw in either direction to the extent that the gage is gripped slightly between the rocker arm and bridge cap.



(b) After adjusting the clearance, tighten the lock nut. Inspect the clearance again and make sure that it is correct.

1.2 Fuel System Priming

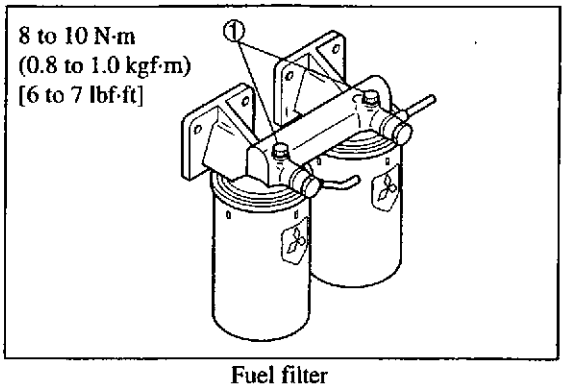
First prime the fuel filters, then prime the fuel injection pumps.

(1) Fuel filter

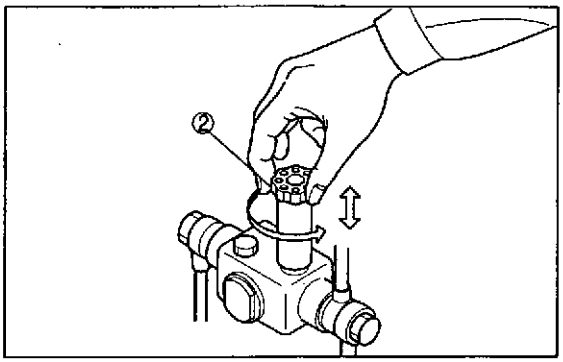
(a) Loosen the vent plug ① by turning it about 1.5 rotations.

(b) Unlock the priming pump handle ② by turning it counterclockwise. Operate the priming pump by moving the handle up and down.

(c) Tighten the air vent plug when fuel flows from the vent hole without bubbles.



Fuel filter



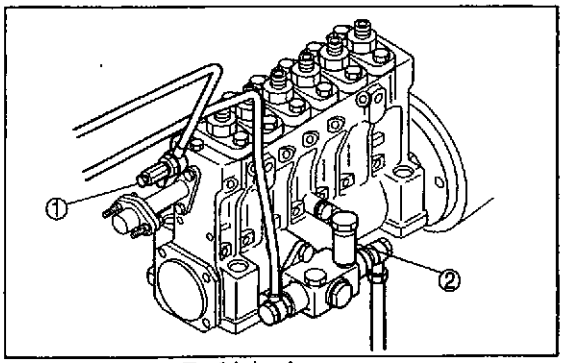
Priming pump

(2) Fuel injection pumps

(a) Loosen the air vent plug ① by turning it about 2 rotations.

(b) Operate the priming pump handle ②.

(c) Tighten the air vent cock when fuel flows from the vent hole without bubbles. Lock the priming pump by turning its handle clockwise while pushing it down before tightening the last vent plug.



Fuel injection pump

NOTE

(a) If the vent plugs are tightened before the priming pump Handle is locked, fuel pressure acts on the feed pump, making it impossible to restore the Handle.
(b) Use a cloth to wipe off fuel spilled from the vent holes.

(3) Tightening priming pump cap

(a) Tighten the priming pump cap by hand, and stop turning immediately after the tightening force suddenly increases.

NOTE

Mark the priming pump cap in this position to facilitate the following procedure.

(b) After step (a), further turn the priming pump cap by 90° ± 10° using a wrench.

NOTE

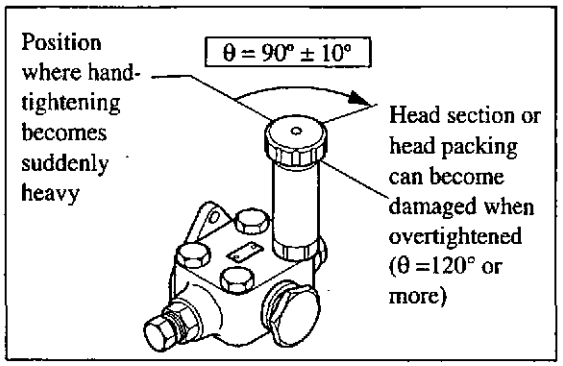
After tightening the priming pump cap, check that the priming pump head packing is not projecting.

⚠CAUTION

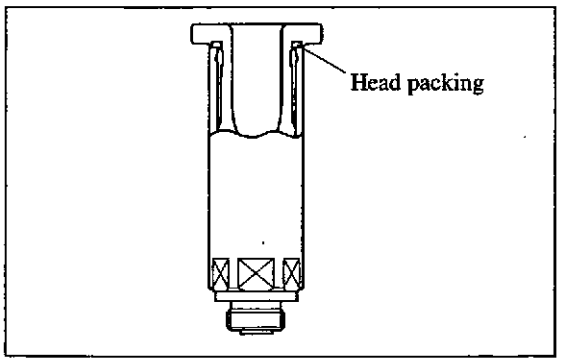
Be sure to tighten the priming pump cap according to the specified angle (θ = 90° ± 10°). If the priming pump cap is not tightened firmly, engine operations can result in the wear of internal threads. This can cause the priming pump cap to eject and fuel to flow out.
If the priming pump cap is tightened with excessive force (θ = 120° or more), the head section of the priming pump can become damaged.

⚠CAUTION

(a) If the head packing is projecting, check that it is not damaged. Loosen the air vent plug of the fuel injection pump, and retighten the priming pump cap.
(b) If the head packing is broken due to projection, change the priming pump or fuel feed pump.



Fuel feed pump

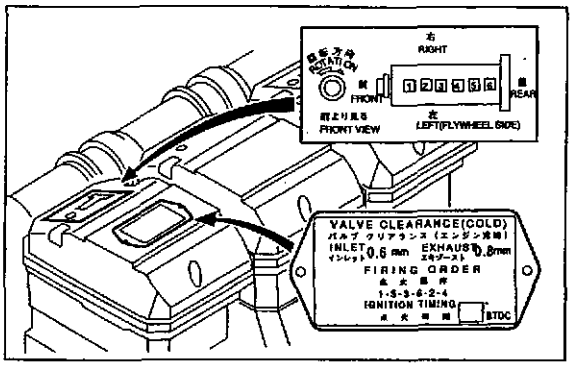


Cross section of priming pump

1.3 Fuel Injection Timing

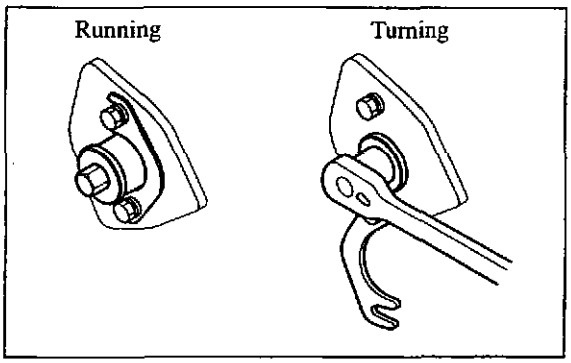
(1) Fuel injection timing and indication

The injection timing is stamped on the caution plate attached to the No. 1 rocker cover. Be sure to verify the timing by referring to this caution plate. The injection timing for each engine model varies according to its output, speed, and specifications.



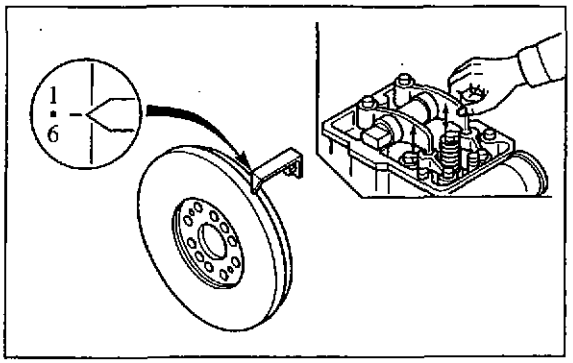
(2) Confirming the position of the No. 1 piston's top dead center on the compression stroke

(a) Use the ratchet handle to turn in the normal direction.



(b) Stop turning when the timing mark (1•6) on the torsional vibration damper is aligned with the pointer.

(c) Move the No. 1 cylinder inlet and exhaust valve rocker arms up and down to make sure that they are not being pushed up by their push rods.

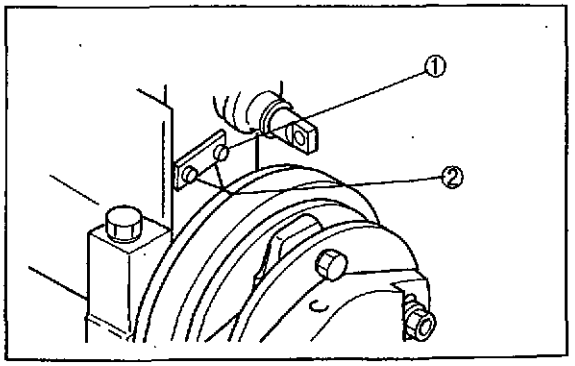


⚠CAUTION

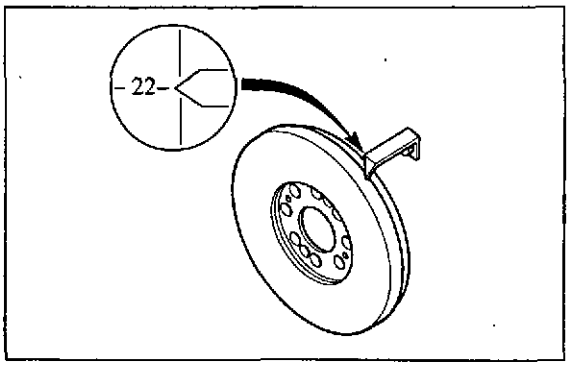
Do not confuse the top dead center on the compression stroke for No. 1 cylinder with that for the No. 6 cylinder.

(3) Inspecting fuel injection timing

(a) Turn the crankshaft once about 60° in the reverse direction. Turn it a little at a time in the normal direction to align the timing mark ② on the pump drive coupling with the pointer ① on the pump case.



(b) Read the degrees of an angle (injection timing) on the scale on the vibration damper, indicated by pointer. Minus (–) mark on the scale and caution plate means "BEFORE" top dead center.

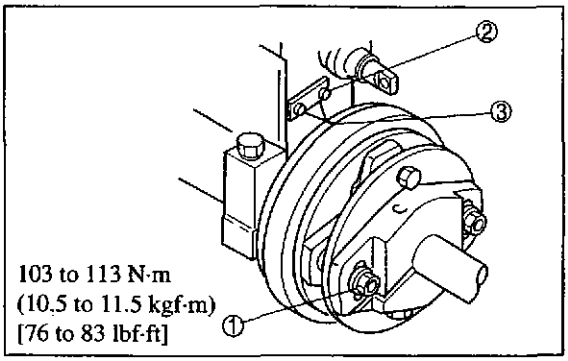


(4) Adjusting fuel injection timing

(a) Make sure that the timing mark for No. 1 cylinder on the damper is aligned with the pointer.

(b) Loosen two coupling (laminated plate) bolts ①, and displace the injection pump to align pointer ② on the pump case with timing mark ③ on the flywheel. Then, tighten one bolt to the specified torque and, after turning the crankshaft, similarly tighten the other.

(c) Again inspect the timing by cranking the engine for verification.



1.4 Idling Speed and Maximum Speed Setting Inspection and Adjustment

⚠CAUTION

(a) No-load minimum (idling) speed and maximum speed are set for each engine on the test bench at the factory and the set bolts are sealed. These settings must be checked and adjusted at our designated service shop.

(b) After authorized adjustment of the governor, which has to be effected by breaking the seals, be sure to re-seal all visible stoppers, making them appear as if they were sealed at the factory.

(c) The stoppers to be sealed are specified. Whether the seals are intact or not has important bearing on the validity of claims, if any, under warranty.

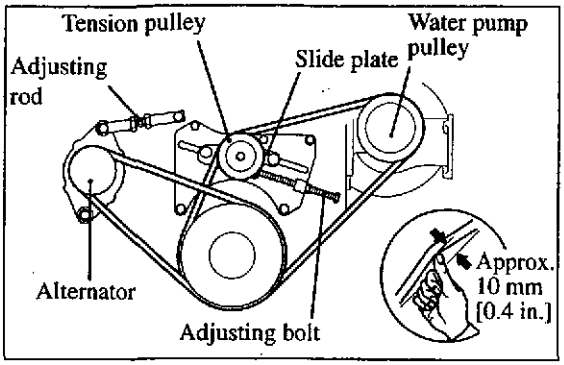
(d) When checking and adjusting these settings, be on standby to operate the engine stop lever manually in the event of engine overrun.

NOTE

For inspection and adjustment, warm up the engine thoroughly until the coolant and oil temperature rises to 70°C [158°F] or higher.

1.5 Inspecting and Adjusting Water Pump and Alternator Drive Belt

With your thumb apply pressure 98 to 147 N (10 to 15 kgf) [22 to 33 lbf] approx. to the belt midway between the pulleys to insoect the belt tension. If the tension is incorrect, adjust it using adjusting bolt Ⓐ and turnbuckle Ⓑ.



Unit: mm [in.]

Item	Assembly Standard
Water pump belt deflection	10 to 15 [22 to 33.1]
Alternator belt deflection	10 to 15 [22 to 33.1]

NOTE

Be sure the drive belt tension is not excessively tight.

2. Bench Testing

An overhauled engine should be tested for performance on a dynamometer. This test is also for breaking in the major running parts of the engine. To test the engine, follow the procedures described below:

2.1 Starting Up

(1) Inspect the levels in the radiator, oil pan, and fuel tank. Prime the fuel and cooling systems to bleed air out.

(2) Turn the SP trimmer fully to the left.

(3) Crank the engine with the starter for about 10 seconds to permit lubricating oil to circulate through the engine. For this cranking, do not supply fuel to the engine, placing the stop lever in stop position.

(4) While operating the starter to crank the engine, slowly turn the SP trimmer to the right. After the engine starts, set the SP trimmer so that the engine operates at specified idling speed.

2.2 Inspection After Starting Up

After starting up the engine, check the following points. If you find anything wrong, immediately stop the engine, then investigate the cause.

(1) Lubricating oil pressure should be 0.49 to 0.59 MPa (5 to 6 kgf/cm²) [71 to 85 psi] at rated speed or over 0.20 to 0.29 MPa (2 to 3 kgf/cm²) [28 to 43 psi] at idling speed.

(2) Coolant temperature should be 70 to 90 °C [158 to 194 °F].

(3) Lubricating oil temperature should be in the range of 70 to 110°C [158 to 230°F] when measured in the oil pan.

(4) Check for leakage of oil, coolant, fuel, especially oil leakage from oil pipe connections for turbocharger lubrication.

(5) Knocking should die away as coolant temperature rises. No other defective noise should be heard.

(6) Check for exhaust color and abnormal odors.

2.3 Bench Testing (Dynamometer) Conditions

Here is a summary table of bench testing conditions.

Step	Speed (min^{-1})	Load (kW(PS))	Time (min.)
1	Idling	No load	5
2	1000	No load	5
3	1200	No load	10
4	Rated (varies depending on specifications)	25%	10
5		50%	10
6		75%	30
7		100%	20

Rated speed: Varies according to specifications.

2.4 Inspection and Adjustments After Bench Testing

(a) Adjusting valve clearance

(b) Adjusting injection timing

(c) Re-tightening external bolts and nuts

3. Performance Tests

There are various performance test procedures, and here the procedures for "Earth moving machinery Engines, Part 1 : Test code of net power (JIS D 0006-1)" and "Earth moving machinery Engines, Part 2 : standard format of specifications and tests methods of diesel engines (JIS D 0006-2)" are described. Other test items may be required on application. Engine performance is judged with integrated test results.

3.1 Engine Equipment Condition

Engine must be equipped with such standard auxiliaries as cooling fan, air cleaner and alternator.

3.2 Tests and Their Purposes

(1) Operation load test

Conduct this test to evaluate engine output, torque, fuel consumption rate and governor performance under various load conditions.

(2) Continuous load test

Operate the engine continuously for 10 hours at 90% load (continuous load application) of nominal net brake power while engine speed is maintained at revolutions corresponding to the nominal brake power. In this test, evaluate fuel consumption rate and operating condition and confirm continuous engine operation.

(3) No-load minimum idle speed test

Conduct this test to confirm that the engine can operate stably at the specified no-load minimum idle speeds.

3.3 Other Inspections

During performance testing, inspect for leakage of gases, coolant, lubricating oil, or fuel, and for noise or hunting. Make adjustment, as needed.

3.4 Adjustment Engine Output

Diesel engine output is affected by atmospheric pressure, temperature, and humidity. Therefore, the engine output should be set for standard atmospheric conditions.

(1) Standard atmospheric conditions

Base temperature	298 K (25°C) [77°F]
Atmospheric pressure	100 kPa [750 mmHg]
Atmospheric vapor pressure	99 kPa [743 mmHg]

(2) Calculation of corrected power

Multiply the measured brake power or torque by the calculated diesel engine correction factor (see below) to obtained a corrected value.

Corrected output = Correction factor (αc) × Measured brake power

• Atmospheric conditions for test

Temperature (T): 283 K (10°C) [50°F] ≦ T ≦ 313 K (40°C) [104°F]

Dry atmospheric pressure (Pd): 80 kPa (600 mmHg) ≦ Pd ≦ 110 kPa (825 mmHg)

(3) Calculation of correction factor (αc)

$\alpha c = (fa)^{fm}$

fa: Atmospheric factor fm: Engine factor

(a) Calculation of atmospheric factor (fa)

① Natural aspiration engine and engine with mechanically driven air charger

$$fa = \left(\frac{99}{Pd}\right) \cdot \left(\frac{T}{298}\right)^{0.7}$$

② Turbocharged engine without air cooler (after cooler) or with air-to-air cooler

$$fa = \left(\frac{99}{Pd}\right)^{0.7} \cdot \left(\frac{T}{298}\right)^{1.2}$$

③ Turbocharged engine with air-to-liquid cooler

$$fa = \left(\frac{99}{Pd}\right)^{0.7} \cdot \left(\frac{T}{298}\right)^{0.7}$$

(b) Calculation of engine factor (fm)

$fm = 0.036\,qc - 1.14$

① qc (Corrected fuel supply volume) $= \frac{q}{r}$

$$q = \frac{(z) \times (\text{Fuel flow rate g/s})}{(\text{Stroke volume } \ell) \times (\text{Engine idle speed min}^{-1})}$$

z = 120000 (4-cycle engine)

r: Ratio of pressure at turbocharger or air cooler to atmospheric pressure
(r = 1 for natural aspiration engine)

② Applicable range of engine factor (fm)

37.2 ≦ qc ≦ 65 mg/(ℓ-cycle)

• qc ≦ 37.2 mg/(ℓ-cycle) : fm = 0.2 (Constant)
• 65 mg/(ℓ-cycle) ≦ qc : fm = 1.2 (Constant)

(c) Range of correction equation use

The range of correction factor (αc) use is as follows: 0.9 ≦ αc ≦ 1.1.

If this range is exceeded, indicate the corrected value and record the test conditions on the test record sheet.

ENGINE AUXILIARY REMOVAL AND INSTALLATION

This section explains the procedures and tips for removal and installation of the auxiliaries – the preliminary process to go through for overhauling the engine.

1. Preparation

(a) Shut off the fuel supply, and disconnect the starting system from the engine.

(b) Loosen the drain cocks, on the left rear side of crankcase, and drain coolant.

(c) Loosen the oil pan drain plug, and drain engine oil.

Oil capacity:	approx. 82 liters [21.7 U.S. gal] (oil pan) approx. 92 liters [24.3 U.S. gal] (entire engine)

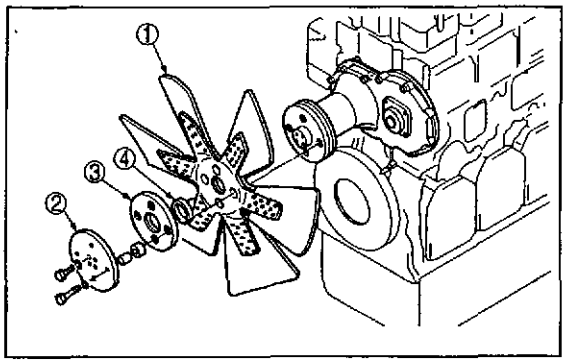
⚠WARNING

Hot engine oil can cause personal injury if it contacts the skin. Use caution when you drain the oil.

2. Engine Auxiliary Removal

(1) Removing fan

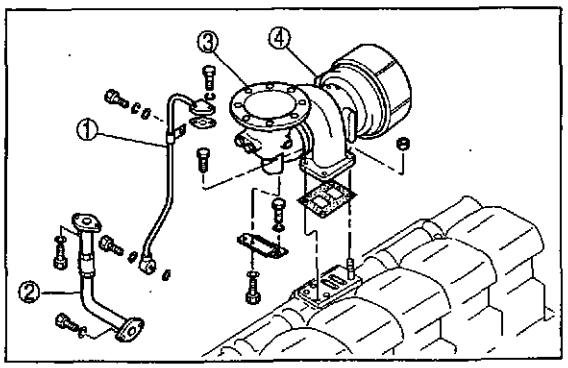
Unscrew fan mounting bolts, and remove fan ①, plate ②, friction rubber ③ and spacer ④.



(2) Removing turbocharger

(a) Disconnect turbocharger lubricating oil pipe ① and drain pipe ②.

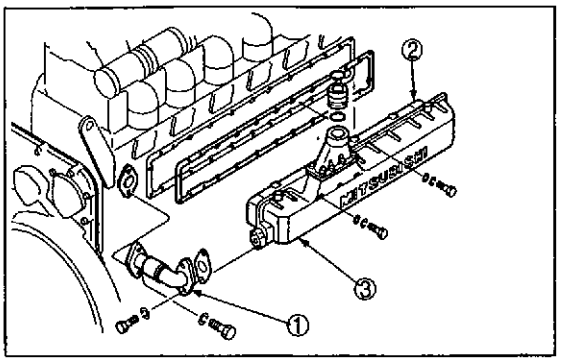
(b) Remove turbocharger ④ and exhaust pipe ③ as a set.



(3) Removing air cooler

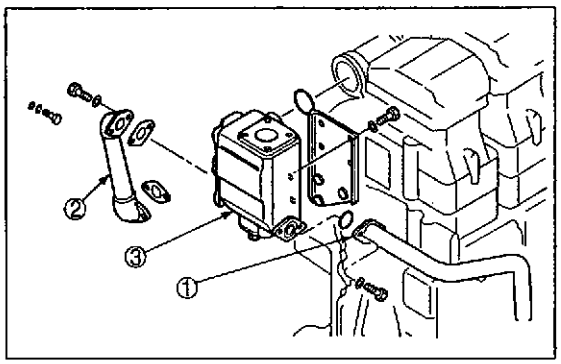
(a) Disconnect water pipes ①.

(b) Remove air cooler ② and air cooler cover ③ as a set.



(4) Removing thermostat case

Remove water bypass pipe ① and water pipe ②, then remove thermostat case ③.



(5) Removing exhaust manifolds

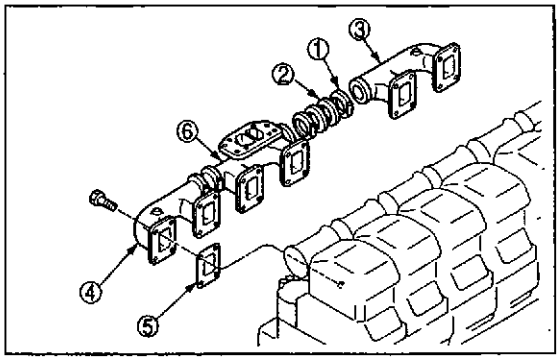
(a) Remove couplings ①and joints ②.

(b) Unscrew the bolts securing manifolds, and remove the manifolds ③④ and gaskets ⑤.

NOTE

When installing the manifolds, place each gasket with its side marked as "MANIFOLD" facing the manifold.

(c) Remove manifold ⑥.

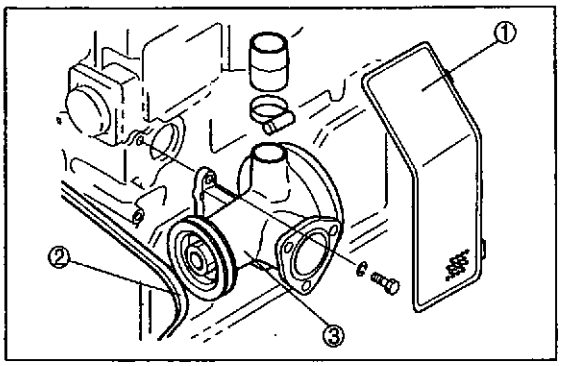


(6) Removing water pump

(a) Remove belt cover ①.

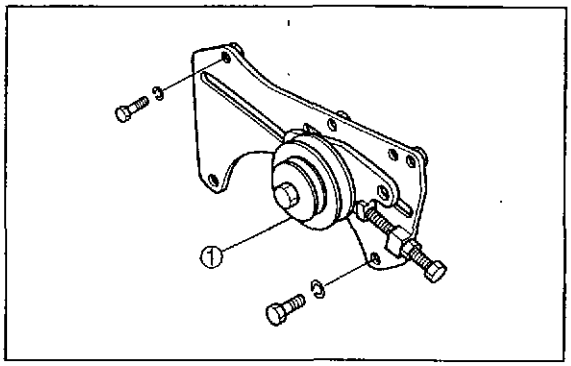
(b) Loosen the tension pulley, then remove water pump drive belt ②.

(c) Remove water pump ③ by unscrewing mounting bolts.



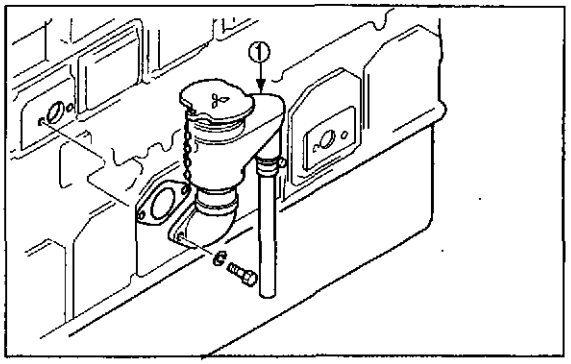
(7) Removing tension pulley

Remove the tension pulley mounting bolts, and remove tension pulley ①.



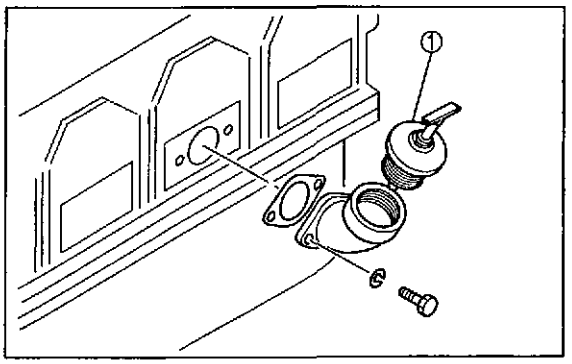
(8) Removing breather

Remove breather ① by unscrewing mounting bolts.



(9) Removing oil filler

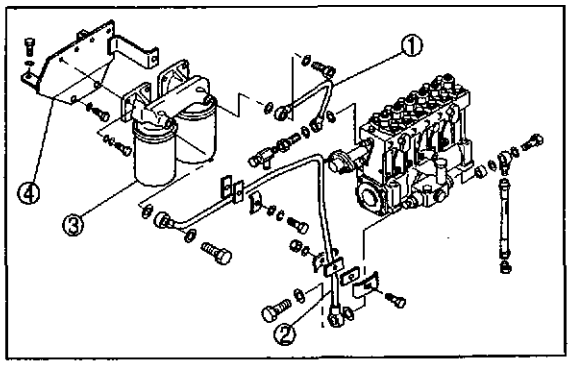
Remove oil filler ① by unscrewing mounting bolts.



(10) Removing fuel filters

(a) Disconnect fuel pipes ① and ②.

(b) Remove fuel filter ③ and filter bracket ④.

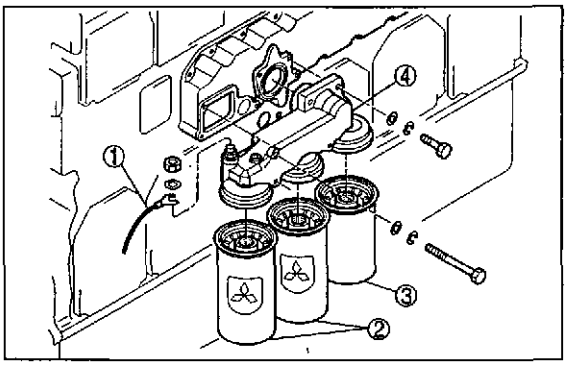


(11) Removing oil filters

(a) Disconnect harness ① for the oil filter alarm.

(b) Remove oil filter element ② and by-pass oil filter element ③.

(c) Remove oil filter bracket ④ by unscrewing mounting bolts.



(12) Removing actuator

⚠CAUTION

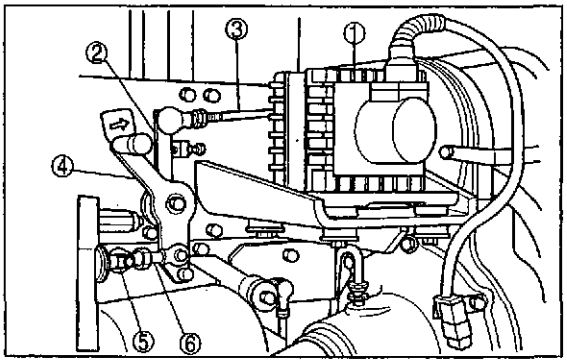
Before disconnecting the control linkage, mark the seal attachment locations.

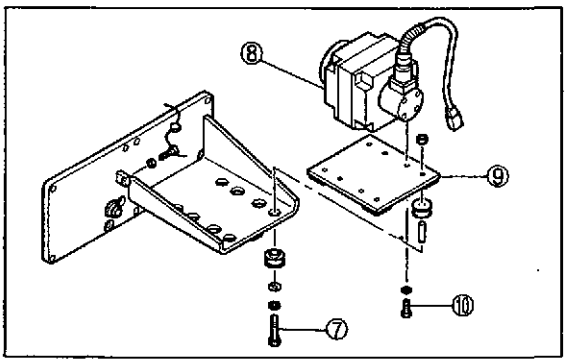
(a) Disconnect link ③ between actuator ① and cancel lever A②.

(b) Disconnect link ⑥ between cancel lever B④ and injection pump control rack ⑤.

(c) Unscrew four bolts ⑦, and remove actuator ⑧ and proact plate ⑨ as a set.

(d) Unscrew four bolts ⑩, and separate actuator ⑧ from proact plate ⑨.



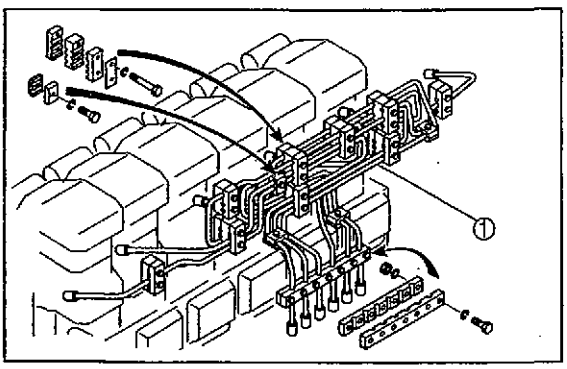


(13) Disconnecting fuel pipes

Remove clamps, then disconnect fuel pipes ① (6 pcs).

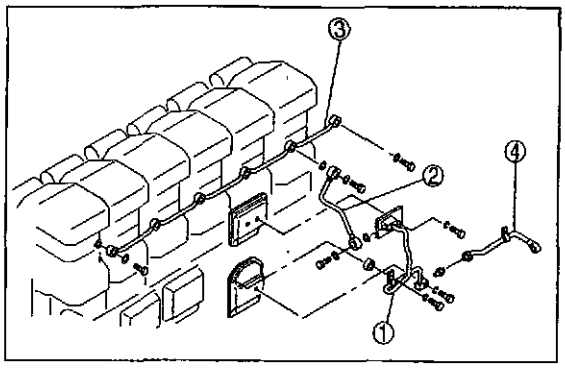
⚠CAUTION

Be sure to fit rubber caps to the openings of injection pump and nozzle inlet connectors to prevent dust from getting inside the fuel system.



(14) Removing fuel leak-off pipes

Remove the mounting bolts and eyebolts from fuel leak-off pipes ①, ②, ③, and ④, and dismount the fuel leak-off pipes.



(15) Removing fuel injection pump

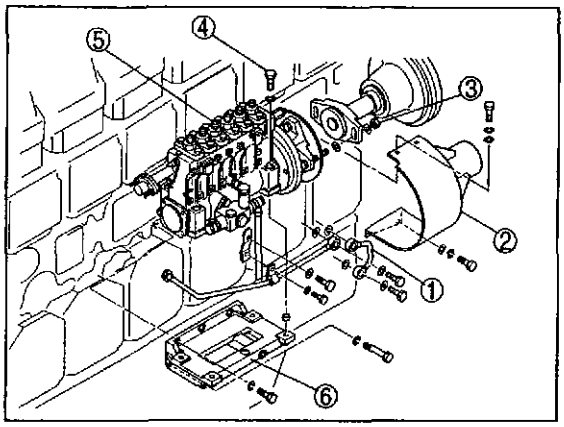
(a) Disconnect lubrication oil pipe ①.

(b) Remove coupling cover ②.

(c) Unscrew nut ③ securing the coupling.

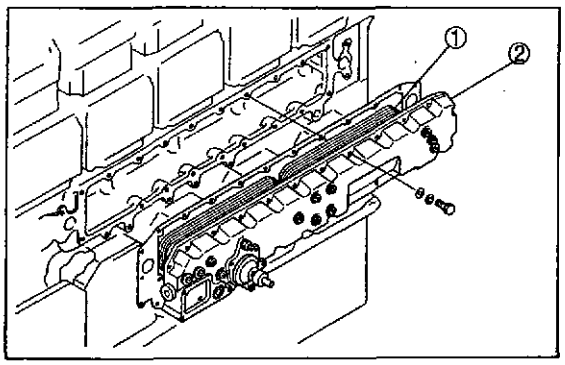
(d) Unscrew bolts ④ securing injection pup ⑤ to the engine. Remove the pump complete with coupling by prying it toward the front side of the engine with a bar [Weight: 60 kg [132.3 lb]].

(e) Remove bracket ⑥ by unscrewing mounting bolts.



(16) Removing oil cooler

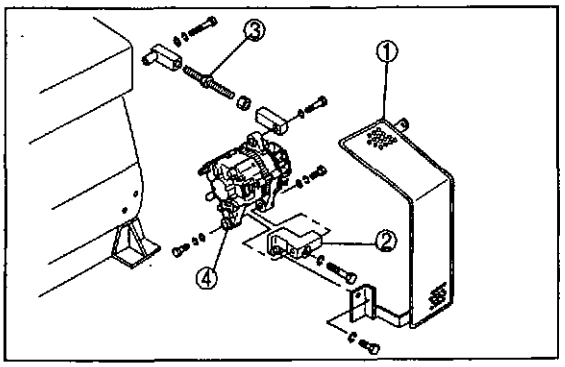
Remove oil cooler ① and cover ② as a set.



(17) Removing alternator

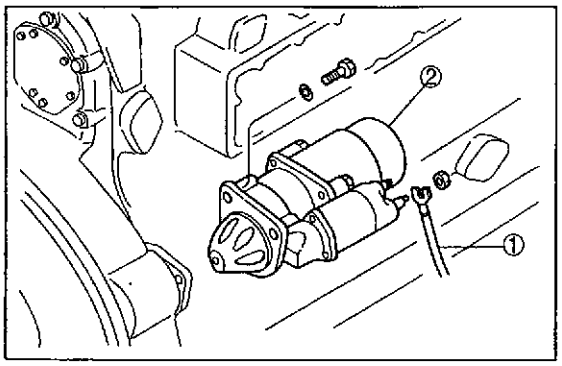
(a) Remove belt cover ①.

(b) Disconnect harness. Remove alternator mounting bracket ② and belt adjusting turnbuckle ③, and take off alternator ④.



(18) Removing starter

Disconnect harness ① and remove starter ② by unscrewing mounting bolts.



(19) Removing stop solenoid

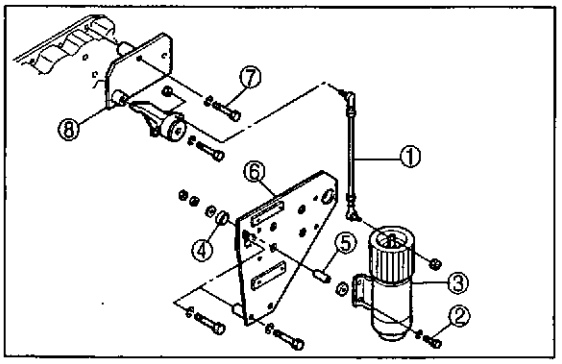
(a) Remove ball joint ① and cut linkage.

(b) Remove bolt ② to remove stop solenoid ③.

(c) Remove rubber cushion ④ and spacer ⑤.

(d) Remove solenoid bracket ⑥.

(e) Remove bolt ⑦ to remove lever bracket ⑧.



3. Engine Auxiliary Installation

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

To install the engine auxiliaries, use reverse of the removal procedures. After installing them, service them follows:

(a) Refill the engine with recommended oil up to the specified level.

(b) Refill the cooling system with coolant.

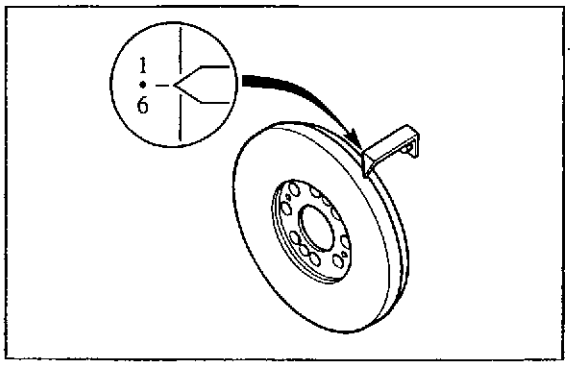
(c) Check each pipe connection for oil or coolant leaks.

(d) Prime the fuel system.

(e) After installing the fuel injection pump, inspect and adjust the injection timing. (Refer to 1.3, Group No. 5.)

Fuel Injection Pump Installation

(a) Turn the crankshaft in normal direction to align No.1·6 timing mark on the torsional viscous damper with the pointer on the engine.



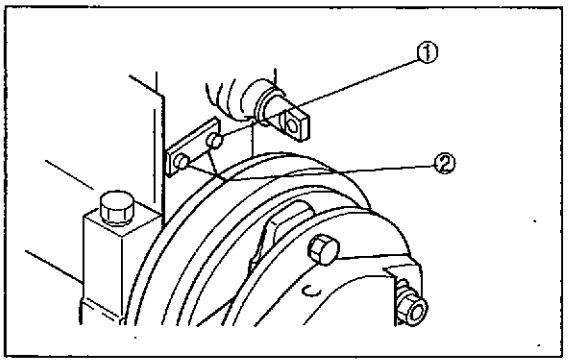
(b) Make sure that the inlet and exhaust valve rocker arms are not being pushed up by their pushrods.

(c) Turn the crankshaft in reverse direction about 60° once, the slowly turn it in normal direction until the timing mark on the damper is aligned with the pointer.

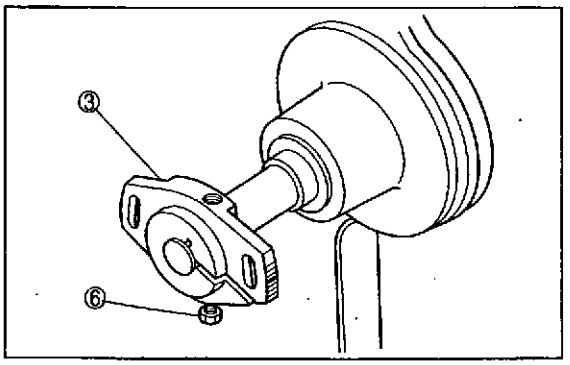
NOTE

Ascertain in advance the beginning-of-injection timing punched on the caution plate attached to No. 1 cylinder rocker cover.

(d) Before installing the injection pump, align mark ② on the flywheel with pointer ① on the pump case.



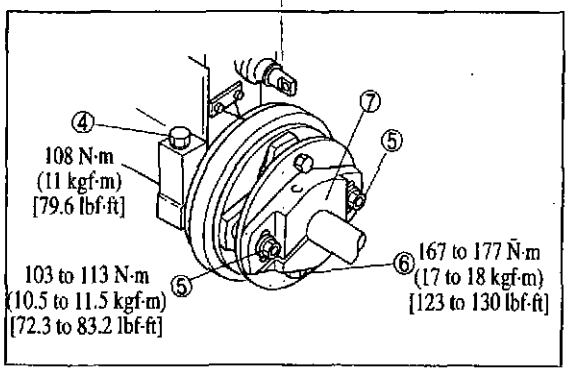
(e) Loosen the securing bolt ⑥ and install the pump drive-side coupling ③ half-way to the drive shaft.



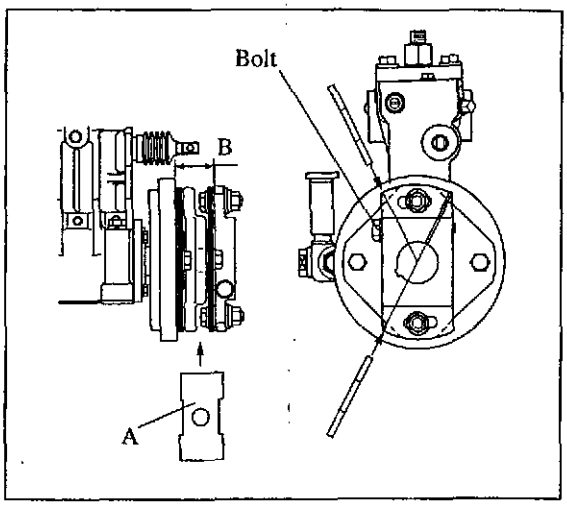
(f) Place the injection pump proper on the bracket, and temporarily tighten bolts ④.

(g) Connect the fuel pipe and lubrication oil pipes to the pump.

(h) Temporarily tighten coupling nuts ⑤ (2 locations).



(i) Using injection coupling gage (A) (37591-06100), adjust the clearance between the flywheel and coupling.
1) Insert the side of the gage marked with "GO" to determine clearance (B) between the flywheel and coupling, then tighten the bolt.
2) Make sure the side of the gage marked with "NO GO" does not enter the gap. Only the side marked with "GO" should fit into the gap.
(Clearance between flywheel and coupling: 49±0.25 mm [1.93±0.010 in.])
3) If the inspection in step 2) shows that the clearance is not 49±0.25 mm [1.93±0.010 in.], loosen the bolt and readjust the clearance.



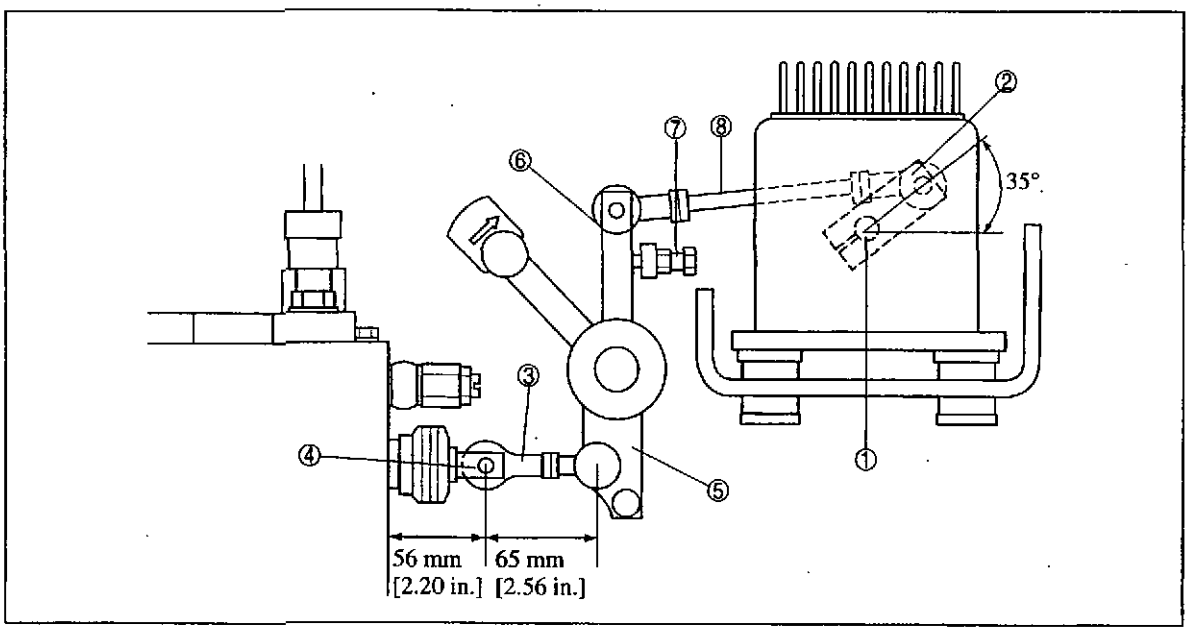
(j) After firmly tightening pump mounting bolt ④, check to make sure pointer ① on the pump case end face is aligned with line ② on the coupling. Then, tighten two connecting nuts ⑤ to the specified torque.

(k) Tighten coupling shaft tightening bolt ⑥ to the specified torque.

⚠CAUTION

Tighten the bolts of the coupling evenly to the specified torque to ensure secure mounting.
If the bolts are tightened with excessive force or insufficient force, parts damage and/or incorrect injection timing can result.

(2) Installing actuator link



(a) Check that actuator output shaft ① is set to "0" (no injection side).

(b) Install throttle lever ② at an angle of 35°, as indicated in the diagram.

(c) Adjust the length of link ③ to 65 mm [2.56 in.], and install it to injection pump contorol rack ④ and cancel lever B ⑤.

(d) Adjust cancel lever A ⑥ with adjusting bolt ⑦ so that the center of the link mounting hole of control rack ④ is positioned 56 mm [2.20 in.] from the end surface of the injection pump.

(e) With the parts installed as described in steps (a) through (d), connect link ⑧ to throttle lever ② and cancel lever A ⑥.

NOTE

Engage the threads of the rod ends and ball joints 8 mm [0.315 in.] or more.

(f) Check that the rack stroke is approximately 2 mm [0.08 in.] when cancel lever B ⑤ is pulled fully to the stop side.

(3) Adjusting and checking stop solenoid

[RUN-ON solenoid]
(Adjusting)

(a) Deenergize (or extend) solenoid ①.

(b) Adjust with rod ④ so that the gap between follower ② of the cancel lever B and stop lever ③ becomes 0.5 to 1.0 mm [0.020 to 0.039 in.].

NOTE

Engage the threads of the rod ends and ball joints 8 mm [0.315 in.] or more.

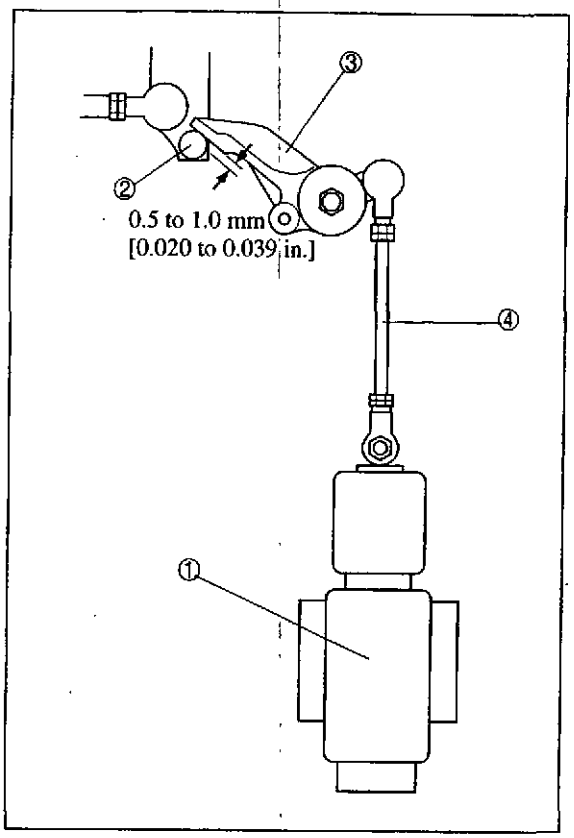
(Checking)

(a) Energize (or contract) solenoid ①.

(b) Idle the engine.

(c) Deenergize (or extend) solenoid ①.

(d) Check that the engine stops completely.



4. Adjusting Governor Controller

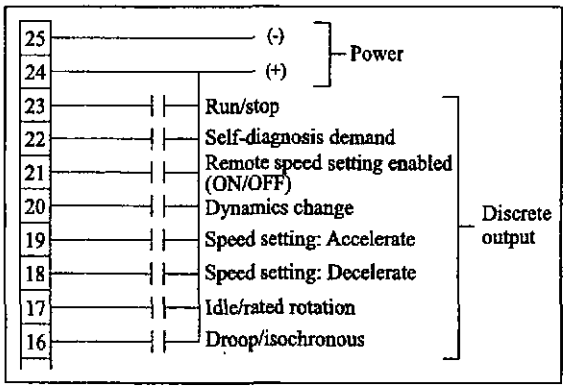
⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Work related to the exhaust emission regulations can be conducted only at our designated service factories.

4.1 Wiring Controller

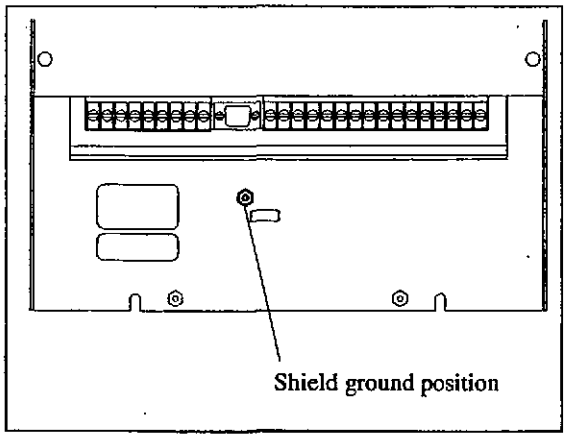
(1) Wire the controller as shown on the wiring diagram.
Prepare a switch box or the like so that the contract inputs to terminals 17 to 23 can be turned on and off during operation.

(2) Have the contacts of terminals 17 to 23 set as shown in the table right before the start of operation.



Contact No.	Name	Initial contact condition	Remarks
16	Droop/isochronous operation change	Open	
17	Idle/rated rotation change	Open	Rated rotation in closed condition
18	Speed setting: Decelerate	Open	Deceleration in closed condition
19	Speed setting: Accelerate	Open	Acceleration in closed condition
20	Dynamics change	Open	Rated rotation in open condition
21	Remote speed setting enabled (ON/OFF)	Open	
22	Self-diagnosis demand	Open	
23	Run/stop	Open	Run in closed condition

(3) Connect the shield wires of the actuator, rotation pickup, and boost sensor to the ground terminal of the controller.

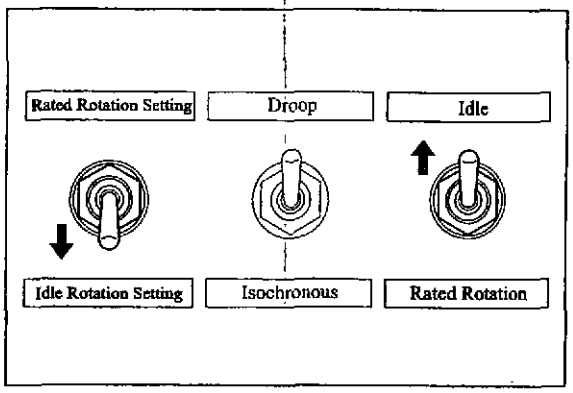


4.2 Initial Settings of Controller

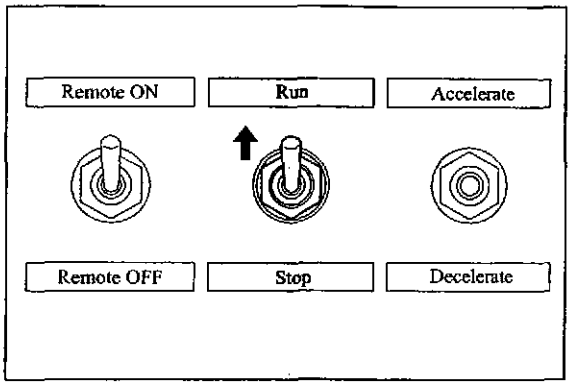
Do not change the initial set values unless otherwise required.

4.3 Adjusting Governor during Idling

(1) Turn the Idle/Rated Rotation selector switch to "Idle" and the Dynamics selector switch to "Idle Rotation Setting".



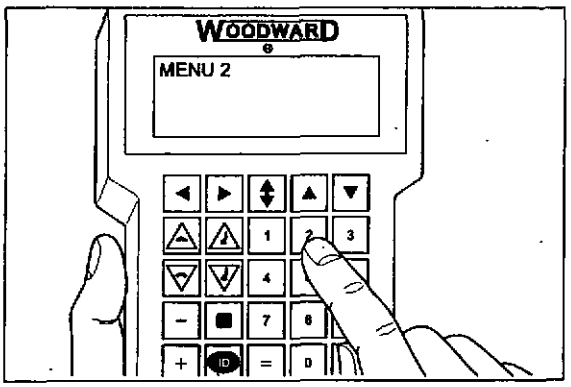
(2) Turn the Run/Stop selector switch to "Run", and start the engine.



(3) Adjusting hunting

When hunting or rotational fluctuation occurs, adjust the control parameters of the controller as described below.

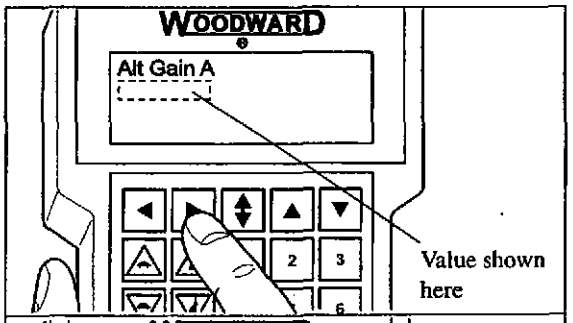
(a) Press the numeric key "2" of the handy programmer to select "MENU 2" of the control parameters.



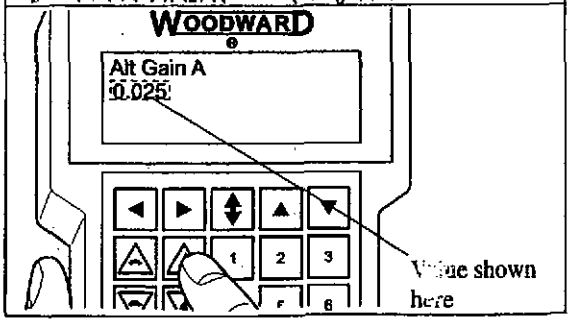
(b) Press the arrow key ◀ or ▶ to show "Alt Gain A" in the window.

(c) Adjust the value of "Alt Gain A" with the key △ or ▽ so that hunting or rotational fluctuation is eliminated.

Key △ : Value slowly increases in small increments
Key ▽ : Value slowly decreases in small increments
Key △ : Value rapidly increases in large increments
Key ▽ : Value rapidly decreases in large increments

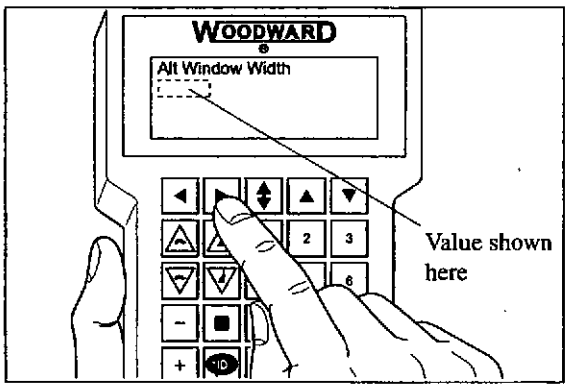


Set "Alt Gain A" to 0.025.

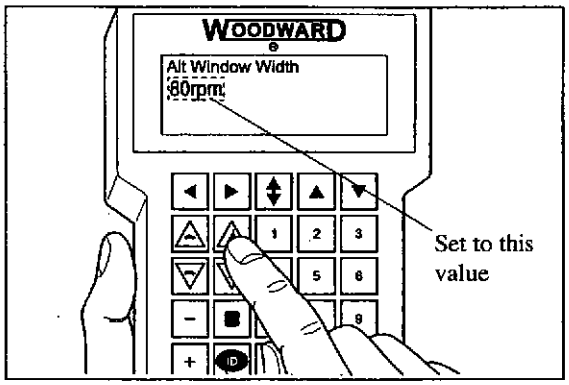


The value of "Alt Gain A" is related to hunting and rotational fluctuation as follows:
When the value of "Alt Gain A" is large, hunting increases, and rotational fluctuation decreases.
When the value of "Alt Gain A" is small, hunting decreases, and rotational fluctuation increases.
If hunting is not eliminated by the adjusting procedure described in the previous step, adjust it as described below.

(a) Press the arrow key ◀ or ▶ to select "Alt Window Width" or "Alt Gain Ratio".



(b) Adjust with the key △ or ▽.
The values of "Alt Window Width" and "Alt Gain Ratio" are related to hunting as follows:
When the value of "Alt Window Width" is large, hunting decreases.
When the value of "Alt Window Width" is small, hunting increases.
When the value of "Alt Gain Ratio" is small, hunting decreases.
When the value of "Alt Gain Ratio" is large, hunting increases.

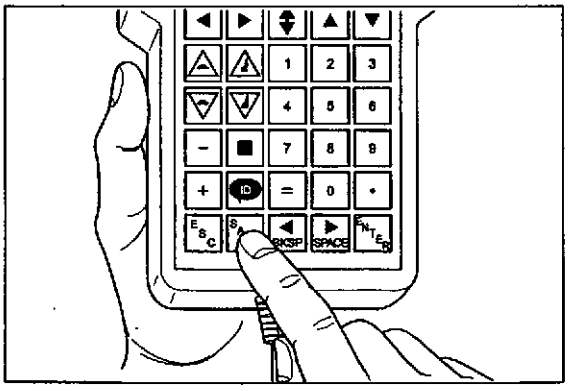


NOTE

When the value of "Alt Gain Ratio" is too small, response is too poor for the engine to start.

Set "Alt Window Width" to 80 rpm (min^{-1}).
Set "Alt Gain Ratio" to 4.0.

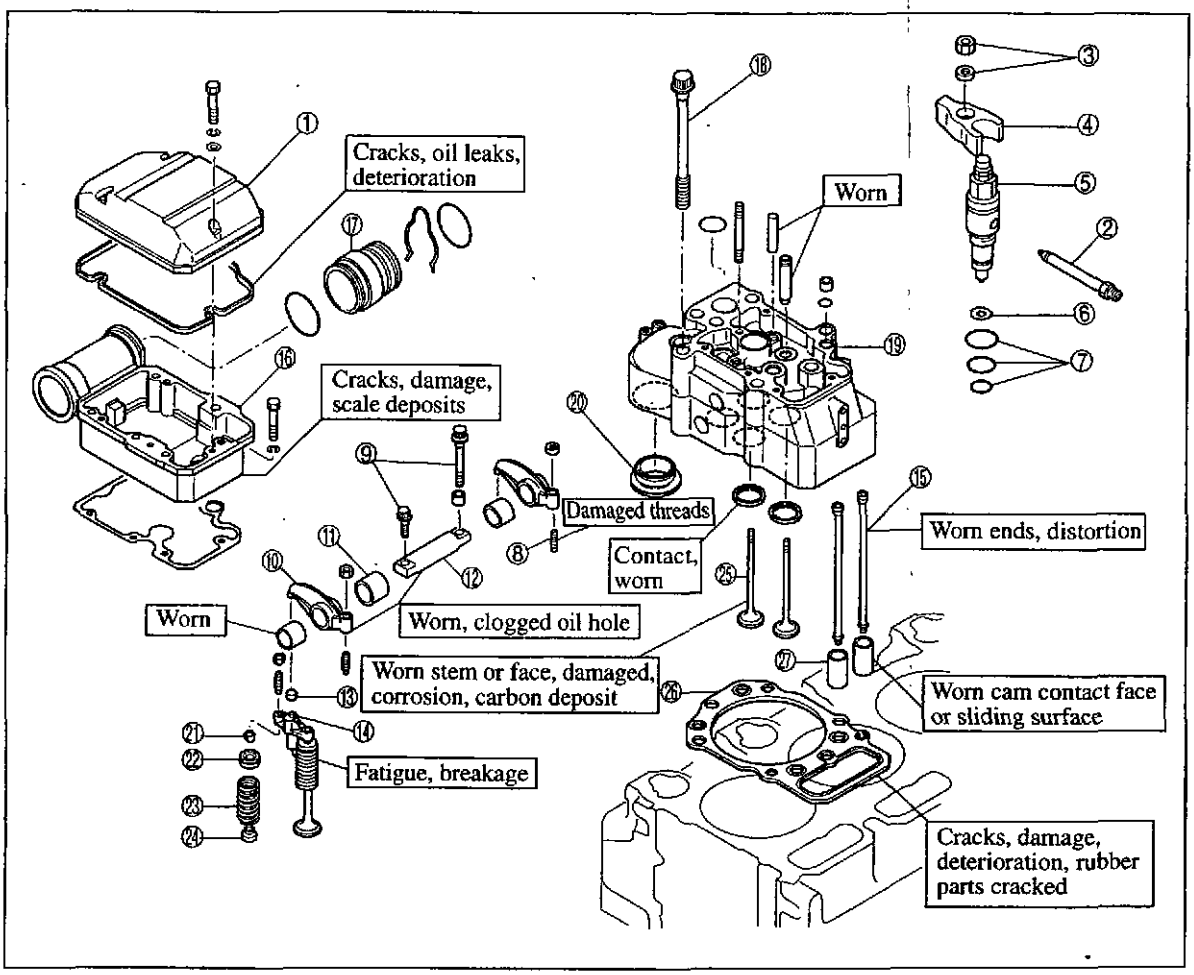
(d) After completing the adjusting procedure, press the SAVE key to store the set values.



ENGINE MAIN PARTS

1. Cylinder Heads and Valve Mechanism

1.1 Disassembly



Disassembly sequence

① Rocker cover
② Fuel inlet connector pipe
③ Nut, washer
④ Injection nozzle gland
⑤ Injection nozzle
⑥ Gasket
⑦ O-ring
⑧ Adjusting screw
⑨ Bolt
⑩ Rocker
⑪ Spacer
⑫ Rockershaft
⑬ Bridge cap
⑭ Valve bridge
⑮ Push rod
⑯ Rocker case
⑰ Water outlet connector
⑱ Cylinder head bolt
⑲ Cylinder head
⑳ Inlet port packing
㉑ Valve cotter
㉒ Valve rotator
㉓ Valve spring
㉔ Stem seal
㉕ Valve
㉖ Cylinder head gasket
㉗ Tappet

⚠CAUTION

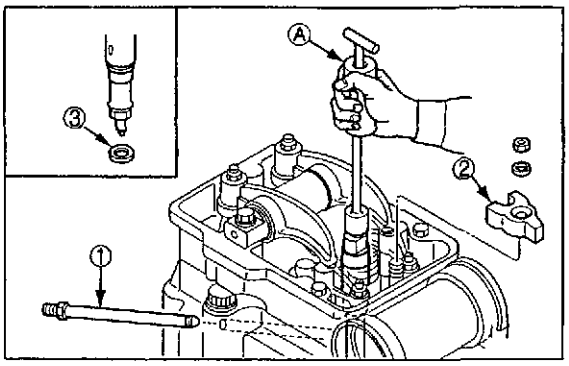
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(1) Removing fuel injection nozzle

(a) Remove the fuel inlet connector pipe ① and the nozzle gland ②.

(b) Use the nozzle remover Ⓐ (33591-10101), to remove the fuel injection nozzle assembly. Take out the gasket ③ left behind in the cylinder head.

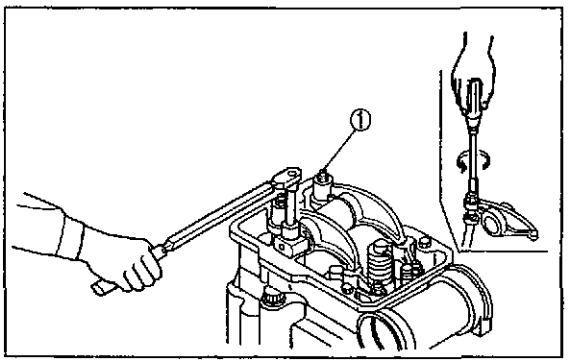
(c) Put away the fuel injection nozzle and the inlet connector pipe where you can find them later. Do not damage the nozzle tip.



(2) Removing the rockershaft assemblies

(a) Loosen the adjusting screw ① of each rocker.

(b) Keep the shaft assembly and mounting bolts together as a set.

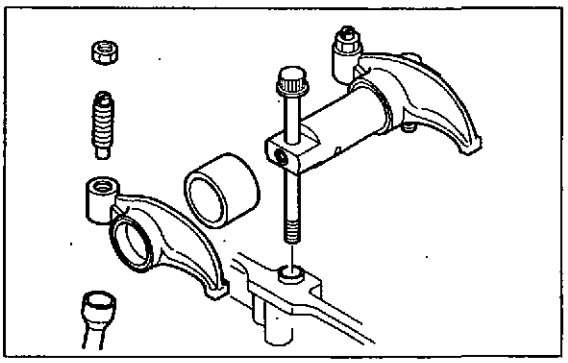


(3) Disassembling rockershaft assemblies

Arrange the disassembled rockers in the order removed, so you can install them in that order at reassembly. This will ensure the same rockershaft clearance as before.

(4) Removing the valve bridge

Remove the valve bridge and bridge cap.



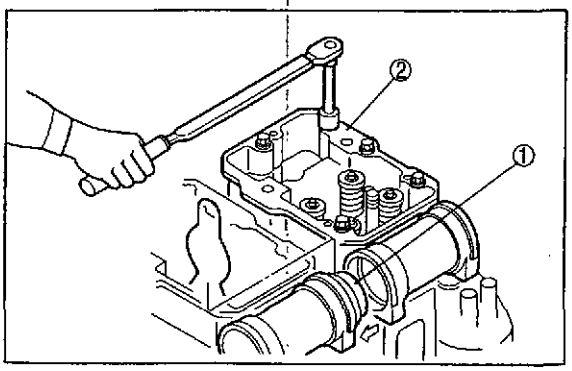
NOTE

Do not drop the bridge cap or other parts into the crankcase through the push rod hole.

(5) Removing the rocker case

(a) Remove the snap ring of the water outlet connector. Slide the connector ① towards the snap ring.

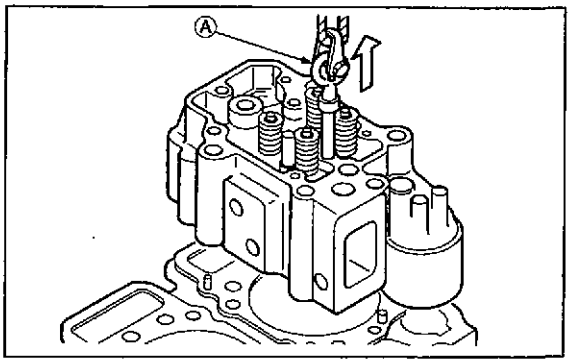
(b) Unscrew the rocker case mounting bolts, then remove the rocker case ② from the cylinder head.



(6) Removing cylinder head assemblies

(a) Each cylinder head is located relative to the crankcase with the dowel pins. Use the eye nut Ⓐ (37591-02400) to lift the head off the crankcase.

Cylinder head weight: approx. 35kg [77 lb].



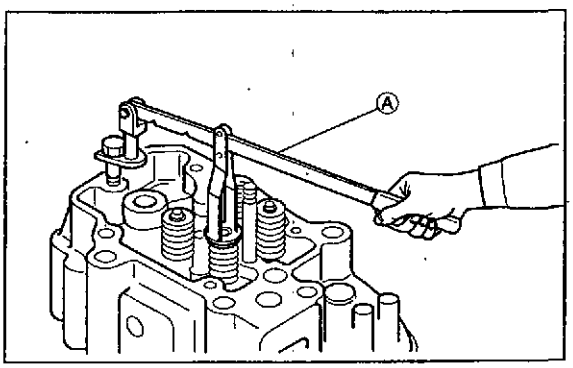
⚠CAUTION

Do not damage the cylinder head or crankcase surfaces when you remove the gasket with a screwdriver or other tool.

(b) Remove the cylinder gasket.

(7) Removing valves and valve springs

Use a valve spring pusher Ⓐ (33591-04500) to compress the valve spring squarely, then remove the valve cotters.

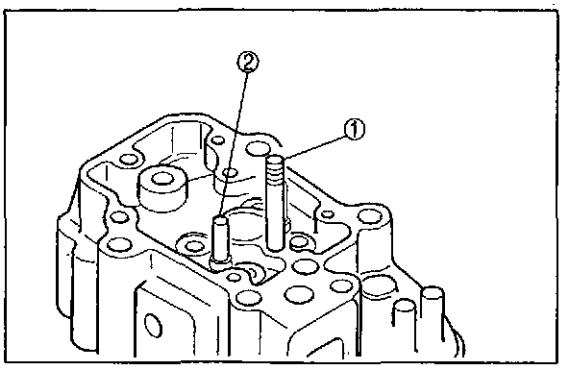


NOTE

If the valves can be reused, place identification marks to indicate the installation locations. Do not change the original combinations of valve seat and valve guide during reassembly.

(8) Removing studs, guides, etc.

Do not remove the nozzle gland mounting studs ① or the bridge guide ② from the cylinder head unless absolutely necessary. If any of these parts have been removed, apply thread ashesive to the threads when installing it or a new part to the cylinder head.



1.2 Inspection and Repair

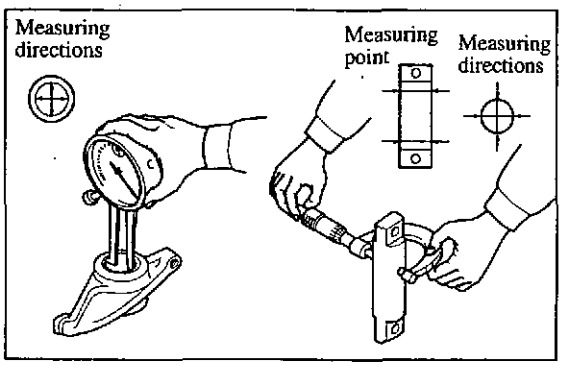
Rocker Bushings and Rockershaft

(1) Measuring rocker bushing inside diameter and rockershaft diameter

If the measurement exceeds the service limit, replace the bushing or shaft.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Rocker bushing inside diameter	Ø36 [1.42]	36.000 to 36.040 [1.41732 to 1.41889]	36.090 [1.42086]
Rockershaft diameter	Ø36 [1.42]	35.966 to 35.991 [1.41598 to 1.41697]	35.940 [1.41496]



Measuring rocker bushing and rockershaft

(2) Replacing rocker bushings

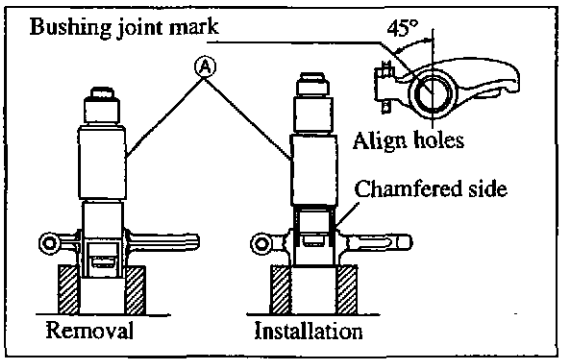
Use the rocker bushing tool Ⓐ (37591-02600) to remove the rocker bushings for replacement.

NOTE

(a) Press a new bushing into the rocker from the internally chamfered side of the bore.

(b) Align the oil holes in the bushing and rocker.

(c) After installing the bushing, measure its inside diameter to make sure that it is $ø36^{+0.04}_{0}$ mm [$1.42^{+0.002}_{0}$ in.]. If the diameter is not within this tolerance, refinish to standard tolerance by reaming ($ø36^{+0.04}_{0}$ mm [$1.42^{+0.002}_{0}$ in.] 0.8 Ra).



Replacing the rocker bushing

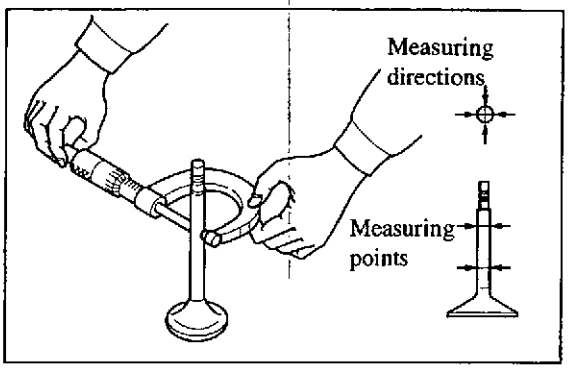
Valve Guide and Valve Stems

(1) Measuring valve stem diameter and valve guide inside diameter

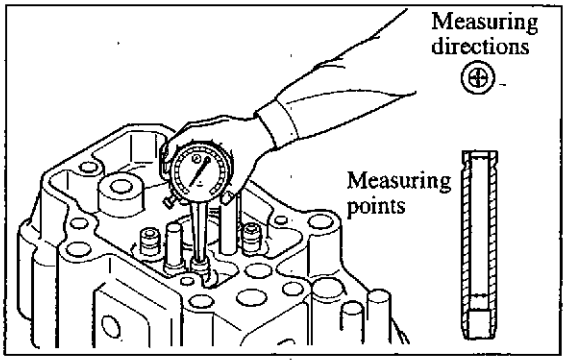
The valve guide wears more rapidly at its ends than at any other location. Measure the inside diameter of the guide at its ends in two directions. If the service limit is exceeded, replace the guide.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Valve stem diameter	ø10 [0.39]	9.940 to 9.960 [0.39134 to 0.39213]	9.910 [0.39016]
Valve guide inside diameter	ø10 [0.39]	10.000 to 10.015 [0.39370 to 0.39429]	10.060 [0.39606]



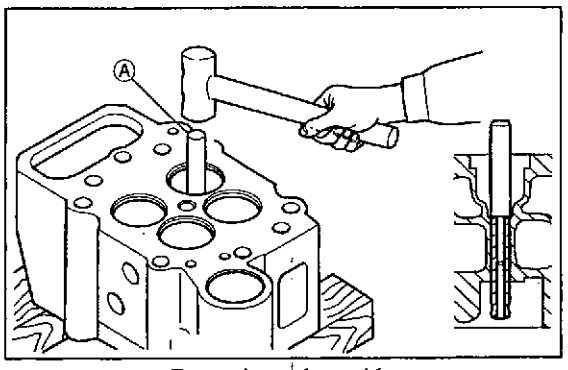
Measuring valve stems



Measuring valve guide inside diameter

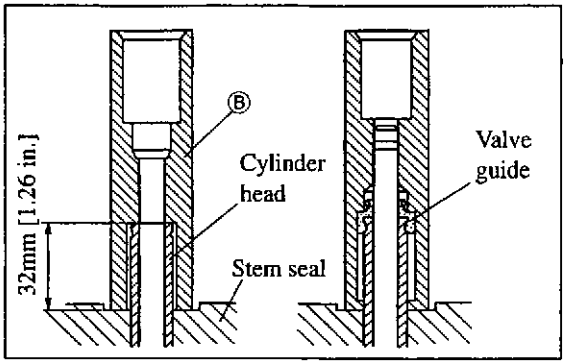
(2) Replacing valve guides and stem seals

(a) Use the valve guide remover Ⓐ (33591-04300) to remove the valve guide for replacement.



Removing valve guide

(b) Use the valve guide seal installer Ⓑ (37191-01500) to install slowly a new guide with a press.



Installing valve guide and stem seal

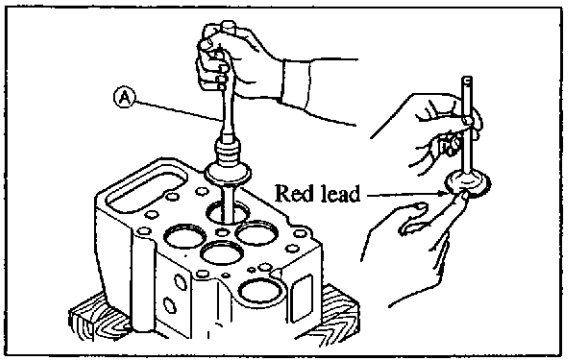
⚠CAUTION

(a) The installation depth for the valve guide is specified, so that use the valve guide seal installer to secure the correct depth.
(b) Do not apply any oil or sealant to the surface of the stem seal that contacts with the valve guide. When installing the stem seal, apply lub oil to valve stem to ensure initial lubrication of the stem seal lip.
(c) Use a new stem seal, whenever removed.

Valves and Valve Seats

(1) Inspecting the valve face

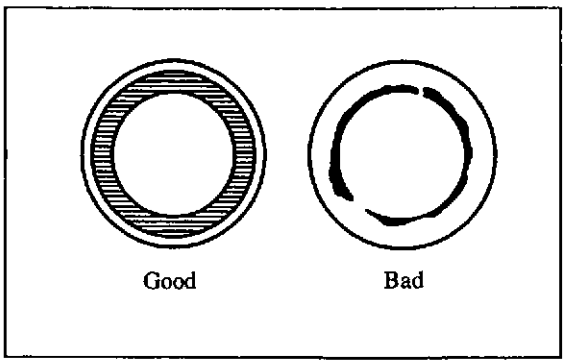
Coat the valve face lightly with red lead. Use the valve lapper Ⓐ (30091-08800) to inspect the valve contact with its seat. If the contact is not uniform, or if the valve is defective, or if the repair limit is exceeded, repair or replace the valve and valve seat.



Inspecting the valve face

NOTE

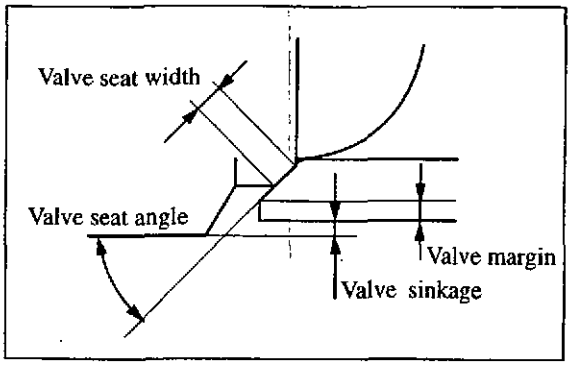
(a) Inspect the valve face after the inspection or replacement of the valve guide.
(b) When you press the valve coated with red lead into the valve seat, do not rotate the valve.



Valve contact with its seat

Unit: mm [in.]

Item		Assembly Standard	Repair Limit
Valve seat	Angle	30°	
	Valve sinkage	-0.2 to 0.2 [-0.008 to 0.008]	1.0 [0.039]
	Width	2.15 to 2.45 [0.0846 to 0.0965]	2.8 [0.110]
Valve margin		2.8 to 3.2 [0.110 to 0.126]	2.5 [0.098] by refacing

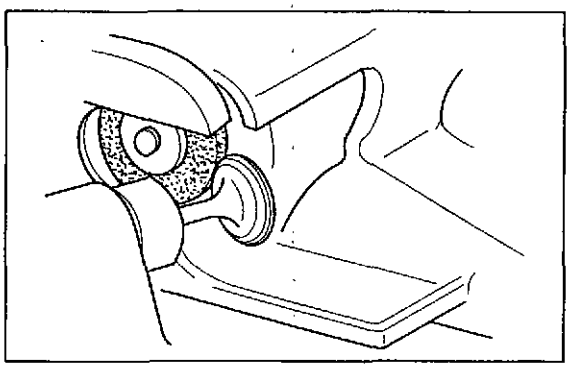


(2) Refacing the valve face

If the valve face is excessively worn, reface it with a valve re-facer.

NOTE

(a) Set a valve refacer at an angle of 30°.
(b) Grind the valve as little as possible. If the margin seems to exceed the repair limit as a result of grinding, replace the valve.

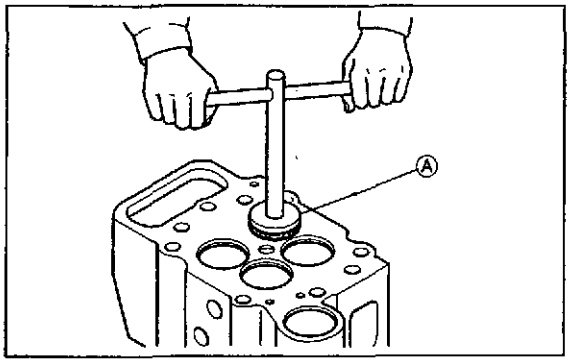


Refacing a valve

(3) Refacing valve seats

(a) Use the valve seat cutter Ⓐ (37591-06400, 37591-06430) or valve seat grinder to reface the valve seat. After refacing, grind the seat lightly using #400 grade sandpaper inserted between the cutter and valve seat.

(b) Lap the valve in the valve seat.



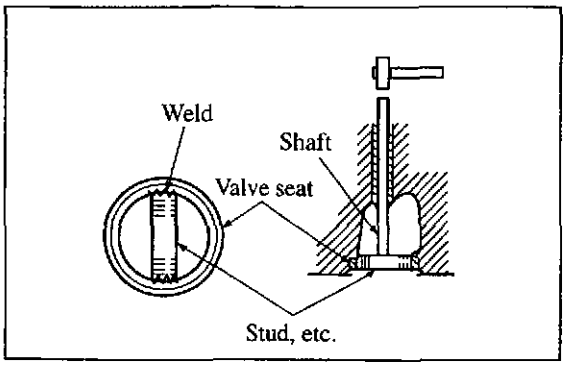
Refacing valve seats

NOTE

(a) Cut or grind the valve seat only as needed for refacing.
(b) Replace the valve seat if the seat width is more than the repair limit as a result of wear or cutting.
(c) Replace the valve seat if the valve sinkage exceeds the repair limit after refacing.

(4) Replacing valve seats

(a) (i) Weld a stud to the valve seat. Insert a shaft into the valve guide holder from the upper side of the cylinder head. Drive the seat off the head as shown.

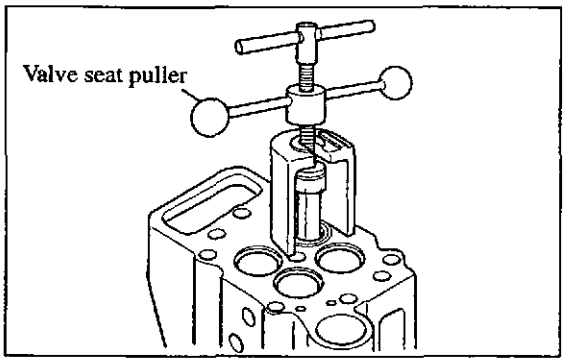


Removing a valve seat

NOTE

When you weld the stud, do not permit splatter to come in contact with the machined surfaces of the cylinder head.

(ii) Use the valve seat puller (32591-04200) to remove valve seats.

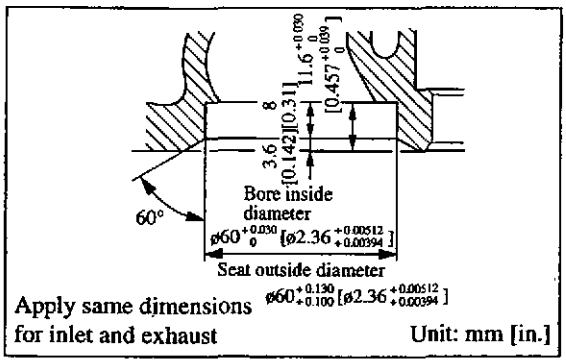


Removing a valve seat (Using valve seat puller)

(b) Before inserting a new valve seat, measure the inside diameter of the cylinder head bore and the outside diameter of the seat to make sure that clearance (fit) is within the clearance standards.

Unit: mm [in.]

Item	Nominal Value	Standard Clearance
Cylinder head bore inside diameter and valve seat outside diameter	ø60 [2.36]	–0.070 to –0.130 [–0.00276 to –0.00512]

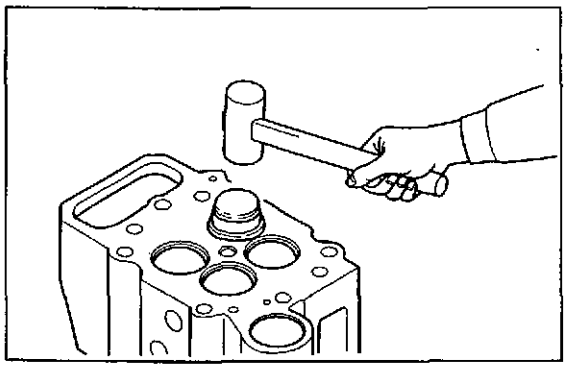


Valve seat dimensions

NOTE

A minus (-) indicates interference.

(c) Chill the valve seat in liquid nitrogen (about -170°C ([-274°F])) for more than 4 minutes with the cylinder head kept at normal temperature, or heat the cylinder head to 80 to 100°C [176 to 212°F] with the valve seat chilled in either ether or alcohol containing dry ice.


Installing a valve seat

(d) Use the Installer to install the valve seat.

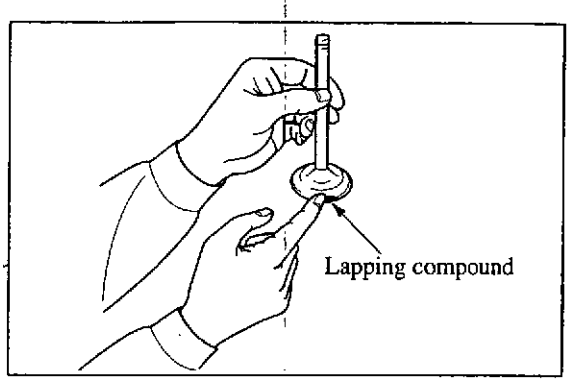
(5) Lapping valves in valve seats

Be sure to lap the valves in the valve seats after the seats have been replaced.

(a) Coat the valve face lightly with a lapping compound.

NOTE

(a) Do not permit the compound to come in contact with the valve stem.
(b) Use a compound of 120 to 150 mesh for initial lapping and a compound finer than 200 mesh for finish lapping.
(c) Mixing the compound with a small amount of engine oil will facilitate coating.



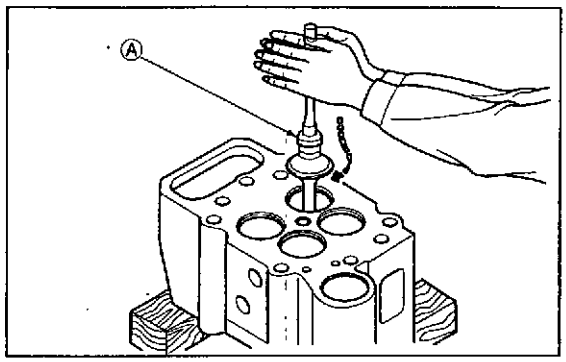
Coating valve with lapping compound

(b) Use the valve lapper Ⓐ (30091-08800) to lap the valve in the seat. To lap, raise the valve off the seat, then rotate the valve only a partial turn and strike it against the seat.

(c) Wash off the compound with diesel fuel.

(d) Coat the valve face with engine oil, then lap the valve again.

(e) Check the valve face for contact.

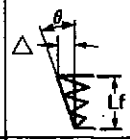


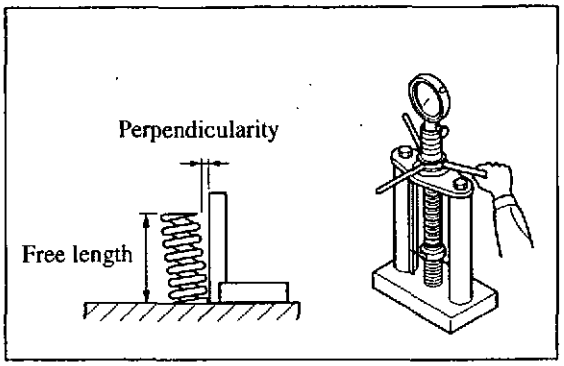
Lapping a valve in its valve seat

(6) Measuring valve spring perpendicularity and free length

Measure the free length and perpendicularity of each valve spring. If the free length or perpendicularity exceeds the service limit, replace the spring.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Free length	73 [2.87]	71 [2.80]
Perpendicularity	 θ=1.5° Δ=1.9 [0.075] Lf=73 [2.87]	Δ=2.2 [0.087] at the end
Set length/set force mm [in.]/ N (kgf) [lbf]	66.0 [2.6]/ 289 to 319 (29.45 to 32.55) [64.9 to 71.8]	

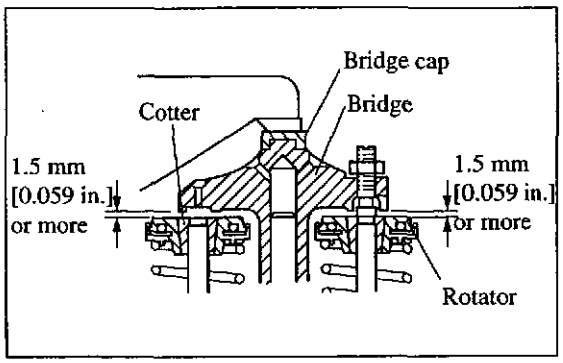


Measuring a valve spring perpendicularity and free length

(7) Checking bridge-to-rotator clearance

(a) If the clearance is less than 1.5 mm [0.059 in.], check the valve stem top for cupping. When the stem top is badly cupped, replace the valve to obtain more than 1.5 mm [0.059 in.] clearance.

(b) Check the condition of the bridge cap. Replace it if it is excessively worn.

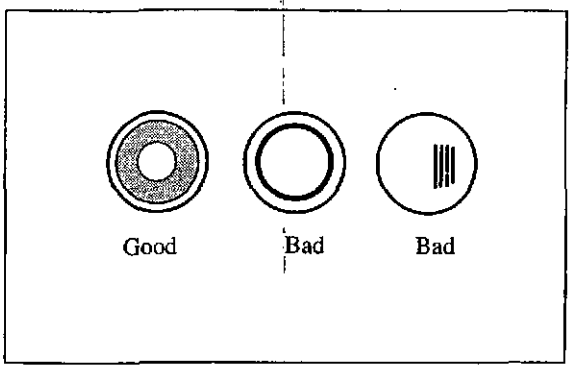


Checking bridge-to-rotator clearance

Tappets and Pushrods

(1) Inspecting cam contact faces of tappets

Replace the tappets if their cam contact faces are abnormally worn.



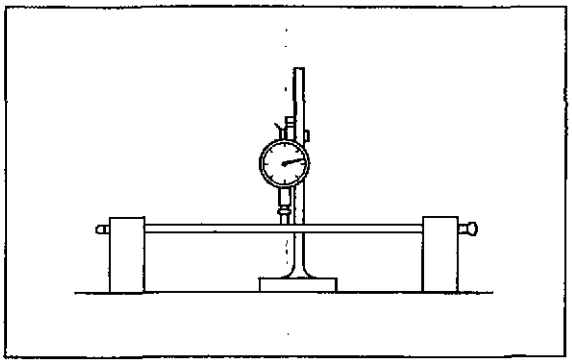
Tappet cam contact face

(2) Measuring valve pushrods deflection

If the deflection exceeds the assembly standard, replace the pushrods.

Unit: mm [in.]

Item	Assembly Standard
Pushrod deflection	0.50 [0.020] or less



Measuring valve pushrod deflection

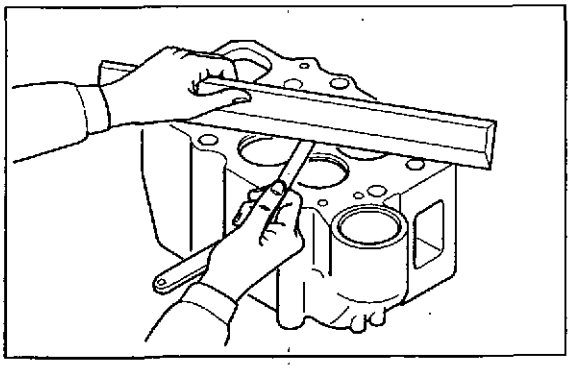
Cylinder Head

(1) Measuring head gasket flatness of surface

Use a straight edge and feeler gages to measure warping on each cylinder head. If warping exceeds the repair limit, reface the gasket surface with a surface grinder.

Units: mm [in.]

Item	Assembly Standard	Repair Limit	Service Limit
Flatness	0.03 [0.0012] or less	0.07 [0.0028]	0.50 [0.0197]



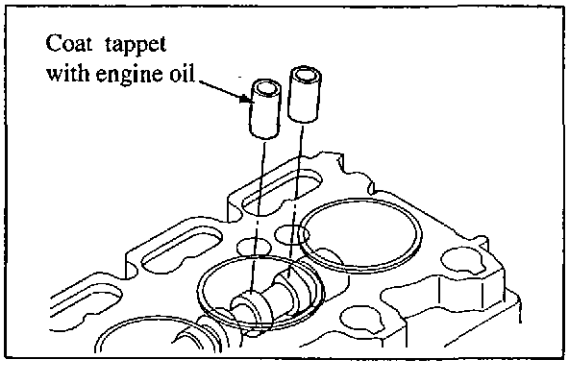
Measuring head gasket flatness

1.3 Reassembly

To reassemble, follow the reverse of disassembly

(1) Installing tappets

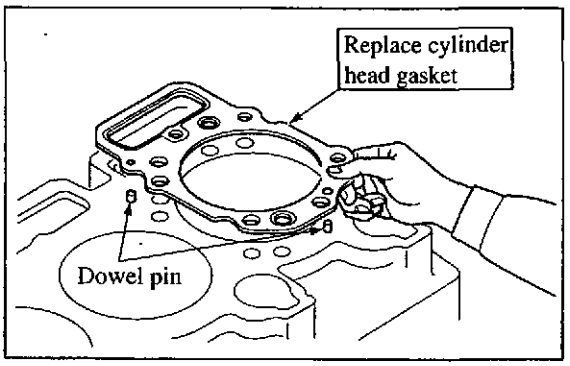
Coat the tappets with engine oil and make them seat softly on the camshaft.
Insert tappets coated with engine oil into the tappet holes and place them softly on the camshaft.



(2) Installing cylinder head gaskets

(a) Clean the gasketed surfaces of the cylinder head and crankcase thoroughly with a solvent or degreasing solution.

(b) Place the gaskets on the crankcase, making sure that the dowel pins enter their holes in the gaskets.

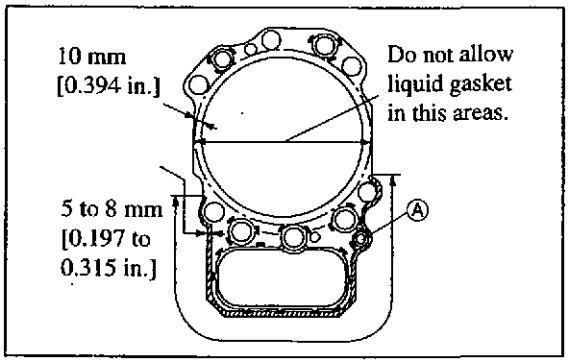


- Application of liquid gasket
  Apply a thin coat of ThreeBond 1211 (37594-01300) around tappet holes and oil passage holes on both sides of the head gasket. Install the gasket before the liquid gasket dries.

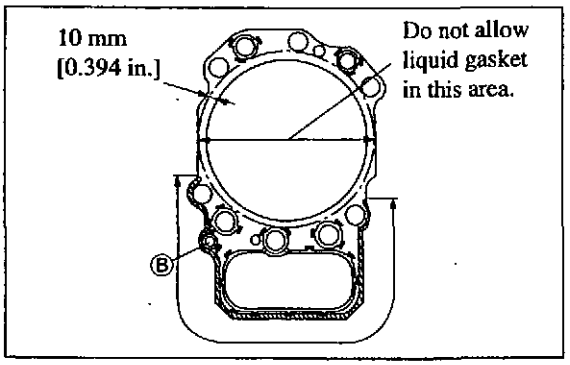
  Do not apply an excessive amount of liquid gasket, since it can press the head gasket O-ring and cause deformation. Do not allow liquid gasket to adhere around the bore; otherwise, gas leakage can occur.

  Before installation, be sure to wipe off oil and grease from the bottom face of the cylinder head, the top face of the crankcase and the head gasket.

  The diagrams on the right show the areas and amounts of liquid gasket application.



Application of liquid gasket on head-facing side



Application of liquid gasket on crankcase-facing side

NOTE

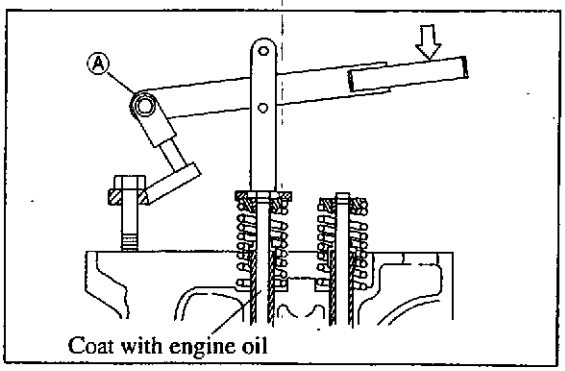
(a) Apply liquid gasket (37594-01300) to areas 5 to 8 mm [0.197 to 0.315 in.] from the periphery of the head gasket.
(b) Liquid gasket should be applied to areas indicated in the diagrams on the right.
(c) Apply liquid gasket to both sides of the head gasket. Spread the liquid gasket with a finger to a thickness of 0.2 to 0.5 mm [0.0079 to 0.0197 in.].
(d) Sections Ⓐ and Ⓑ are very close to O-rings. Make sure there is no large amount of liquid gasket on the edge at these sections.

(c) Install the cylinder head gasket by aligning holes with the dowel pins.

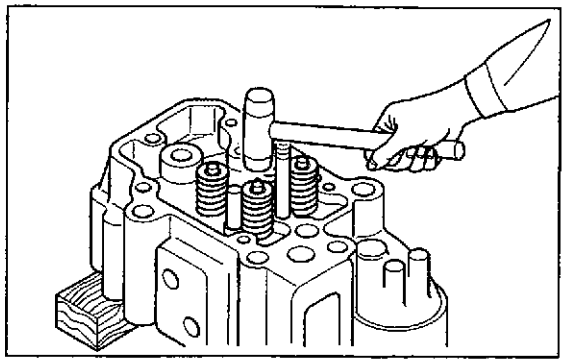
(3) Reassembling the cylinder heads

(a) Coat the valve stems with engine oil, then insert them into the valve guides.

(b) Install the valve springs and rotators to the valve guides. Compress each valve spring with the valve spring pusher Ⓐ (33591-04500), then install the valve cotters on the valve stem.

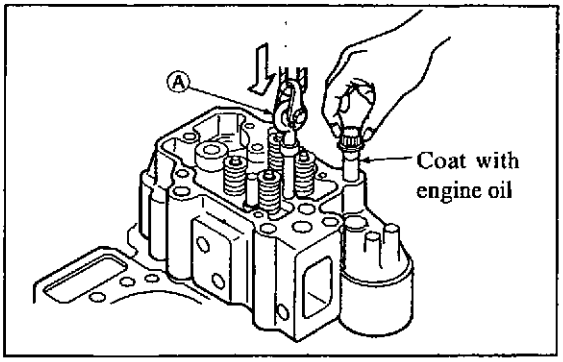


(c) Lightly tap on the top of each valve stem with a soft hammer to make sure that the valve spring and cotters are properly installed.

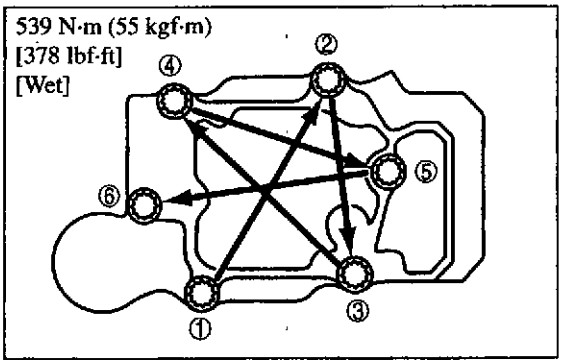


(4) Installing cylinder head assemblies

(a) Install eye nut Ⓐ (37591-02400) on the stud bolt. Attach a shackle and wire rope to the eye nut and lift the cylinder head assembly. Align the holes on the cylinder head with the dowel pins, and keep the head assembly slightly lifted. Coat engine oil with the threads of the head bolts and the bolt seats, and install the bolts into the head assembly.



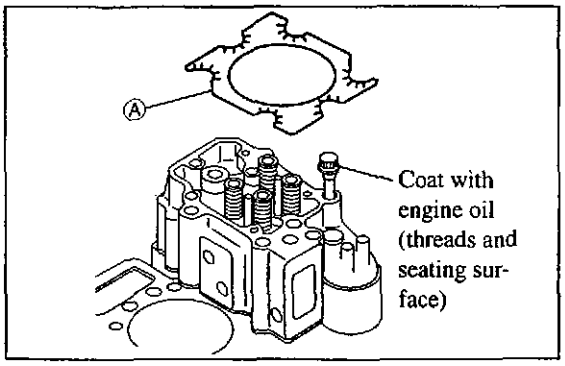
(b) Tighten the cylinder head bolts with the specified torque in the order shown in the drawing.



Head bolt tightening sequence

- **Tightening cylinder head bolts based on angle-of-turn procedure**

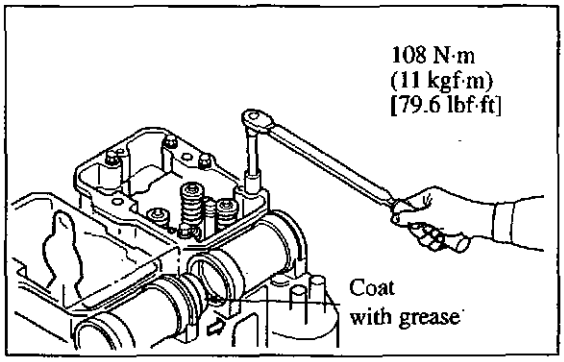
(a) Place the head bolt plate Ⓐ (37598-08900) on the cylinder head.
(b) Tighten each head bolt to 294 N·m (30 kgf·m) [217 lbf·ft] torque (initial torque).
(c) The head bolt plate has graduations at 30° intervals. Place a reference point mark on each head bolt.
(d) Turn each head bolt by 30°. After tightening all bolts, turn each bolt again by 30° (total of 60° turn).



Head bolt tightening by turn angle method

(5) Installing the rocker case

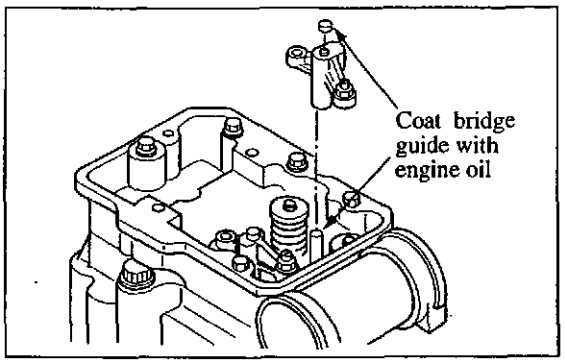
(a) Insert the water outlet connector fully into the rocker case.
(b) Install the rocker case so that it meets the dowel pins.
(c) Tighten the rocker case mounting bolts to the specified torque.
(d) Insert the water outlet connector by sliding it from the next rocker case after coating the O-ring with grease. Install the snap ring.



(6) Installing valve bridges and caps

(a) Coat the bridge guides with engine oil, then install the bridges to the guides with the adjusting screw positioned on the exhaust manifold side.

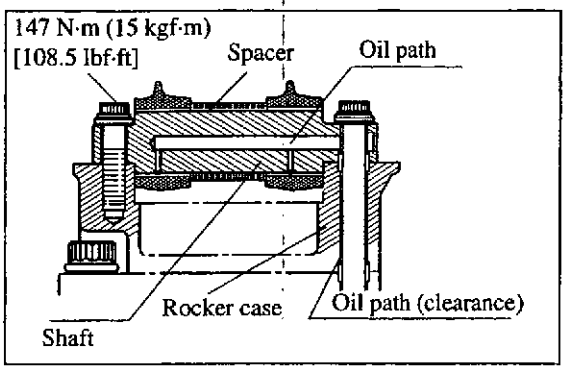
(b) Coat the bridge contact face of the bridge caps with engine oil. Install the caps in position, being careful not to let them fall into the crankcase through the pushrod holes.



(7) Installing rockershaft assemblies

(a) Install the spacer to the rocker shaft and mount the rockers on both sides.

(b) Align the pin hole of the rocker shaft with the positioning pin, and install the rocker shaft assembly to the rocker case.



⚠CAUTION

(a) Move the rocker arm up and down to make sure that the arm is free.
(b) While tightening the bracket mounting bolts temporarily, install the bracket in place so the rocker tip comes in contact with the bridge caps evenly.
(c) Tighten the long bolt securing the head and rocker bracket first, then tighten the short bolt to the specified torque.

(8) Installing injection nozzle assemblies

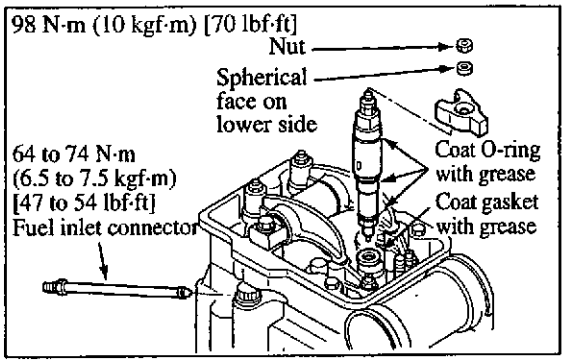
(a) Disconnect the fuel inlet connector pipe from the nozzle assemblies.

(b) Install three O-rings to the nozzle and coat with grease.

(c) Coat the gasket with grease then install the gasket to the nozzle. Insert the nozzle assembly into the cylinder head. Watch the center of the connector installation hole.

(d) Tighten the fuel inlet connector pipe to the specified torque.

(e) Tighten nozzle gland mounting nut to the specified torque.



NOTE

(a) Maintain equal distances between the fuel inlet connector pipe and and the cylinder head before tightening to the specified torque.
(b) Be sure to install the gasket when installing the nozzle assemblies.

⚠CAUTION

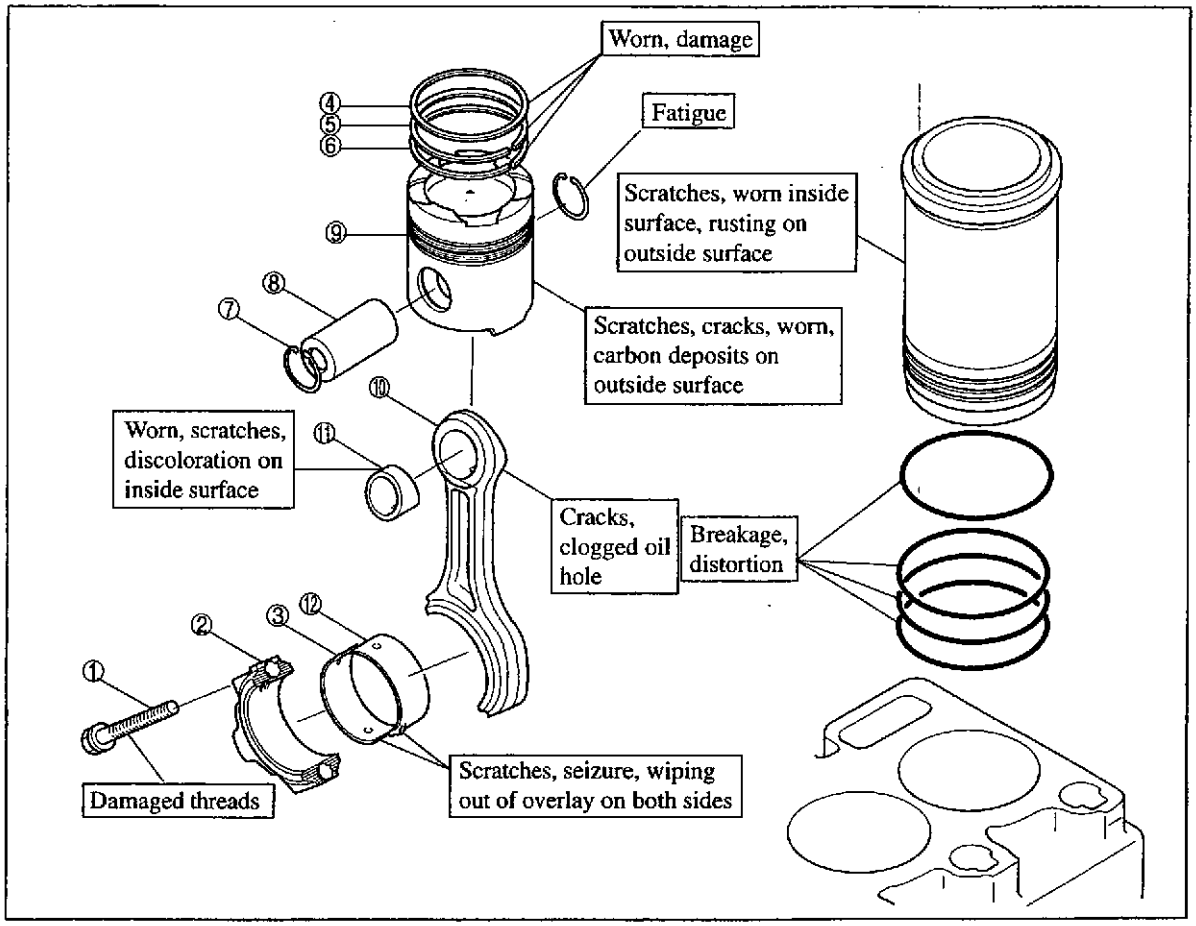
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(9) Adjusting valve clearance

Refer to section 1.1, Group No. 5.

2. Cylinder Liners, Pistons and Connecting Rods

2.1 Disassembly



Disassembly sequence

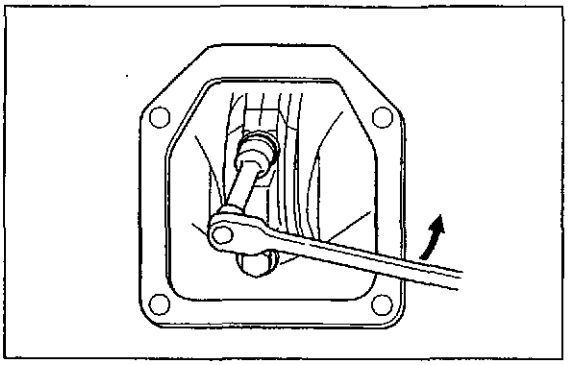
① Bolt
② Connecting rod cap
③ Connecting rod bearing (lower)
④ Top compression ring
⑤ Second compression ring
⑥ Oil ring
⑦ Snap ring
⑧ Piston pin
⑨ Piston
⑩ Connecting rod
⑪ Connecting rod bushing
⑫ Connecting rod bearing (upper)

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(1) Removing connecting rod caps

Unscrew the cap bolts from the inspection window, then remove the cap.

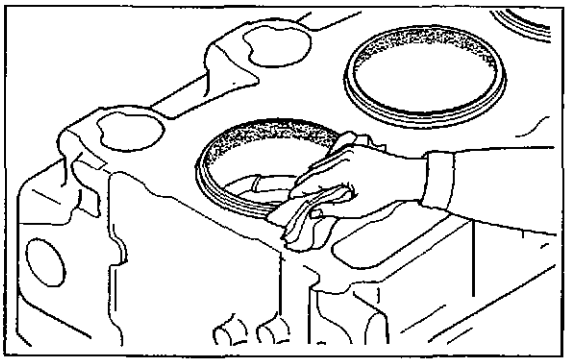


NOTE

(a) Do not damage the bearings or drop them into the oil pan.
(b) Mark the removed connecting rod bearings for identification of cylinder numbers and for upper and lower shells.

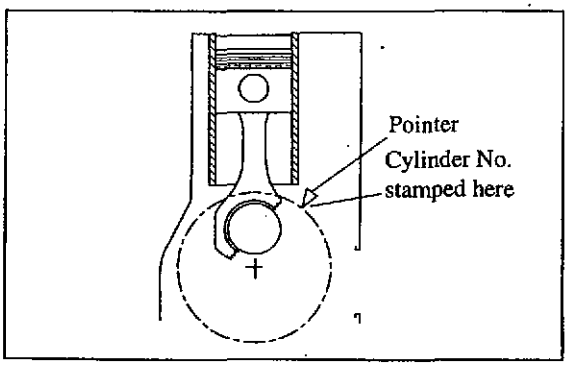
(2) Preparation before removing pistons

Use a cloth or oil paper to remove all carbon deposits from the upper areas of the cylinder liner. If any carbon deposits are present, this will make it difficult to pull a piston up.

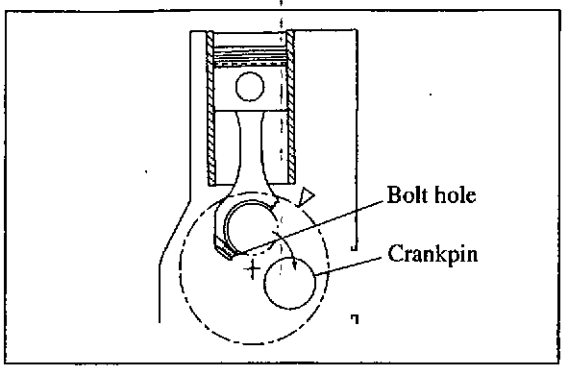


(3) Removing pistons (By the use of a bar)

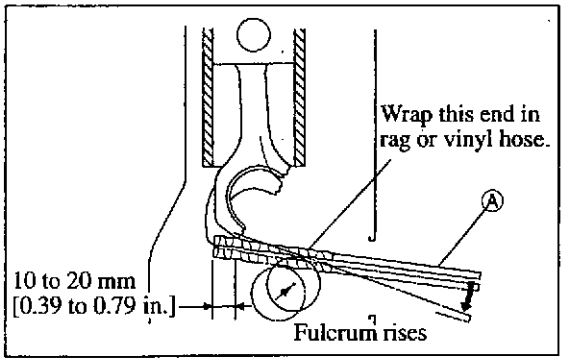
(a) Turn the crankshaft to bring the piston assembly (from which the connecting rod cap has been removed) to top dead center.



(b) Turn the crankshaft in normal direction until the crank pin comes off the connecting rod and the joint of the rod is visible in the inspection hole on the side of the crankcase.



(c) Cover the turning bar Ⓐ with a cloth to protect it. Put the tip of the bar under the bottom of the big-end of the connecting rod, then pry up the piston assembly a small amount by making use of the crank pin as a fulcrum.



⚠CAUTION

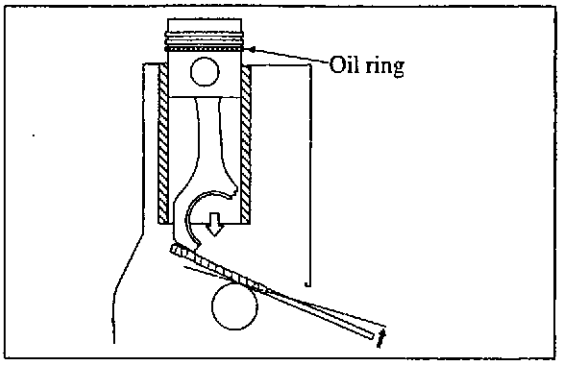
If you force the turning bar, you may not be able to remove the piston assembly. Insert the bar so it protrudes about 10 to 20 mm [0.39 to 0.79 in.] mm from the bottom end of the big-end.

(d) Turn the crankshaft in reverse direction just a little at a time to raise the crank pin (fulcrum) while pushing down on the outer end of the bar to raise the piston assembly.

⚠CAUTION

Raise the piston assembly carefully so that the connecting rod will not interfere with the oil jet nozzle for piston cooling.

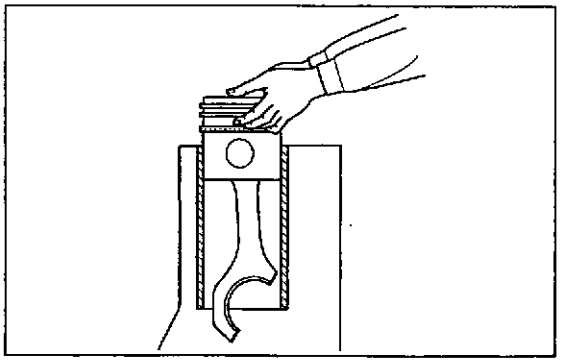
(e) When the oil ring of the piston comes out of the cylinder liner, lower the piston a little and carefully rest the oil ring on the edge of the liner.



⚠CAUTION

To avoid damage to the oil ring, lower the piston slowly and carefully. Do not rotate the piston.

(f) While holding the compression ring portion of the piston with your hands, carefully pull the piston from the cylinder liner, then rest its skirt on the top of the crankcase.

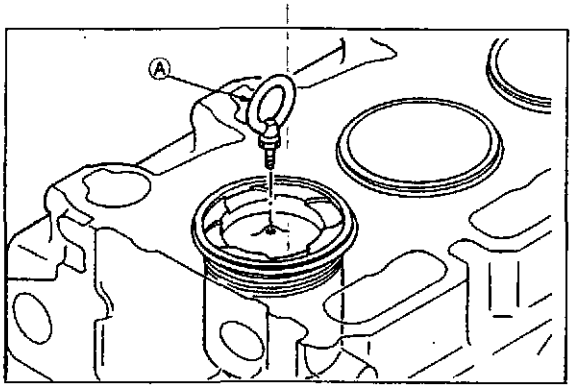


(g) With your hands holding the piston pin portion of the piston, lift the piston assembly off the liner.

(4) Using the piston remover

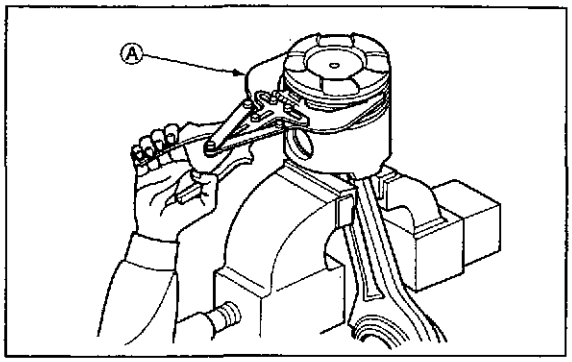
(a) Turn the crankshaft to bring the piston assembly to be removed to 50° before top dead center.

(b) Attach piston remover Ⓐ (MM321420) to the top of the piston. Grip the handle of the remover, then lift the piston and the connecting rod off the liner.



(5) Removing the piston ring

Use the piston ring tool Ⓐ (37191-03200) to remove the piston rings.

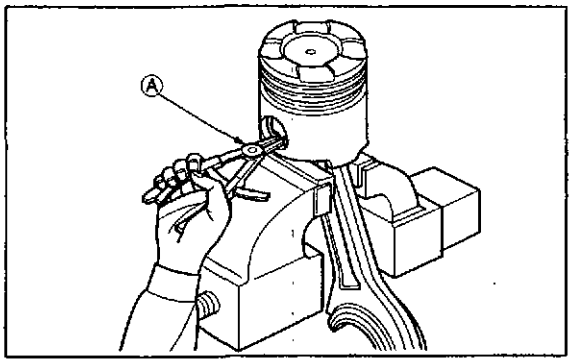


(6) Removing piston pins from a piston

(a) Use ring pliers Ⓐ (45191-08400) to remove the snap rings.

(b) Remove the piston pin to separate the piston from the connecting rod.

(c) If it is difficult to pull out the pin, heat the piston with a piston heater or in hot water to expand the pin bore.



2.2 Inspection and Repair

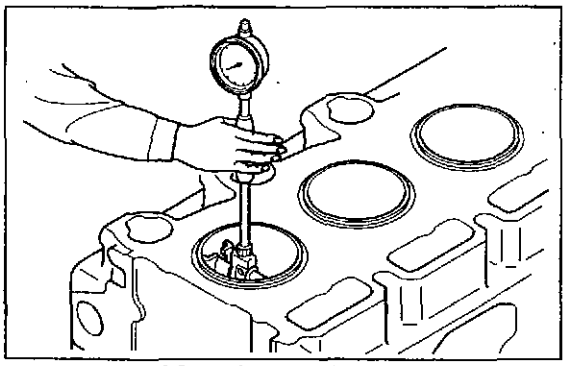
Cylinder Liners

(1) Measuring cylinder liner inside diameter

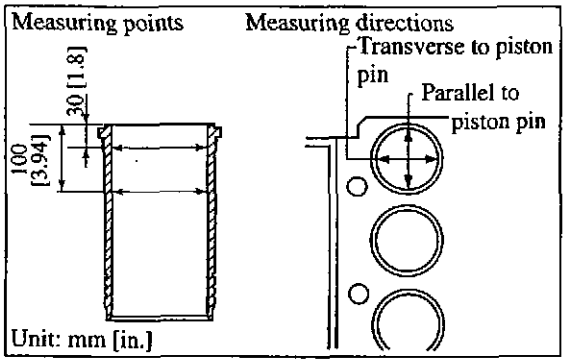
Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions, top (weared position), middle and low. If measurements exceed the service limit, replace the liner.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Cylinder liner inside diameter	ø170 [6.69]	170.000 to 170.040 [6.6929 to 6.6945]	170.500 [6.7126]



Measuring cylinder liner



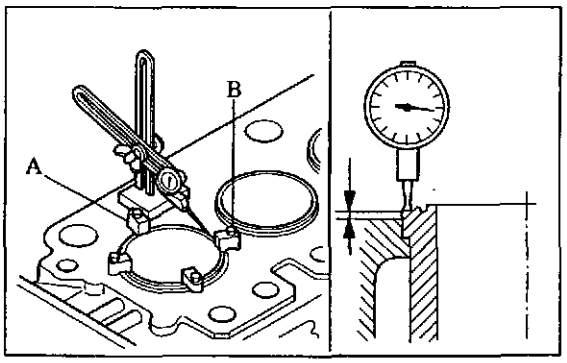
Cylinder liner measuring diagram

(2) Measuring cylinder liner protrusion

Measure the protrusion of each liner at its flange with dial gage as shown. If the protrusion is not within the assembly standards, change the position of the liner relative to its bore, or use the liner in another bore.

Unit: mm [in.]

Item	Assembly Standard
Cylinder liner protrusion at flange	0.11 to 0.20 [0.0043 to 0.0079]



Measuring cylinder liner protrusion

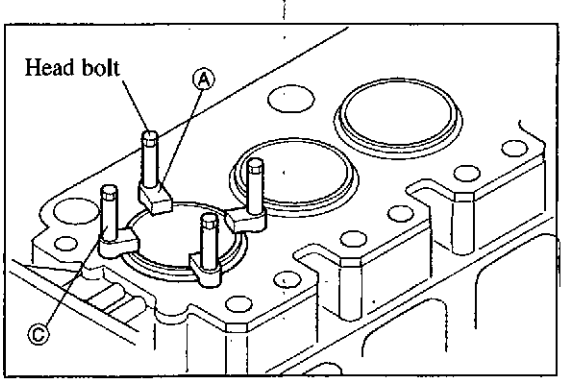
⚠CAUTION

If the protrusion is less than the assembly standard, the gasket will fail to seal the bore resulting in gas leakage.

- When cylinder head has just been removed

(a) Clean the gasketed surface of the crankcase and the top of the liners.

(b) Secure the top of the liner uniformly at four places with liner pusher Ⓐ (37591-06200) and bolt Ⓑ (37591-06300).



NOTE

Use the head bolt spacers Ⓒ (37598-09100) when tightening the line pushers using head bolts.

(c) Set up the dial gage at the top of the crankcase, then set the gage pointer to 0 (zero).

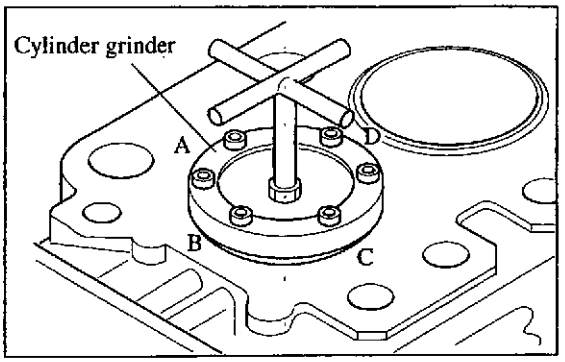
(d) Measure the protrusion at four places on top of the liner. Take the average of the four measurements.

(e) If the average is less than the assembly standard, insert a shim under the collar of the cylinder liner.

- When cylinder liner is replaced (See section (3).)

(a) Remove the cylinder liner, and study the cylinder liner contacting surface of the crankcase.

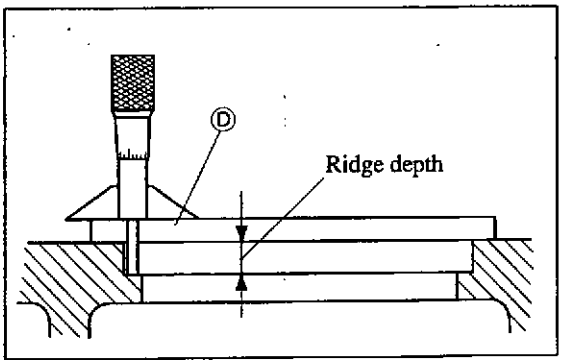
(b) If the cylinder liner contacts the crankcase only on one side, use a grinder (37591-07010) to grind the surface to keep the differences of depth in four directions A, B, C and D within 0.05 mm [0.0020 in.].



(c) Measure the ridge depth of the crankcase. Since the top surface of the crankcase may be slightly distorted, use projection plate Ⓓ (37598-09201) to obtain accurate measurements.

(d) Measure at four locations A, B, C and D, and obtain the average.

(e) Measure the thickness (standard measurement: 15 mm [0.591 in.]) of the projection plate using a micrometer. Subtract the projection plate thickness from the measured ridge depth to obtain the actual ridge depth from the top surface of the crankcase.



Unit: mm [in.]

Item	Assembly Standard
Crankcase ridge depth	$14^{+0.05}_{0}$ [$0.551^{+0.0020}_{0}$]

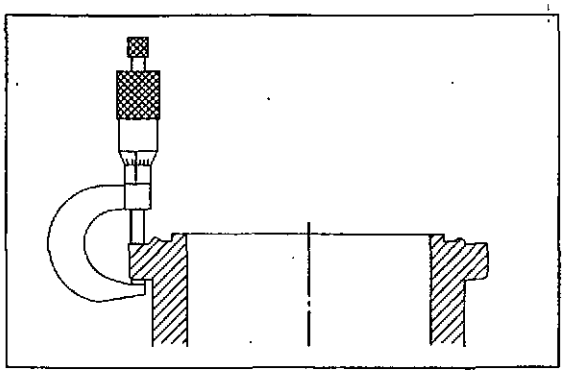
(f) Measure the thickness of the cylinder liner collar.

Unit: mm [in.]

Item	Assembly Standard
Thickness of cylinder liner collar	$14^{+0.20}_{+0.16}$ [$0.551^{+0.0079}_{+0.0063}$]

(g) Subtract the crankcase ridge depth from the cylinder liner collar thickness. This value is the cylinder liner projection.

(h) If the value is less than the assembly standard, insert a shim under the collar of the cylinder liner.



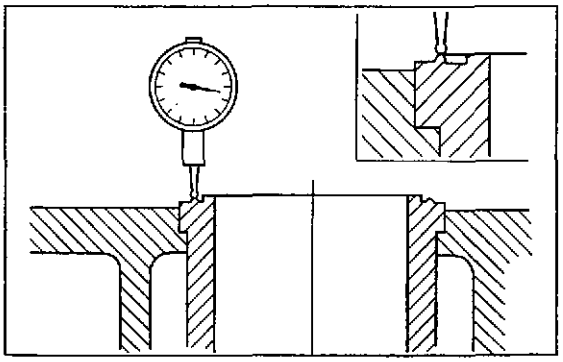
- Measuring step height of cylinder liner collar

(a) Place a dial gage on the rim of the liner collar, and set the indicator to 0 (zero).

(b) Measure the cylinder liner protrusion at four locations, and obtain the average.

Unit: mm [in.]

Item	Assembly Standard
Cylinder liner step height	0.2±0.04 [0.008±0.0016]



Measuring height of liner collar

(c) If the average is less than the assembly standard or if the protrusion has sectional chipping, replace the cylinder liner. (See section 3.)

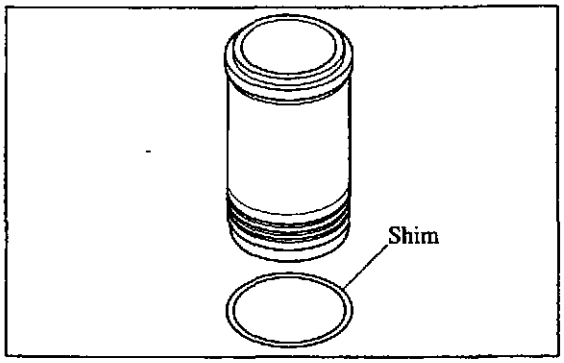
- Inserting cylinder liner shim

(a) Remove the cylinder liner. Insert a shim between the cylinder liner and crankcase.

NOTE

From the table below, select the appropriate shim thickness that achieves the largest protrusion within the assembly standard range.

Thickness of shim	Part No.
0.05 mm [0.0020 in.]	37507-12510
0.10 mm [0.0039 in.]	37507-12500
0.15 mm [0.0059 in.]	37507-12520



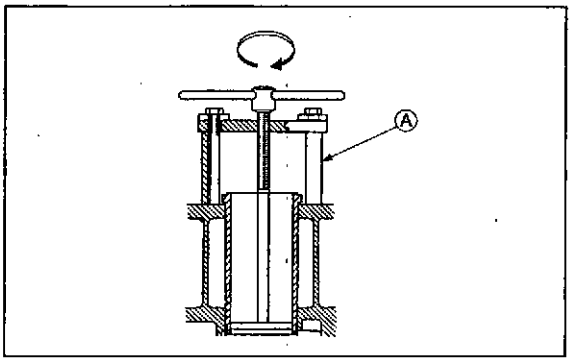
Inserting cylinder liner shim

(a) Clean the gasketed surface of the crankcase and the top of the liners.

(b) Secure the top of the liner uniformly at two places with the clamps and bolts (M22 × 2.5 mm [0.87 × 0.098 in.]).

(c) Set up the dial gage at the top of the crankcase, then set the gage pointer to 0 (zero).

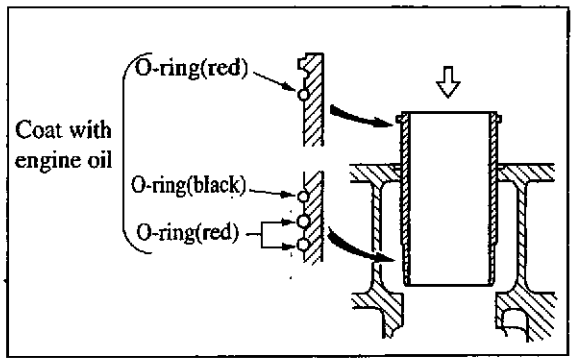
(d) Measure the protrusion at four places on top of the liner. Take the average of the four measurements.



(3) Replacing cylinder liners

(a) Use the cylinder liner remover Ⓐ (37591-04100) to remove the cylinder liner from the crankcase for replacement.

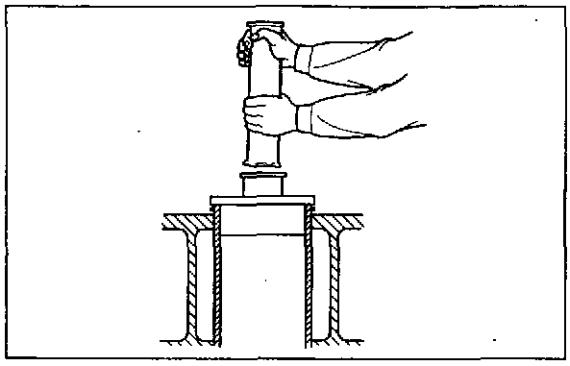
(b) Attach O-rings to the new cylinder liner, then carefully insert the liner into the bore of the crankcase.



⚠CAUTION

Before you insert the liner, coat the O-rings with engine oil to prevent them from twisting.

(c) After inserting the liner into the bore, lightly tap it on the top with the installer so it rests on its flange in the counterbore formed by the crankcase. After seating the liner, tap on it several times more to secure the proper seating.



NOTE

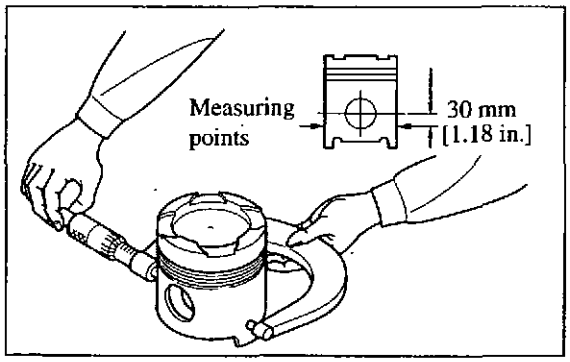
(a) After installing the liners on all bores, test the liner joints for water tightness by applying water under pressure.
(b) Check each liner to be sure its protrusion is within assembly standards.

Pistons

Check the combustion chamber and inside surfaces of the piston bosses. Replace the piston if any defects are found.

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.



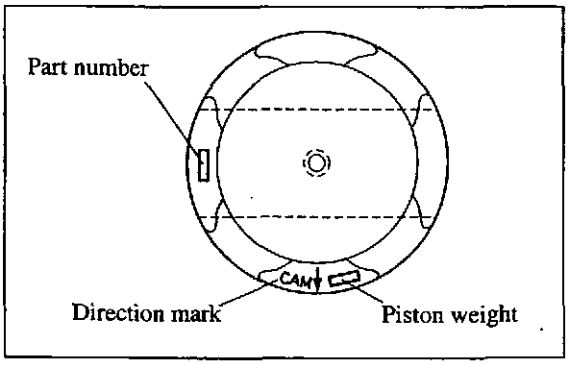
Measuring piston diameter

(1) Measuring piston diameter

(a) Using a micrometer, measure the diameter of each piston in the transverse direction to the piston pin (at the position shown). If the diameter exceeds the service limit, replace the piston. If any pistons have to be replaced, select new pistons so the variance in weight among pistons per engine is within assembly standards.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Piston diameter	ø170 [6.69]	169.76 to 169.80 [6.6885 to 6.6850]	169.66 [6.6795]
Weight variance among pistons		±10 g [±0.35 oz.] or less	

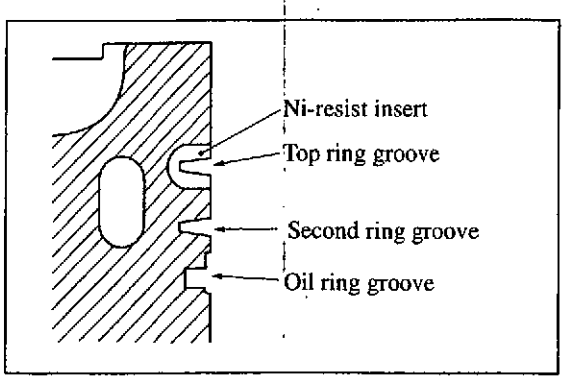


Piston weight stamp location

(b) The piston weight is stamped on the top of each piston.

(2) Inspecting piston ring grooves

Check the piston ring grooves for wear and damage, then replace the piston if necessary. Check the Ni-resist insert for cracks. Replace the piston if the insert is cracked.



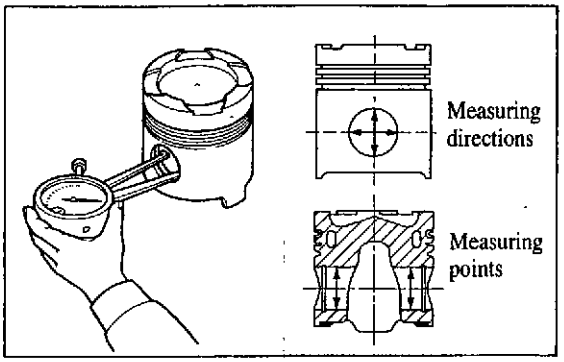
Inspecting piston ring grooves

(3) Measuring piston pin bore diameter

Using calipers or a cylinder gage, measure the piston pin bore diameter. If the diameter exceeds the service limit, replace the piston.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Piston pin bore diameter	ø 70 [2.76]	70.002 to 70.015 [2.75598 to 2.75649]	70.040 [2.75747]



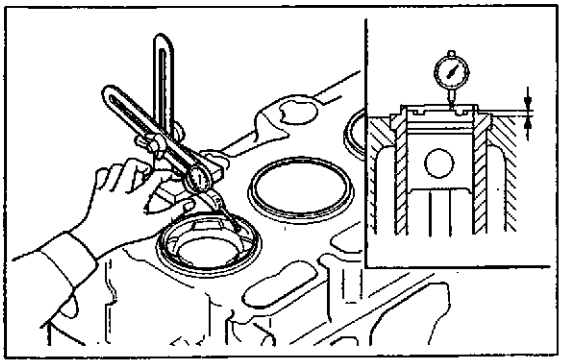
Measuring piston pin bore diameter

(4) Measuring piston protrusion

Measure the protrusion of each piston. If it is not within standards for piston protrusion measurement, inspect the clearance of the parts.

(a) Measure the top dead center of the pistons with a dial gage.

(b) Set up the dial gage at the top of the crankcase. Set the gage pointer to 0 (zero).



Measuring piston protrusion

(c) Measure the protrusion at four places on the piston head. Average the four measurements to determine the protrusion. Subtract the piston protrusion from the thickness of the cylinder head gasket (as installed) to determine the clearance between the piston top and cylinder head.

Unit: mm [in.]

Item	Assembly Standard
Piston protrusion	0.14 to 0.64 [0.0055 to 0.0252]
Installed thickness of cylinder head gasket	1.77 to 1.83 [0.0697 to 0.0720]
Clearance between piston top and cylinder head	1.24 to 1.99 [0.0488 to 0.0783]

⚠CAUTION

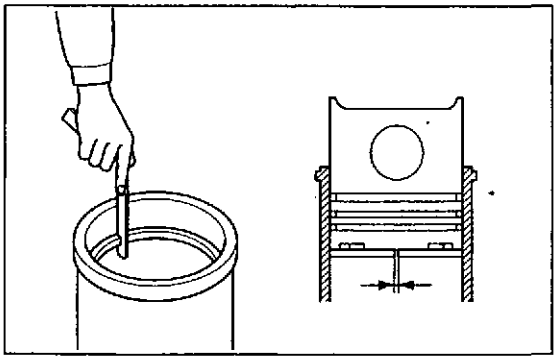
Keep the piston protrusion with assembly standard range to maintain high engine performance and to prevent the valves from interfering with the piston.

Piston Rings

(1) Measuring piston ring gaps

Place the rings for the new master cylinder liner, then measure the gap of each ring. If the gap of any ring exceeds the service limit, replace all the rings as a set.

Master cylinder liner inside diameter : 170 ± 0 mm [6.70±0 in.]



Measuring piston ring gap

NOTE

Use a piston to place the piston ring in the liner by pushing it squarely.

Unit: mm [in.]

Item		Standard Clearance	Service Limit
Piston ring gaps	Top	0.6 to 0.8 [0.024 to 0.031]	2.0 [0.079]
	Second	0.6 to 0.8 [0.024 to 0.031]	
	Oil	0.3 to 0.45 [0.012 to 0.018]	

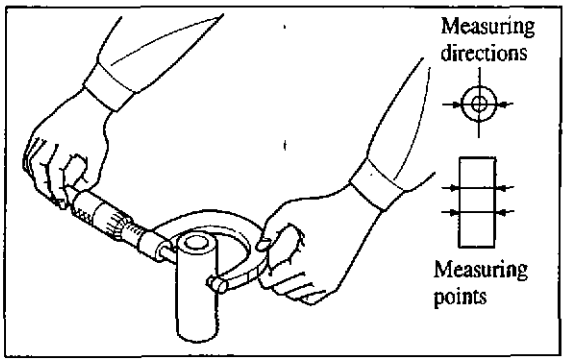
Piston Pins

(1) Measuring piston pin diameter

Using a micrometer, measure the outside diameter of each piston pin. If the outside diameter exceeds the service limit, replace the pin.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Piston pin outside diameter	ø70 [2.76]	69.987 to 70.000 [2.7559 to 2.7554]	69.970 [2.7547]



Measuring piston pin diameter

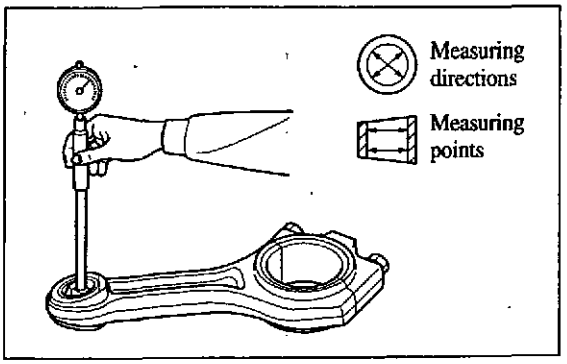
Connecting Rods, Connecting Rod Bearings, and small-end Bushings

(1) Measuring small-end bushing inside diameter

Using a cylinder gage, measure the inside diameter of each bushing. If the inside diameter exceeds the service limit, replace the bushing.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Connecting rod bushing inside diameter	ø70 [2.76]	70.020 to70.040 [2.7567 to 2.7575]	70.070 [2.7587]

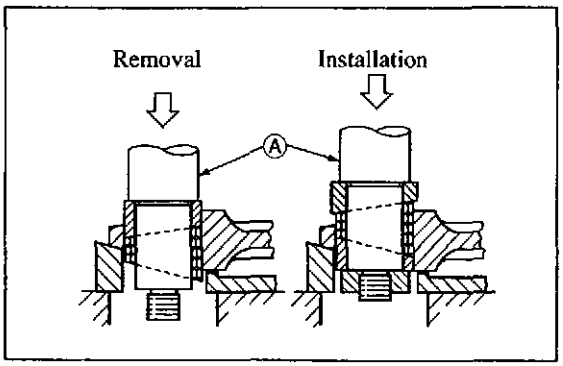


Measuring connecting rod small-end bushing inside diameter

(2) Replacing connecting rod small-end bushings

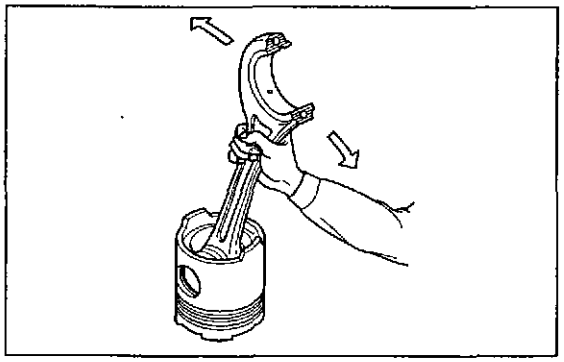
(a) Use a connecting rod small-end bushing installer Ⓐ (37591-01010) to remove the bushing for replacement as shown.

(b) When installing a new bushing, align the oil holes in the bushing and connecting rod.



Replacing connecting rod bushing

(c) After installing the bushing, insert the piston pin, and make sure that the pin rotates freely without rattling.

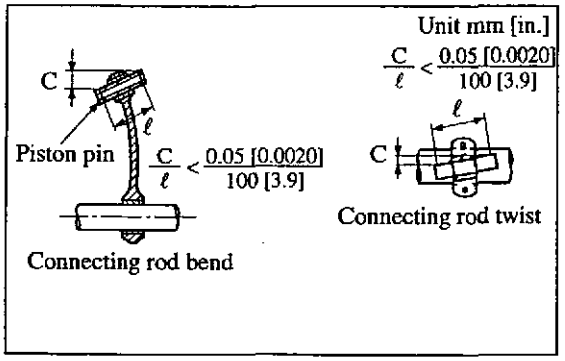


(3) Inspecting connecting rods for bend and twist.

(a) Measure C and ℓ. If the measurement at C is larger than 0.05 [0.0020 in.] mm per 100 mm [3.9 in.] of ℓ; straighten the rod with a press.

NOTE

To inspect for bend, install the cap to the connecting rod, then tighten the cap bolts to the specified torque.

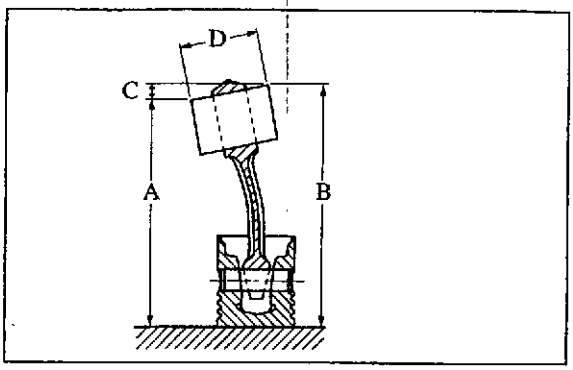


Inspecting connecting rod

(b) To inspect the rod installed to the piston, place the piston on a surface plate, insert a round bar the same diameter as the crank pin into the big-end bore, then measure heights (A) and (B) of the bar.

Unit: mm [in.]

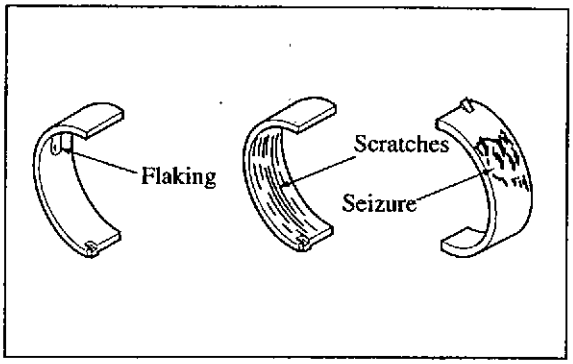
Item	Assembly Standard
Connecting rod bend and twist (C/D)	0.05/100 [0.0020/3.9] or less



Inspecting connecting rod installed on piston

(4) Inspecting connecting rod big-end bearings

Inspect each bearing shell for flaking, scratching, seizure, pitting and other defects. If any defect is found, replace the shell.



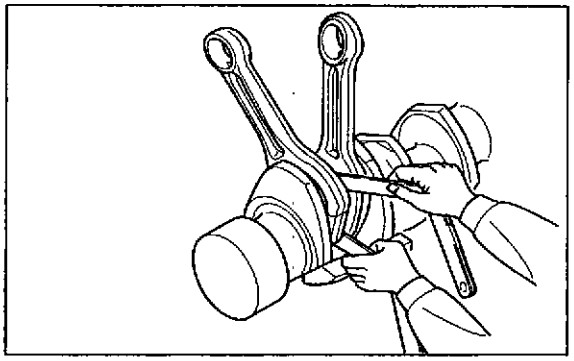
(5) Measuring connecting rod end play

Install the connecting rod to its crank pin, then tighten its cap bolts to the specified torque. Use a feeler gage to measure the end play. If the end play exceeds the service limit, replace the connecting rod.

Unit: mm [in.]

Item	Nominal Value	Standard Clearance (Nominal)	Service Limit
Connecting rod end play*	67 [2.64]	0.4 to 0.6 [0.016 to 0.024]	1.0 [0.039]

*Widths of connecting rod and crank pin



Measuring connecting rod end play

(6) Variance weight difference of connecting rods per engine

When replacing connecting rods, make sure that the weight difference of connecting rods per engine is within the assembly standards below.

Unit: mm [in.]

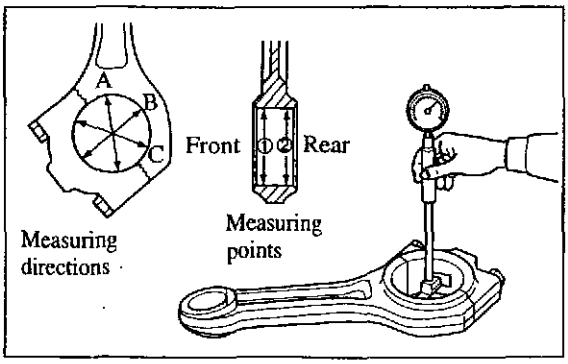
Item	Assembly Standard
Variance in weight among connecting rods per engine	±30 g [±1.06 oz.] or less

(7) Measuring connecting rod big-end bore diameter

Measure the connecting rod big-end bore diameter in directions A, B and C and at front and rear positions ① and ②, as shown in the diagram. To obtain the Roundness valve, substract the smallest measured value from the largest measured value.
If the diameter exceeds the service limit, replace the connecting rod.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit	Roundness Service Limit
Connecting rod big-end bore diameter	ø131 [5.16]	131.000 to 131.025 [5.1547 to 5.1585]	131.050 [5.15944]	0.100 [0.0039]



Measuring connecting rod big-end bore diameter

(8) Inspecting serration on connecting rod big-end bore

Inspect the serration on connecting rod big-end bore by conducting a Magnalux (magnetic particle) test. If cracking or damage is found, replace the connecting rod.

(9) Measuring connecting rod bearing thickness

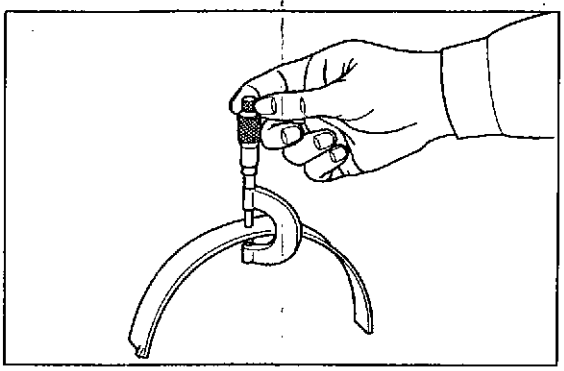
Use a ball-point micrometer to measure the center of each bearing shell. If the thickness exceeds the service limit on the upper or lower shell, replace both shells as a set.

Unit: mm [in.]

Item		Nominal Value	Assembly Standard	Service Limit
Connecting rod bearing thickness	STD	3.000 [0.1181]	2.957 to 2.970 [0.1164 to 0.1169]	2.930 [0.1154]
	-0.25 [-0.0098]	3.125 [0.1230]	3.082 to 3.095 [0.1213 to 0.1219]	3.055 [0.1203]
	-0.50 [-0.0197]	3.250 [0.1280]	3.207 to 3.220 [0.1263 to 0.1268]	3.180 [0.1252]
	-0.75 [-0.0295]	3.375 [0.1329]	3.332 to 3.345 [0.1312 to 0.1317]	3.305 [0.1301]
	-1.00 [-0.0394]	3.500 [0.1378]	3.457 to 3.470 [0.1361 to 0.1366]	3.430 [0.1350]

NOTE

Four sizes are available for the connecting rod bearings (see column 2 of the table above).



Measuring connecting rod bearing thickness

2.3 Reassembly

Reassembly is done in the reverse order of disassembly.

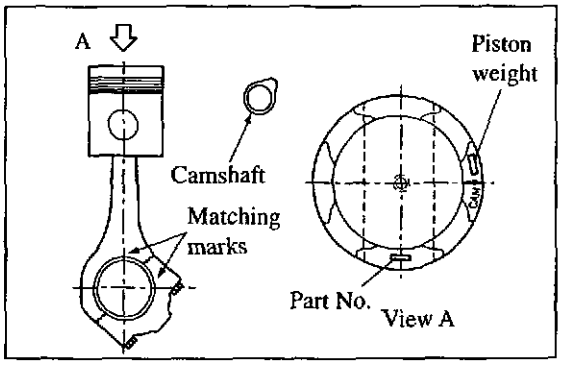
(1) Reassembling pistons on connecting rods

(a) The piston pin is clearance-fitted to the piston. To facilitate pin insertion, heat the piston with a piston heater or in hot water.

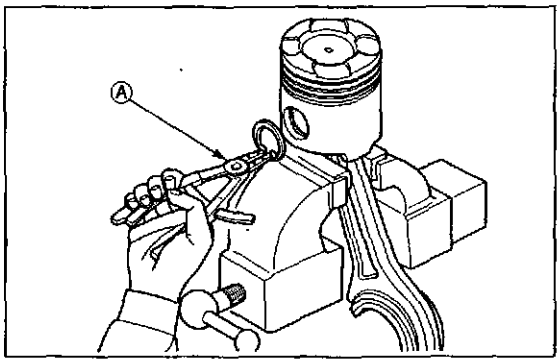
(b) Coat the piston pin with engine oil, then insert it in position through the connecting rod.

(c) Install the connecting rod to the piston with the matching marks on the big-end on the camshaft side.

(d) Use the ring pliers Ⓐ (45191-08400) to install the snap rings in the grooves of the pistons. Make sure that the rings are not fatigued and that they fit in the grooves properly.



Matching marks on connecting rod

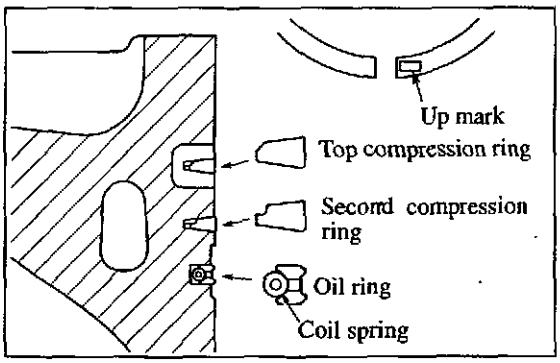


NOTE

Position the ends of both snap rings at the bottom of the pin bore.

(2) Installing piston rings

(a) Use the piston ring tool (37191-03200) to install the piston rings on the piston.

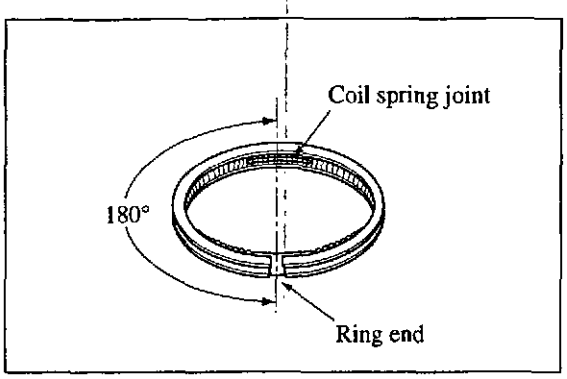


Piston and piston rings

⚠CAUTION

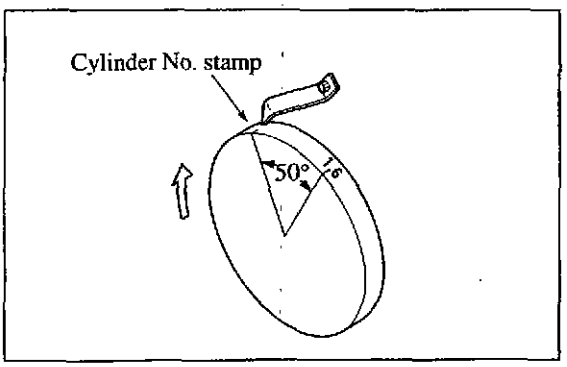
The top piston ring and second piston ring are marked "RH", and the oil ring is marked "R" near the gap on the side. Install the rings with these marks upside down. If not, excessive oil consumption and overheating will result.

(b) Install the oil ring with its gap positioned at 180° to the coil spring joint.

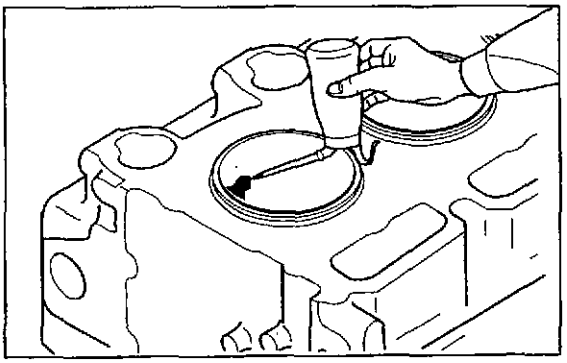


(3) Preparation before installing pistons

(a) Turn the crankshaft in the normal direction until the number (stamped on the damper) of the cylinder to which the piston is to be installed is at the position of approximately 50° before top dead center.

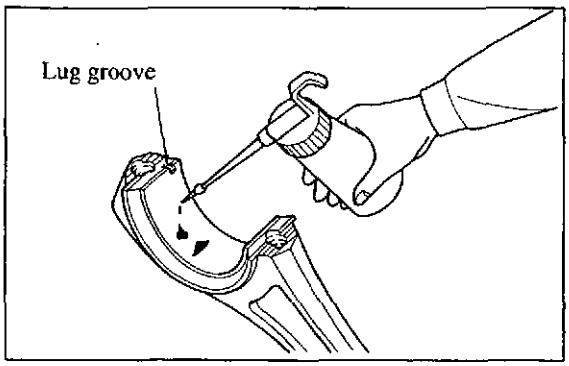


(b) Clean the cylinder liner bore surface and crank pin by wiping with a cloth, then coat it with engine oil.



(4) Installing connecting rod bearing upper shells

Install the upper shell of the bearing in the rod by fitting its locking lip in the recess provided in the rod. Coat the inside surface of the shell with engine oil. Make sure the oil holes in the rod and bearing are aligned.

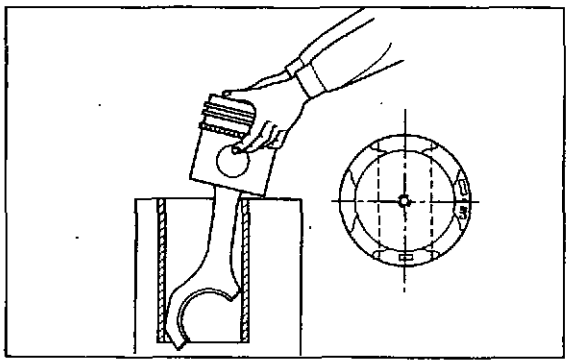


(5) Inserting pistons

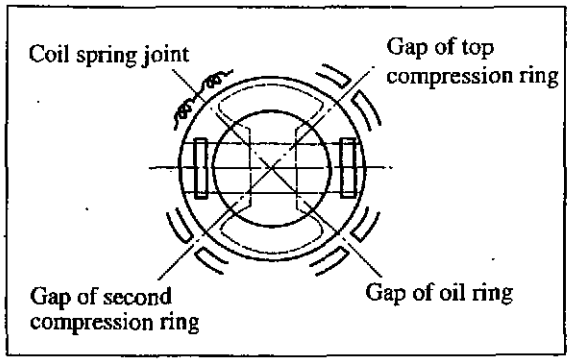
(a) Put the connecting rod in the cylinder liner, and carefully rest the piston on top of the crankcase.

⚠CAUTION

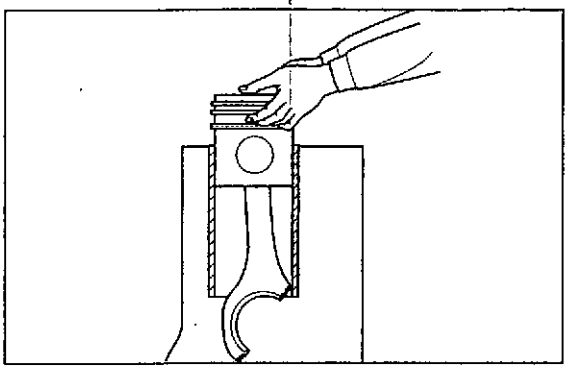
Make sure the arrow mark "CAM" on top of the piston points the camshaft side.
When placing the connecting rod in the liner, keep it away from the oil jet nozzle by observing the rod through the inspection hole of the crankcase. And do not rotate the piston.



(b) Coat the piston rings with engine oil, then position the ring gaps away from the axis of piston pin and antithrust direction.



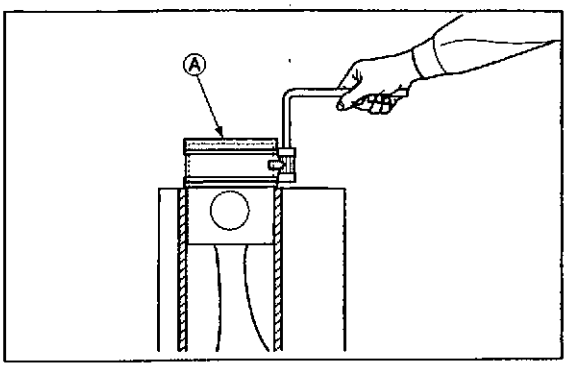
(c) With your hands, hold the compression ring portion of the piston, then carefully insert the piston into the cylinder liner.



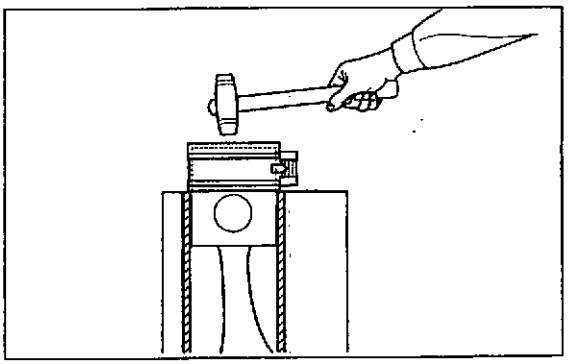
NOTE

(a) Do not pinch your finger between the oil ring and cylinder liner.
(b) Slowly insert the piston to avoid damaging it.

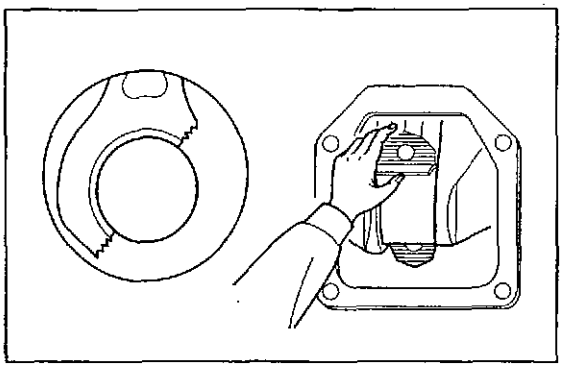
(d) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, then clamp them, using the piston installer Ⓐ (37191-07100). At this time, coat the inside surface of the installer with engine oil.



(e) Lightly tap on the piston head with a soft hammer to insert the piston into the cylinder liner. If the piston will not go into the liner, move the big-end of the connecting rod back and forth through the crankcase inspection hole.

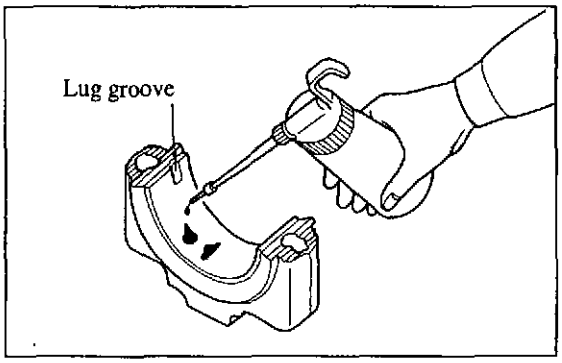


(f) By inserting your hand through the crankcase inspection hole, make sure that the upper shell of the bearing is properly positioned in the big-end of the connecting rod.

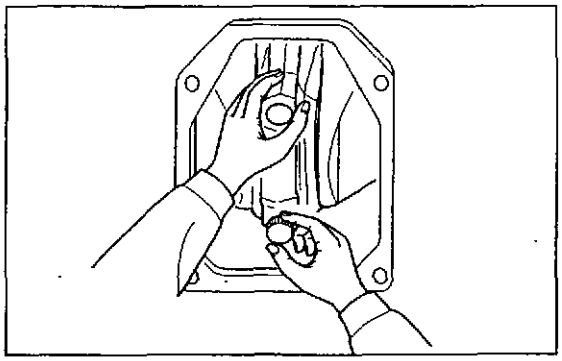


(6) Installing connecting rod cap bolts

(a) Place the connecting rod bearing on the connecting rod cap fitting with its lug in the lug groove. Coat the threads of the cap bolts and the inside surface of the lower shells of the connecting rod bearing with engine oil.



(b) Install each cap in position. With your hand, hold the upper end of the cap, then tighten the bolt at the lower end first. This will prevent the cap from dropping into the oil pan. Coat the threads of the bolts with engine oil, then tighten the bolts temporarily.

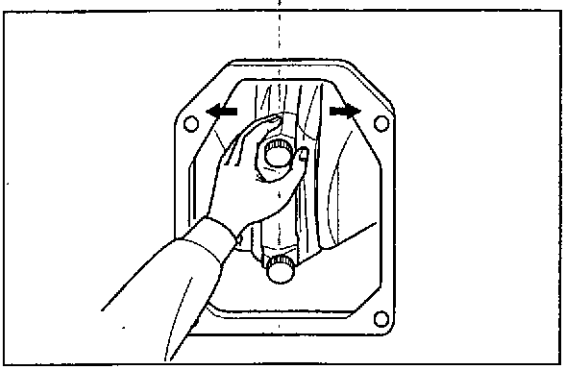


(c) With the cap bolts tightened temporarily, touch the joint between the cap and rod. Make sure that the cap is normally held in place, and tighten the bolts to the specified torque.

⚠CAUTION

Make sure that the matching marks on the cap and rod are on the same side and aligned.

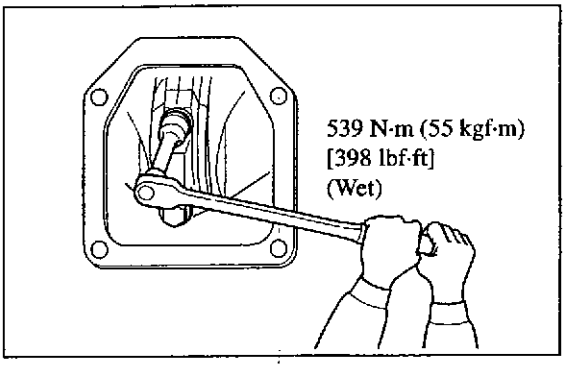
(d) Install the other connecting rod to the crankpin. Temporarily tighten the cap bolts of the rod installed later, then press it squarely toward the rod already installed by tapping. Move the big-end of this rod in the thrust direction. Make sure that the rod has correct end play.



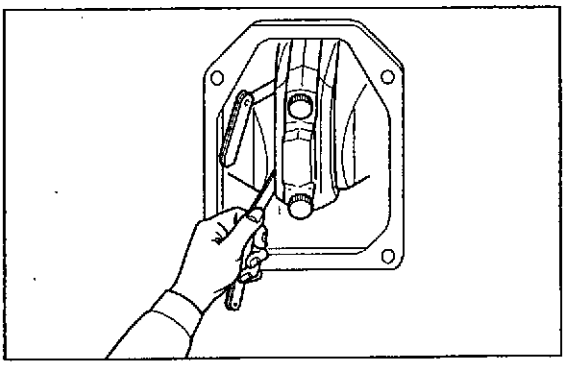
(e) After tightening the connecting rod cap mounting bolts to the specified torque, loosen them completely, then tighten to the specified torque again. (2-step tightening method)

NOTE

To tighten connecting rod cap bolts according to the angle method, tighten to 245 N·m (25 kgf·m) [181 lbf·ft], then turn each bolt by 30°. After tightening all the bolts, turn each bolt again by 30° (total of 60° turn).



(f) Use a feeler gage to measure the end play of the connecting rod. Make sure that the end play is equal on both top and bottom sides of the crank pin.

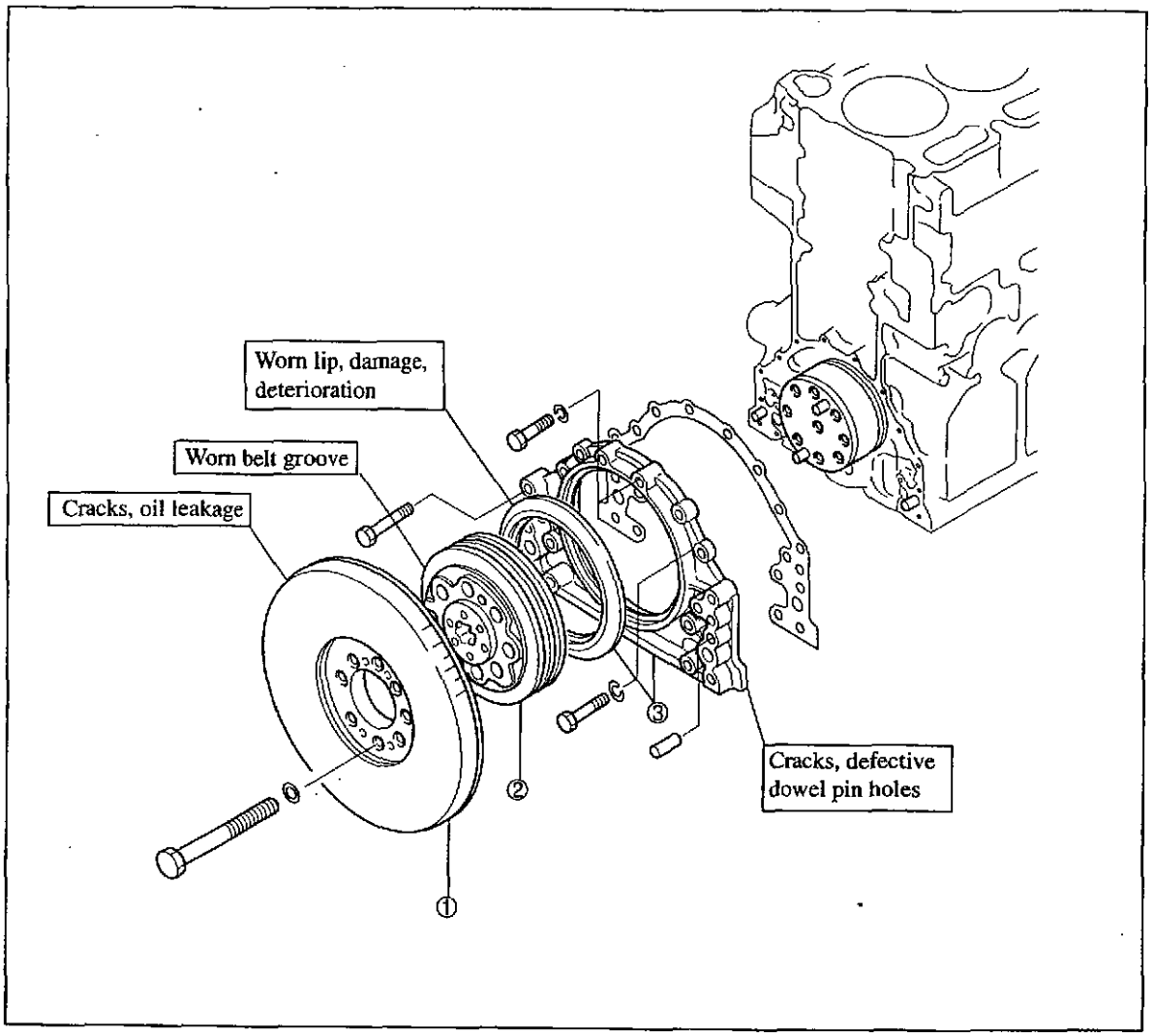


⚠CAUTION

Before installing the cylinder head, measure the protrusion of piston. Make sure that the measurement is correct.

3. Damper

3.1 Disassembly



Disassembly sequence

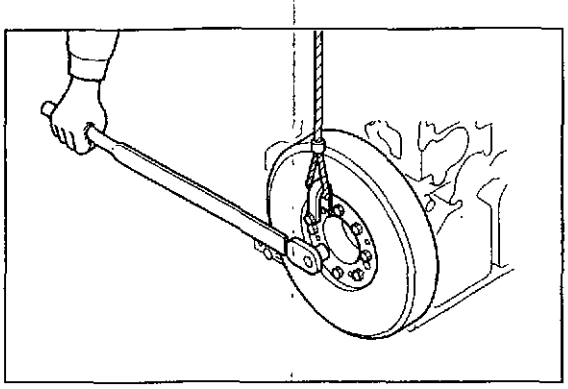
① Damper
② Pulley (water pump and alternator drive)
③ Front cover, oil seal

(1) Removing the damper

(a) Attach a sling to the damper. Unscrew the damper mounting bolts.

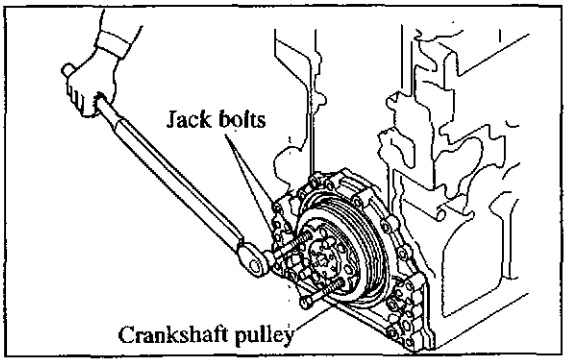
(b) To remove the damper, install two jack bolts (M12 × 1.25 - 40 mm [0.47 × 0.049 - 1.57 in.]) in bolt holes and screw the bolts evenly while lifting the damper.

Weight : approx. 50 kg [110 lb]



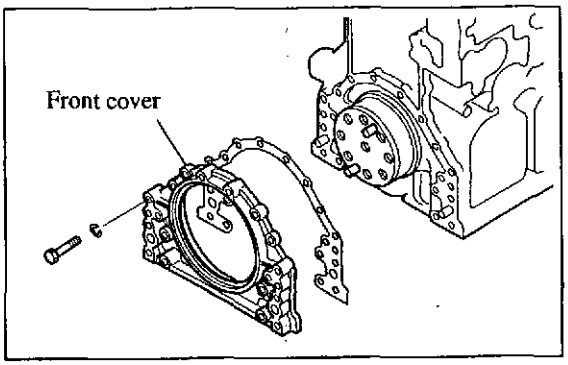
(2) Removing crankshaft pulley (water pump & alternator drive)

Screw in two jack bolts (M10 × 1.25 - 120 mm [0.394 × 0.049 – 4.72 in.]) evenly to remove the crankshaft pulley.



(3) Removing front cover

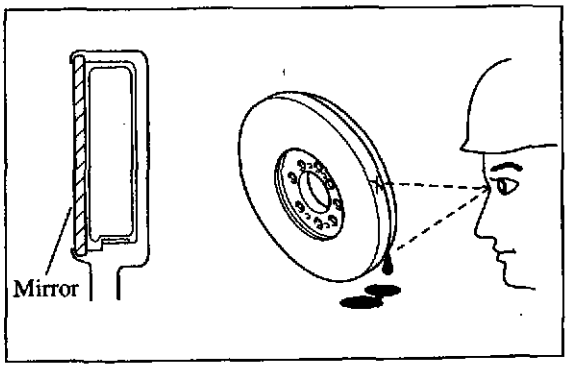
Unscrew the front cover mounting bolts, and remove the cover, being careful not to damage the oil seal.



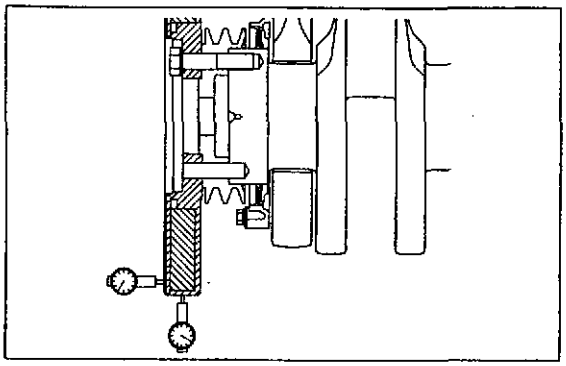
3.2 Inspection and Repair

(1) Damper inspection

(a) Check the damper for external cracks, swelling and cracking of the polished plate, silicon oil leaks, paint discoloration due to heat, and loss of overlay.



(b) Measure damper circular and face runout. With the damper installed on the engine, place dial gages on the periphery and side face near the periphery, and turn the crankshaft slowly to measure runout. If the measured value exceeds the service limit, replace the damper. The damper should be replaced every 8,000 operating hours even if there is no sign of abnormality.



Measuring damper runout

Unit: mm [in.]

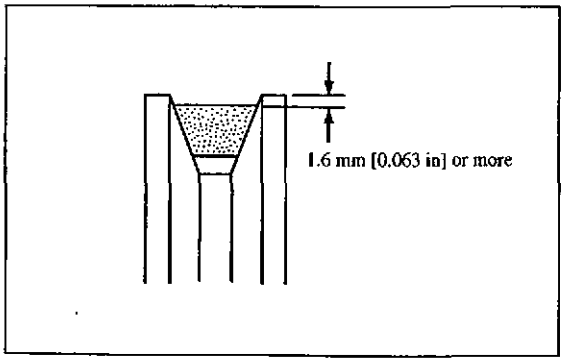
Item	Assembly Standard	Service Limit
Circular runout (at periphery)	0.5 [0.020] or less	1.5 [0.059]
Face runout	0.5 [0.020] or less	1.5 [0.059]

(2) Inspecting crankshaft pulley

Check the V-belt groove of the pulley for wear. To evaluate wear, wind a new V-belt tightly around the pulley and check if the outer surface of the belt is above the outer edge of the groove.

If the outer surface of the belt extends from the outer edge of the groove (and the amount of extension is the same for all belts if the pulley has two or more grooves), it is not necessary to replace the pulley.

If the outer surface of the belt is below the outer edge of the pulley by 1.6 mm [0.063 in.] or more, replace the pulley.

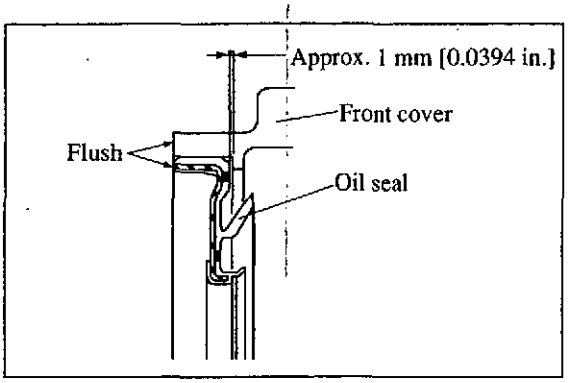


Checking V-belt groove for wear

3.3 Reassembly

(1) Installing front cover

(a) Apply engine oil to the lip section of the oil seal. Install the oil seal in the front cover, making sure that the oil seal is flush with the end face of the oil seal installation hole of the front cover.

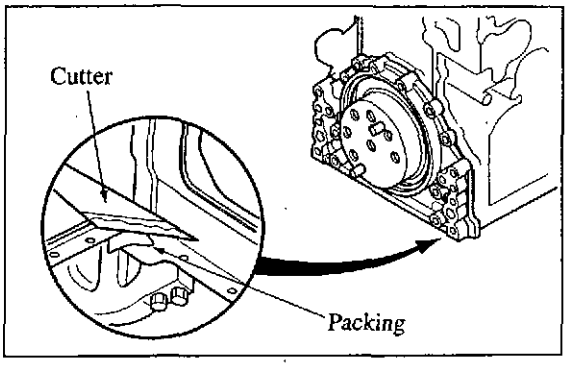


(b) Apply sealant (Herdite) to the front cover packing mounting surface of the crankcase, position the packing on the surface, then apply sealant on the packing. Install the front cover.

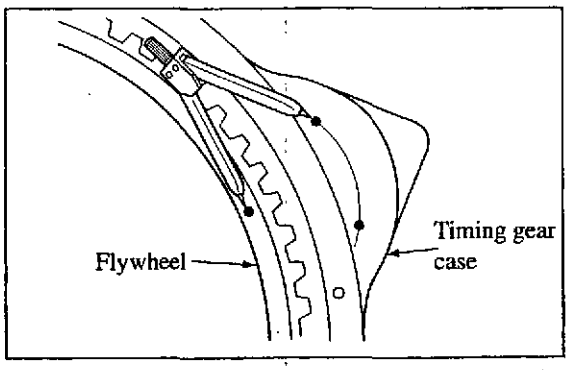
(c) If the dowel pins are worn or the cover has been replaced, install new dowel pins.

(d) Tighten the case mounting bolts evenly.

(e) Check to make sure the bottom surfaces of the front cover and crankcase are flush. Carefully remove excess packing protrusion from the joined surfaces.

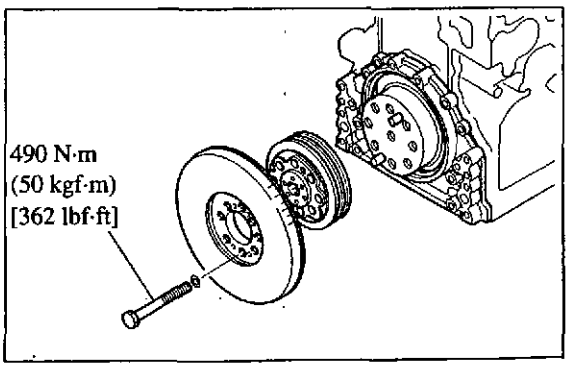


(When the pointer was removed or dislocated accidentally)
To determine the top dead center of No. 1 piston in compression stroke, bring the mark on the flywheel to the position where it is at the equal distances from the two marks punched on the timing gear case. When these mark are positioned at the equal distance from one another, No. 1 and No. 6 pistons are at the top dead center.



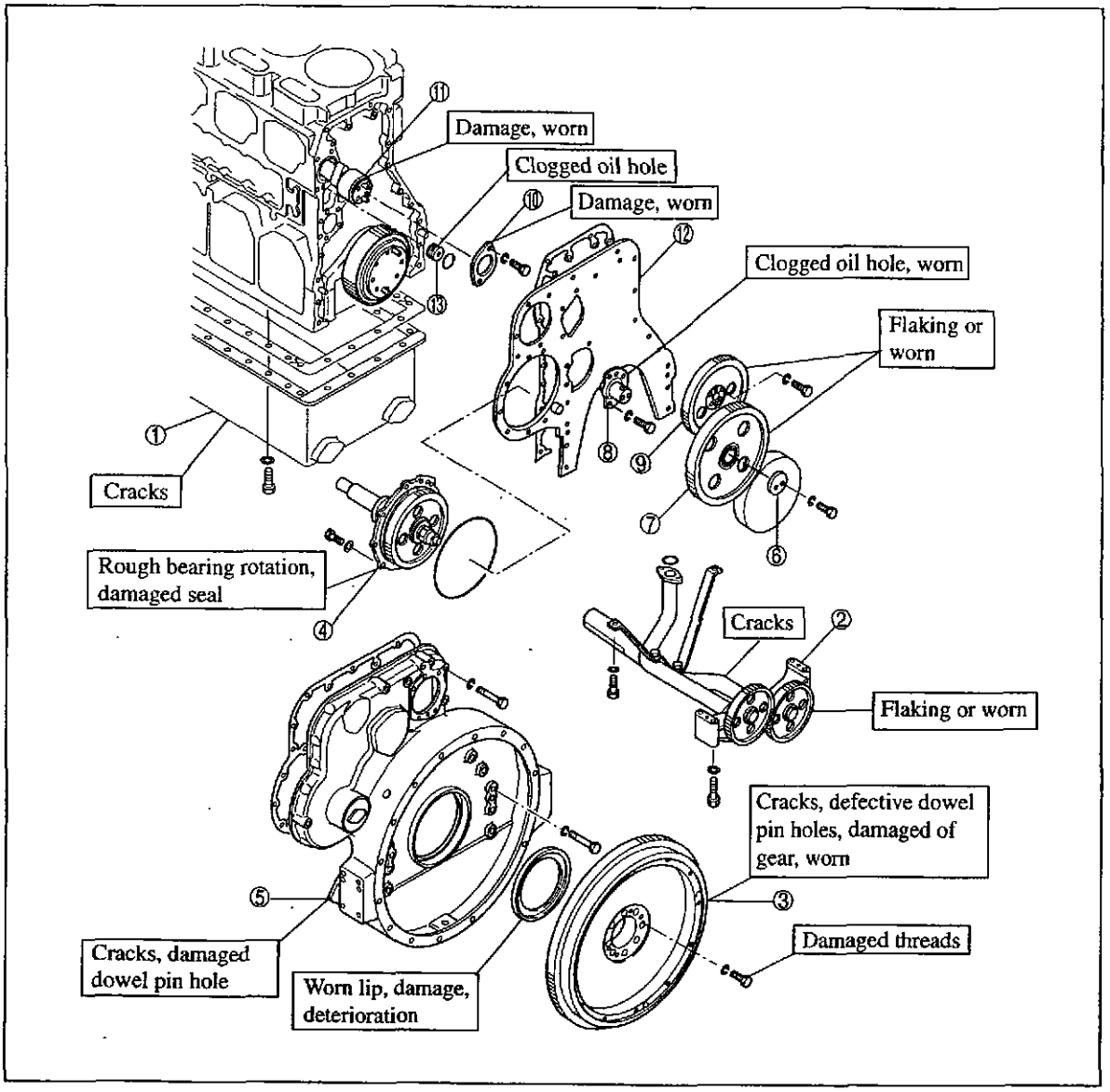
(2) Installing pulley and torsional damper

Tighten the pulley and damper mounting bolts to the specified torque.



4. Flywheel, Timing Gears and Camshaft

4.1 Disassembly



Disassembly sequence

① Oil pan
② Oil strainer, oil pipe, oil pump
③ Flywheel
④ Injection pump accessory drive
⑤ Timing gear case, oil seal
⑥ Thrust plate
⑦ Idler gear
⑧ Idler shaft
⑨ Camshaft gear
⑩ Thrust plate
⑪ Camshaft
⑫ Rear plate
⑬ Nozzle plate

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

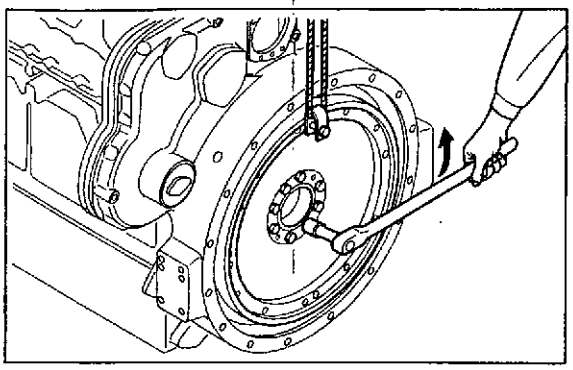
(1) Removing flywheel

(a) Attach a sling on the flywheel.

(b) Remove the flywheel mounting bolts.

(c) Install two jack bolts (64362-68500: M12 × 1.25 mm [0.47 × 0.049 in.]) in the holes provided for flywheel removal, and screw the bolts evenly to remove the flywheel.

Weight: approx. 140 kg [309 lb]

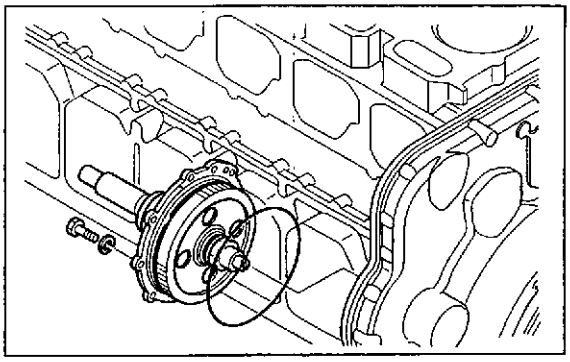


⚠CAUTION

(a) When you move the flywheel, do not drop it or bump it against a hard object.
(b) The ring gear is bolted to the flywheel. Do not remove the ring gear from the flywheel except when it has to be replaced.

(2) Removing injection pump accessory drive

Remove the mounting bolts from the injection pump accessory drive case. Remove the injection pump accessory drive. Be careful not to damage the gear teeth.



(3) Removing timing gear case

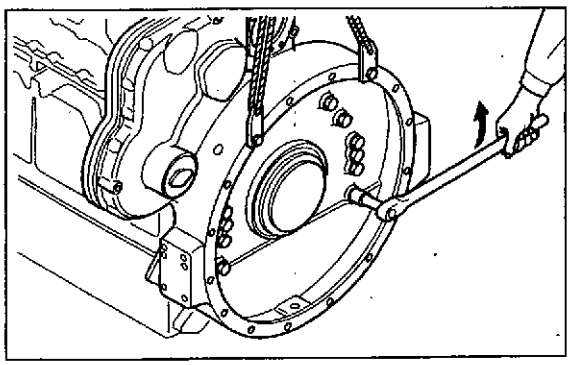
(a) Attach slings to the timing gear case.

(b) Unscrew the timing gear case mounting bolts.

(c) Remove the timing gear case by lifting it up until it separates from the dowel pin. Do not damage the oil seal.

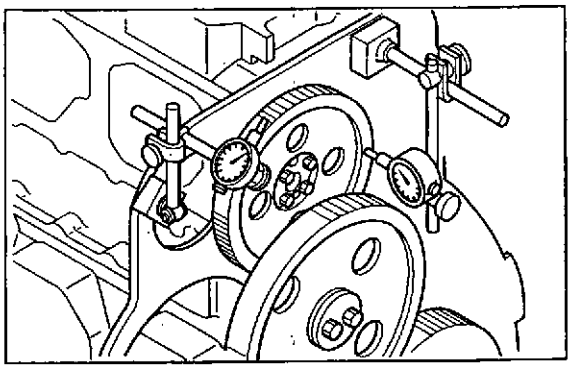
In this step, be sure to keep the timing gear case suspended, and be careful not to damage the oil seal.

Weight: approx. 88 kg [194 lb]



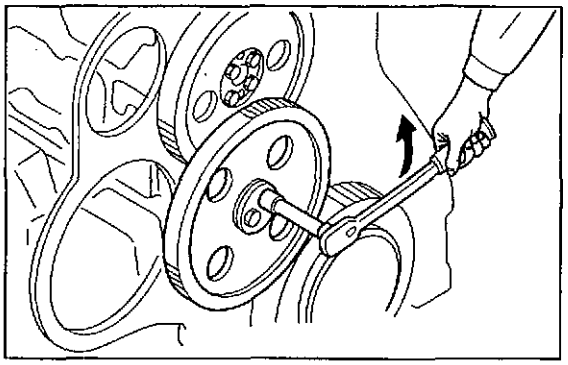
(4) Measuring backlash and end play

Measure the backlash and end play of each gear to obtain the data for parts replacement.



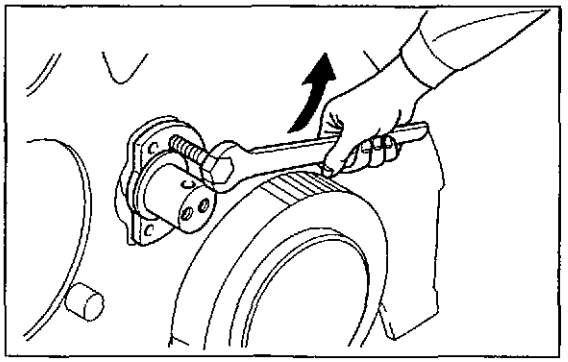
(5) Removing idler gear

Align the pointer with the mark "3" for top dead center of piston No. 1 in compression stroke. Remove the thrust plate mounting bolts, and remove the idler gear.



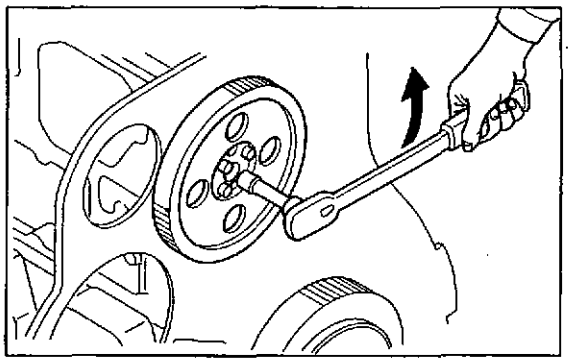
(6) Removing the idler shaft

Remove the idler shaft mounting bolts. Install two jack bolts (M10 × 1.25 mm [0.39 × 0.049 in.]) in the holes provided for shaft removal, and screw the bolts evenly to remove the idler shaft.



(7) Removing camshaft gear

Unscrew the camshaft gear mounting bolts, then remove the camshaft gear.



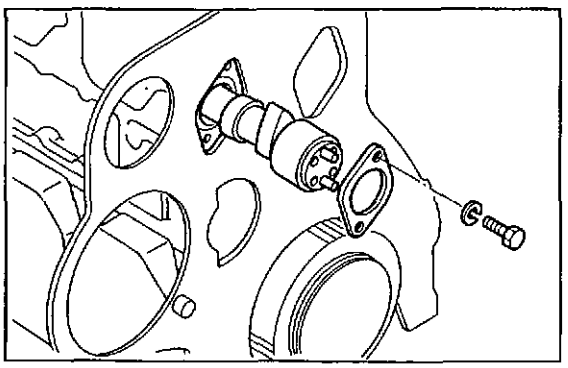
(8) Removing camshaft

Remove the thrust plate mounting bolts. Remove the camshaft from the crankcase.

Camshaft weight: approx. 32 kg [71 lb]

⚠CAUTION

When pulling out the camshaft, support it with a bar inserted through the camshaft inspection window of the crankcase to prevent damaging the cam surfaces and bushings.

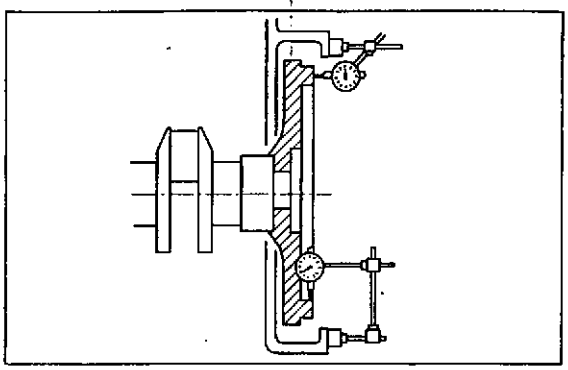


4.2 Inspection and Repair

Flywheel and Ring Gear

Measuring the flywheel face and circular deflections.

Measure the runouts with the flywheel installed on the crankshaft. If the runouts exceed the assembly standard, check for loose bolts or obstacles lodged between the mounting faces of the flywheel and crankshaft.



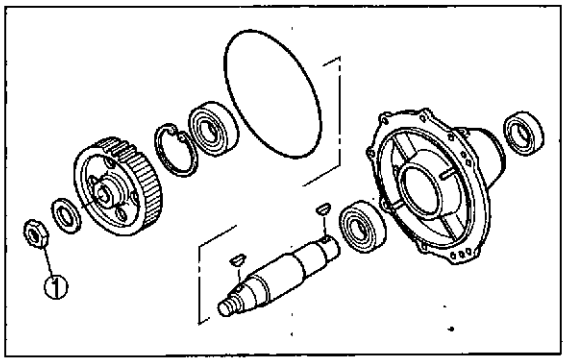
Measuring flywheel deflection

Unit: mm [in.]

Item		Assembly Standard
Flywheel	Face runout	0.285 [0.0112] or less
	Circular runout	0.127 [0.0050] or less

Injection Pump Drive Diameter and Inside Diameter of Bearings

Remove nut ① using socket (58309-73100).



Inspect each bearing for smooth rotation. Replace the bearing if its rotation is not smooth.

Inspect the fit of the bearing inner race on the drive shaft. Replace excessively worn parts.

Inspect the fit of the bearing outer race in the drive case. Replace excessively worn parts.

Inspect the drive shaft and oil seal. Replace any defective part.

Unit: mm (in.)

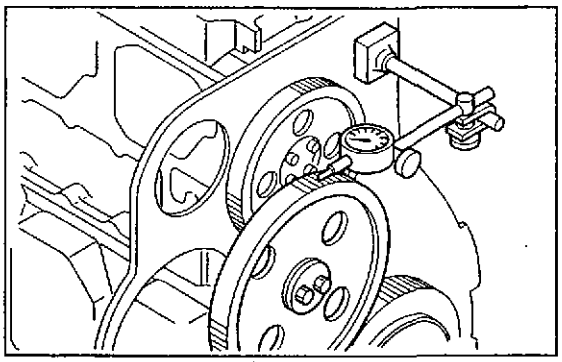
Item		Nominal Value	Assembly Standard
Case bearing bore inside diamter		ø90 [3.54]	89.987 to 90.022 [3.5428 to 3.5442]
		ø100 [3.94]	99.987 to 100.022 [3.9365 to 3.9379]
Bearing	Outside diameter	ø90 [3.54]	89.985 to 90.000 [3.5427 to 3.5433]
		ø100 [3.94]	99.985 to 100.000 [3.9364 to 3.9370]
	Inside diameter	ø45 [1.77]	44.988 to 45.000 [1.7712 to 1.7717]
		ø50 [1.97]	49.988 to 50.000 [1.9680 to 1.9685]
Drive shaft bearing diameter		ø45 [1.77]	45.002 to 45.013 [1.7717 to 1.7722]
		ø50 [1.97]	50.002 to 50.013 [1.9686 to 1.9690]

Timing Gears: Measuring Backlash

To measure the backlash between the gears, set up a dial gage so that it contacts the pitch circle of the gear to measure. If a dial gage is not available, measure the backlash by inserting a feeler gage between the gear teeth. If the backlash exceeds the service limit, replace the worn gear.

Unit: mm [in.]

Item	Standard Clearance	Repair Limit	Service Limit
Timing gear backlash	0.12 to 0.18 [0.0047 to 0.0071]	0.30 [0.0118]	0.50 [0.0197]



Measuring timing gear backlash

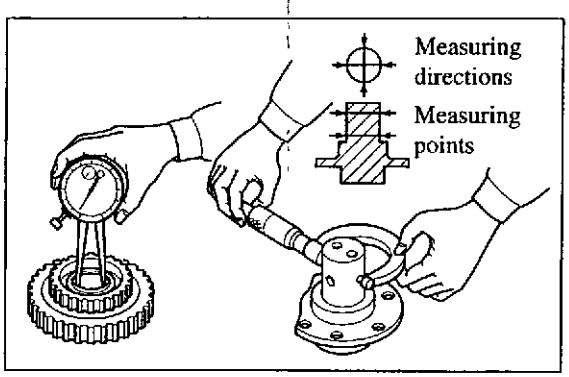
Idler Gears, Idler Gear Bushing, and Idler Gear Shafts

(1) Measuring the idler gear bushing inside diameter and idler gear shaft diameter

If the diameter exceeds the service limit, replace the bushing or shaft if either is worn.

Unit: mm [in.]

Item	Norminal Value	Assembly Standard	Service Limit
Idler gear, bushing inside dia.	ø50 [1.97]	50.000 to 50.025 [1.9685 to 1.9695]	50.060 [1.9709]
Idler gear shaft dia.	ø50 [1.97]	49.950 to 49.975 [1.9665 to 1.9675]	49.900 [1.9646]



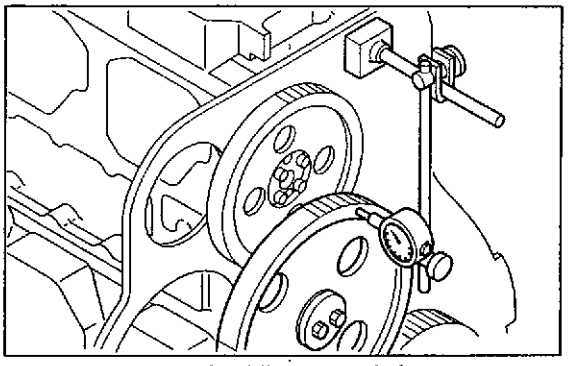
Measuring idler gear bushing and shaft

(2) Measuring idler gear end play

Measure the end play with a feeler gage or a dial gage. If the end play exceeds the repair limit, replace the thrust plate.

Unit: mm [in.]

Item	Standard Clearance	Service Limit
Idler gear end play	0.2 to 0.4 [0.008 to 0.016]	0.6 [0.024]

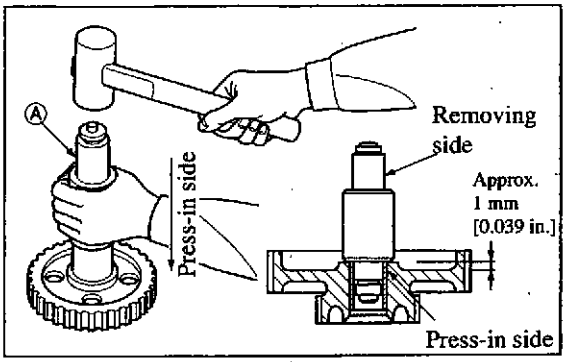

Measuring idler gear end play

(3) Replacing idler bushings

(a) Use an idler bushing puller Ⓐ (32591-02500) to remove the existing bushing.

(b) Install a new bushing to the gear by pressing it until the end face of the bushing 1 mm [0.04 mm] recessed from that of the gear boss.

(c) After installing the bushing, be sure its inside diameter is within the assembly standard. If it is less than assembly standard, ream the bushing to the inside diameter of $ø50^{+0.025}_{0}$ mm [$1.97\,^{+0.00098}_{0}$ in.] 0.4Ra.



Replacing the idler gear bushing

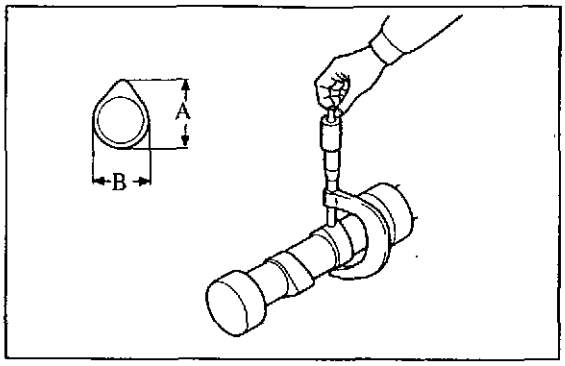
Camshafts and Camshaft Bushings

(1) Measuring cam lift

Use a micrometer to measure the diameters of "A" and "B" on each cam to determine the loss in cam lift. If the cam lift is less than the service limit, replace the camshaft.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Cam lift (A-B)	9.197 to 9.297 [0.3621 to 0.3660]	8.45 [0.3327]



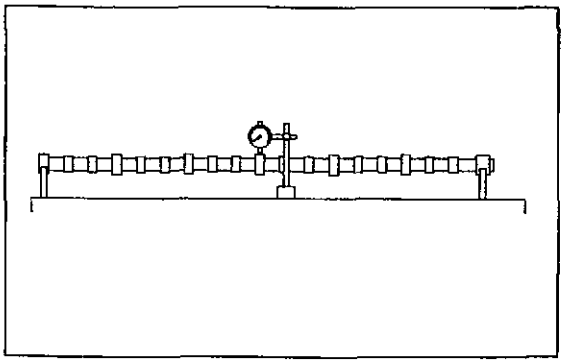
Measuring cam lift

(2) Measuring camshaft deflection

If the runout exceeds the repair limit, straighten the camshaft with a press, or replace it with a new one.

⚠CAUTION

Set up a dial gage on the camshaft, then turn the camshaft. Take one-half of the gage indication as the deflection.


Measuring camshaft deflection

Unit: mm [in.]

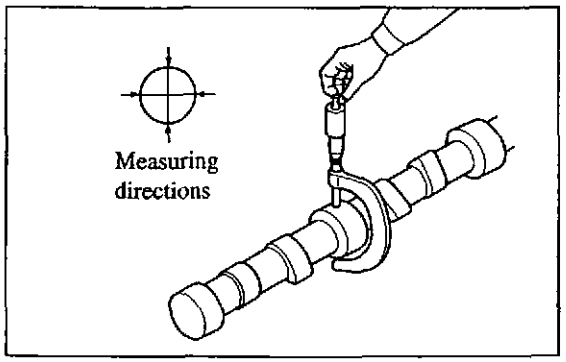
Item	Assembly Standard	Repair Limit
Camshaft deflection	0.05 [0.0020] or less	0.08 [0.0031]

(3) Measuring camshaft journal diameter

Use a micrometer to measure each camshaft journal in two directions at right angles to each other. If the diameter exceeds the service limit, replace the camshaft.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Camshaft journal diameter	ø84 [3.31]	83.92 to 83.94 [3.3039 to 3.3047]	83.87 [3.3031] 3.3047]



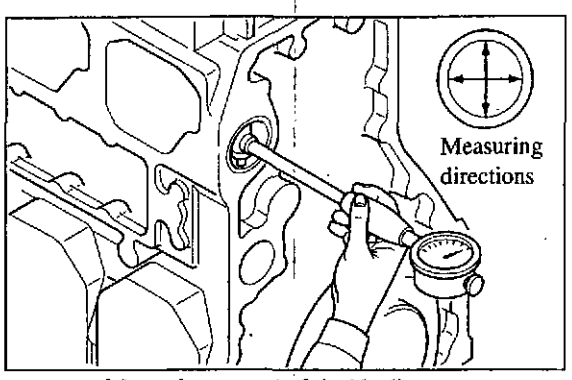
Measuring camshaft journal diameter

(4) Measuring camshaft bushing inside diameter

Use a cylinder gage to measure the inside diameter of the camshaft bushings fitted to the crankcase. If the inside diameter exceeds the service limit, replace the bushings.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Camshaft bushing inside dia.	ø84 [3.31]	84.000 to 84.035 [3.3071 to 3.3085]	84.10 [3.3110]



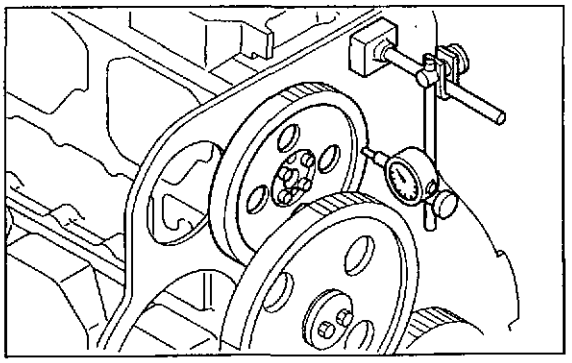
Measuring cam shaft inside diameter

(5) Measuring camshaft end play

Use a dial gage to measure the end play of the camshaft to which the camshaft gear is installed. If the end play exceeds the service limit, replace the thrust plate.

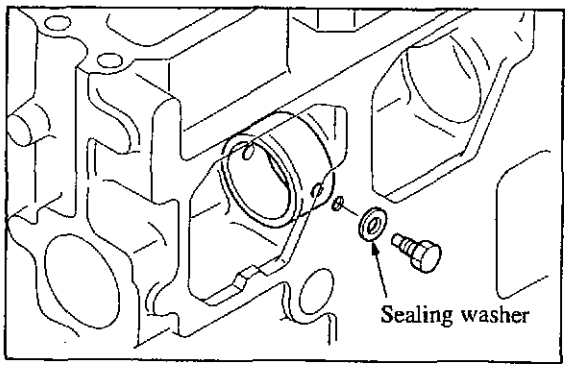
Unit: mm [in.]

Item	Standard Clearance	Service Limit
Camshaft end play	0.10 to 0.25 [0.0039 to 0.0098]	0.40 [0.016]


Measuring camshaft end play

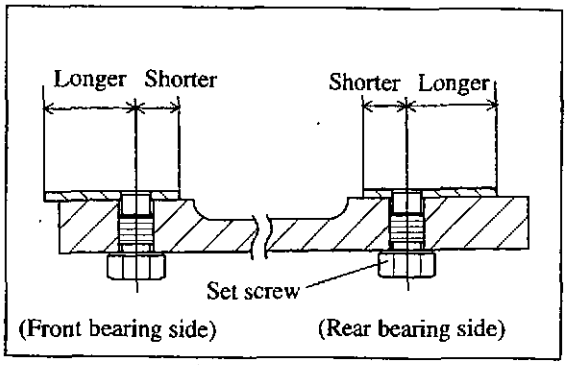
(6) Replacing camshaft bushings

Install the bushings in the crankcase, then secure them in place with the set screws.
Before tightening the screws, make sure that the screw holes in the bushings and crankcase are aligned and that the oil holes in the bushings are aligned with those leading to the oil gallery in the crankcase.



Replacing a camshaft bushing

Install the wide bushing at the rearmost journal correctly,



Rearmost bearing

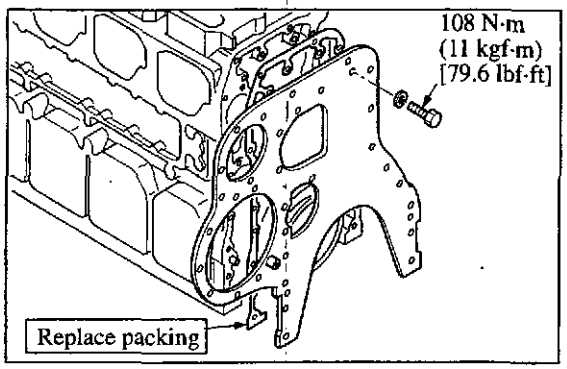
4.3 Reassembly

(1) Installing rear plate

(a) Apply sealant (Herdite) to the rear plate mounting surface of crankcase, then place the packing in position. Apply the same sealant to the packing, then install the rear plate.

(b) Replace the dowel pins if worn, or if the rear plate has been replaced.

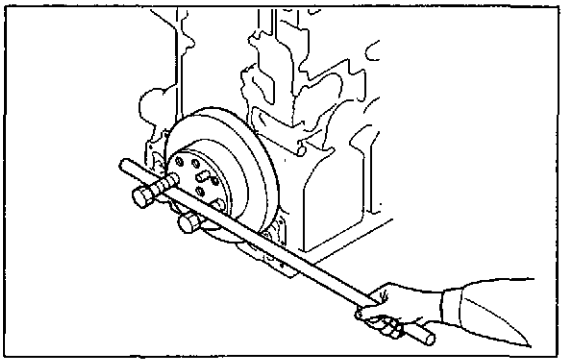
(c) Make sure that the lower end of rear plate is flush with the bottom of crankcase. Cut off the excess of the packing neatly along the edge of the plate.



(2) Cranking engine

(a) Install bolts to the damper mounting holes (M22 × 1.5 mm [0.87 × 0.059 in.]).

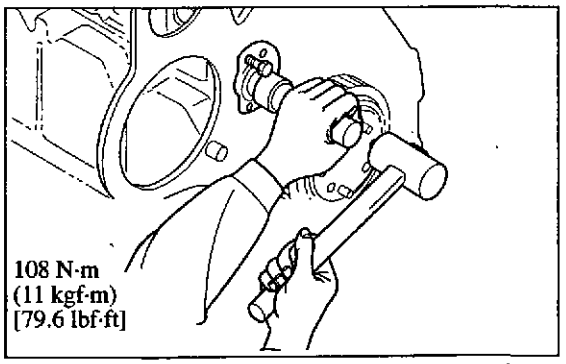
(b) Put the bar to the crankshaft, using the crankshaft pulley mounting bolts, and turn the crankshaft to bring No. 1 cylinder piston to top dead center on compression stroke.



(3) Installing idler gear shaft

(a) Drive in the idler gear shaft, using a guide bolt.

(b) Tighten the idler gear shaft mounting bolts to the specified torque.

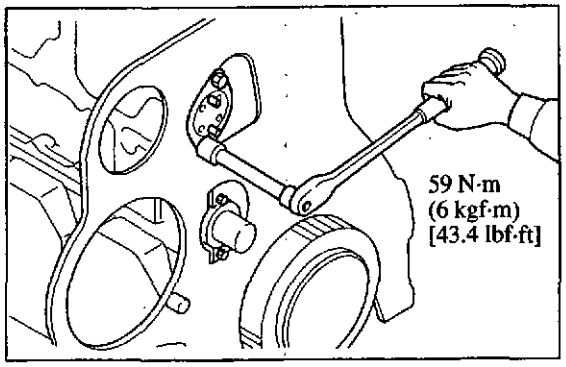


(4) Installing camshafts

(a) Insert the camshaft into the crankcase, then install the thrust plate.

(b) Tighten the thrust plate mounting bolts to the specified torque.

(c) Make sure that the camshaft rotates smoothly.

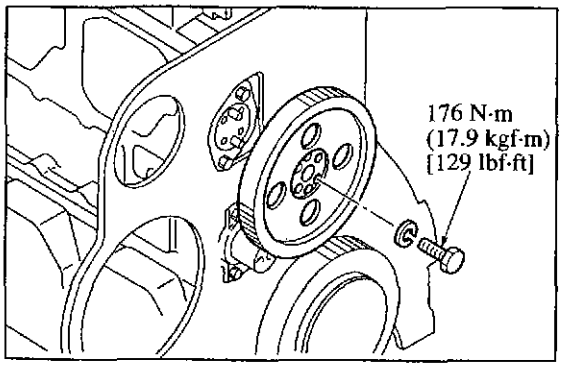


(5) Installing camshaft gear

(a) Install the camshaft gear to the camshaft with the dowel pin entering its hole.

(b) Tighten the gear mounting bolts to the specified torque.

(c) Make sure that the camshaft rotates smoothly.

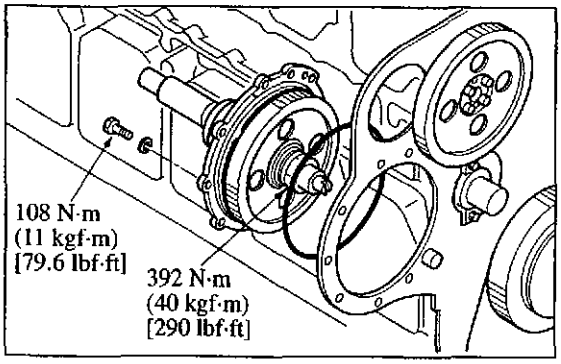


(6) Installing fuel injection pump accessory drive

(a) Install the injection pump drive gear to the drive shaft, and tighten the mounting nut to the specified torque.

(b) Fit the O-ring to the mounting flange of drive case, and install the case to the rear plate.

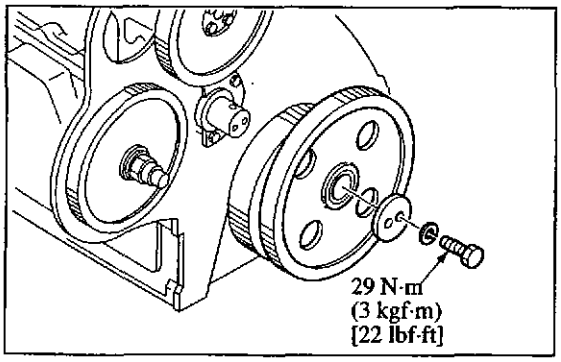
(c) Tighten the drive case mounting bolts to the specified torque.



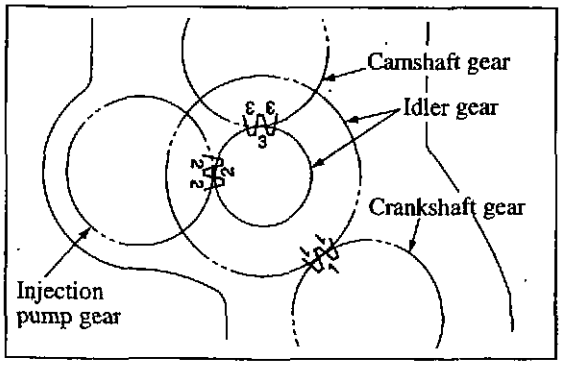
(7) Installing idler gear

(a) Install the idler gear by aligning its matching mark with those on the crankshaft gear, injection pump gear and camshaft gear, and install the thrust plate.

(b) Tighten the thrust plate mounting bolts to the specified torque.



(c) Align the matching marks on the timing gears as shown at right.



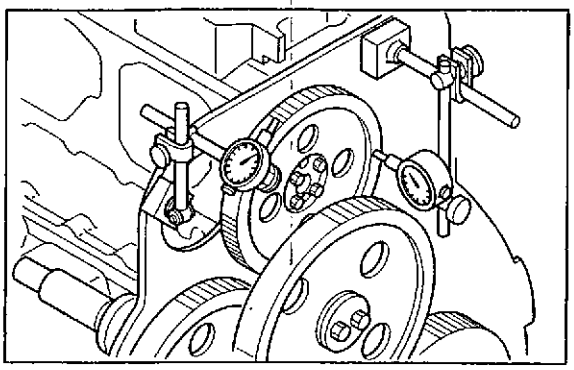
Timing gear train

(8) Inspecting and adjusting timing gears after installation

After installing the timing gears, be sure to inspect and adjust them as follows.

Inspecting Timing Gear Backlash and End Play

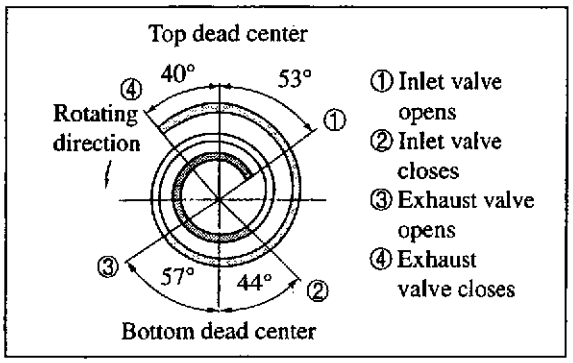
After installing the timing gears, inspect the backlash between the gears in mesh and the end play of each gear. (Refer to 3.2, Group No. 7.)



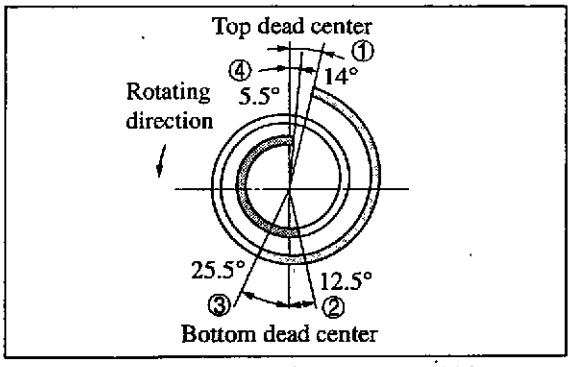
Inspecting Valve Timing

It is not necessary to inspect the valve timing, provided that all matching marks on the timing gears are aligned. Inspect the timing for verification as explained below.

Using a feeler gage 2 mm [0.08 in.] thick, add 2 mm [0.08 in.] clearance to the inlet and exhaust valves of the No. 1 cylinder. Then insert a feeler gage 0.05 mm [0.0019 in.] thick between the bridge cap and rocker. Slowly turn the crankshaft to find the position where the feeler gage is firmly gripped (the valve starts closing). Check that these positions coincide with the angular positions shown in the valve timing diagram with 2 mm [0.08 in.] clearance added to the valves.



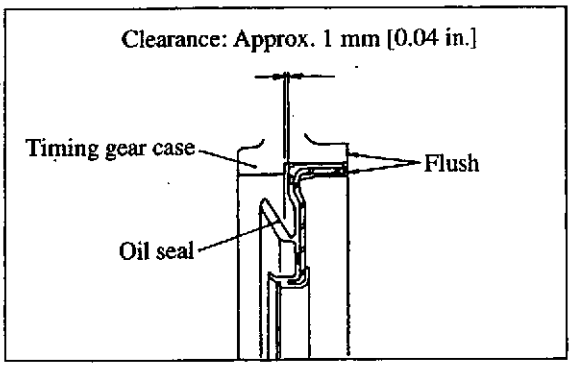
Valve timing diagram



Valve timing diagram with 2 mm [0.08 in.] clearance added to valves

(9) Installing timing gear case

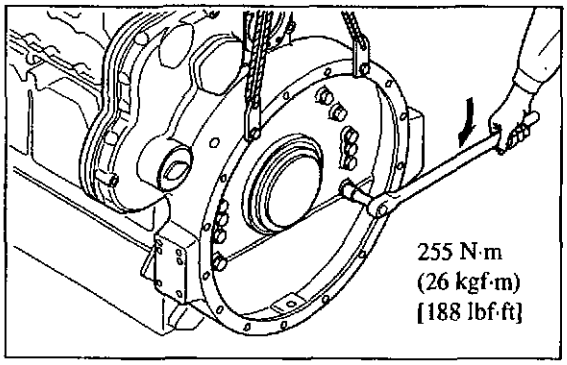
(a) Coat the oil seal lip with engine oil, and insert the seal into the bore of timing gear case until it is flush with the end face of the case.



(b) Apply sealant (Herdite) to the timing gear case surface. Place the packing in position. Apply the sealant on the placed packing. Cut off the excess of the packing neatly along the bottom surface of the crankcase.

(c) Replace the dowel pins if worn, or if the gear case has been replaced.

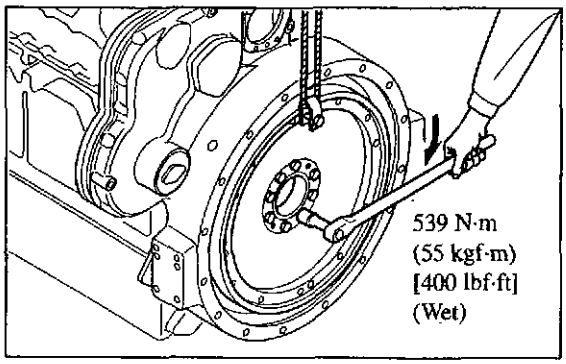
(d) Tighten the gear case mounting bolts evenly to the specified torque.



(10) Installing the flywheel

(a) Install the flywheel. Check that the dowel pins enter their holes.

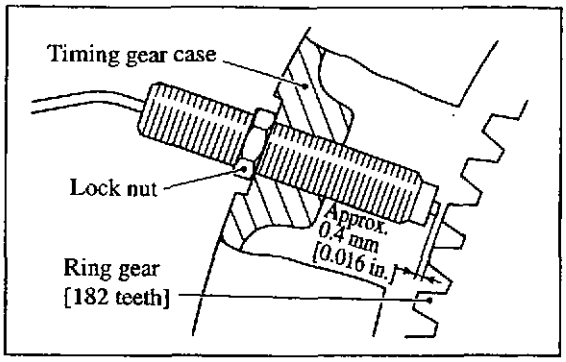
(b) Coat the threads and the bolt bearing surface of the flywheel mounting bolts with engine oil, then the bolts to the specified torque. Inspect the face and circular deflections of the flywheel. (Refer to 3.2, Group No. 7.)



(11) Installing the pick-up

(a) Using the turning gear, rotate the engine until one tooth of the ring gear aligns with the center of the pick-up.

(b) Gently screw the pick-up. When the tip of the pick-up contacts the tooth of the ring gear, unscrew the pick-up slightly by turning 1 turn and secure it in position using the lock nut.

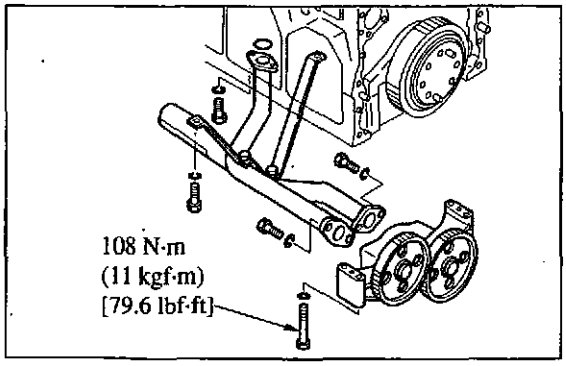


⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(12) Installing oil pump and oil strainer

Measure the backlash between crankshaft gear and oil pump drive gear, and if it is not enough, make a shim adjustment.

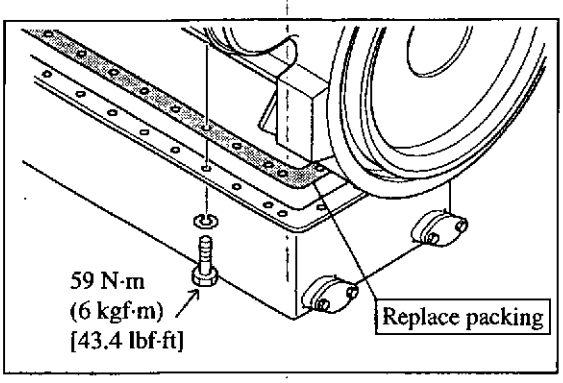


(13) Installing oil pan

(a) Apply sealant (Herdite) to the separated portions (4 locations) of oil pan packing, and place the packing on the oil pan.

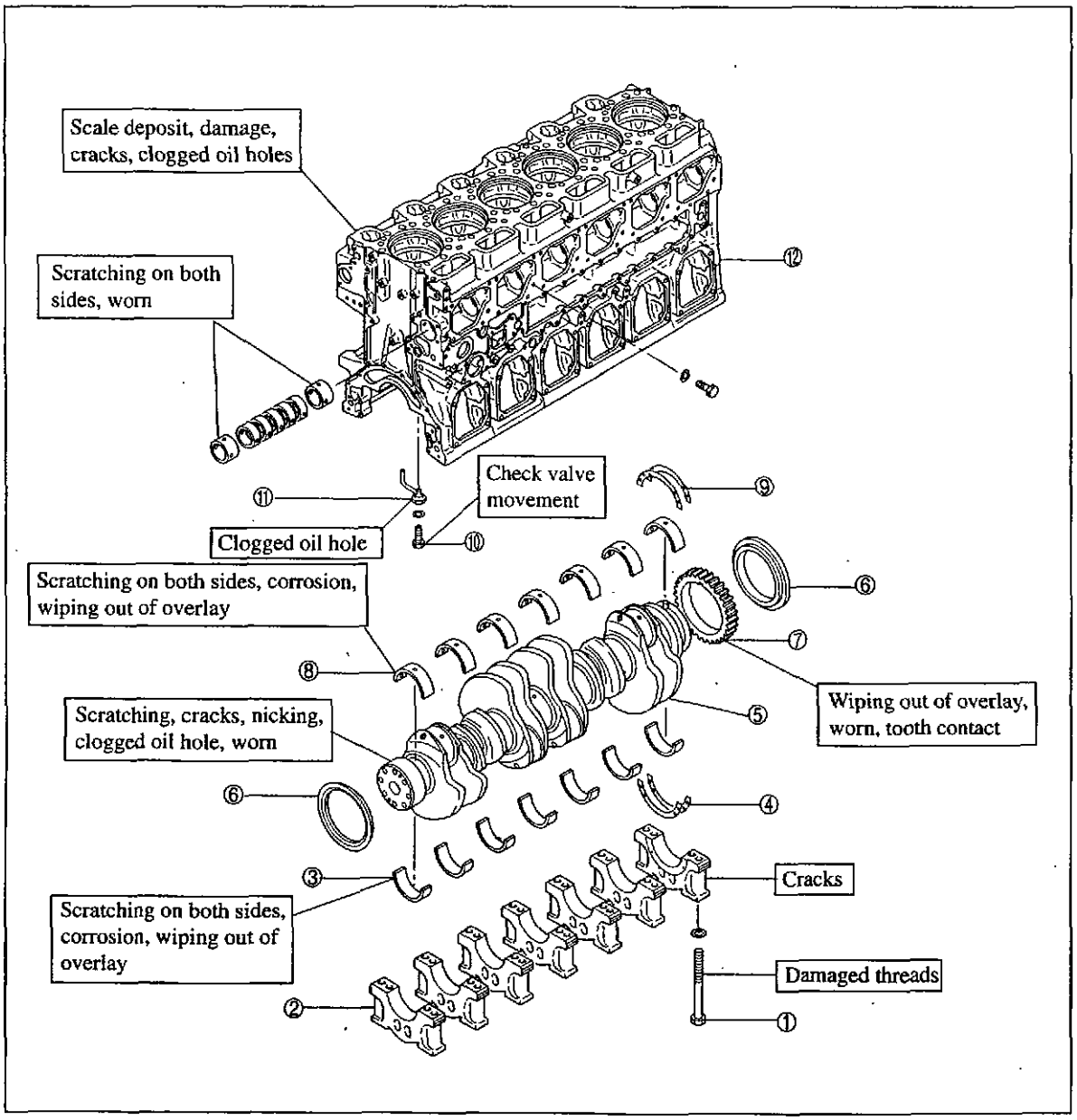
(b) Install the oil pan to the crankcase by screwing two guide bolts.

(c) Tighten the oil pan mounting bolts uniformly to the specified torque.



5. Crankcase, Crankshaft, and Main Bearings

5.1 Disassembly



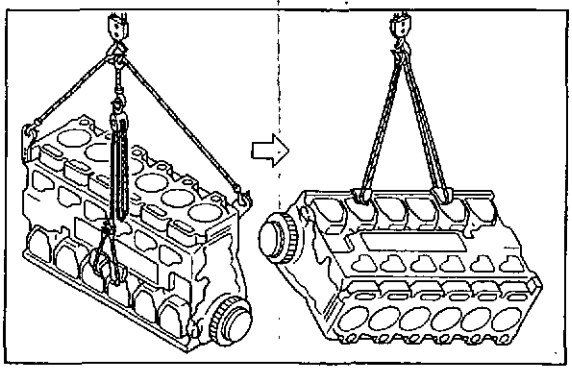
Disassembly sequence

① Bolt
② Main bearing cap
③ Main bearing (lower shell)
④ Thrust plate
⑤ Crankshaft
⑥ Slinger
⑦ Crankshaft gear
⑧ Main bearing (upper shell)
⑨ Thrust plate
⑩ Check valve
⑪ Piston cooling nozzle
⑫ Crankcase

(1) Turning the crankcase upside down

Use a block and tackle to lay the crankcase on its side. Attach wire ropes to the crankcase, then turn it upside down.

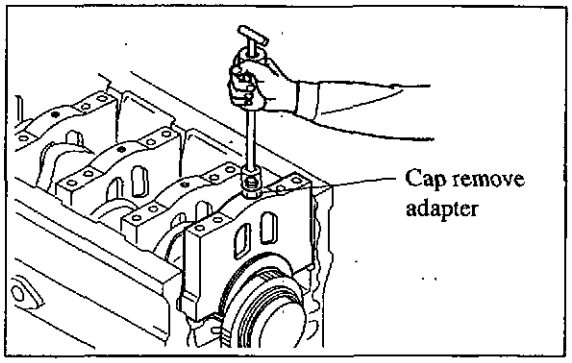
Crankcase and crankshaft weight:
Approx. 1045 kg [2304 lb]



(2) Removing the main bearing caps

(a) Remove the main bearing cap bolts, and remove the main bearing cap by using the combination of sliding hammer (33591-10101) and adapter (37591-04300) or a crane and eyebolt (M10 × 1.25 mm [0.394 × 0.0492 in.]).

(b) Remove the thrust plates from the No. 7 bearing cap. Do not damage the thrust plates.

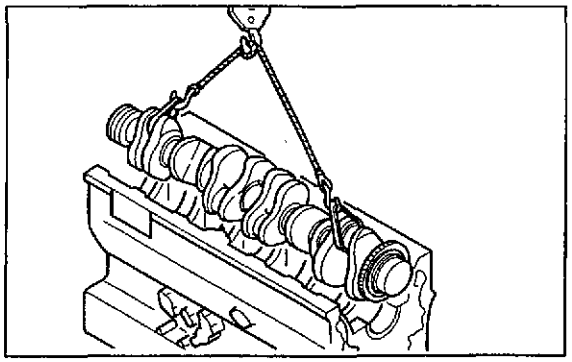


(3) Removing the crankshaft

(a) Remove the upper halves of the thrust plates while rotating the crankshaft slowly.

(b) Carefully lift the crankshaft off the crankcase, keeping it horizontal.

(c) Remove the rear halves of the thrust plates in the upper left of the crankcase.

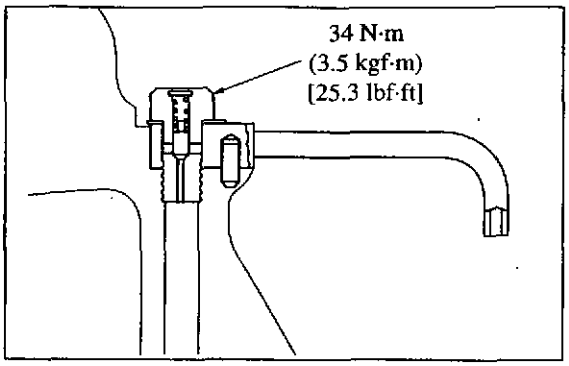


(4) Removing the piston cooling nozzles

Do not remove the nozzles unless such defects as oil hole clogging are observed.

NOTE

Tighten the piston cooling nozzle to the specified torque when reassembling.



5.2 Inspection and Repair

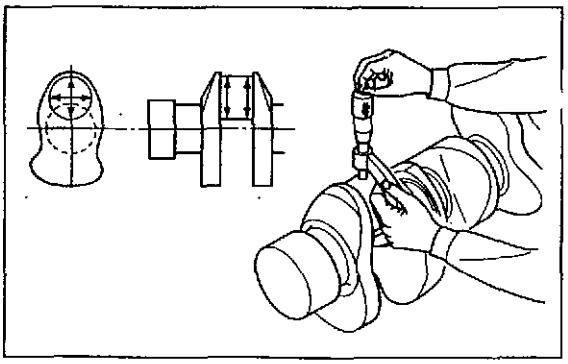
Crankshaft

(1) Measuring crankpin and journal diameters

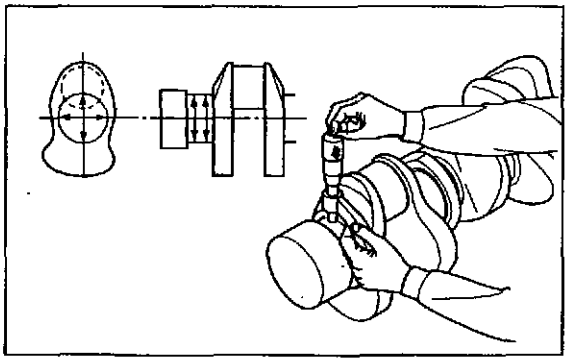
(a) Using a micrometer, measure the crankpin and journal diameters. If the diameter exceeds the repair limit, grind them to the next lower size: -0.25 mm [-0.0098 in.], -0.5 mm [-0.0197 in.], -0.75 mm [-0.0295 in.], or -1.00 mm [-0.0394 in.].

(b) Measure the crankpins and journals to determine the amount of roundness and taper.

(c) If the -1.00 mm [-0.0394 in.] undersize journals and crankpins exceed the repair limit, replace the crankshaft.



Measuring crankpin diameter



Measuring journal diameter

Unit: mm [in.]

Item		Nominal Value	Assembly Standard	Repair Limit
Crank pin diameter		ø125 [4.92]	124.930 to 124.950 [4.9185 to 4.9193]	124.890 [4.9169]
Journal diameter		ø140 [5.51]	139.930 to 139.950 [5.5091 to 5.5098]	139.890 [5.5075]
Pin, journal	Roundness		Diameter difference 0.01 [0.0004] or less	0.03 [0.0012]
	Cylindricity		Diameter difference 0.02 [0.0008] or less	0.03 [0.0012]
	Fillet radius	7R [0.28]	6.8 to 7.0 [0.268 to 0.276]	
	Hardness		Hv > 620	

Grinding dimensions for an undersize crankshaft

Unit: mm [in.]

	Undersize	Finishing Dimension	Roundness	Cylindricity
Crankpin diameter	0.25 [0.0098]	124.68 to 124.70 [4.9087 to 4.9094]	Diameter difference 0.01 (0.0004) or less	Diameter difference 0.02 (0.0008) or less
	0.50 [0.0197]	124.43 to 124.45 [4.8988 to 4.8996]		
	0.75 [0.0295]	124.18 to 124.20 [4.8890 to 4.8898]		
	1.00 [0.0394]	123.93 to 123.95 [4.8791 to 4.8799]		
Journal diameter	0.25 [0.0098]	139.68 to 139.70 [5.4992 to 5.5000]		
	0.50 [0.0197]	139.43 to 139.45 [5.4894 to 5.4901]		
	0.75 [0.0295]	139.18 to 139.20 [5.4795 to 5.4803]		
	1.00 [0.0394]	138.93 to 138.95 [5.4697 to 5.4705]		

(2) Grinding the crankshaft

If the crankshaft is refinished in compliance with any grinding dimensions of the undersizes of the main bearing and the connecting rod bearing, and if the bearings are replaced by undersized bearings, it is not necessary to check the bearing contact pattern.

When grinding the crankpins and journals, be sure to produce the same fillet radius as the original. They should have a hardness of 620 (Vickers Hardness Number). If necessary, re-harden the crankpins and journals, and inspect them for cracks by conducting a Magnalux (magnetic particle) test. After grinding, finish the journals and crankpins to 0.2Ra.

(3) Measuring crankshaft end play

(a) Install the thrust plates in position, then secure the bearing cap. Under this condition, measure the end play. If the end play exceeds the standard clearance, replace the thrust bearings.

(b) If the end play still exceeds the repair limit even after the new thrust bearings have been installed, replace the bearings with the next oversize bearings. There are three sizes for the thrust bearings:

+ 0.25 mm [+0.0098 in.]

+ 0.50 mm [+0.0197 in.]

+ 0.75 mm [+0.0295 in.]

Generally the rear journal is likely to wear more rapidly than the front journal. This means that replacement of the rear thrust bearings will generally be sufficient.

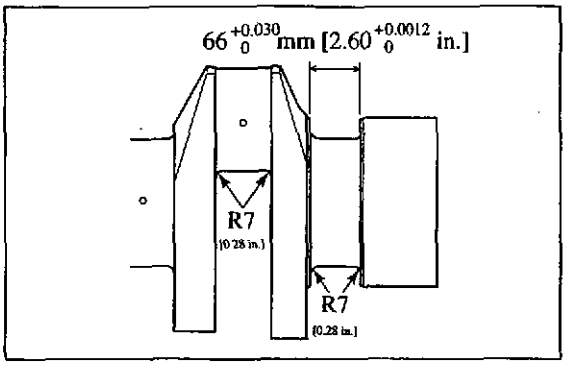
Unit: mm [in.]

Item	Standard Clearance	Service Limit
Crankshaft end play	0.30 to 0.50 [0.0118 to 0.0197]	0.50 [0.0197]

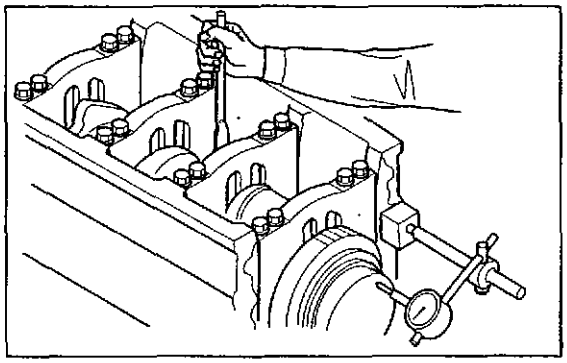
Crankshaft Journal Grinding Dimensions for Oversize Thrust Plates

Unit: mm [in.]

Item	Oversizes for Journal or Thrust Plates	Oversizes for Journal and Thrust Plates	Tolerance
0.25 [0.0098] O.S	66.25 [2.6083]	66.50	+0.03 0 [$^{+0.0012}_{0}$]
0.50 [0.0197] O.S	66.50 [2.6181]	67.00	
0.75 [0.0295] O.S	66.75 [2.6279]	67.50	



Measuring thrust bearing journal length

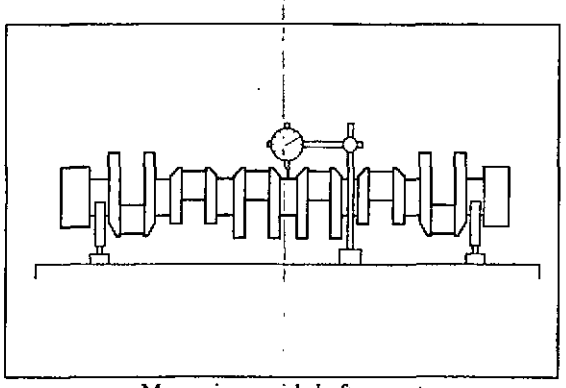

Measuring crankshaft end play

(4) Measuring crankshaft runout

Support the crankshaft on its journals in V-blocks, then measure the runout at the center journal with a dial gage. Depending on the amount of deflection, repair the crankshaft by grinding or straightening with a press. If the runout exceeds the repair limit, replace the crankshaft.

Unit: mm [in.]

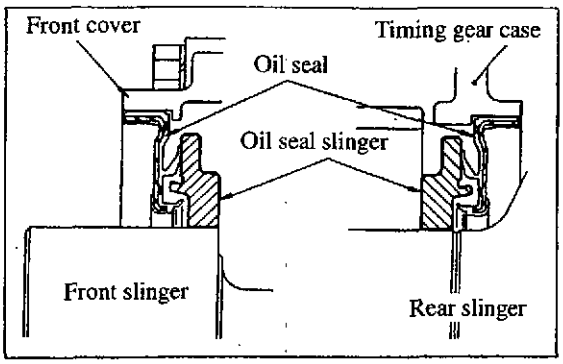
Item	Assembly Standard	Repair Limit
Crankshaft deflection	0.04 [0.0016] or less	0.10 [0.0039]



Measuring crankshaft runout

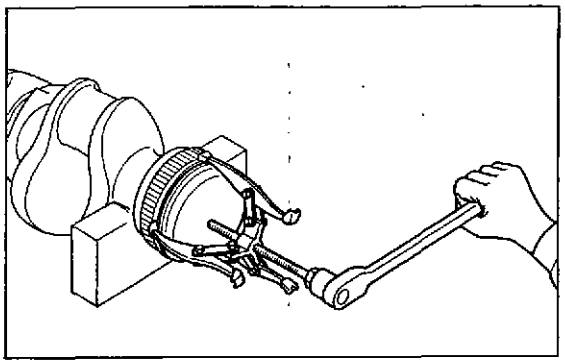
(5) Replacing the oil seal slinger

Replace the slinger if it is pitted, scratched, or distorted enough to cause oil leaks.



Removing the Slinger

Use a gear puller to remove the slinger from the crankshaft.

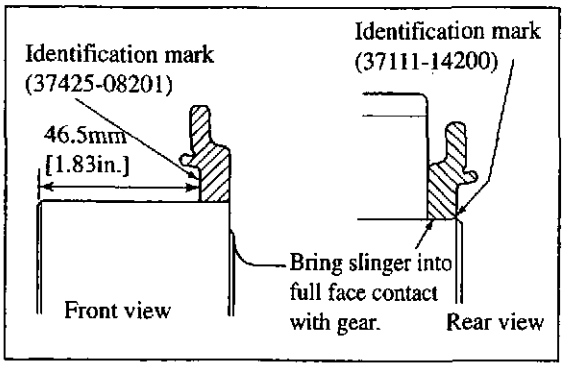


Installing the slingers

(a) Identify the front slinger and the rear slinger, and pay attention to their attitudes.

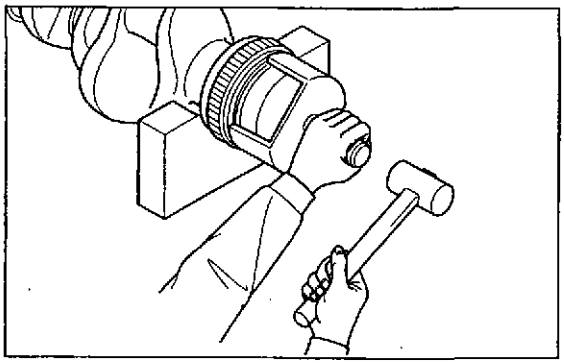
NOTE

Be sure to install the front and rear slingers to the front and rear sides of crankshaft respectively, or oil leakage will occur.



(b) Use a slinger installer to install the slinger heated above 110°C [230°F] to the crankshaft until it contacts the gear.

If the slinger has not stopped before it contacts the gear, tap the center or chouldер of the installer with a copper hammer.



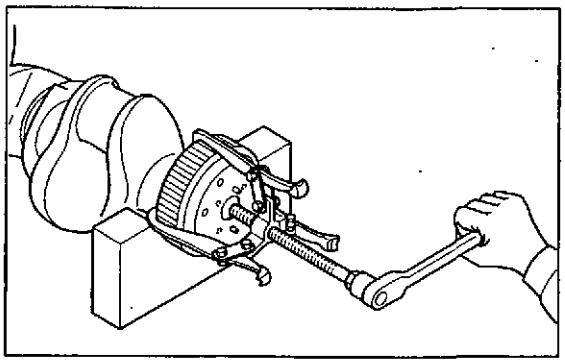
(6) Replacing the crankshaft gear

Removing the Gear

Use a gear puller to remove the gear from the crankshaft.

NOTE

Do not remove the gear by hitting it with a hammer.

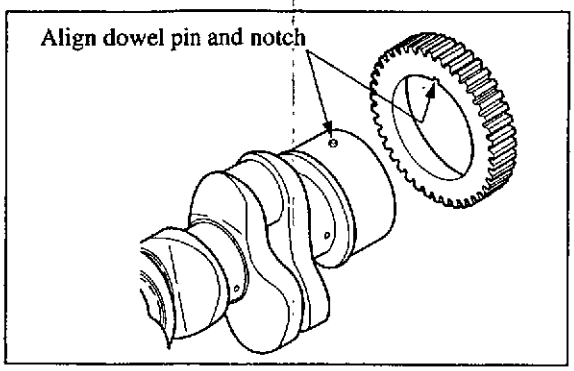


(Installing the Gear)

(a) Before installing the crankshaft gear, measure the inside diameter of the crankshaft gear to be sure that the fit is 0.0106 to 0.171 mm [0.0042 to 0.0067 in.].

(b) Heat the gear to the range 180 to 200°C [356 to 392°F].

(c) Drive the rear crankshaft gear onto the crankshaft by tapping the end face of the gear lightly with a copper hammer. Be sure the crankshaft dowel pin enters the notch in the gear.



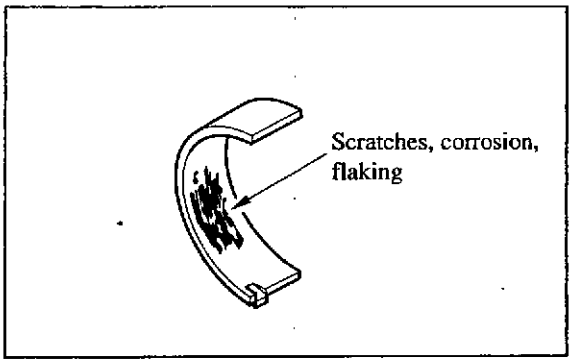
NOTE

(a) Install the gear to the crankshaft until it touches the collar.
(b) Do not mistake the direction of gear installation.

Main Bearing

(1) Inspecting main bearing shell

Inspect each bearing shell for abnormal contact such as scratching, corrosion, wiped overlay, etc. Also check for signs of poor seating in the bore of the crankcase or metal cap.

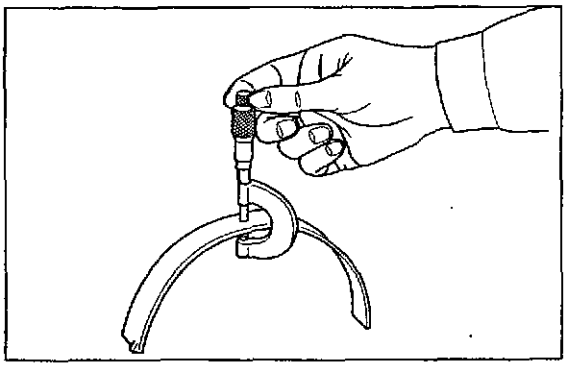


(2) Measuring bearing thickness

Use a ball point micrometer to measure the center of each bearing shell. If the thickness exceeds the service limit on any of the upper or lower shells, replace the upper and lower shells as a set.

Unit: mm [in.]

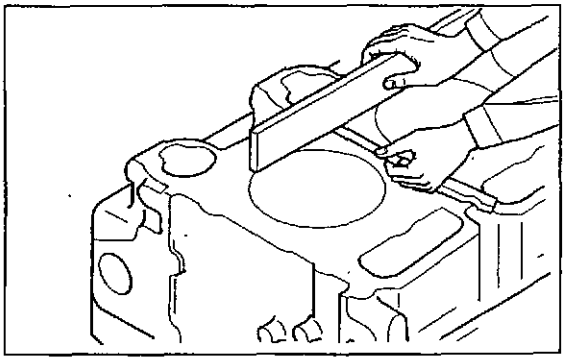
Item		Nominal Value	Assembly Standard	Service Limit
Main bearing thickness (center)	STD	3.500 [0.138]	3.467 to 3.480 [0.1365 to 0.1370]	3.425 [0.1348]
	-0.25 [-0.0098]	3.625 [0.1427]	3.592 to 3.605 [0.1414 to 0.1419]	3.550 [0.1398]
	-0.50 [-0.0197]	3.750 [0.1476]	3.717 to 3.730 [0.1463 to 0.1469]	3.675 [0.1447]
	-0.75 [-0.0295]	3.875 [0.1526]	3.842 to 3.855 [0.1513 to 0.1518]	3.800 [0.1496]
	-1.00 [-0.0394]	4.000 [0.1575]	3.967 to 3.980 [0.1562 to 0.1567]	3.925 [0.1545]



Measuring main bearing thickness

(3) Replacing main bearings

If the thickness exceeds the service limit, either replace the main bearings as above, or refinish the crankshaft and use undersize bearings. If the crankshaft is refinished in compliance with any of the undersizes, it is not necessary to check the metal contact pattern.



Measuring crankcase gasketed surfaces

Crankcase

(1) Measuring gasketed surface warpage

Measure warpage with a straight edge and feeler gage. If the warpage exceeds the assembly standard, reface the gasketed surfaces with a surface grinder.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Crankcase gasketed surface warpage	0.1 [0.004] or less	0.2 [0.0079]

NOTE

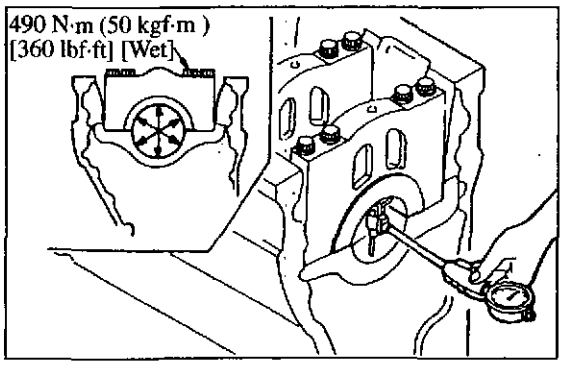
Do not grind the crankcase more than necessary to remove warpage. Excessive grinding can cause the piston protrusion to exceed assembly standard.

(2) Measuring main bearing bore diameter

Secure the end bearing cap to the specified torque, and measure the bore diameter in the cross direction.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Main bearing bore dia.	ø147 [5.79]	147.000 to 147.025 [5.7874 to 5.7884]	147.035 [5.7888]



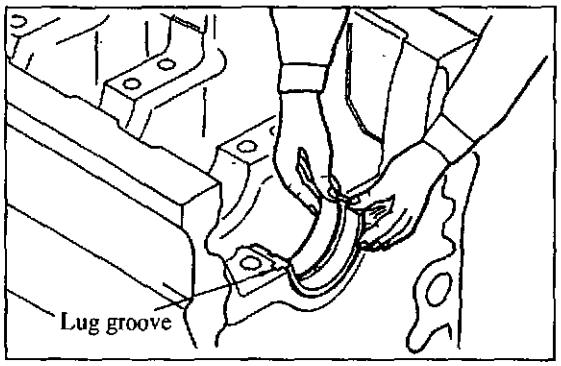
Measuring main bearing bore diameter

5.3 Reassembly

(1) Installing the main bearing

(a) Install each upper shell of the main bearing in the crankcase by fitting its locking lip in the recess. The oil holes in the bearing and crankcase will be aligned when the bearing are installed in this way.

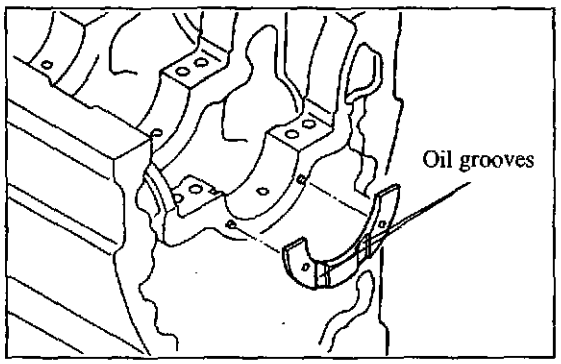
(b) Lightly coat the inside surface of the shells with engine oil.



(2) Installing thrust plates

(a) Install the thrust plates to the No. 7 bearing seat of the crankcase, with the oil groove side of the plates facing out.

(b) After installing the crankshaft, install the inner thrust plate with the oil groove facing inside the crankcase.

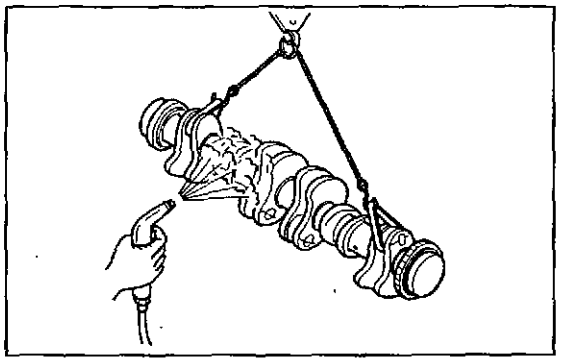


(3) Installing the crankshaft

(a) Wash the crankshaft with cleaning solvent, and dry it by air blow.

NOTE

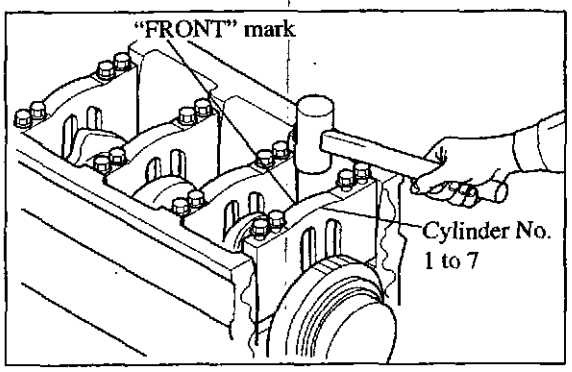
After washing the crankshaft, make sure that the oil holes are clean and not clogged.



(b) Hold the crankshaft horizontally with a hoist, then carefully put it on the crankcase.

(c) Lightly coat the journals with engine oil.

(4) Installing main bearing caps



(a) Fit the lower shell of the bearing to each bearing cap.

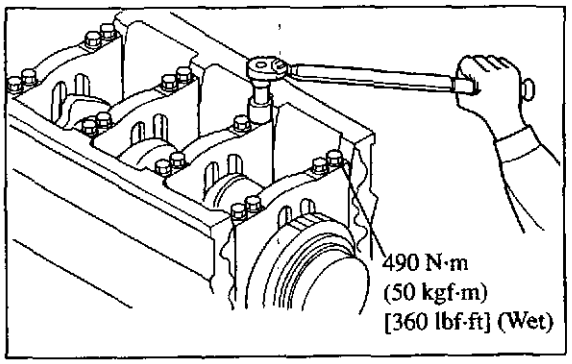
(b) Install the thrust bearings to the No. 7 bearing cap, with the oil groove side of the bearing facing out.

(c) From the front side of the crankcase, bearings No. 1 to No. 7 are stamped on the caps. Install the caps with these numbers on the front of the crankcase.

(d) Coat the threads of the bearing cap bolts with engine oil, then temporarily install the bolts.

(e) Use a soft hammer to drive in the bearing caps evenly.

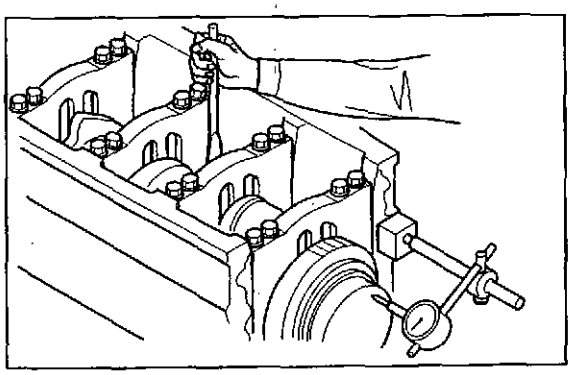
(5) Installing bearing cap bolts



(a) Temporarily tighten the bearing cap coated with engine oil. Tighten the four bolts alternately to the specified torque.

(b) Make sure that the crankshaft rotates smoothly.

(6) Measuring crankshaft end play



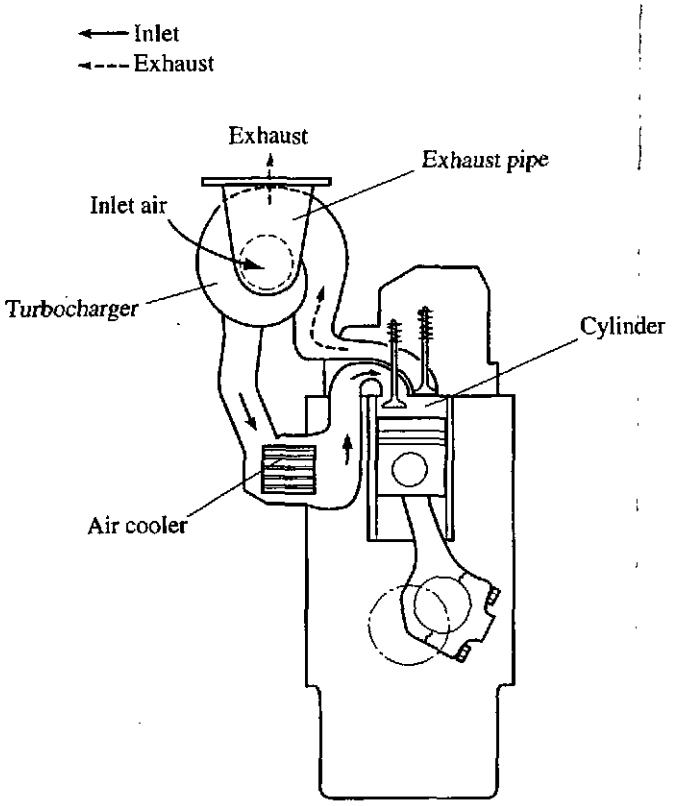
(a) Tighten No. 1 through No. 6 bearing cap bolts and side bolts to the specified torque, with the No. 7 bearing cap bolt temporarily tightened, then measure the end play.

(b) After tightening the No. 7 cap bolts, make sure that the end play is correct.

(c) Confirm that all cap bolts are tightened to the specified torque.

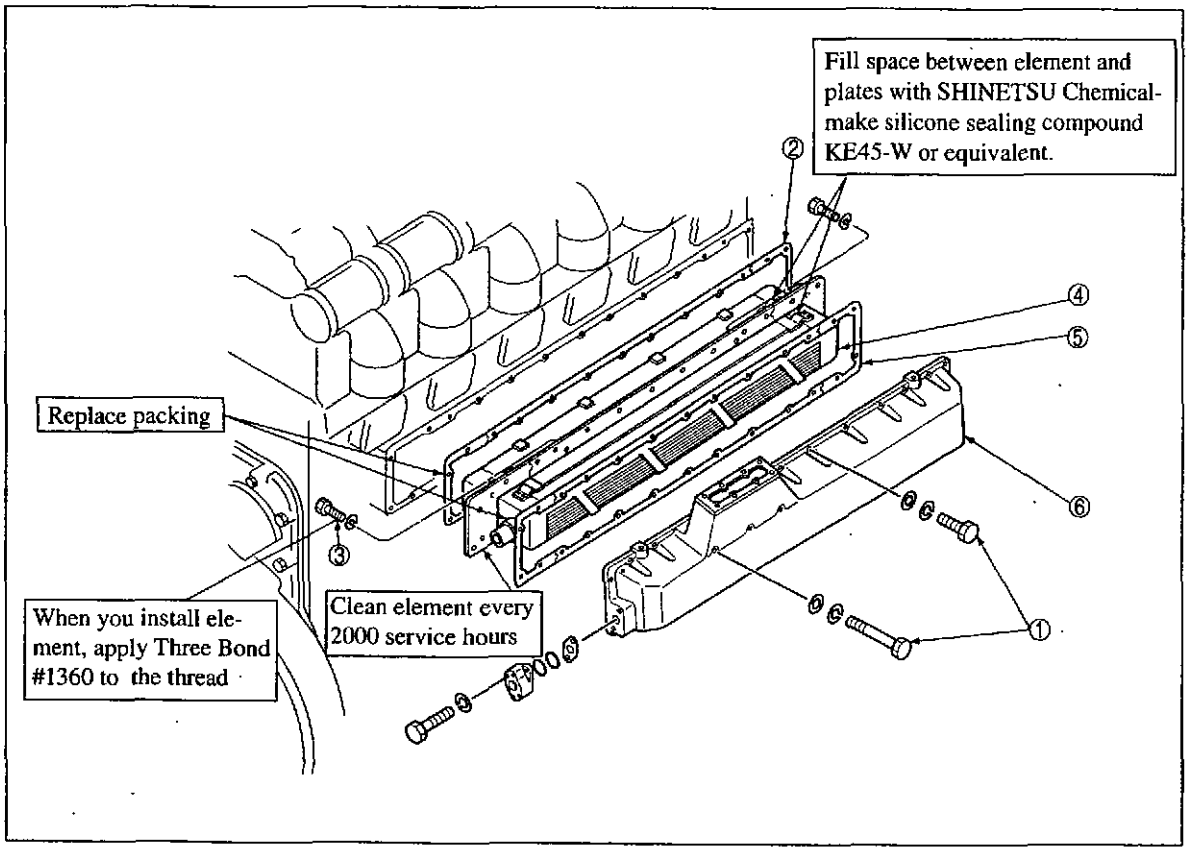
INLET AND EXHAUST SYSTEMS

1. Description



2. Air Cooler

2.1 Disassembly



Disassembly sequence

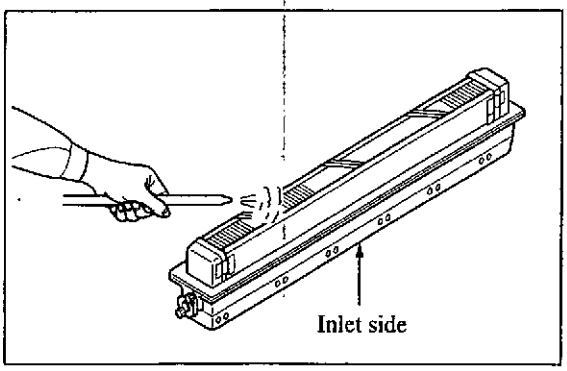
① Bolt
② Packing
③ Bolt
④ Element
⑤ Packing
⑥ Air cooler case

2.2 Inspection

(1) Cleaning air coolers

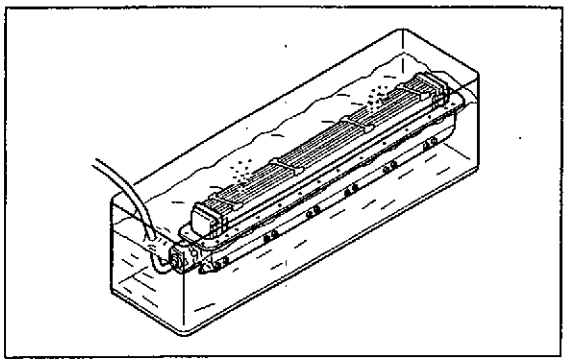
(a) Remove dirt built up from the air cooler by directing high pressure air of 0.3 to 0.5 MPa (3 to 5kgf/cm²) [43 to 71 psi] (maximum) in the direction opposite to air flow. Inspect the cooler for corrosion and cracks.

(b) Wash the fresh water or salt water pipes in water and caustic soda lime, then remove scale deposits.



(2) Inspecting air coolers for air tightness

Immerse the air cooler in water, then apply high pressure air of 0.4 MPa (4 kgf/cm²) [57 psi] to the coolant side to inspect for air leaks.

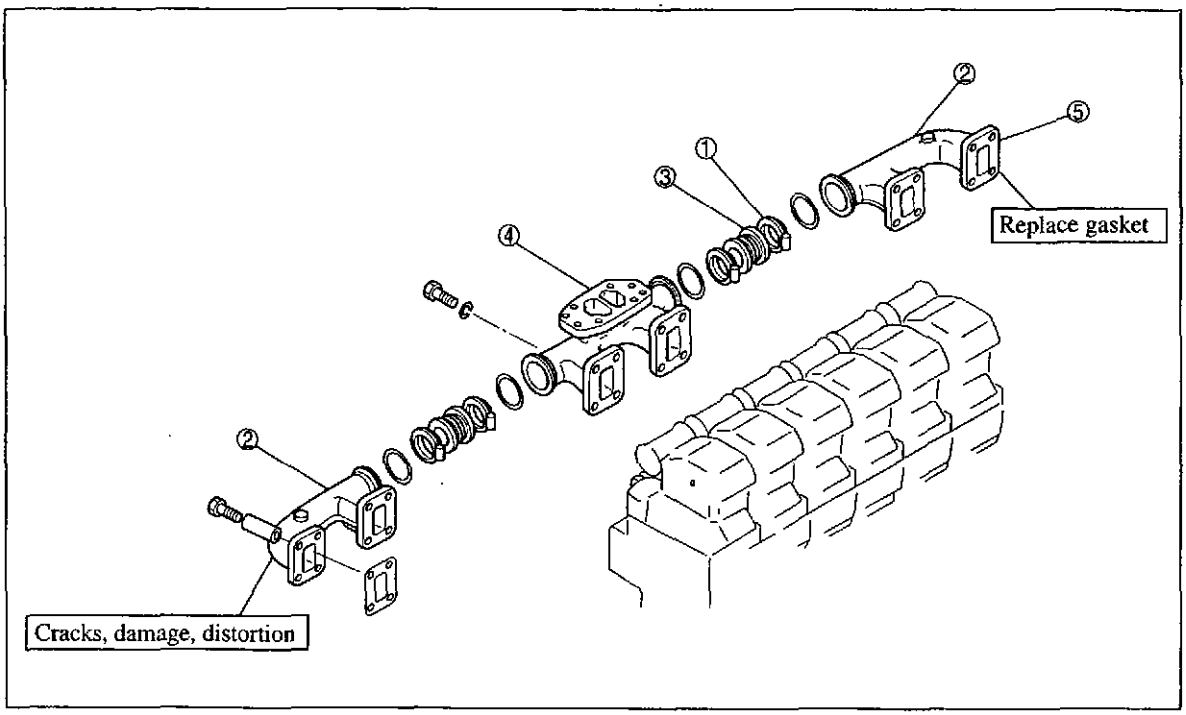


⚠CAUTION

A fresh water air cooler differs from a salt water type in construction and material. Keep this in mind when you handle a cooler.

3. Exhaust Manifold

3.1 Disassembly and Inspection



Disassembly sequence

① Coupling
② Exhaust manifold
③ Flexible joint
④ Exhaust manifold
⑤ Gasket

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

NOTE

(a) Place each gasket with the "MANIFOLD" mark on the exhaust manifold side.
(b) If the gasket requires replacement, replace all the cylinder together.

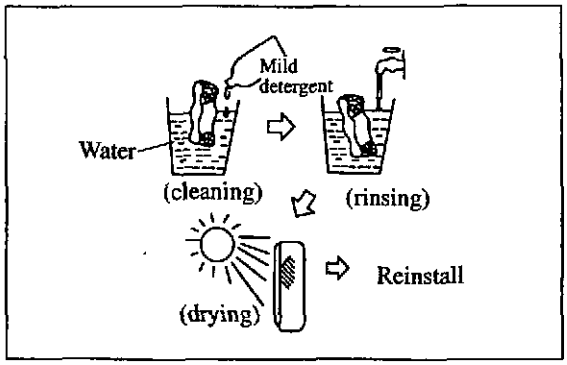
4. Pre-Cleaner

4.1 Washing the Pre-Cleaner

(1) Remove the pre-cleaner from the silencer, and hand-wash with a mild detergent.
(2) Rinse the pre-cleaner with clean water.
(3) After drying thoroughly, reinstall the pre-cleaner in the silencer.

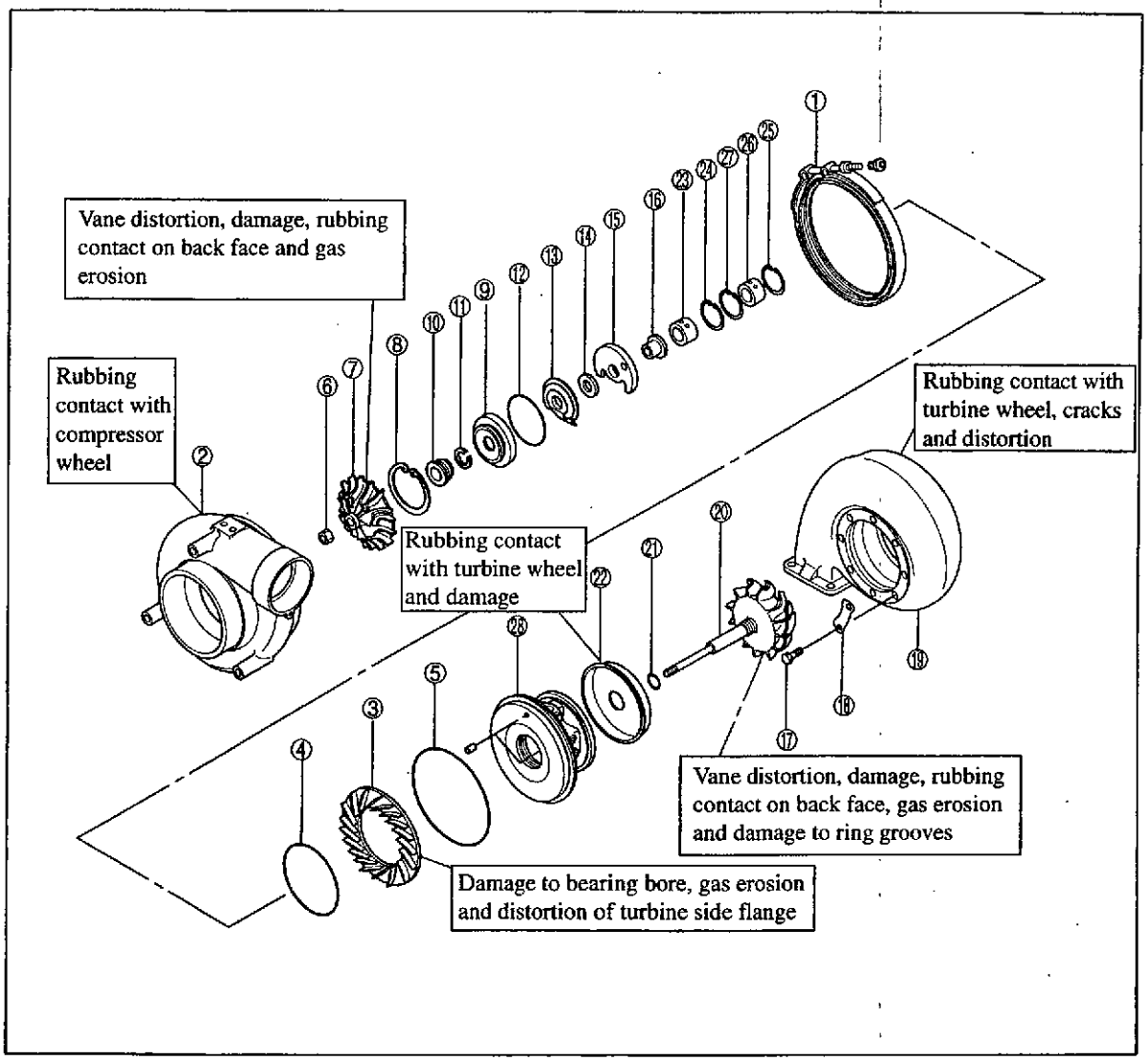
NOTE

If the pre-cleaner is cracked or damaged, replace.



5. Turbocharger (TF15)

5.1 Disassembly



Disassembly sequence

① V-clamp
② Compressor cover
③ Diffuser
④ O-ring
⑤ O-ring
⑥ Lock nut
⑦ Compressor wheel
⑧ Snap ring
⑨ Insert
⑩ Flinger sleeve
⑪ Piston ring
⑫ O-ring
⑬ Oil deflector
⑭ Thrust ring (compressor side)
⑮ Thrust bearing
⑯ Thrust ring (turbine side)
⑰ Bolt
⑱ Lock plate
⑲ Turbine housing
⑳ Shaft & turbine wheel
㉑ Piston ring
㉒ Turbine backplate
㉓ Bearing (compressor side)
㉔ Snap ring (compressor side)
㉕ Snap ring (turbine side)
㉖ Bearing (turbine side)
㉗ Snap ring (turbine side)
㉘ Bearing housing

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

⚠CAUTION

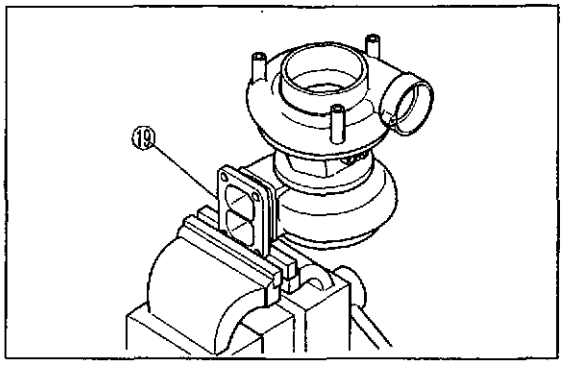
Carefully handle the compressor wheel and turbine wheel during disassembly and assembly, since vanes can easily bend when dropped or hit.

(1) Preparing for disassembly

Mount the turbine housing ⑲ on a vice by clamping at the flange.

⚠CAUTION

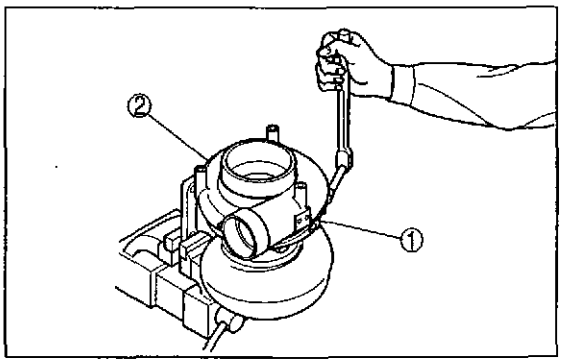
Clamp the flange securely to prevent the turbine housing from loosening or moving during work.



(2) Removing the compressor cover

⚠CAUTION

The compressor cover ②, bearing housing ㉘ and turbine housing ⑲ must be re-assembled in correct orientation. Therefore, put alignment marks with a punch or marker.



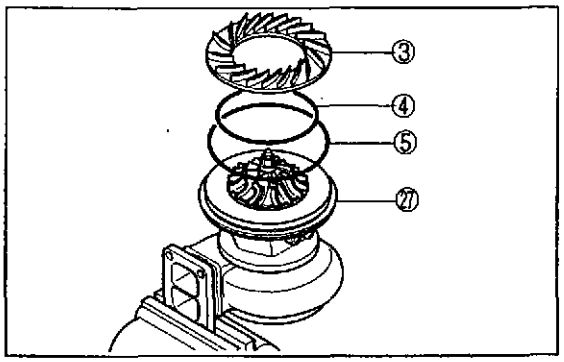
(a) Loosen the V-clamp ① using a socket wrench.

(b) Lightly tap around the compressor cover ② with a soft-faced hammer to remove the cover.

(3) Removing the diffuser

(a) Lightly tap around the diffuser ③ with a soft-faced hammer to remove the diffuser.

(b) Remove O-ring ④, ⑤ from the bearing housing ㉘.

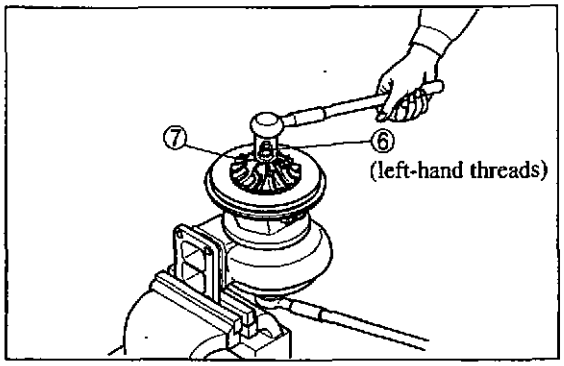


(4) Removing the compressor wheel

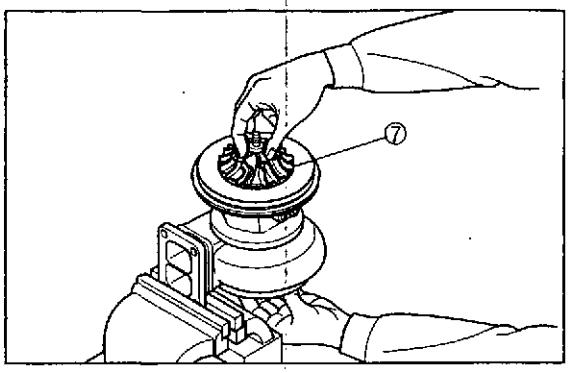
⚠CAUTION

Note that lock nut ⑥ has left-hand threads.

(a) While holding the boss of the shaft & turbine wheel ⑳, remove the lock nut ⑥ fastening the compressor wheel ⑦.



(b) While holding the turbine wheel with one hand, turn the compressor wheel ⑦ lightly with the other hand and remove.

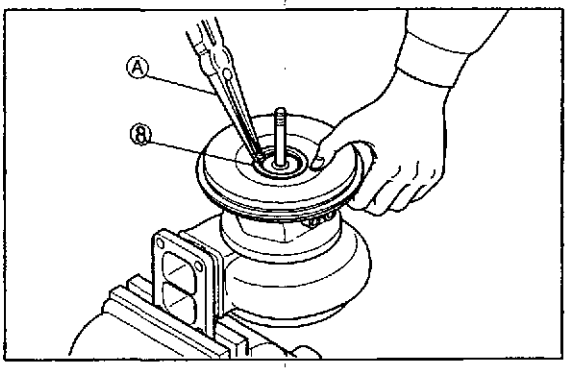


(5) Removing the snap ring

⚠CAUTION

Put a thumb on the snap ring to prevent it from flying out in case the pliers lose grip.

Using the snap ring pliers Ⓐ (49160-90101), remove the snap ring ⑧.

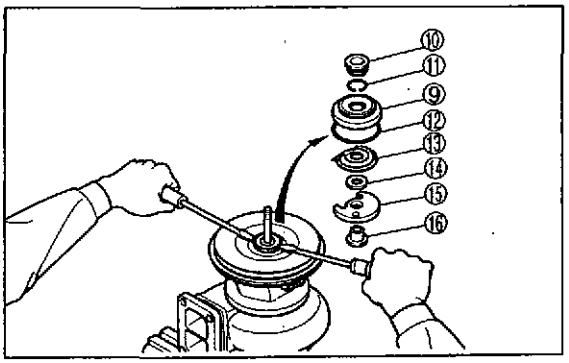


(6) Removing the insert and oil deflector

(a) Using two screwdrivers, gently pry out the insert ⑨ from the bearing housing ㉘.

(b) Separate the flinger sleeve ⑩ together with the piston ring ⑪ from the insert ⑨.

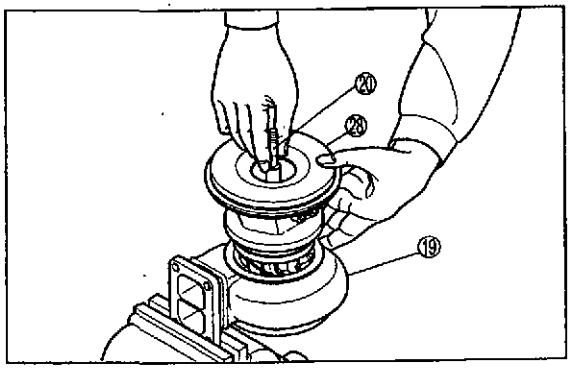
(c) Remove the following parts from the bearing housing ㉘.
⑫ O-ring
⑬ Oil deflector
⑭ Thrust ring (compressor side)
⑮ Thrust bearing
⑯ Thrust ring (turbine side)



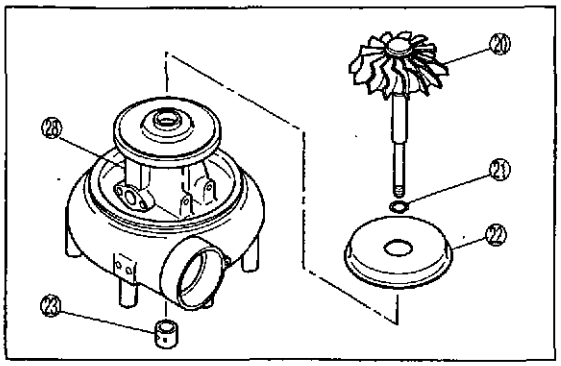
(7) Removing the shaft & turbine wheel

(a) Remove the bolts ⑰ and lock plates ⑱.

(b) While gripping the shaft of the shaft & turbine wheel ⑳ with one hand, hold the bearing housing ㉘ with the other hand and slowly remove the shaft & turbine wheel from the turbine housing ⑲.



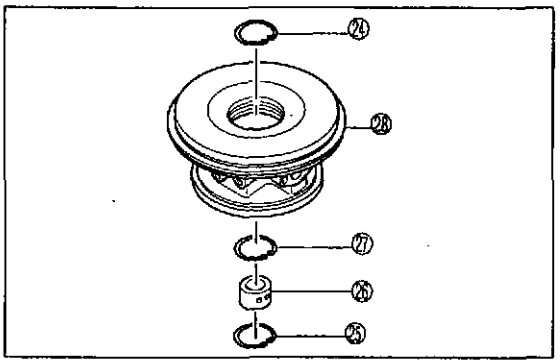
(c) Turn over the bearing housing ㉘ (so the turbine wheel faces up), and place it on the compressor cover. Then, remove the following parts.
- ⑳ Shaft & turbine wheel
- ㉑ Piston ring
- ㉒ Turbine backplate
- ㉓ Bearing (compressor side)



(8) Removing the snap ring and bearing

⚠CAUTION

(a) Use the snap ring pliers (49160-90110) to remove the snap rings ㉔, ㉕ and ㉗.
(b) Carefully remove the snap ring, making sure not to damage the inside surface of the bearing house or the seal (turbine side) of the piston ring.



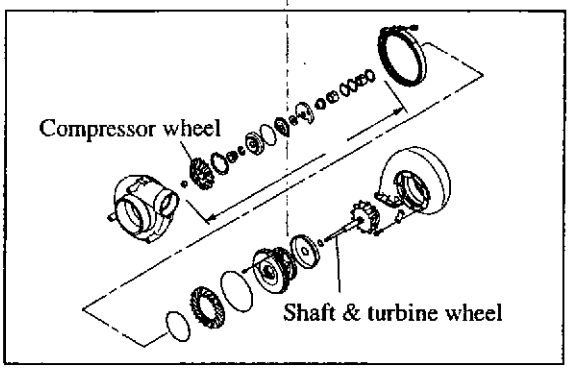
Place the bearing housing ㉘ on a workbench with the compressor side facing up. Then, remove the following parts.
- ㉔ Snap ring (compressor side)
- ㉕ Snap ring
- ㉖ Bearing
- ㉗ Snap ring

} (turbine side)

5.2 Cleaning

Cleaning

Blasting machine are commonly used to clean turbocharger parts by specialized service shops. If a blasting machine is not available, follow the procedures described below for effective cleaning.



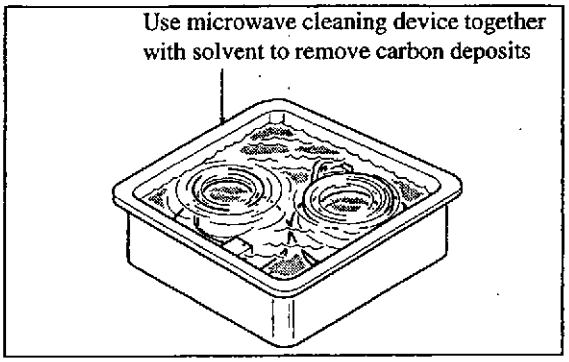
NOTE

When using a shot blasting machine, do not blast on parts in the section marked ·X· in the diagram on the right. Also do not blast on either surface of the compressor wheel or the shaft of the shaft & turbine wheel.

⚠CAUTION

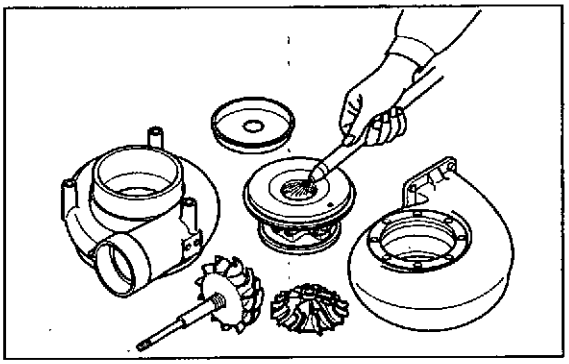
When using a commercial neutral detergent, make sure it is not corrosive.

(1) Visually inspect parts before cleaning. Check for any scorching or scuffing marks which may wash off during cleaning.

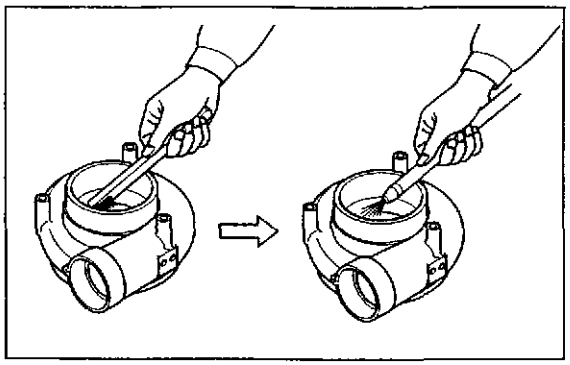


(2) Place removed parts in an incombustible solvent (Cleaner T-30 manufactured by Daido Chemical Industries, etc.) to remove oil and carbon deposits. Do not place O-rings, bearings or thrust bearing in the solvent.

(3) Blow compressed air onto the inside and outside surfaces.



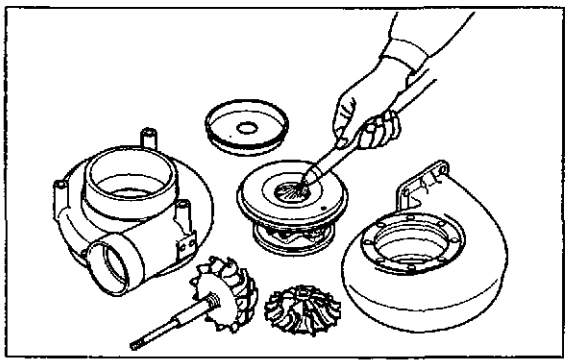
(4) Using a plastic scrubber or hard brush, remove the carbon deposits thoroughly.



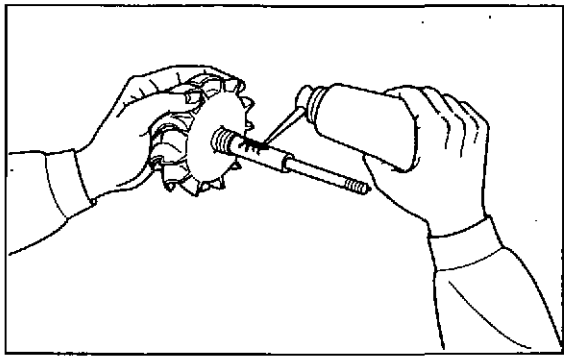
⚠CAUTION

Be careful not to damage the parts.
When using a shot blasting machine, be sure to cover the surfaces of the compressor wheel or the ring groove to avoid damaging the surface parts.

(5) Blow fresh compressed air again onto inside and outside surfaces.



Coat the moving parts with engine oil.
Remove rust from the screw thread, shaft and rings if present by puffing. Never use a file.



5.3 Inspection

⚠CAUTION

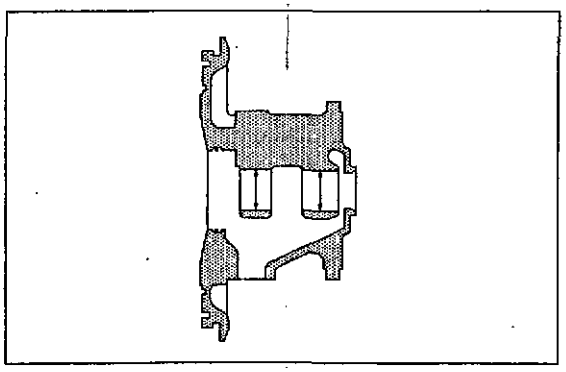
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(1) Measuring inside diameter of bearing-fitted section

If the measured diameter exceeds the service limit, replace the bearing housing.

Unit: mm [in.]

Item	Service Limit
Inside diameter of bearing-fitted section of housing	36.014 [1.4179]

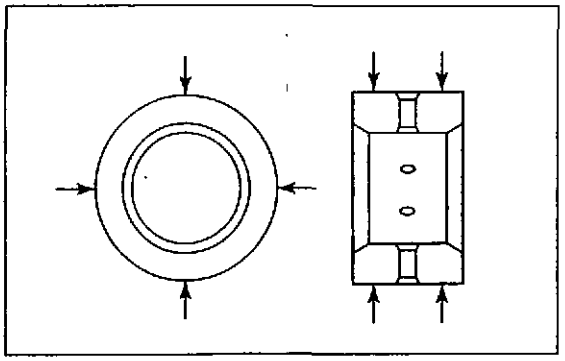


(2) Measuring bearing outside diameter

If the measured diameter is less than the service limit, replace the bearing.

Unit: mm [in.]

Item	Service Limit
Bearing outside diameter	35.847 [1.4113]

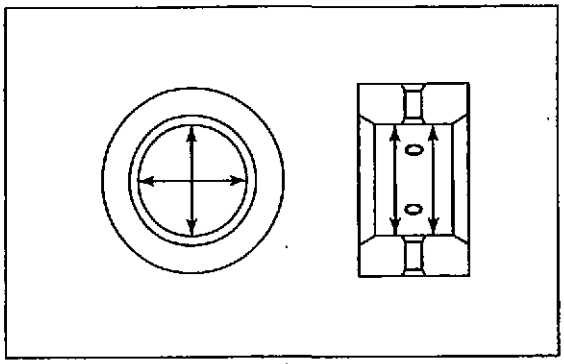


(3) Measuring bearing inside diameter

If the measured diameter exceeds the service limit, replace the bearing.

Unit: mm [in.]

Item	Service Limit
Bearing inside diameter	24.0335 [0.9462]

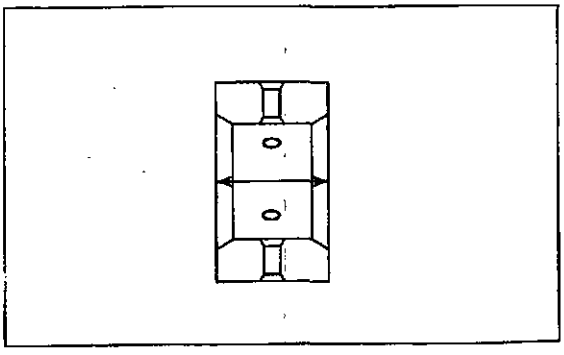


(4) Measuring bearing length

If the measured length is less than the service limit, replace the bearing.

Unit: mm [in.]

Item	Service Limit
Bearing length	23.440 [0.9228]

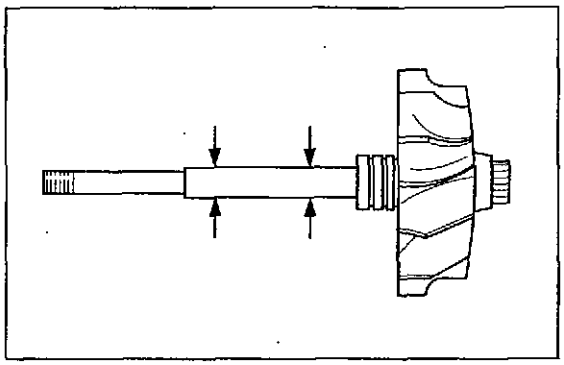


⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(5) Measuring journal diameter of the shaft & turbine wheel

If the measured diameter is less than the service limit, replace the shaft & turbine wheel.

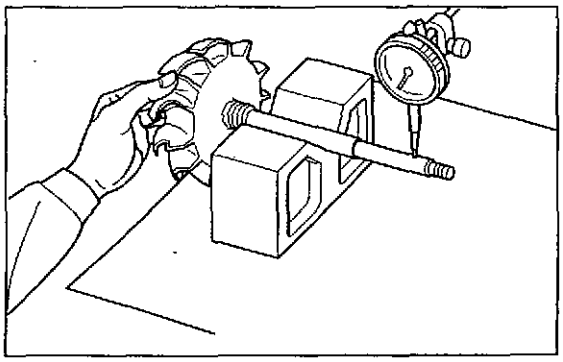


Unit: mm [in.]

Item	Service Limit
Shaft journal diameter	23.996 [0.9447]

(6) Measuring shaft deflection

(a) Set a dial gage at a location next to the threaded section of the shaft, and measure shaft deflection.



⚠CAUTION

If the shaft is bent, replace. Do not attempt to correct the bend.

If the deviation indicated by the dial gage exceeds the service limit, replace the shaft & turbine wheel.

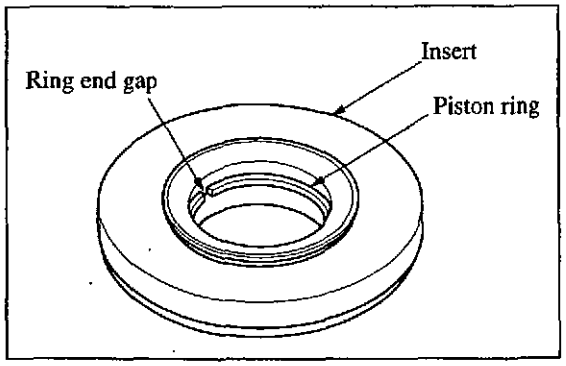
(b) If the surface of the shaft journal is rough, mount the shaft on a lathe, and gently polish the surface using #400 sandpaper and engine oil while rotating at 300-600 min^{-1}.

Unit: mm [in.]

Item	Service Limit
Shaft deflection	0.015 [0.0006]

(7) Measuring piston ring end gap

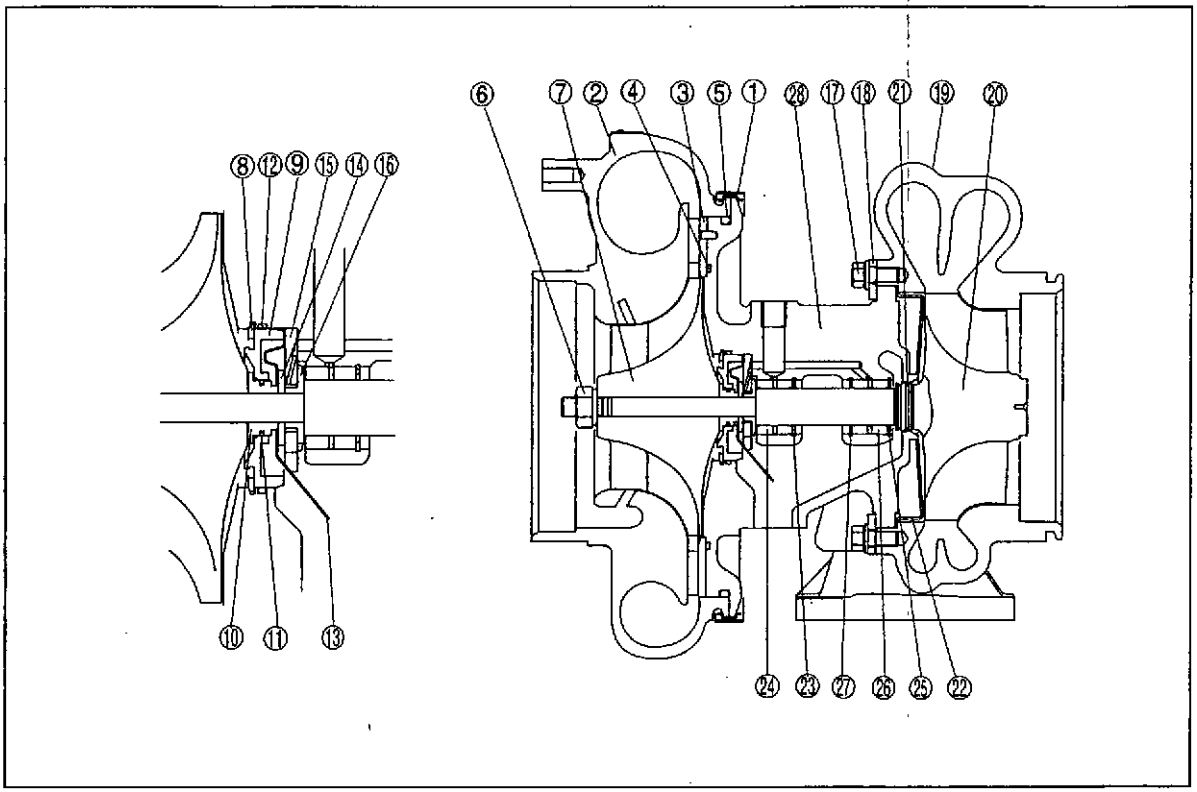
Install a new piston ring squarely in the insert, then measure the piston ring end gap.
If the end gap deviates from the assembly standard, replace the insert.



Unit: mm [in.]

Item	Assembly Standard
Ring end gap	0.05 to 0.20 [0.0020 to 0.0079]

5.4 Reassembly



Reassembly sequence

㉘→㉗→㉖→㉕→㉔→㉓→㉒→⑲→⑱→⑰→⑯→⑮→⑭→⑬→⑫→⑧→⑦→⑥→⑤→④→③→②→①

㉑→⑳ ⑪→⑩→⑨

⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

⚠CAUTION

(a) Replace the following parts once disassembled.
- ⑪ Piston ring
- ㉑ Piston ring
- ④ O-ring
- ⑤ O-ring
- ⑫ O-ring

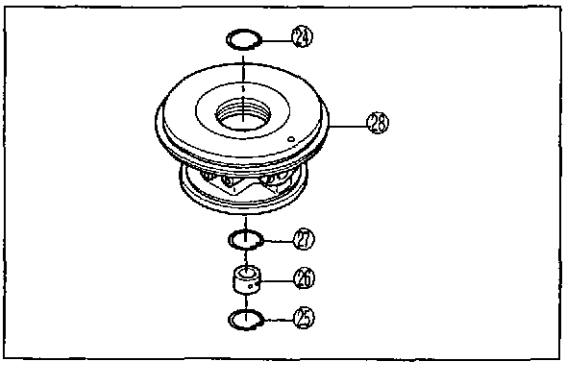
(b) After installing the overhauled turbocharger on the engine, crank the engine with the starter to send lubricating oil to the moving parts in the turbocharger.

⚠CAUTION

If vanes are damaged or cracked, do not reuse the part.
If only one vane is slightly bent or scratched, the part can be reused. However, do not attempt to correct the bend.

(1) Installing the shaft & turbine wheel and bearing

(a) Install the following parts.
㉘ Bearing housing
㉗ Snap ring
㉖ Bearing
㉕ Snap ring
} (turbine side)
㉔ Snap ring (compressor side)



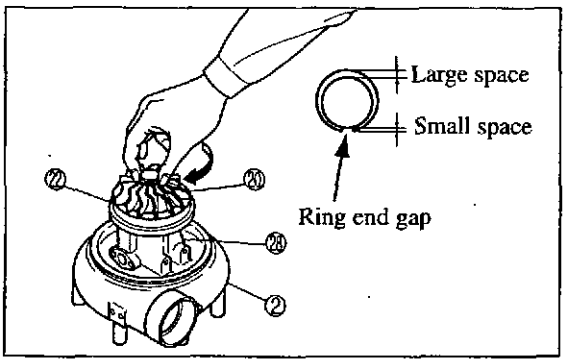
⚠CAUTION

(a) Use the snap ring pliers (49160-90110) to install the snap ring. After installing the snap ring, rotate the ring with a finger to make sure it rotates smoothly.
(b) Apply engine oil to the outside and inside surfaces of the bearing before installation.

(b) Place the bearing housing ㉘ on the compressor cover ②, and install the turbine backplate ㉒.

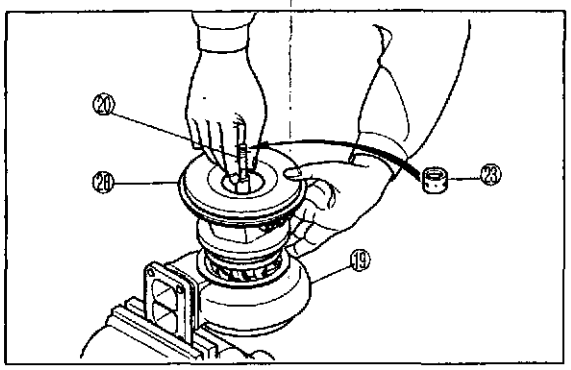
(c) Insert the piston ring ㉑ into the groove on the shaft & turbine wheel ⑳.

(d) When installing the shaft & turbine wheel ⑳ mounted with the piston ring in the bearing housing ㉘, position the ring on the shaft as shown in the drawing, and insert the shaft & turbine wheel ⑳ while rotating.



⚠CAUTION

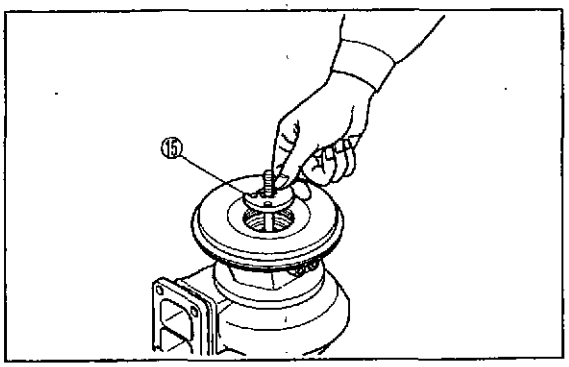
(a) Do not expand the piston ring excessively or twist the ends when installing on the shaft & turbine wheel.
(b) After installing the piston ring in the ring groove, apply Moly Disulfide to the ring before assembly.
(c) Do not apply excessive force without centering the shaft properly during the installation of the shaft & turbine wheel.



(e) After installing the shaft & turbine wheel ⑳, hold the shaft end and turn over the assembly so the compressor side faces up.
Then, install the bearing ㉓ on the compressor side.
After the assembly is completed, mount the bearing housing ㉘ on the turbine housing ⑲ and fasten the bolt ⑰ temporarily.

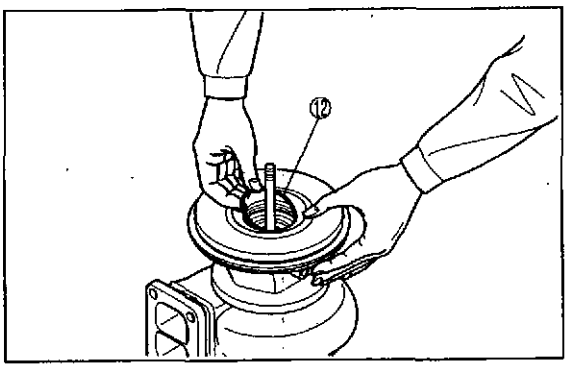
(2) Installing the thrust bearing

Apply engine oil to both sides of the thrust ring ⑯ and thrust bearing ⑮.
To install the thrust bearing, align the notch to the groove pin.



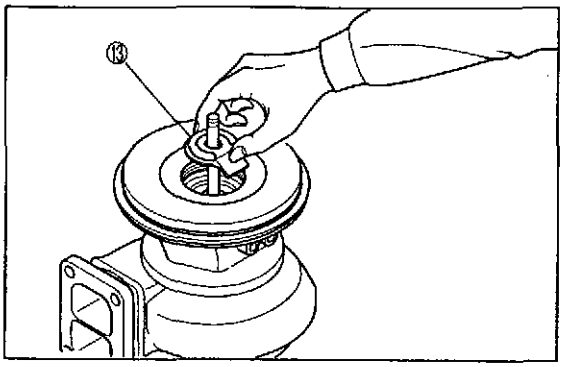
(3) Installing the O-ring

Apply grease to the O-ring ⑫, and install.



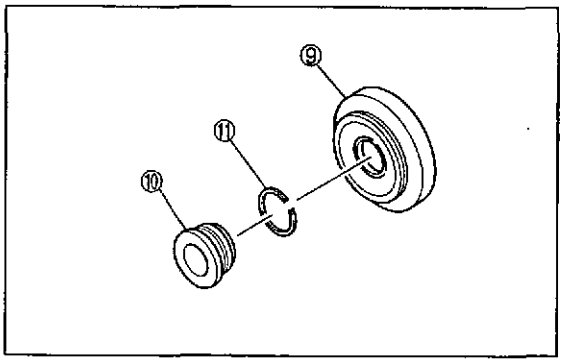
(4) Installing the oil deflector

Apply engine oil to both sides of the thrust ring ⑭, and install. Then, install the oil deflector ⑬ with the baffle facing down.



(5) Assembling the insert sub-assembly

(a) Install the following parts to the insert ⑨.
- ⑪ Flinger sleeve
- ⑩ Piston ring
- ⑨ Insert



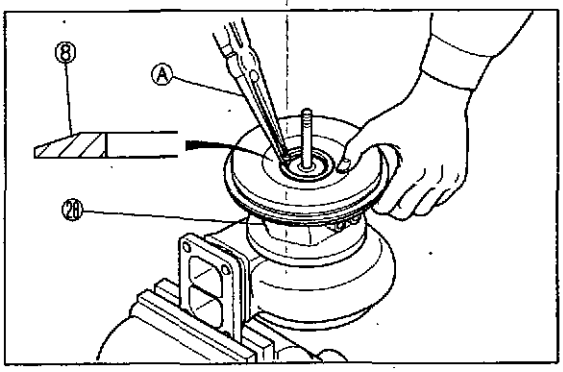
⚠CAUTION

(a) Do not expand the piston ring excessively or twist the ends when installing on the flinger sleeve.
(b) Apply Moly Disulfide to the piston ring installed on the flinger sleeve, then install on the insert carefully so as to avoid piston ring damage.

(b) After installing the above parts, install the sub-assembly in the bearing housing ⑳.

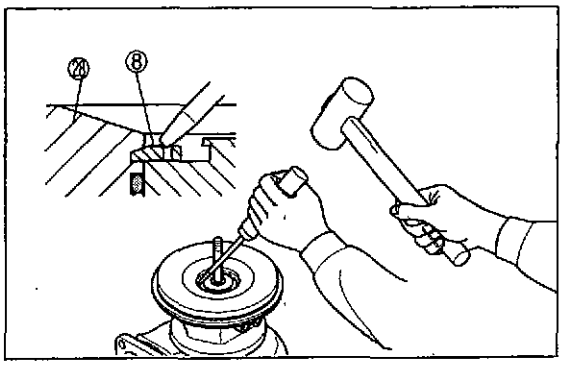
(6) Installing the snap ring

With the tapered face facing up, install the snap ring ⑧ in the bearing housing ㉘ using the snap ring pliers Ⓐ (49160-90101).



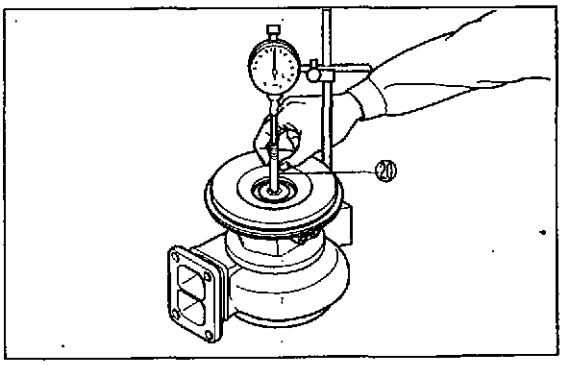
⚠CAUTION

(a) Be sure to install the snap ring in the correct attitude.
(b) Lightly drive both ends of the snap ring, *using a screwdriver and hammer to securely* insert the ring into the groove on the bearing housing.
(c) Make sure the screwdriver does not hit the bearing housing when driving the snap ring with the screwdriver and hammer.



(7) Measuring clearance between the turbine wheel and turbine housing

Set a dial gage on the end face of the shaft & turbine wheel ⑳. Read the dial gage indication while moving the shaft & turbine wheel in the axial direction.
If the dial gage indication deviates from the assembly standard, disassemble and locate the cause of the problem.



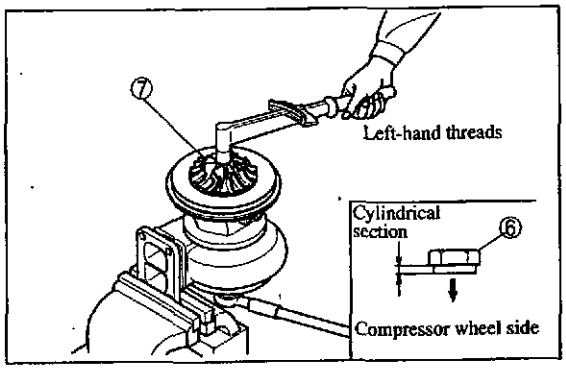
Unit: mm [in.]

Item	Standard Clearance
Clearance between shaft & turbine wheel and turbine housing	0.58 to 1.32 [0.0228 to 0.0520]

(8) Installing the compressor wheel

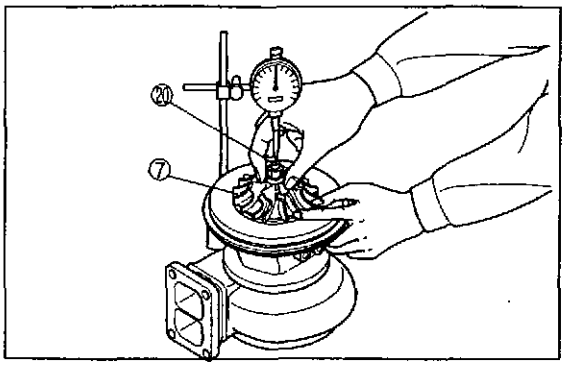
Install the compressor wheel ⑥. Tighten the lock nut ⑤ to the specified torque.

- Lock nut tightening method
  Tighten the lock nut to torque of 69 N·m (7 kgf·m) [51 lbf·ft] first, then loosen it completely. Apply Loctite No. 962T to the threads. Retighten the nut to a snug torque of 9.8 N·m (1 kgf·m) [7.2 lbf·ft], then turn further by 90±3°.



(9) Measuring play of the shaft & turbine wheel in the axial direction

Set a dial gage on the end face of the shaft & turbine wheel ⑳.
Measure the amount of play while moving the compressor wheel ⑦ in the axial direction.
If the measured amount of play deviates from the standard value, disassemble and locate the cause of the problem.

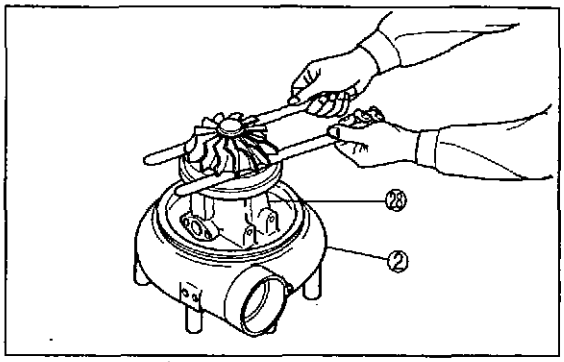


Unit: mm [in.]

Item	Assembly Standard
Play of shaft & turbine wheel in axial direction	0.075 to 0.135 [0.0030 to 0.0053]

(10) Measuring clearance between the turbine backplate and the back side of the turbine wheel

Remove the turbine housing from the bearing housing ㉘. Install the compressor cover ②, and conduct the following measurement.
Using feeler gages, measure clearance between the turbine backplate ㉒ and the back side of the turbine wheel.



⚠CAUTION

Be sure to use two feeler gages, and take the measurement at vane tips.

If the measured clearance deviates from the assembly standard, disassemble and locate the cause of the problem.

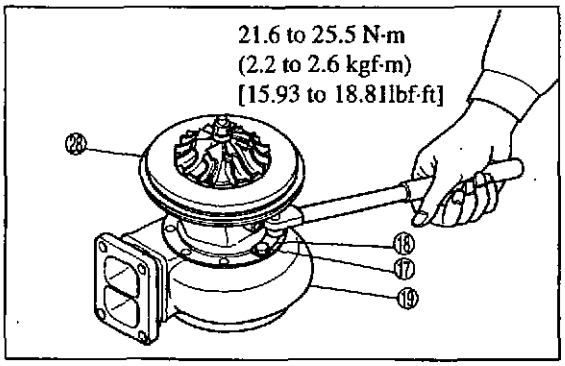
Unit: mm [in.]

Item	Standard Clearance
Clearance between turbine backplate and back side of turbine wheel	0.78 to 1.22 [0.0307 to 0.0480]

(11) Installing the turbine housing

(a) Check the mounting direction of the turbine housing ⑲, then install on the bearing housing ㉘.

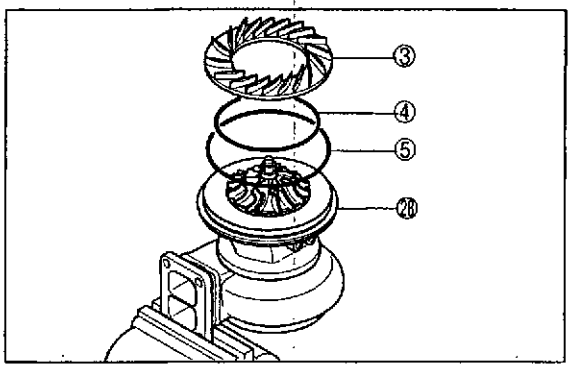
(b) Apply Moly Disulfide to the threads of the bolt ⑰, install lock plate ⑱ and tighten the bolt.



(12) Installing the diffuser

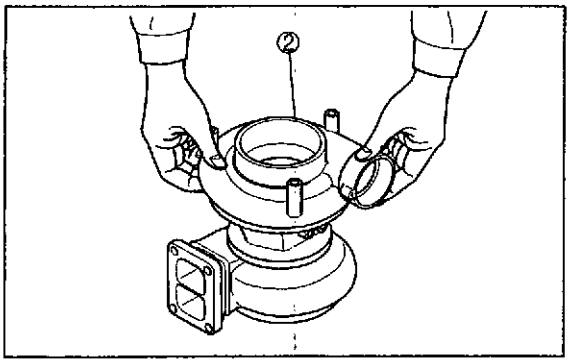
(a) Apply grease to the O-ring ⑤, ④ and install the bearing housing ㉘.

(b) Install the diffuser ③.



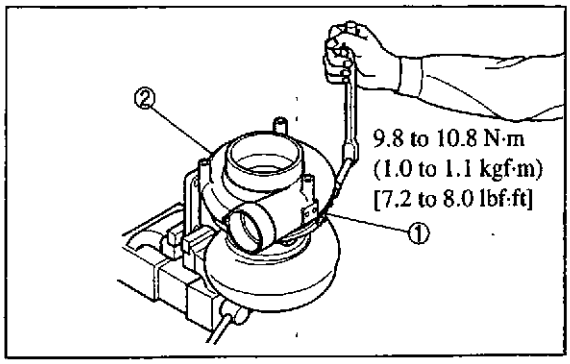
(13) Installing the compressor cover

Check the mounting direction of the compressor cover ②, then install.



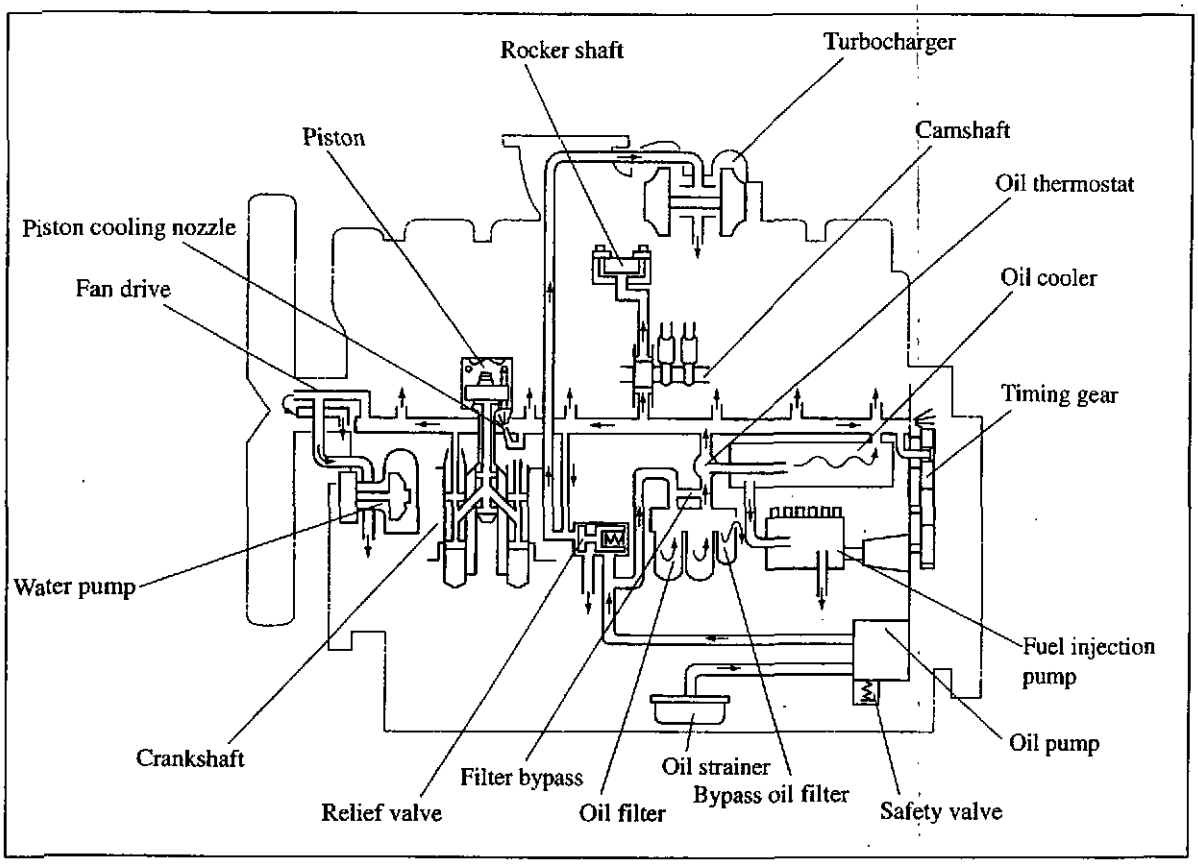
(14) Installing the V-clamp

Install the V-clamp ① to the compressor cover ② and tap around it with a soft-faced hammer for more than 3 times and tighten to the specified torque.



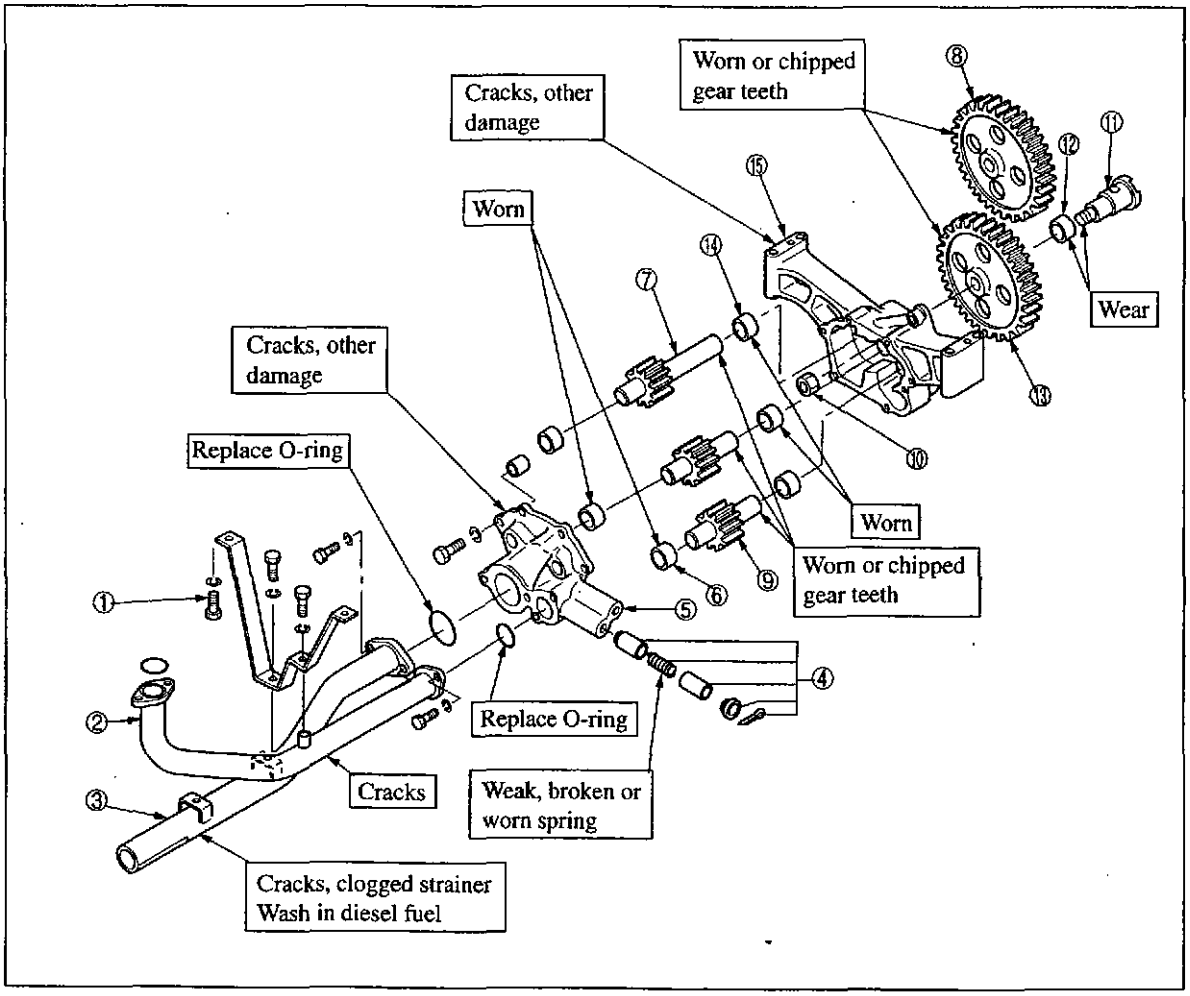
LUBRICATION SYSTEM

1. Description



2. Oil Pump and Safety Valve

2.1 Disassembly



Disassembly sequence

① Support
② Oil pipe
③ Oil strainer
④ Safety valve
⑤ Pump cover
⑥ Bushing
⑦ Drive gear
⑧ Oil pump gear
⑨ Driven gear
⑩ Nut
⑪ Spindle
⑫ Bushing
⑬ Idler gear
⑭ Bushing
⑮ Pump case

NOTE

Before removing the gears, measure the backlash of each pair of gears. If the measurement exceeds the service limit, replace the gears.

2.2 Inspection

(1) Inspecting oil pump gear backlash

If the backlash exceeds the service limit, replace the gears.

Unit: mm [in.]

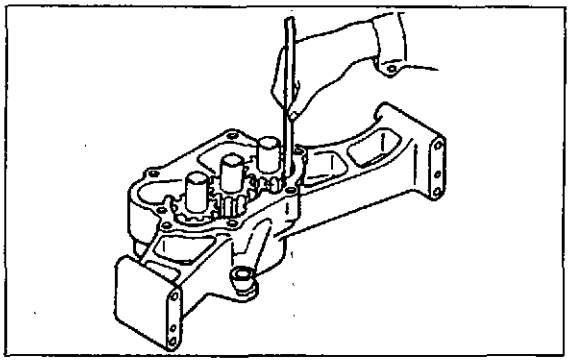
Item	Standard Clearance	Service Limit
Backlash between oil pump gear and idler gear	0.087 to 0.316 [0.0034 to 0.0124]	0.4 [0.016]

(2) Measuring pump gear tip clearance

Use a feeler gage, measure the tip clearance. If the clearance exceeds the service limit, replace the gears or case, whichever is badly worn.

Unit: mm [in.]

Item	Nominal Value	Standard Clearance	Service Limit
Pump gear radial clearance	ø 60 [2.36]	0.100 to 0.196 [0.0039 to 0.0077]	Tip clearance: 0.35 [0.0138]



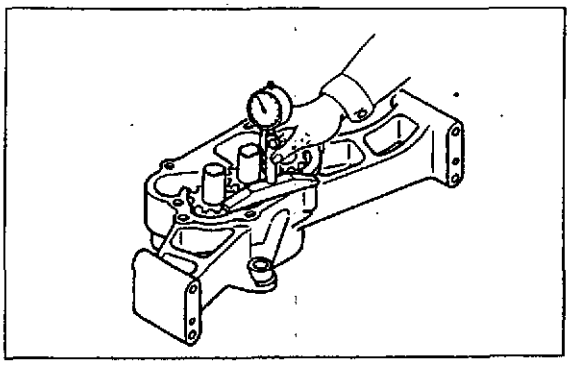
Measuring pump gear radial clearance

(3) Measuring pump gear end clearance

Using a dial gage, measure the end clearance. If the clearance exceeds the service limit, replace the gears or case, whichever is badly worn.

Unit: mm [in.]

Item	Nominal Value	Standard Clearance	Service Limit
Pump gear end clearance	34 [1.34]	0.050 to 0.114 [0.0020 to 0.0045]	0.25 [0.0098]



Measuring pump gear end clearance

(4) Measuring drive and driven gear shaft and bushing diameters

(a) Check the gear teeth. Replace gears if they are defective.

(b) If the diameter exceeds the service limit, replace the gears.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Shaft diameter	ø 25 [0.98]	24.947 to 24.960 [0.9822 to 0.9827]	24.900 [0.9803]
Bushing inside diameter		25.000 to 25.021 [0.9843 to 0.9851]	25.100 [0.9882]

(5) Measuring spindle diameter and idler gear bushing inside diameter

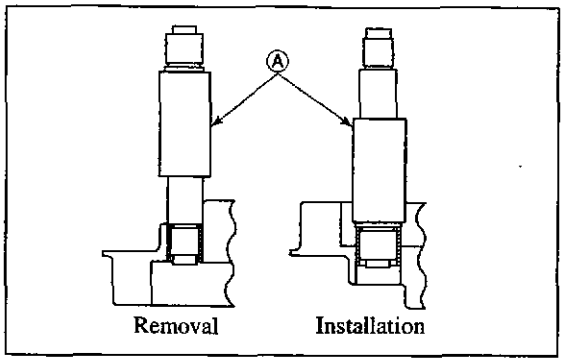
Measure the diameter of the spindle and the inside diameter of the bushing to determine the clearance. If the clearance exceeds the service limit, replace the bushing.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Spindle diameter	ø 25 [0.98]	24.947 to 24.960 [0.9822 to 0.9827]	24.900 [0.9803]
Bushing inside diameter		25.00 to 25.021 [0.9843 to 0.9851]	25.100 [0.9882]

(6) Replacing oil pump bushings

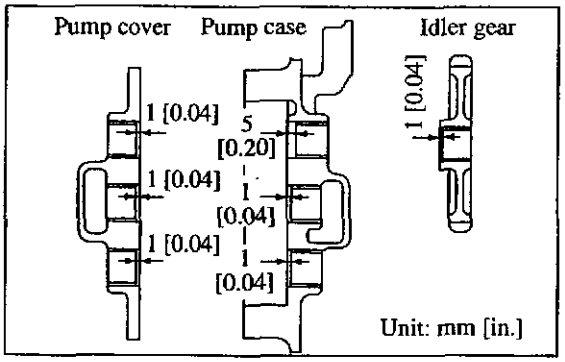
(a) Use oil pump bushing tool Ⓐ to remove the bushings for removal. If it is difficult to remove the bushings, replace the bushings and related parts as an assembly.



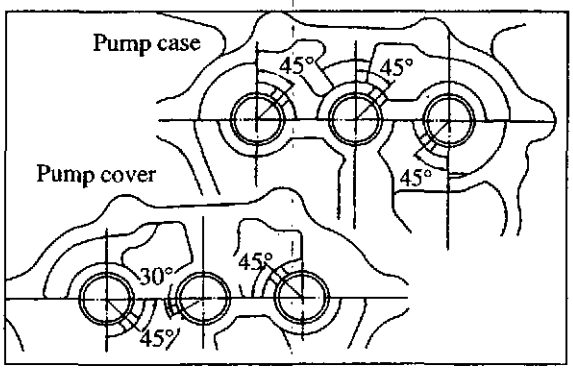
Replacing oil pump case bushing

(b) The press-in depths of the bushings are as shown at right.

(c) After installing each bushings, ream its inside diameter to $25H7^{+0.021}_{0}$ mm [$0.98H7^{+0.00083}_{0}$ in.].



(d) When installing the bushings to the pump case and pump cover, align the bushing ends with oil grooves.



Oil pump bushing end gap position

(7) Inspecting the safety valve

Replace the valve spring if it is fatigued, worn or broken.

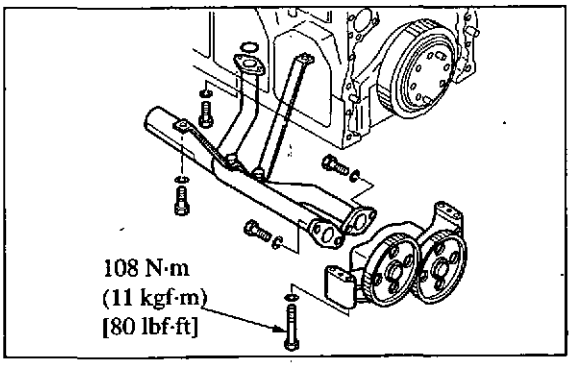
Item	Assembly Standard
Safety valve opening pressure	1.37±0.10 MPa (14.0±1.0 kgf/cm²) [199±14]
Safety valve spring length under test force/test force, mm [in.]/N (kgf) [lbf]	67.2 [2.64]/ 384 (39.2) [86.4]

(8) Adjusting backlash between crankshaft gear and oil pump idler gear

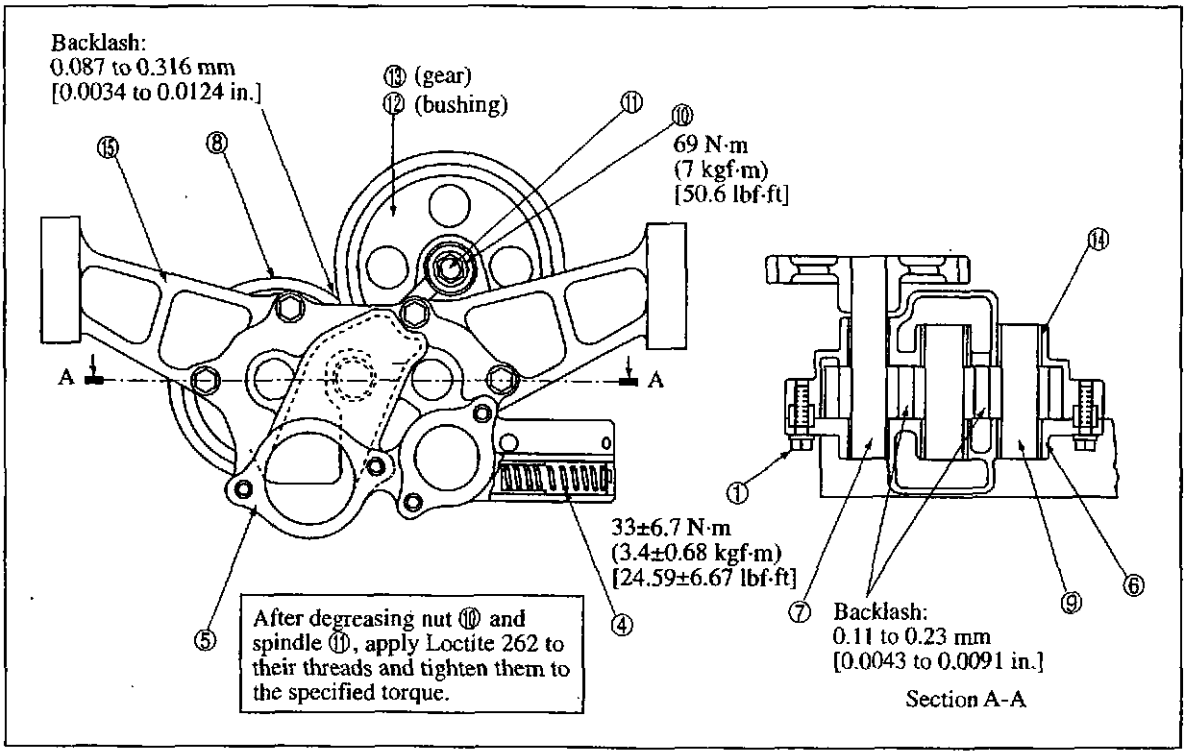
After installing the oil pump to the crankcase, measure the backlash. If the measurement exceeds the assembly standard, adjust the backlash by inserting shim(s).

Unit: mm [in.]

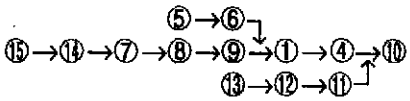
Item	Assembly Standard
Backlash between oil pump idler gear and crankshaft gear	0.12 to 0.18 [0.0047 to 0.0071]



2.3 Reassembly



Reassembly sequence

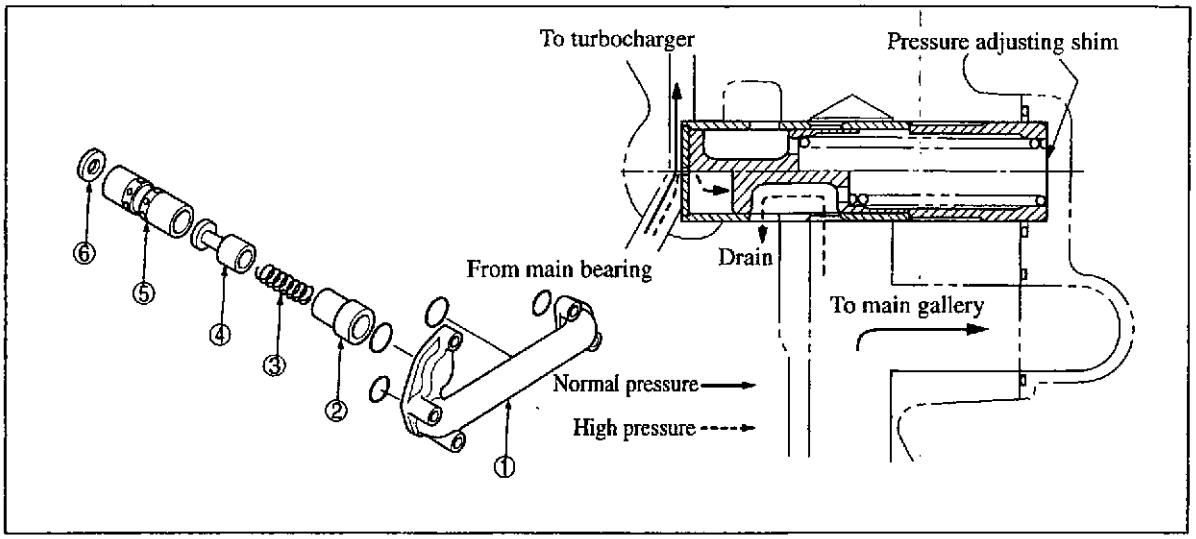


NOTE

Coat the pump parts with engine oil before installing them. Apply a thick coat of engine oil to the threads and seating faces of nuts (except for flange nuts) and bolts when thightening them.

3. Relief Valve

3.1 Disassembly



Disassembly sequence

① Oil pipe, O-ring
② Stopper
③ Spring
④ Relief valve
⑤ Sleeve
⑥ Plate

3.2 Inspection

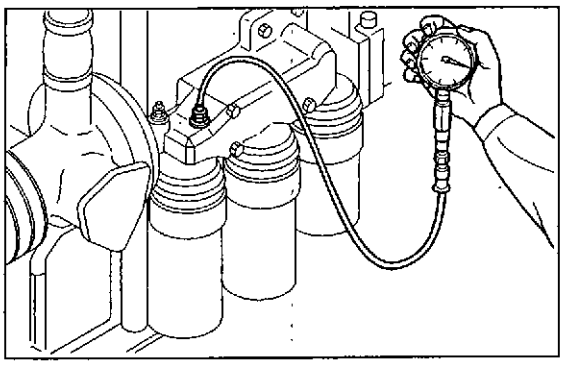
(1) Measuring relief valve pressure

(a) Remove the taper plug (PT 1/8) at the upper of oil filter bracket, and attach a pressure gauge.

(b) Warm up the engine until the oil temperature rises to 70 to 90°C [158 to 194°F].

(c) Measure the oil pressure at idling speed and at maximum speed.

(d) If the relief valve setting is below the Assembly standard, remove the oil pipe, and adjust the setting by inserting shims into between the oil pipe and spring.



Testing relief valve setting

Unit: MPa (kgf/cm²) [psi]

Item	Assembly Standard
Set pressure (at maximum speed)	0.49 to 0.64 (5 to 6.5) [71.1 to 92.4]
Relief valve opening pressure	0.46 (4.7) [66.86]

NOTE

The measured oil pressure might be above the set pressure when oil temperature is low, but it returns to the set pressure when oil temperature rises.

(e) If the setting does not vary after the adjustment has been made, replace the relief valve and spring.

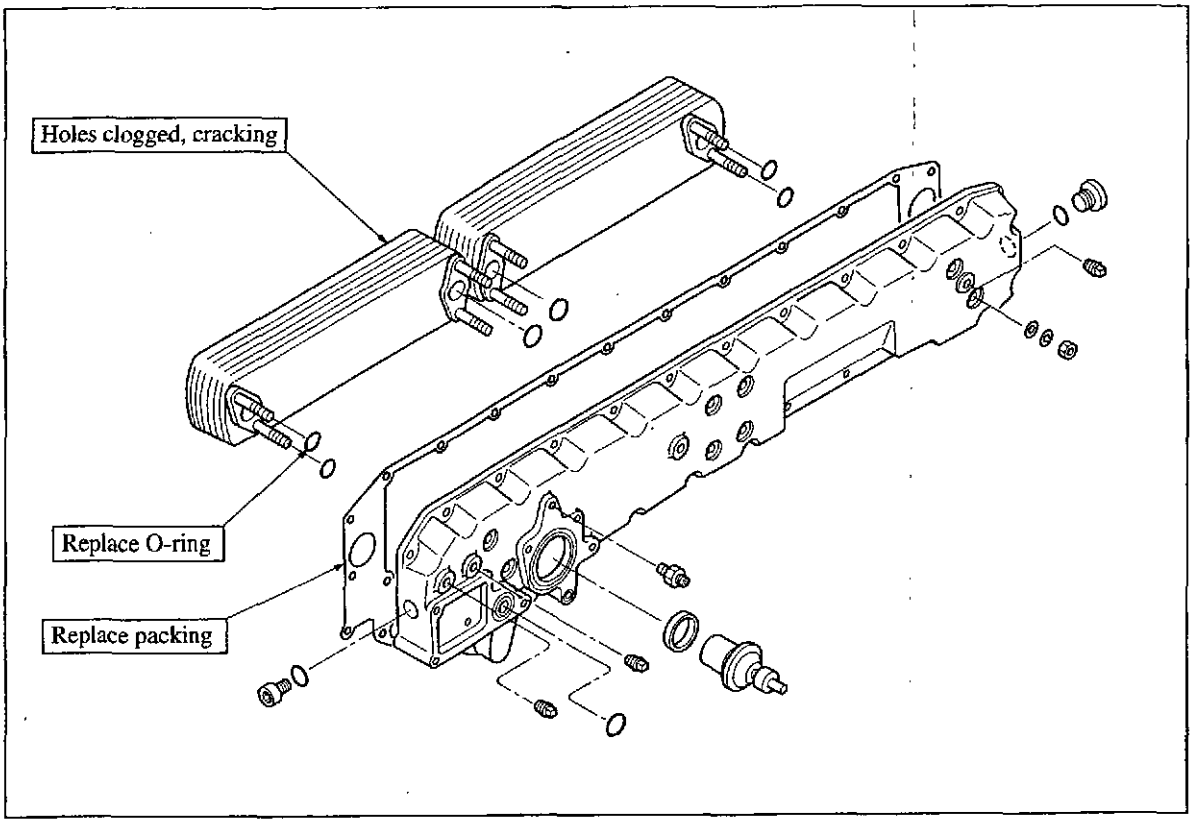
3.3 Reassembly

Reassembly is the reverse procedure of disassembly.

Install new O-rings during reassembly.

4. Oil Cooler and Oil Thermostat

4.1 Disassembly



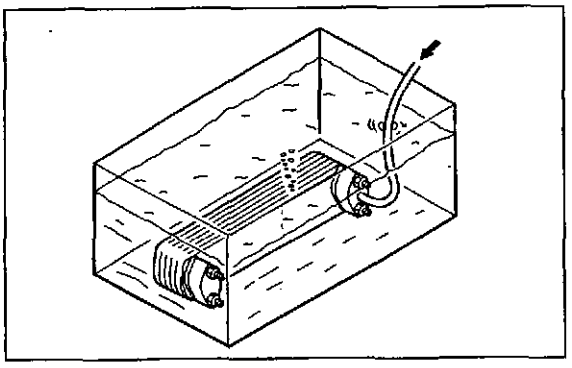
⚠CAUTION

Replace packings and O-rings with new ones at reassembly.

4.2 Inspection

(1) Inspecting oil cooler element

Test the oil path with compressed air of 1.47 MPa (15 kgf/cm²) [213 psi] for damage or cracks in the element. If there is any leakage, replace the element.

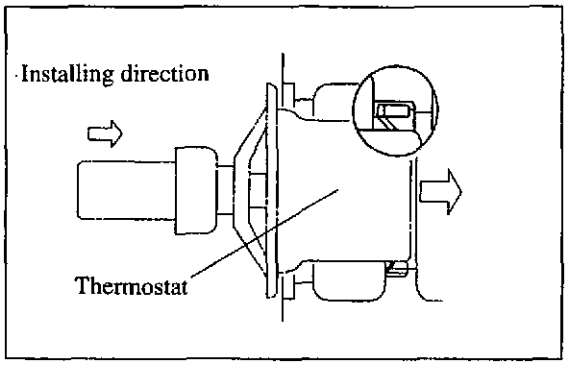


(2) Inspecting oil thermostat

(a) Inspect the oil thermostat seal for deterioration and cracks. If any are found, replace the seal.

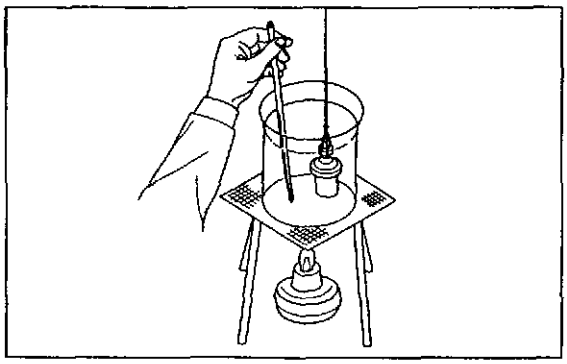
(b) Refer to the drawing on the right that shows the correct direction for seal installation.

(c) Operation testing



Installing seal for thermostat

Immerse the thermostat in a oil tub, and test it for thermostat action by heating the tube to raise the oil temperature. In the test, measure the temperature at which the valves starts opening and that at which the valve lift is more than 10 mm [0.39 in.]. If these temperature measurements are out of the assembly standard, replace the thermostat.



Unit: °C [°F]

Item	Assembly Standard
Temperature at which valve starts opening	80 to 84 [176 to 183]
Temperature at which valve lift reaches 10 mm [0.39 in.] or more	95 [203]

NOTE

(a) Stir the water in the tub with a stick to maintain even temperatures uniform during test.
(b) At reassembly, confirm the valve opening temperature stamped on its mounting flange.

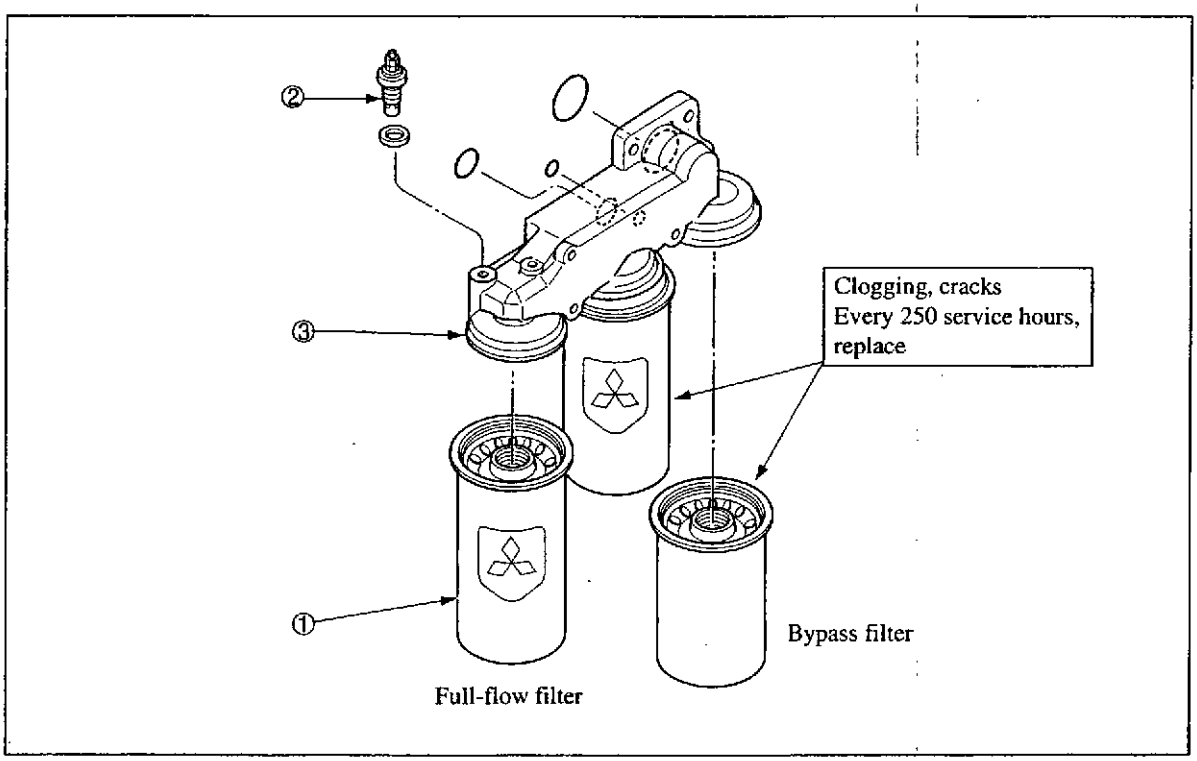
4.3 Reassembly

(1) Replace new packing and O-rings for reassembly.

(2) Before reassembly, clean the oil paths of the oil filter bracket, etc. by flushing them with oil and blowing them with air.

5. Oil Filters and Oil Filter Alarm

5.1 Disassembly



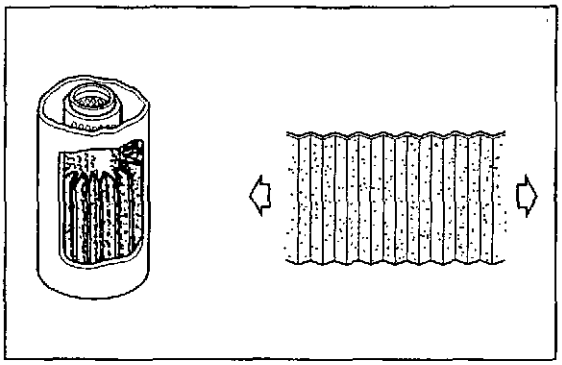
Disassembly sequence

① Oil filter (cartridge type) ② Oil filter alarm ③ Filter bracket

5.2 Inspection

(1) Inspecting the oil filter

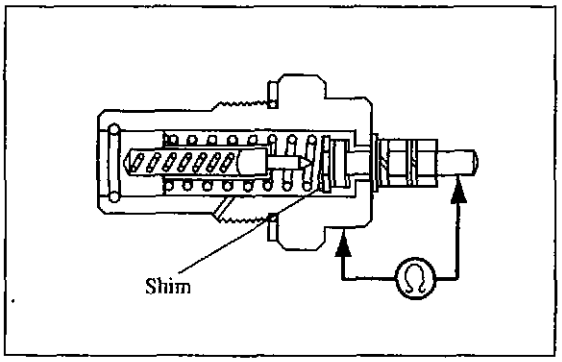
When you replace the paper element, sample about 500 cm^3 [30.5 cu.in.] of oil and check for metal particles. If any metal particle is found, unfold the pleats of element and check the color and shape of the particles trapped in the pleats to identify the cause.



(2) Inspecting the oil filter alarm

(a) Use a tester to check the alarm for insulation and continuity. If the alarm is found defective, disassemble and repair it. Replace the alarm if the bakelite or rubber insulators are deteriorated or damaged.

(b) If the alarm pressure is not within the assembly standard, adjust it by inserting shims. For the thickness of a shim, 1 mm [0.04 in.] corresponds to a change in pressure of 0.007 MPa (0.07 kgf/cm^2) [1.00 psi].



Unit: MPa (kgf/cm^2) [psi]

Item	Assembly Standard
Pressure difference across oil filter alarm that makes its valve open	$0.15\ ^{+0.03}_{0}$ ($1.5\ ^{+0.3}_{0}$) [$21.3^{+4.27}_{0}$]

5.3 Reassembly

Reassembly is the reverse procedure of disassembly.

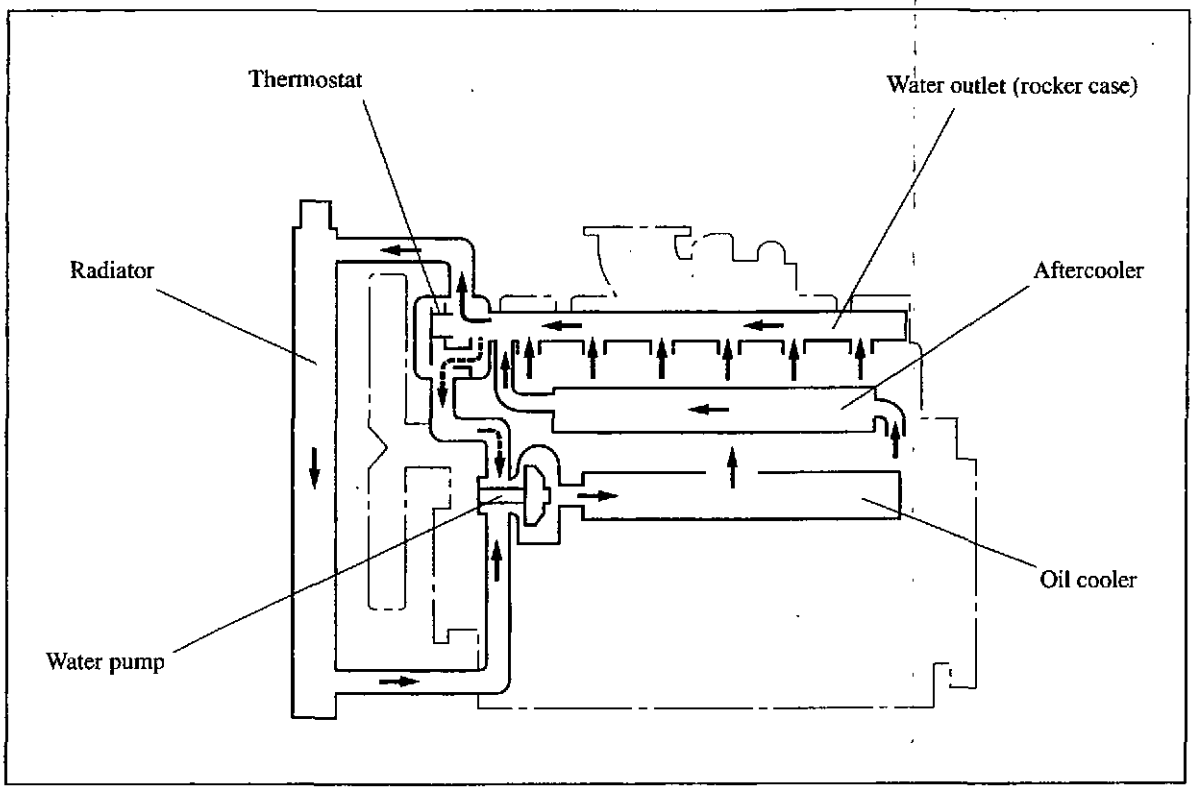
(1) Replace packing and O-rings for reassembly.

(2) Before reassembly, clean the oil paths of the oil filter bracket, etc. by flushing them with oil and blowing them with air.

(3) Mount the oil filter element on the bracket before installation.

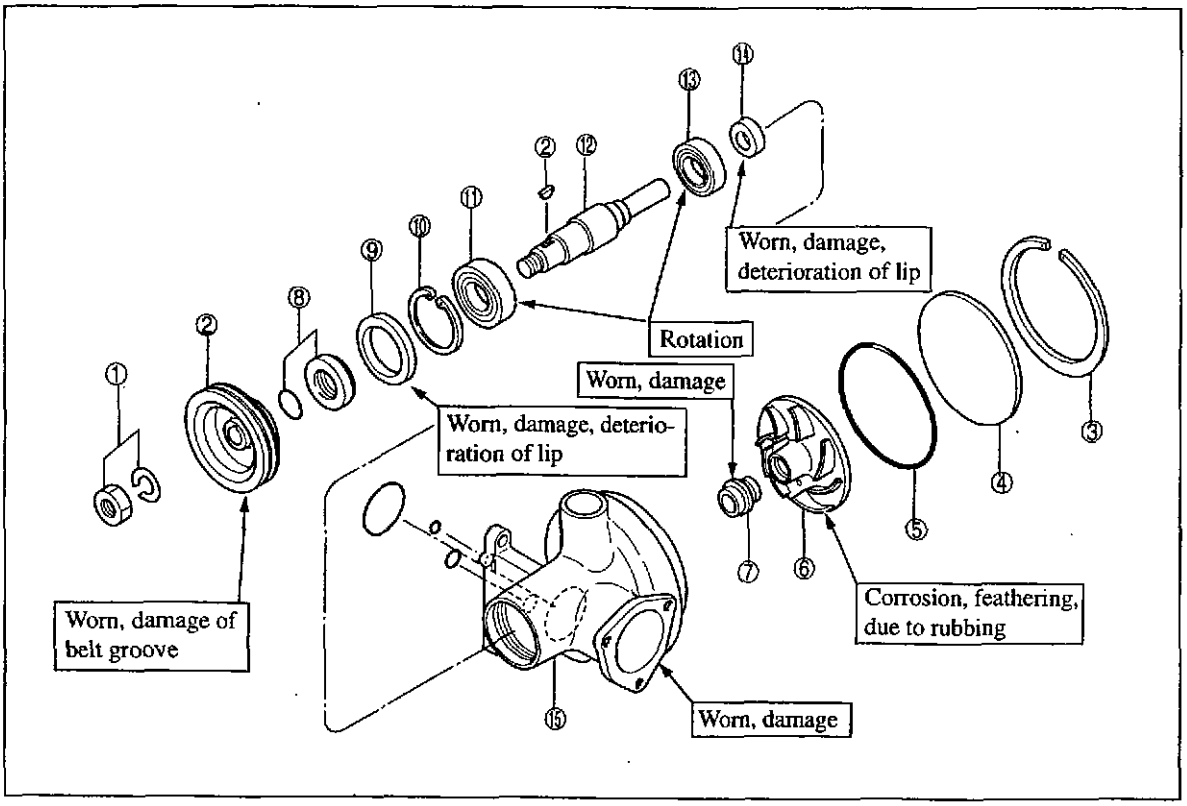
COOLING SYSTEM

1. Cooling System with Radiator



2. Water Pump

2.1 Disassembly

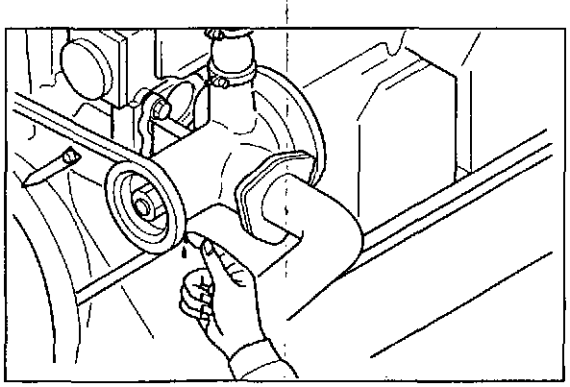


Disassembly sequence

① Nut, washer
② Water pump pulley, key
③ Snap ring
④ Cover
⑤ O-ring
⑥ Impeller
⑦ Unit seal
⑧ Spacer, O-ring
⑨ Oil seal
⑩ Snap ring
⑪ Bearing
⑫ Water pump shaft
⑬ Bearing
⑭ Oil seal
⑮ Case

(1) Inspecting the wear pump on the engine

If the port is wet with water, inspect the unit seal for water leakage. If it is wet with oil, inspect the oil seal for oil leakage.



(2) Removing the impeller

(a) Remove the snap ring, with the water pump pliers Ⓐ (37591-03100), then remove the cover.

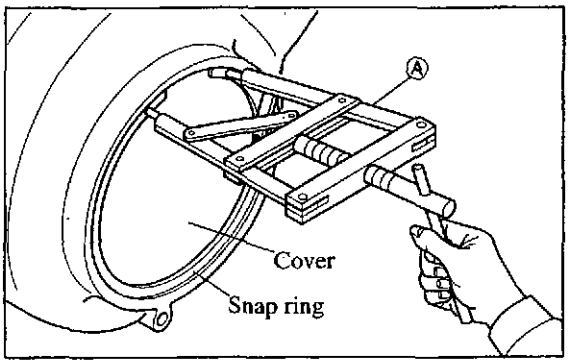
(b) Remove the impeller with the impeller remover Ⓑ (37591-03200).

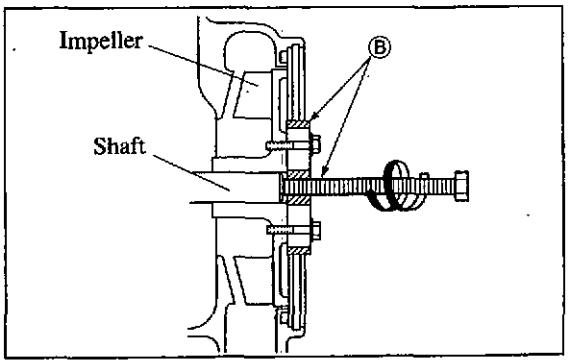
(3) Removing water pump shaft

Remove the snap ring from the front bearing. Using a press or soft hammer, drive out the pump shaft complete with the bearing toward the gear side.

⚠CAUTION

Be careful not to damage the water pump shaft and impeller during removal of the impeller from the shaft.





Removing water pump impeller

2.2 Inspection

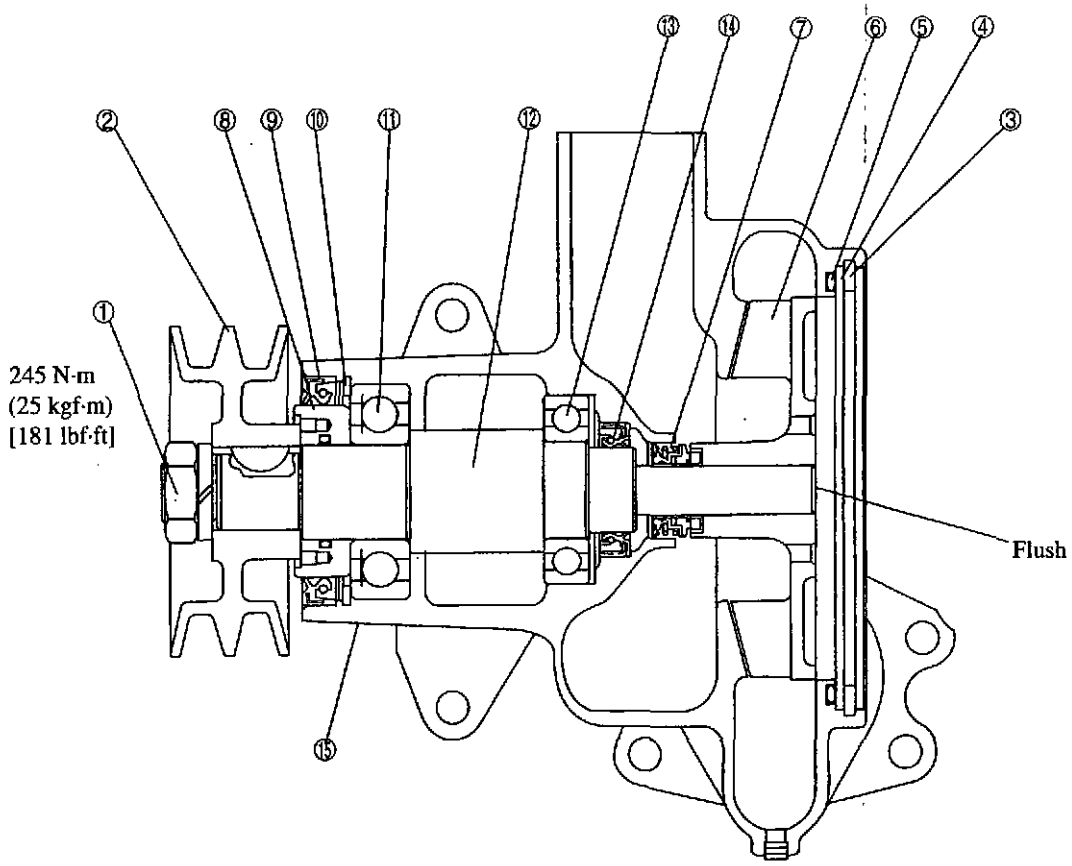
Water Pump

Measure the inside diameter of the pump case bore to which the bearing outer race is fitted. Measure the diameter of the pump shaft on which the bearing inner race is fitted. If the bearing, case, or shaft is excessively worn, replace it.

Unit: mm [in.]

Item		Nominal Value	Assembly Standard	Service Limit
Inside diameter of pump case bearing		ø 80 [3.15]	79.988 to 80.018 [3.1491 to 3.1503]	80.025 [3.1506]
Inside diameter of cover to which the bearing outer race is fitted		ø 90 [3.54]	89.987 to 90.022 [3.5428 to 3.5442]	90.025 [3.5443]
Bearing	Diameter	ø 80 [3.15]	79.987 to 80.000 [3.1491 to 3.1496]	
		ø 90 [3.54]	89.985 to 90.000 [3.5427 to 3.5433]	
	Inside diameter	ø 40 [1.57]	39.988 to 40.000 [1.5743 to 1.5748]	
Diameter of pump shaft on which bearing inner race is fitted		ø 40 [1.57]	40.002 to 40.013 [1.5749 to 1.5753]	39.995 [1.5749]

2.3 Reassembly



Apply sealant (ThreeBond 1102) to outside surface of unit seal

Apply grease to oil seal lip

Apply LLC solution (antifreeze solution) to floating portion of unit seal at two places when pressing the seal into impeller

Reassembly sequence

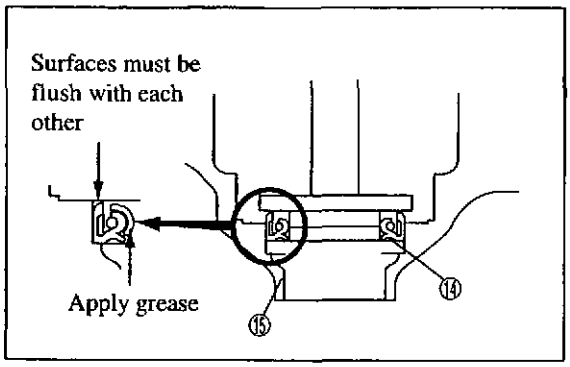
⑮→⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

NOTE

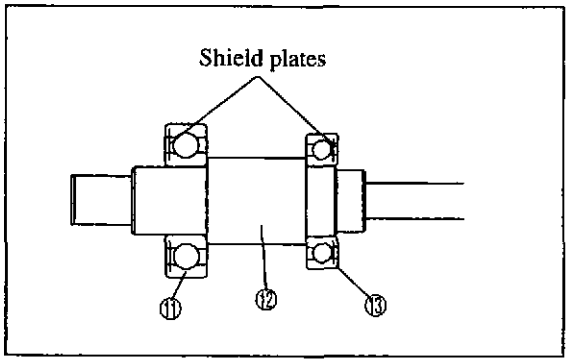
(a) Replace O-rings, oil seals and unit seal during reassembly.

(b) Install the ball bearings to the pump shaft with their sideplates on the oil seal side.

(1) Using an installer, press-fit oil seal ⑭ into case ⑮. Make sure the oil seal surface is flush with the case face.
Apply grease to the lip surface of the oil seal.



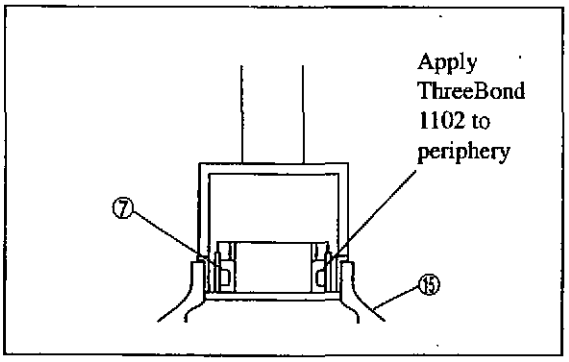
(2) Install bearings ⑪, ⑬ to water pump shaft ⑫ by striking with a hammer. Make sure the shield plate of each bearing faces the oil seal side.



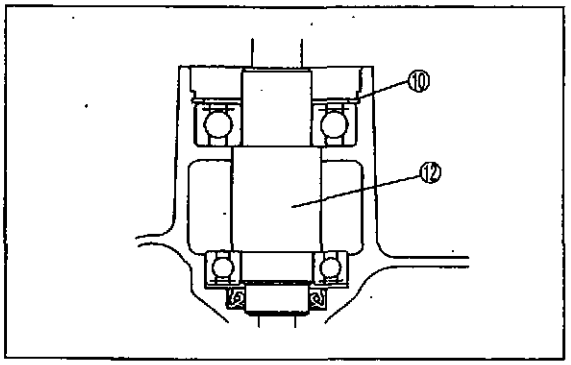
(3) Press-fit unit seal ⑦ in case ⑮ using an installer.

NOTE

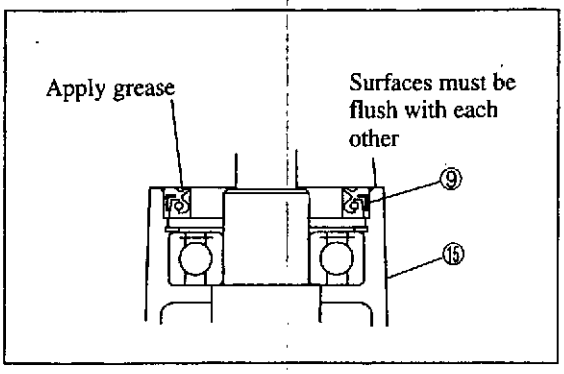
If the unit seal is removed from the pump case, install a new seal during reassembly.
Apply sealant (ThreeBond 1102) to the periphery of the unit seal.



(4) Install water pump shaft ⑫ to the case by striking with a hammer, and install snap ring ⑩ to secure it in place.



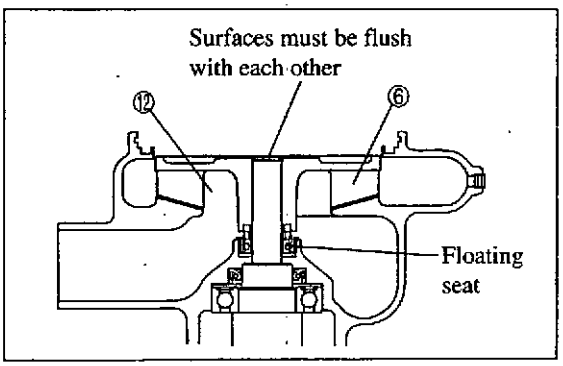
(5) Using an installer, press-fit oil seal ⑨ into case ⑮. Make sure the oil seal surface is flush with the case face.
Apply grease to the lip surface of the oil seal.



(6) Install the floating seat of the unit seal to impeller ⑥, and install the impeller to water pump shaft ⑫ by striking with a hammer. Make sure end faces are flush with each other.

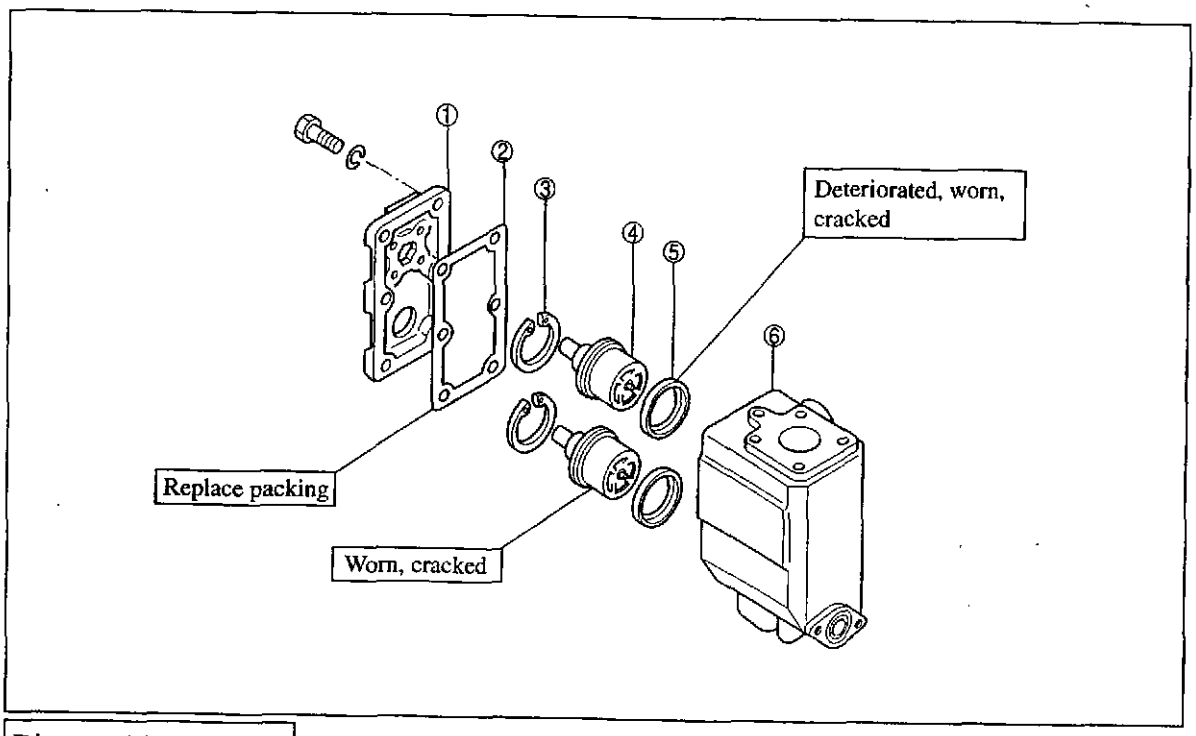
NOTE

Apply LLC solution (anti-freeze solution) to two sections on the floating seat.



3. Thermostats

3.1 Disassembly

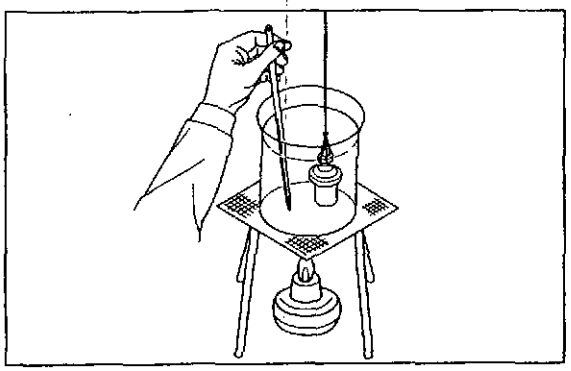


Disassembly sequence

① Thermostat cover
② Packing
③ Snap ring
④ Thermostat
⑤ Thermostat seal
⑥ Thermostat case

3.2 Inspection

Immerse the thermostat in water, then measure the temperature where the valve opens, then measure it again when the valve lift is 9 mm [0.35 in.]. Replace the thermostat if temperatures are not within standard.



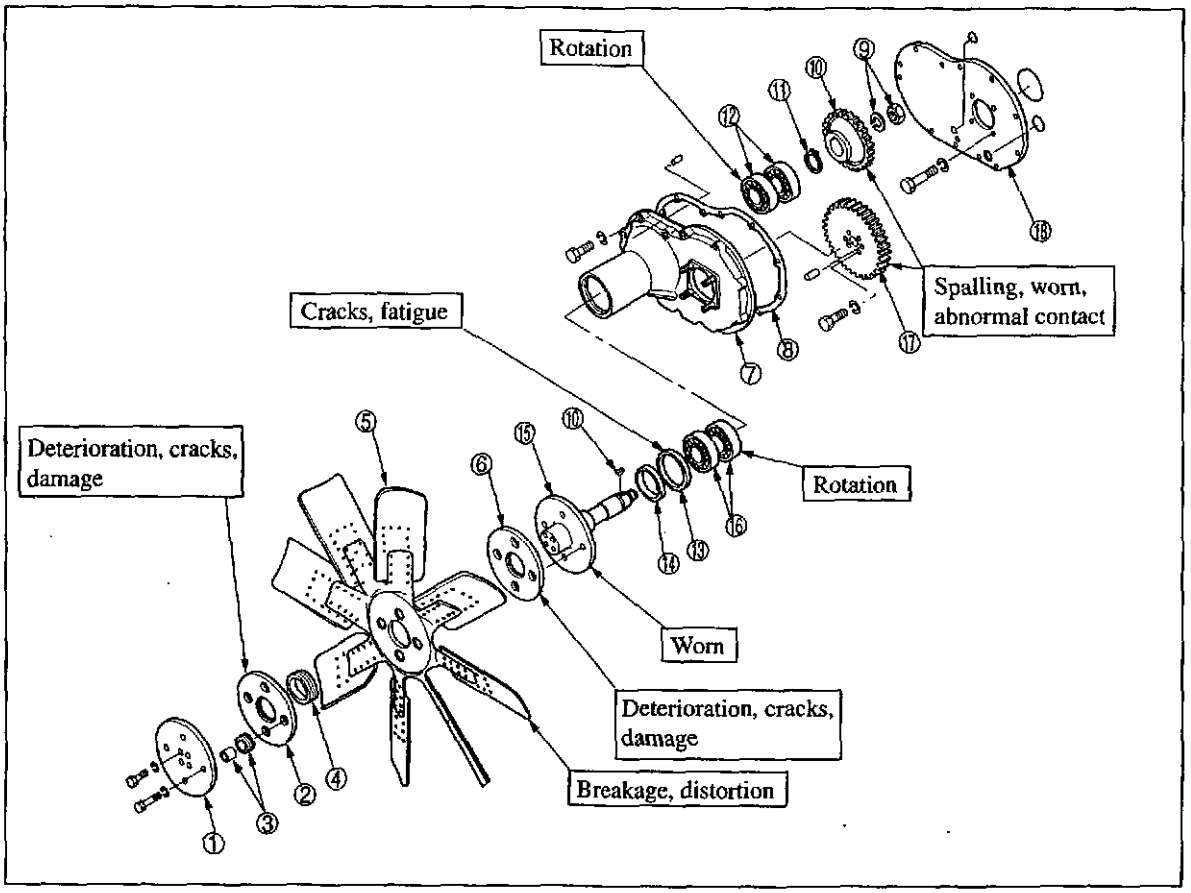
Item	Assembly Standard
Temperature for opening	71 ± 2 °C [159.8 ± 3.6 °F]
Temperature for 9 mm [0.35 in.] valve lift	85 °C [185 °F]

⚠CAUTION

(a) Stir the water to maintain even temperatures during the test.
(b) At reassembly, confirm the valve opening temperature stamped on its mounting flange.

4. Fan drive

4.1 Disassembly



Disassembly sequence

① Plate
② Friction rubber
③ Spacer, grommet
④ Busing
⑤ Fan
⑥ Friction rubber
⑦ Fan drive case
⑧ Packing
⑨ Nut, washer
⑩ Fan drive gear, key
⑪ Snap ring
⑫ Bearings
⑬ Oil seal
⑭ Sleeve
⑮ Fan drive shaft
⑯ Bearings
⑰ Camshaft gear
⑱ Plate

⚠CAUTION

If one of the fan blades is broken, this can cause excessive vibration and weaken the opposite blade. Carefully inspect each blade for cracks or warping.

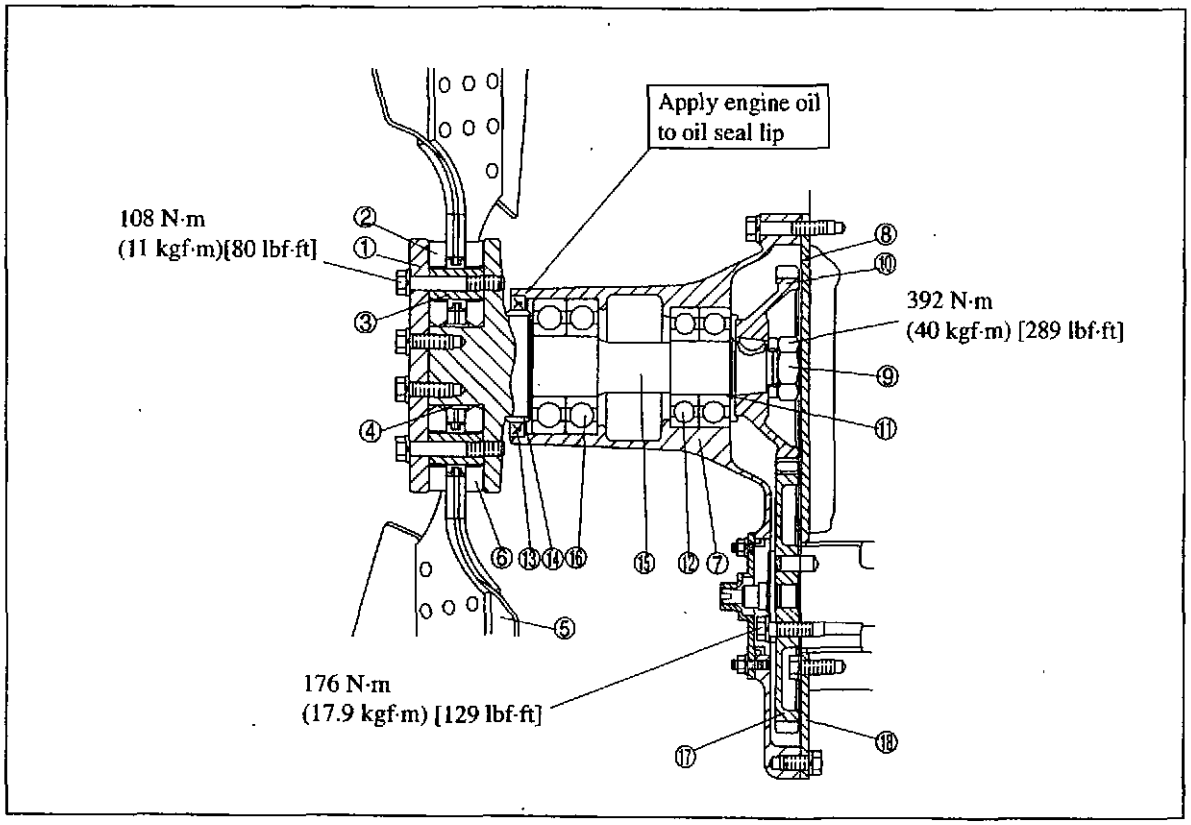
4.2 Inspection

(1) Measure the inside diameter of the bracket to which the bearing outer race is fitted.
Measure the diameter of the shaft to which the bearing inner race is fitted. If any bearing, shaft, or bracket is worn, replace it.
(2) Check the fan bushing for wear and damage and replace if anything abnormal is found.
(3) Check the friction rubber for deterioration, cracks, or damage. Replace it if necessary.

Unit: mm [in.]

Item		Nominal Value	Assembly Standard
Inside diameter of fan drive case bore to which bearer outer race is fitted		ø 100 [3.94]	99.987 to 100.022 [3.9365 to 3.9379]
		ø 110 [4.33]	109.987 to 110.022 [4.3302 to 4.3316]
Bearing	Diameter	ø 100 [3.94]	99.985 to 100.000 [3.9364 to 3.9370]
		ø 110 [4.33]	109.985 to 110.000 [4.3301 to 4.3307]
	Inside diameter	ø 45 [1.77]	44.988 to 45.000 [1.7712 to 1.7717]
		ø 50 [1.97]	49.985 to 50.000 [1.9679 to 1.9685]
Diameter of pump shaft on which bearing inner race is fitted		ø 45 [1.77]	45.002 to 45.013 [1.7717 to 1.7722]
		ø 50 [1.97]	50.002 to 50.013 [1.9686 to 1.9690]

4.3 Reassembly

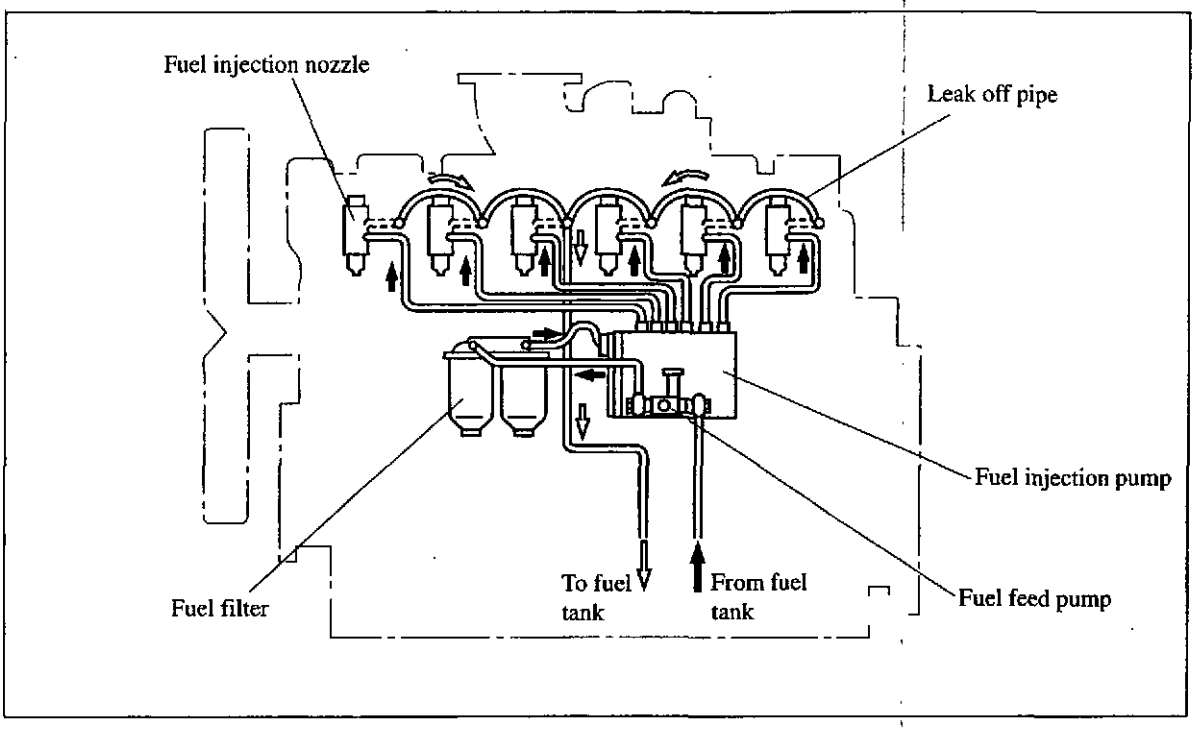


Reassembly sequence

⑦ → ⑯ → ⑬ → ⑫ → ⑪ → ⑩ → ⑨ → ⑧ → ⑥ → ④ → ③ → ⑤ → ② → ①
⑮ → ⑭
⑱ → ⑰

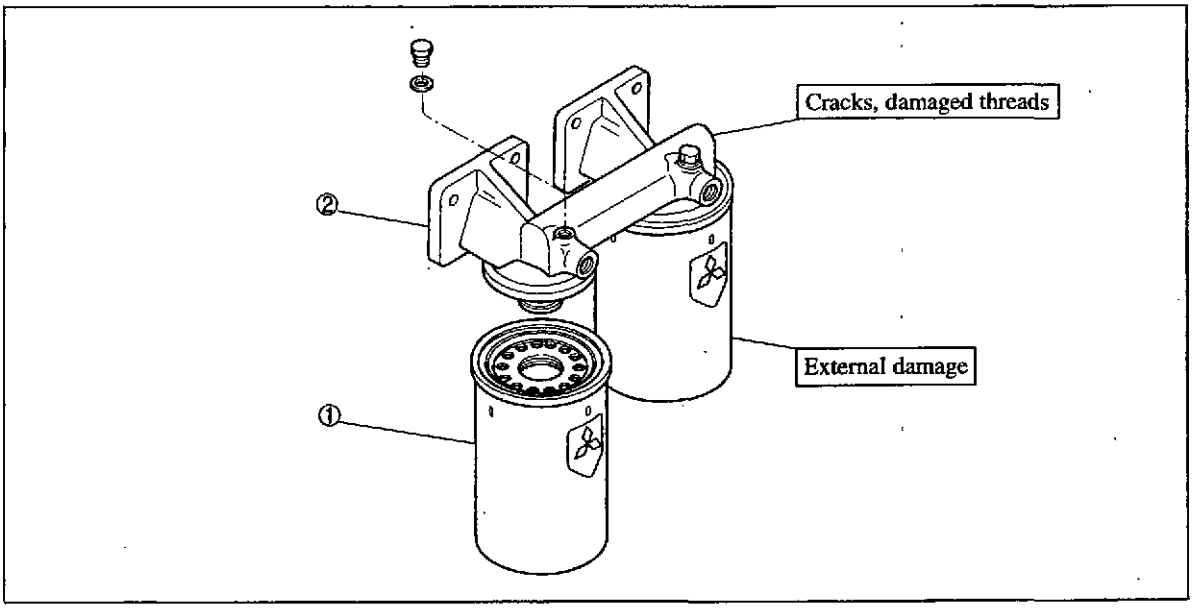
FUEL SYSTEM

1. Description



2. Fuel Filters

2.1 Disassembly and Inspection

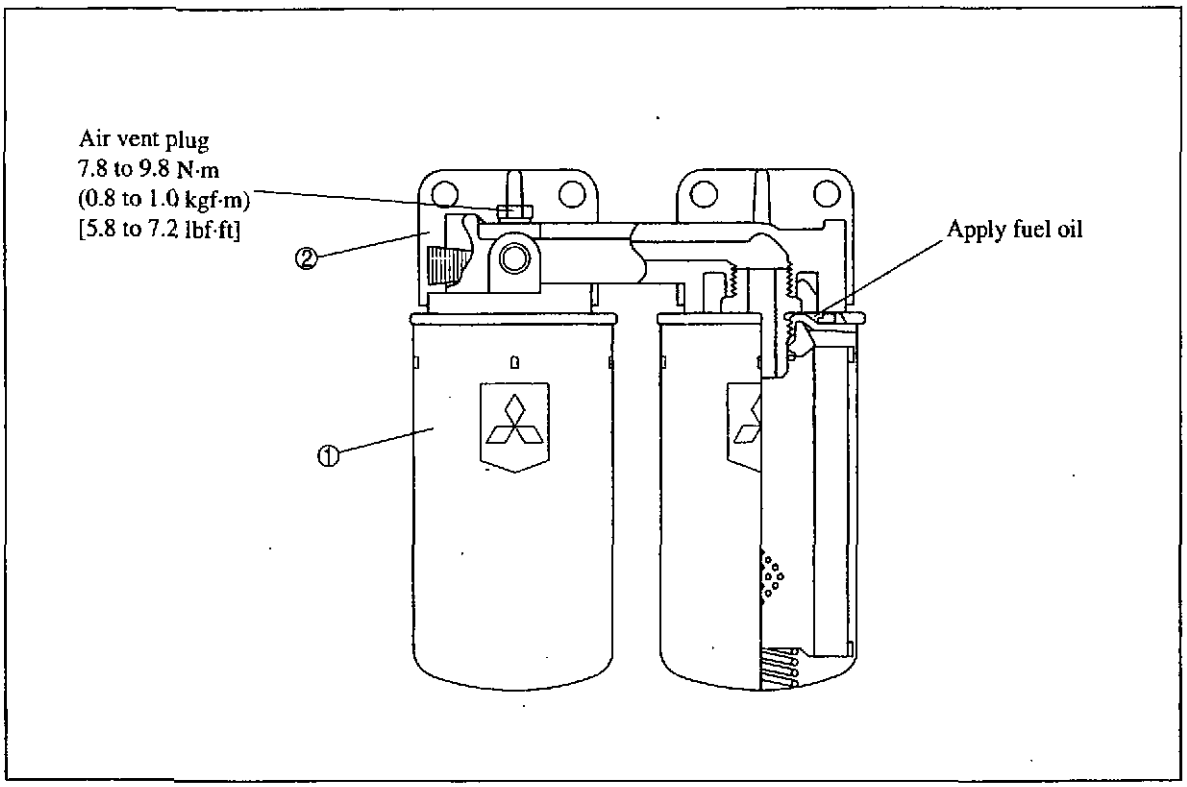


Disassembly sequence

① Element

② Fuel filter bracket

2.2 Reassembly

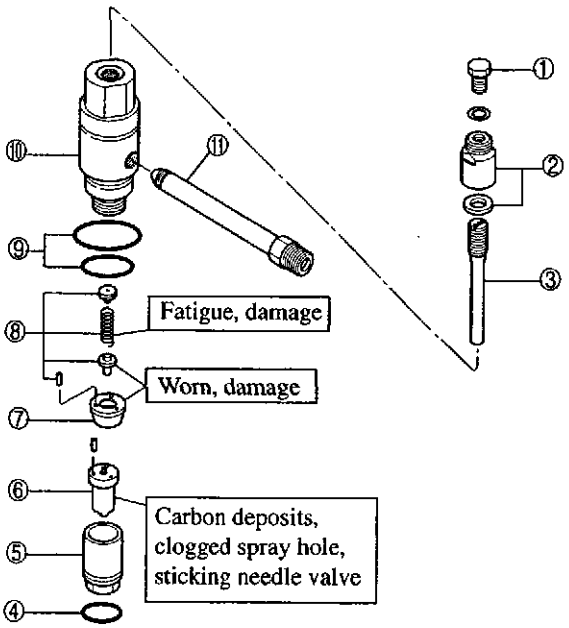


Reassembly sequence

②→①

3. Fuel Injection Nozzles

3.1 Disassembly



Disassembly sequence

① Set screw
② Cap nut, gasket
③ Adjusting screw
④ O-ring
⑤ Retaining nut
⑥ Nozzle tip
⑦ Spacer
⑧ Pushrod, nozzle spring, spring seat
⑨ O-ring
⑩ Nozzle holder
⑪ Fuel inlet connector

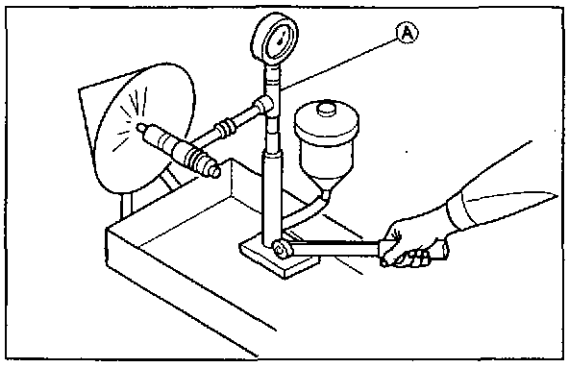
⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

3.2 Inspection and Adjustment

(1) Injection Pressure

(a) Install the nozzle on the tester Ⓐ (83091-03301). Operate the handle of the tester at a rate of about 1 stroke per second to observe the pressure at which fuel is being injected. If the pressure is out of standard, adjust the pressure of the nozzle.



Unit: MPa (kgf/cm²) [psi]

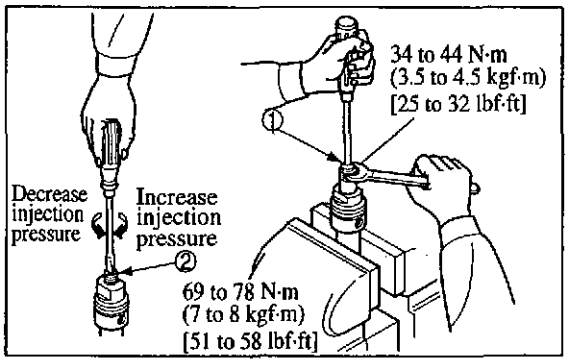
Item	Assembly Standard
Injection pressure (Valve opening pressure)	34.32 to 34.81 (350 to 355) [4977 to 5048]

⚠CAUTION

During injection testing, never attempt to touch the spray hole of the injection nozzle.

(b) To adjust the injection pressure, remove setscrew ①. While holding cap nut ② in a loosened condition, turn the internal adjusting screw with a screwdriver to adjust the pressure.

(c) After the adjustment, tighten cap nut ② and setscrew ① to the specified torque.



NOTE

When tightening cap nut ②, use a screwdriver to hold the internal adjusting screw and prevent the screw from turning.

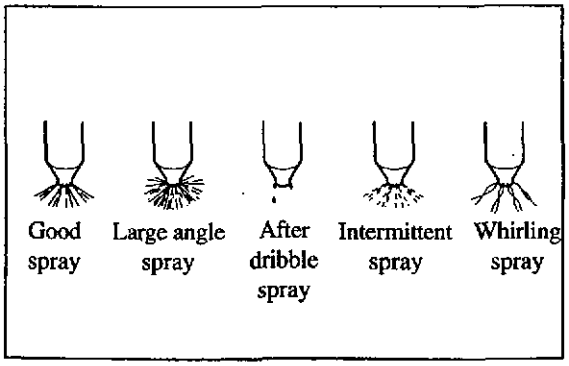
(d) After tightening setscrew ①, check the injection pressure again to make sure it complies to the assembly standard.

(2) Spray pattern

(a) When you are testing the injection pressure, inspect each nozzle for clogged spray holes and fuel leaks from the holes.
Also examine the spray pattern. If the nozzle is faulty, wash or replace the nozzle tip.

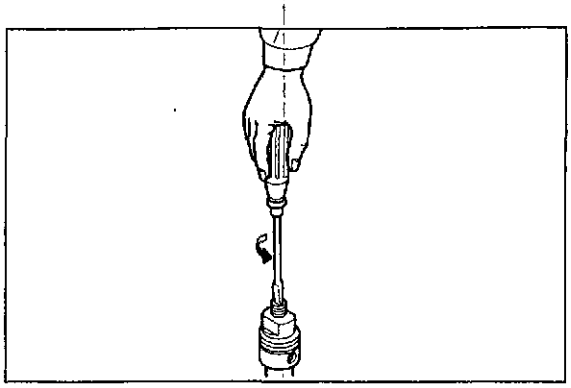
⚠CAUTION

When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.



Spray patterns

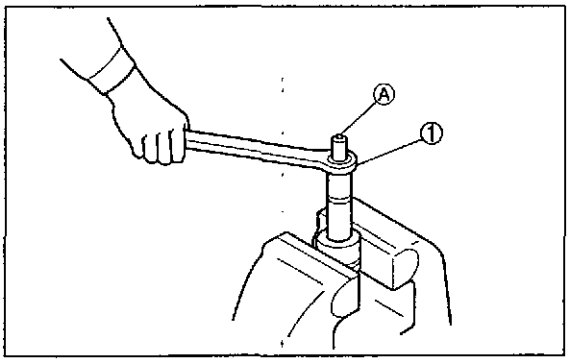
(b) When tested on the nozzle tester, the nozzle should spray fuel from its ten holes at the same time in a straight cone of 160 degrees. The spray should consist of finely atomized fuel particles without any large droplets. The spray should terminate with no dripping.



(3) Washing or replacing the nozzle tip

(a) The nozzle tip is spring loaded. Remove the cap nut and with a screwdriver, loosen the adjusting screw until it can be loosened by hand.

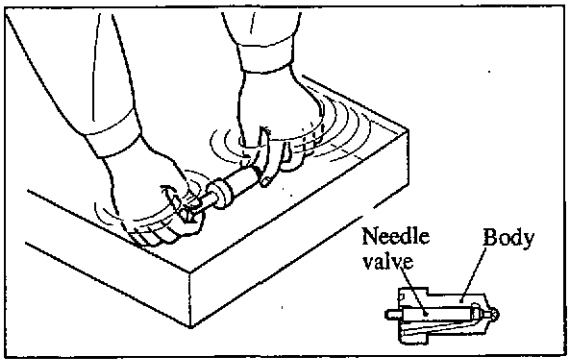
(b) Loosen the retaining nut ①, remove the nozzle tip and wash the needle valve and body.



⚠CAUTION

When pulling out the nozzle tip, do not damage the tip Ⓐ.

(c) Wash the nozzle tip in clean cleaning oil. After washing, assemble the needle valve and body in clean diesel fuel.



⚠CAUTION

The needle valve and body are finely finished. Do not change the combination of the valve and body.

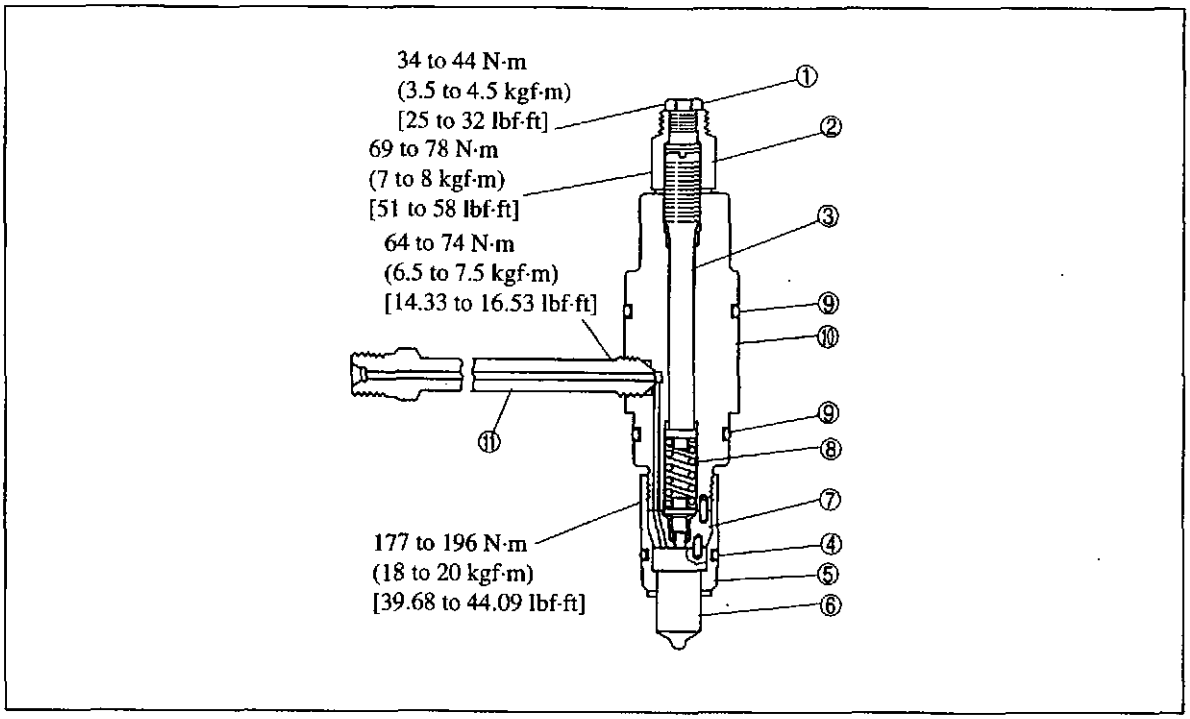
(d) Tighten the retaining nut to the specified torque.

(e) If the spray pattern is still bad after the nozzle has been adjusted and cleaned, replace the nozzle tip.

NOTE

New nozzle tips are coated with vaseline to preserve them. Wash them twice, first in gasoline then in diesel fuel before you inslall them.

3.3 Reassembly



Reassembly sequence

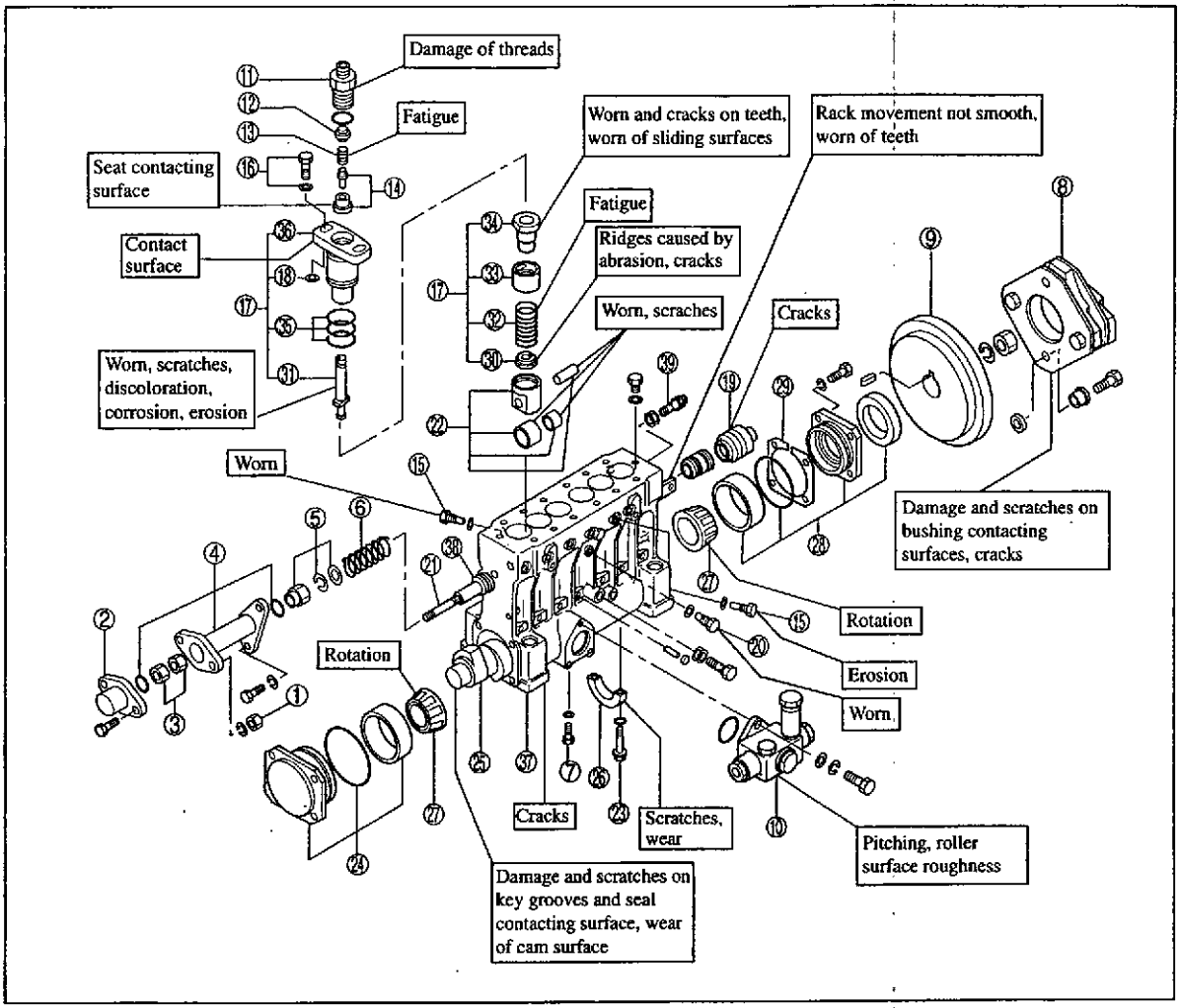
⑩→④→⑨→⑧→⑦→⑥→⑤→⑪→③→②→①

⚠CAUTION

Tighten the retaining nut ④ to the specified torque. Excessive torque on the retaining nut will cause sticky movement of the needle and will result in exhaust smoke or the needle to stick.

4. Fuel Injection Pump (PS6)

4.1 Disassembly

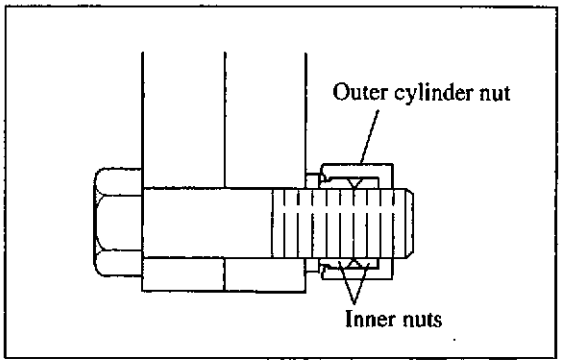


Disassembly sequence

① Taper-proof nut
② Rack set cap
③ Jam nut
④ Spring case
⑤ Self-locking nut
⑥ Return spring
⑦ Drain plug
⑧ Coupling
⑨ Flywheel, woodruff key
⑩ Feed pump
⑪ Valve holder
⑫ CPV delivery valve spring seat
⑬ CPV delivery valve spring
⑭ CPV delivery valve assembly
⑮ Deflector bolt
⑯ Barrel bolt, washer
⑰ Plunger assembly
⑱ Barrel shim
⑲ Bellows
⑳ Set screw
㉑ Control rack
㉒ Tappet
㉓ Bolt
㉔ Front cover, bearing outer race
㉕ Camshaft
㉖ Center bearing
㉗ Bearing inner race
㉘ Rear cover, oil seal, bearing outer race
㉙ Shim
㉚ Lower spring seat
㉛ Plunger
㉜ Plunger spring
㉝ Upper spring seat
㉞ Pinion
㉟ O-ring
㊱ Barrel
㊲ Pump case
㊳ Rack bushing
㊴ Check valve

(1) Preparing for disassembly

(a) The taper-proof nuts are of double construction, freely rotate, and cannot be simply removed. Cut the outer cylinder nut and turn the inner nuts to remove each taper-proof nut.

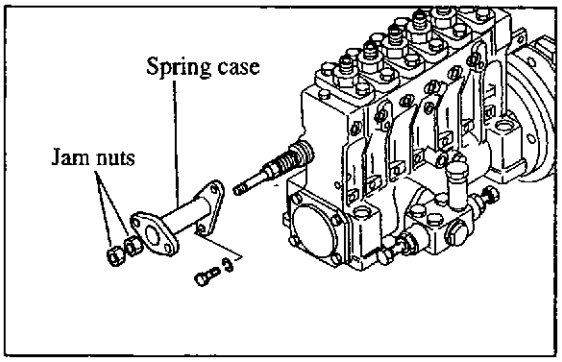


⚠CAUTION

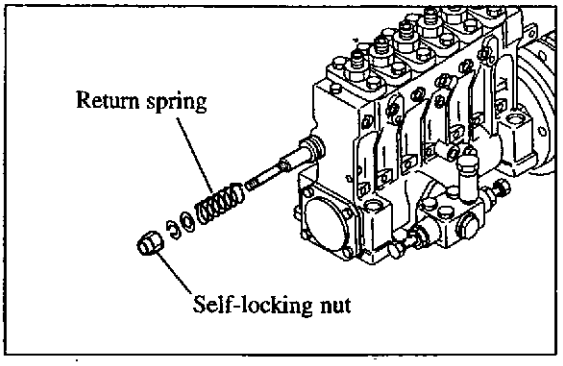
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Work related to the exhaust emission regulations can be conducted only at our designated service factories.

(b) Remove the rack set cap.

(c) Remove the two jam nuts, and then remove the spring case.



(d) Remove the self-locking nut, and then remove the return spring.



⚠CAUTION

Do not reuse the removed self-locking nut.

⚠WARNING

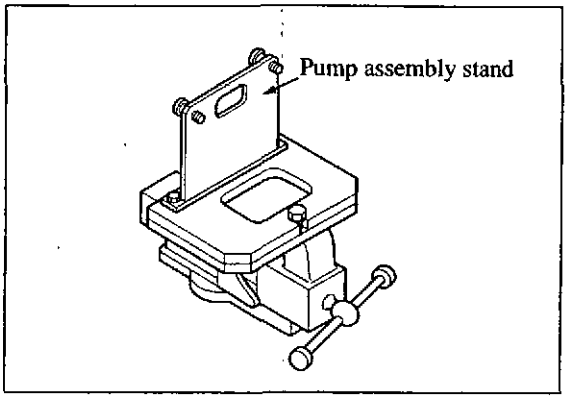
When lifting the injection pump with a crane or other hoisting equipment, be careful not to drop the pump. Also, do not allow anyone to walk or stand under the crane's operating range.

⚠CAUTION

- Keep flames away when washing the injection pump with a cleaning solvent.
- Wear goggles and other protective gear when using compressed air.

(e) Hold the pump assembly stand (special tool) with a vice.

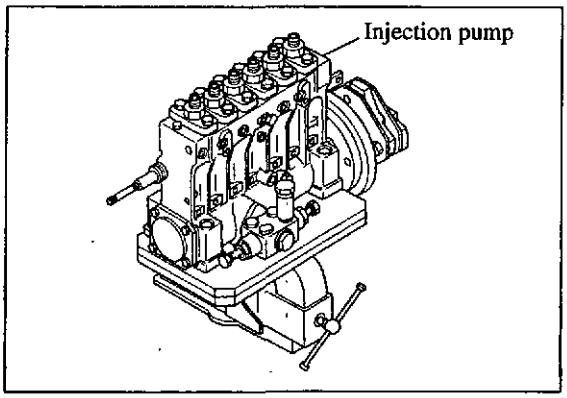
Name of special tool	Part No.
Pump assembly stand	48291-00100



(f) Remove the drain plug from the bottom of the pump and drain oil from the case.

(g) Clean the outer surface of the injection pump, and mount the pump on the pump assembly stand (special tool).

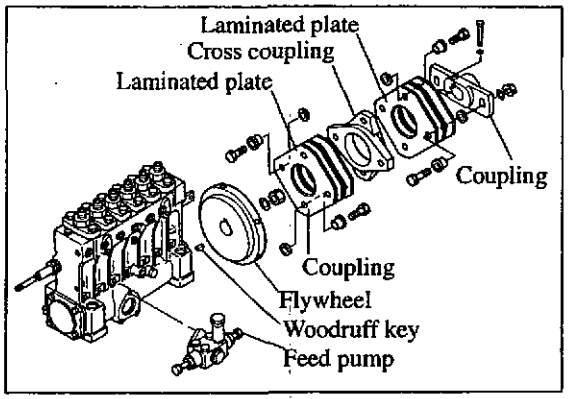
Injection pump mass	60 kg [132 lb]



(h) Remove the couplings, laminated plates, cross coupling, flywheel and feed pump.

NOTE

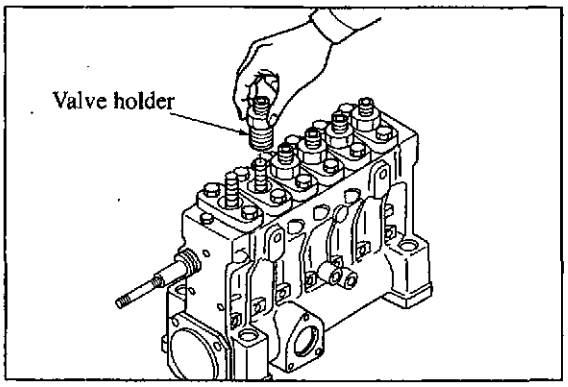
When removing the flywheel mounting nut, insert turning bar into the turning bar hole located at the flywheel periphery, in order for tthe flywheel to avoid slipping.



(2) Removing CPV delivery valves

⚠CAUTION

- Keep flames away when using diesel fuel.
- Place each set of CPV and CPV seat in clean diesel fuel. Do not change the original combinations of CPVs and CPV seats.

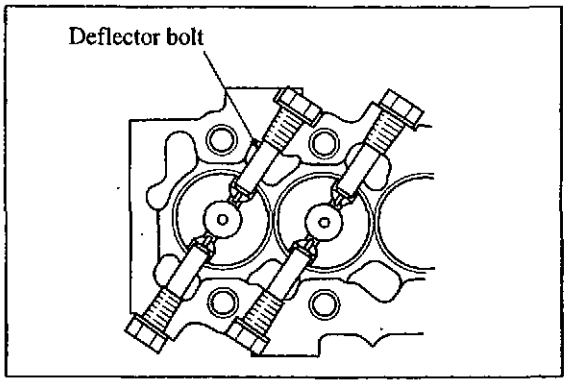


Dismount valve holders, and remove spring seats CPVs and CPV seats.

(3) Removing plunger assemblies

⚠CAUTION

Be sure to remove the deflector bolts before removing the plunger assembly. If the plunger assembly is removed without removing the deflector bolts first, damage results in the deflector bolts and plunger assembly.



Both-side type (both-side lead)

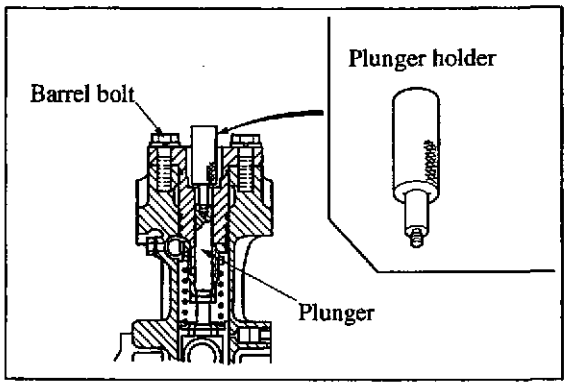
(a) Position the cam at the bottom dead center in the cylinder from which the plunger assembly is removed.

(b) Remove the deflector bolts from the pump case.

(c) Install the plunger holder (special tool) to the threaded section at the top of the plunger.

Name of special tool	Part No.
Plunger holder	48291-00301

(d) Loosen the two barrel bolts alternately, and lift the plunger assembly and remove.



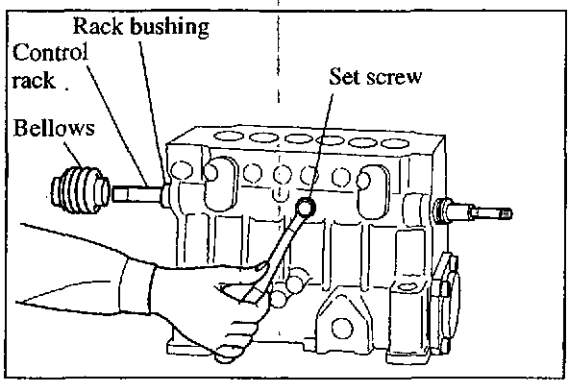
⚠CAUTION

Before disassembly, be sure to install the plunger holder.
Due to the friction of the O-ring installed on the barrel, the plunger spring may remain compressed. When this happens, the valve does not come out on its own.
If an impact is applied to the barrel in this condition, the plunger spring can extend suddenly and ejects the barrel. This can cause fingers to be caught between the barrel bolt and barrel, or results in other unexpected injury.

(4) Removing the control rack

(a) Dislodge the bellows from the grooves of the rack and rack bushing, and remove the bellows.

(b) Remove the set screw from the back side of the pump case, and pull out the control rack.



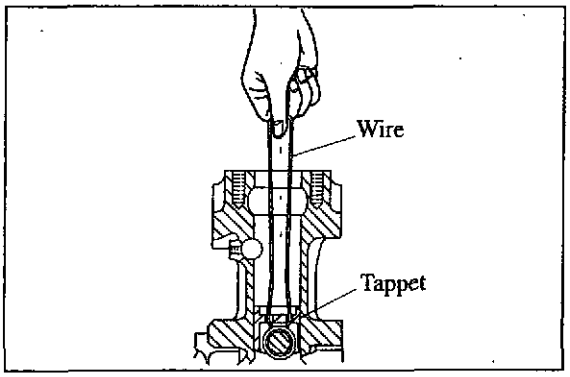
NOTE

(a) After removing the set screw, conduct a color check or magnaflux inspection to make sure there are no cracks.

(b) Do not remove the rack bushing unless necessary.

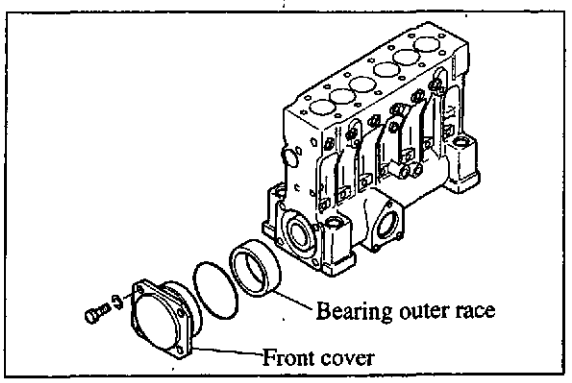
(5) Removing tappets

Hook a wire to two small holes (4 mm [0.16 in.] in diameter) on the upper side of the tappet, and pull out the tappet.



(6) Removing the camshaft

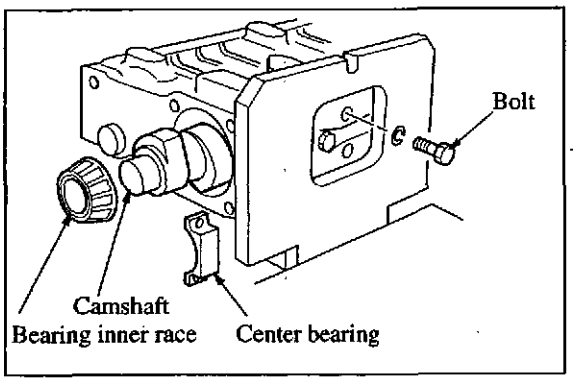
(a) Unscrew four front cover mounting bolts, and remove the front cover and bearing outer race.



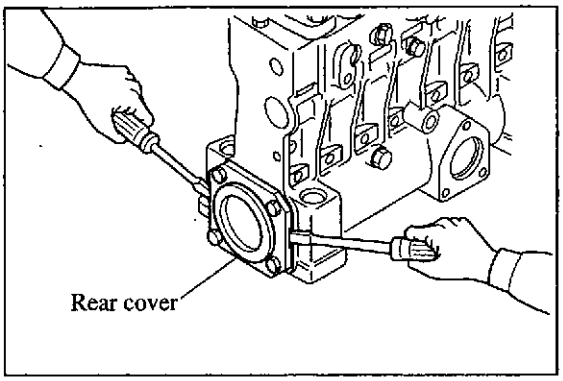
(b) Lay the pump case on its side, and remove two center bearing mounting bolts.

(c) Strike the camshaft on the drive-side end with a soft hammer to remove the camshaft and center bearing.

(d) Remove the bearing inner races from both ends of the camshaft.



(7) Removing the rear cover
Remove the rear cover mounting bolts. Insert the tips of screwdrivers into the notches located on the sides of the rear cover, and pry out the rear cover (together with bearing outer race) and the shim.



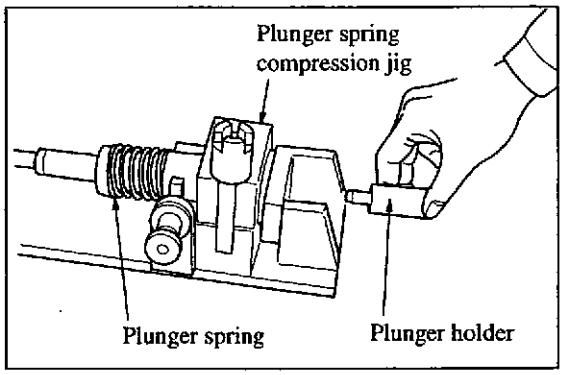
(8) Disassembling plunger assemblies

⚠CAUTION

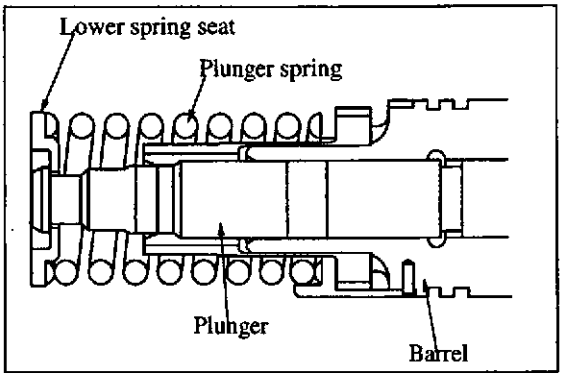
- Keep flames away when using diesel fuel.
- Handle plungers carefully to prevent damage and scratches.
- Place the removed plungers in a tray filled with clean diesel fuel, arranging parts neatly to ensure correct installation in original cylinders.
- Do not change the original combinations of plungers and barrels.

(a) Mount the plunger assembly on the plunger spring compression jig (special tool).
(b) Press the knob on the jig to compress the plunger spring, then remove the plunger holder.

Name of special tool	Part No.
Plunger spring compression jig	48291-00200
Plunger holder	48291-00301



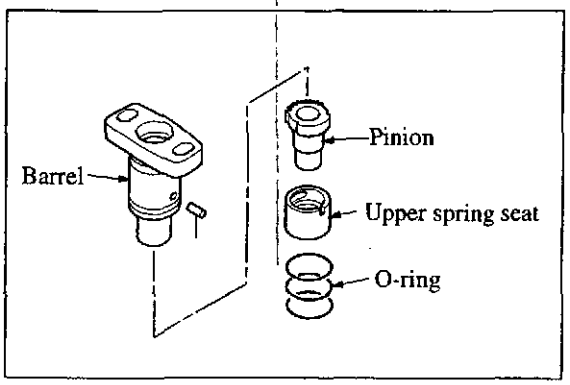
(c) Release the compression of the plunger spring gradually, and remove the lower spring seat, plunger and plunger spring from the barrel.



(d) Remove the barrel from the plunger spring compression jig, then remove the upper spring seat, pinion and O-ring.

NOTE

Do not remove the dowel pin.



4.2 Inspection

⚠CAUTION

Keep flames away when using diesel fuel.

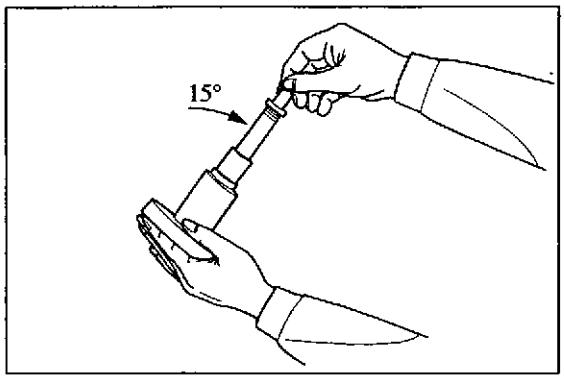
After disassembly, wash each part with clean diesel fuel. Replace defective and damaged parts.

(1) Plungers and barrels

(a) Inspect the lead section and tip of each plunger for wear, scratches, discoloration and erosion.

(b) After washing with clean diesel fuel, check each plunger by tilting it approximately 15° and lifting it approximately 30 to 35 mm [1.18 to 1.38 in.], as shown in the right diagram. Change the plunger position by turning it slightly, and check again. Repeat this inspection two or three times for each plunger.

(c) If the plunger falls too quickly or sticks before it reaches the bottom, replace the plunger and barrel as a set.



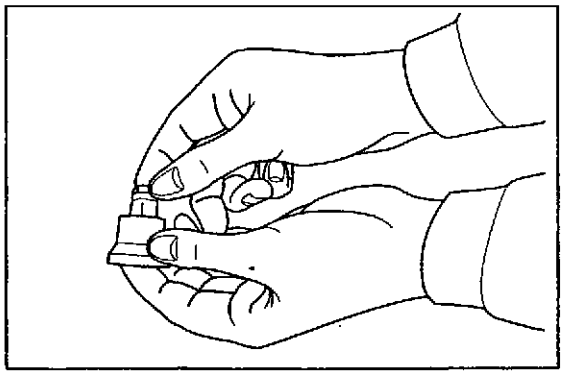
Inspecting plunger for smooth movement

(2) CPV delivery valve

(a) In each CPV, inspect the CPV seat face and piston's sliding surface, and check the barrel contacting surface.

(b) Wash parts with clean diesel fuel. Lift the valve and let it fall, making sure that it slides down smoothly to the CPV seat.

(c) If the valve sticks, replace the CPV and CPV seat as a set.



Inspecting CPV for smooth movement

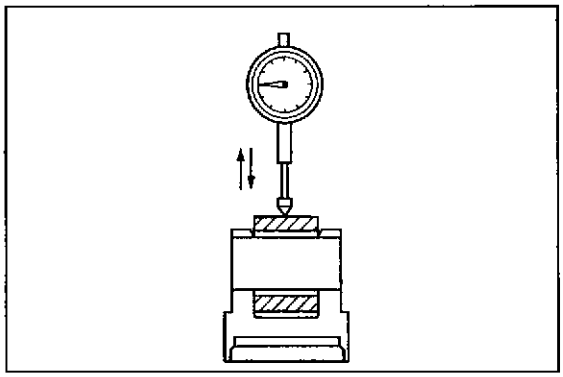
(3) Tappets

(a) Check each tappet roller, roller bearing and tappet pin for flaking, sectional wear and scratches.

(b) Check overall clearance of tappet, tappet roller, roller bearing and tappet pin. If the measurement exceeds the service limit, replace with a new assembly.

Unit: mm [in.]

Item	Service Limit
Overall clearance of tappet roller	0.2 [0.008]

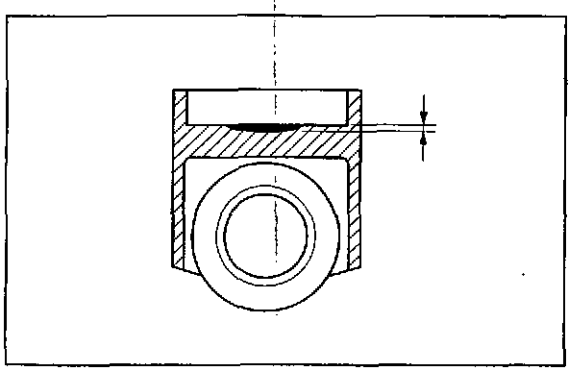


Measuring overall clearance of tappet roller

(c) Inspect the plunger contacting surface of each tappet.
If the amount of wear exceeds the service limit, replace with a new assembly.

Unit: mm [in.]

Item	Service Limit
Wear of plunger contacting surface of tappet	0.2 [0.008]

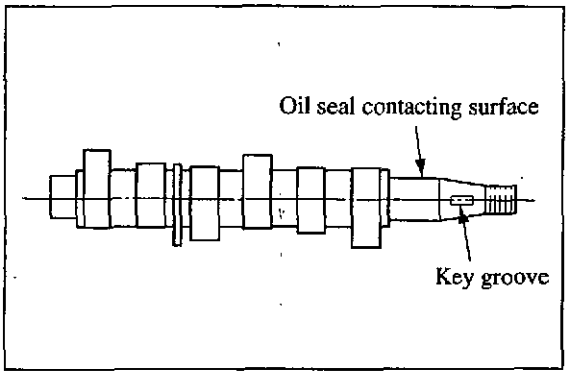


Inspecting wear of tappet

(4) Bearings
Check each bearing for flaking, abrasion and abnormal noise. If damage is found, replace with a new part.

(5) Camshaft
(a) Check the key and key groove for excessive play. Also check the tapered section for scratches, and the cam faces for flaking, sectional wear and scratches. If damage is found, replace the camshaft.

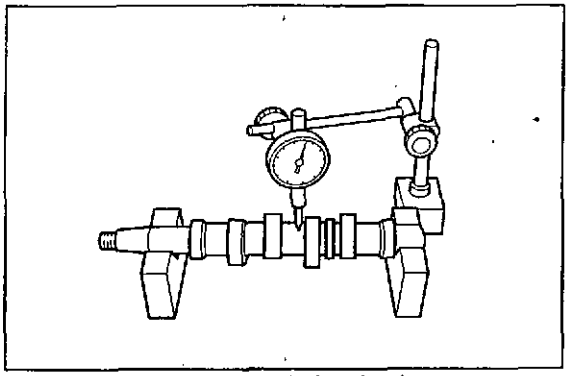
(b) Support both ends of the camshaft with V blocks, and measure runout at the center bearing section with a dial gage. If the amount of runout exceeds the service limit, correct with a press or replace with a new part.



Inspecting camshaft outer surfaces

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Camshaft deflection	0.05 [0.0020]	0.15 [0.0059]



Measuring camshaft deflection

(c) Check the oil seal contacting surface for wear. If the amount of wear exceeds the service limit, insert an oversized sleeve.

⚠CAUTION

- Insert the oversize sleeve after installing the bearing inner race.
- The bearing inner race cannot be installed after the oversize sleeve is mounted in place.

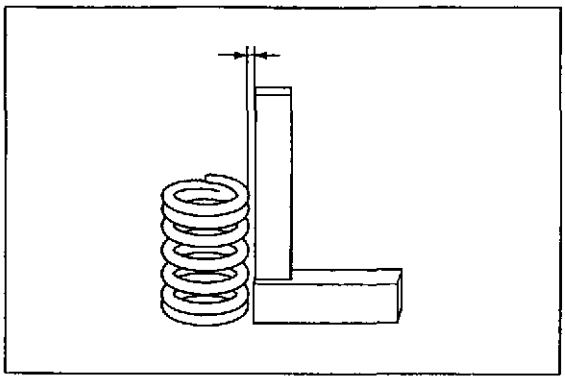
Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Outside diameter of camshaft at oil seal contacting section	ϕ35 [1.38]	34.938 to 34.963 [1.37551 to 1.37649]	34.800 [1.37008]

(6) Plunger springs and CPV springs
  (a) Check the surface of each part for scratches and rust.
  (b) Using a square, measure the gap at the upper end of the spring.
  If the measurement exceeds the service limit, replace the spring.

Unit: mm [in.]

Item		Service Limit
Perpendicularity of spring	Plunger spring	1.8 [0.071]
	CPV spring	0.6 [0.024]



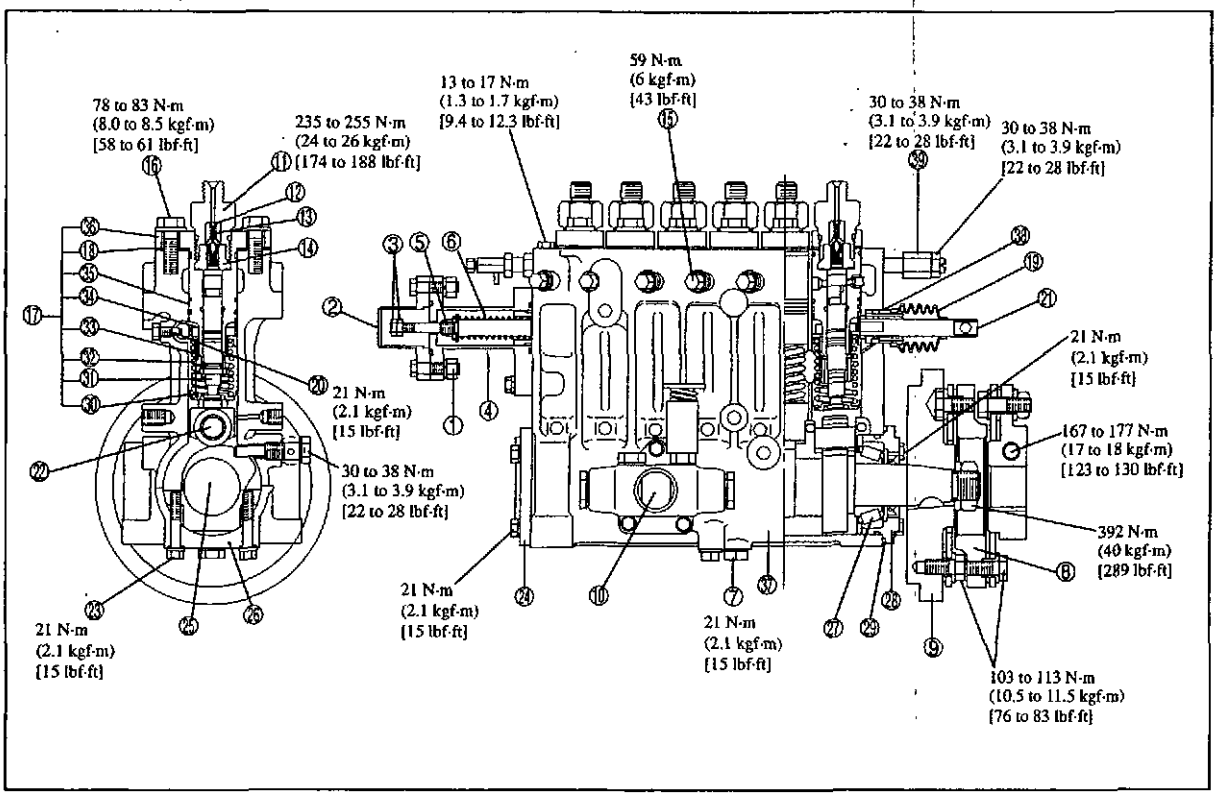
Measuring perpendicularity of spring

(7) Valve holders
  (a) Inspect the surfaces that contact high-pressure pipes and CPVs for scratches.
  (b) If the contact surfaces are scratched, replace the valve holder, since surface scratches can cause fuel leakage.

(8) Pump case
  Check the pump case for surface scratches, dents, cracks and damage. If critical flaws are found, replace with a new part.

(9) O-rings, bellows and sealing washers
  Replace all removed O-rings, bellows and sealing washers with new parts.

4.3 Reassembly



Reassembly sequence

㊳→㊴→㊲→㊷→㉕→㉖→㉚→㉗→㉔→㉘→㉙→㉑→⑳→⑰→⑱→⑯→⑮→⑭→⑬→⑫→⑪→⑲→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

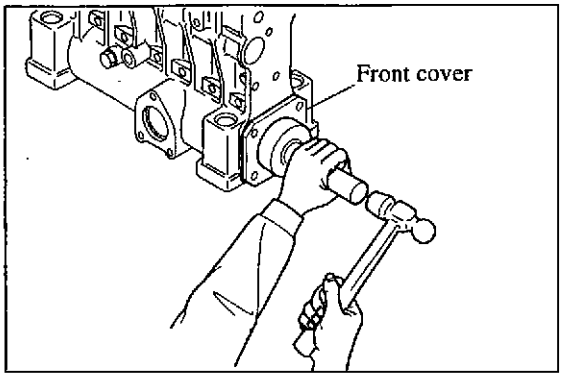
㉖→㉟→㉞→㉝→㉜→㉛→㉚

⚠CAUTION

Reassemble the fuel injection pump without attaching the parts ③ to ①, and install it on the engine.

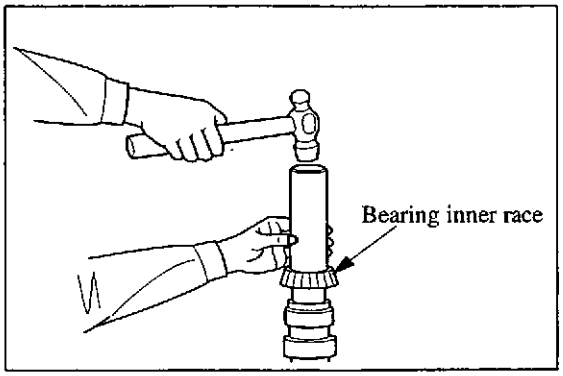
Perform a bench test, properly adjust the fuel injection pump, and then attach the parts ③ to ①.

(1) Installing the bearing and front cover
  (a) Install the O-ring and bearing outer race on the front cover. To prevent damage to the O-ring, apply engine oil or grease.
  (b) Install the front cover to the pump case by striking with a hammer.
  (c) Tighten the mounting bolts to 21 N·m (2.1 kgf·m) [15.2 lbf·ft].



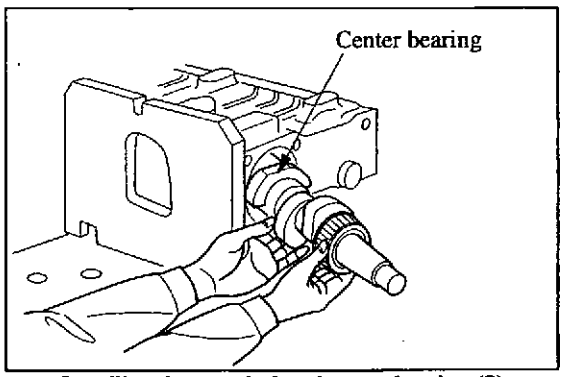
Installing the bearing and front cover

(2) Installing the camshaft and center bearing
  (a) Install the bearing inner races on both sides of the camshaft by striking with a hammer.



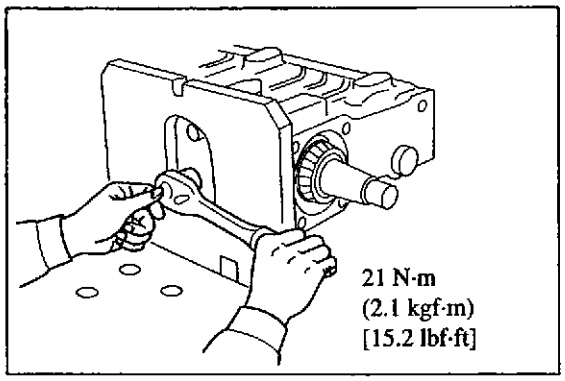
Installing the camshaft and center bearing (1)

  (b) Lay the pump case on its side.
  (c) Place the center bearing on the camshaft, and insert the shaft into the pump case.



Installing the camshaft and center bearing (2)

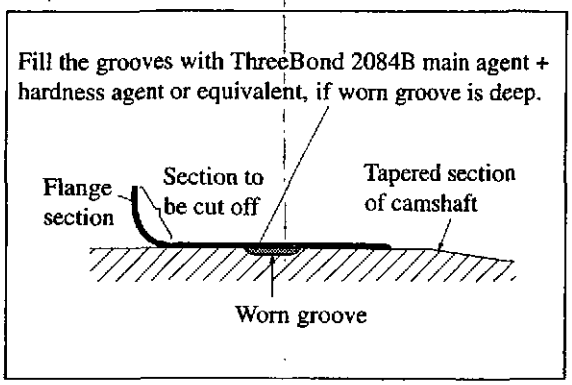
  (d) Slowly turn the camshaft until the bolt holes of the center bearing align with the bolt holes of the pump case. Alternating the tightening operation between the upper and lower mounting bolts before reaching the specified torque to ensure even tightening force.



Installing the camshaft and center bearing (3)

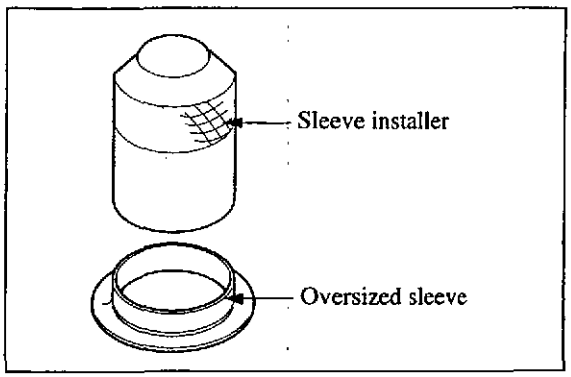
[Installation of oversized sleeve]

- Cautions in installation
  - Clean the seal contacting surface, and remove burrs from the camshaft before inserting an oversized sleeve.
  - If the camshaft has deep grooves due to abrasion, fill the grooves with metal-powder-containing epoxy filler (ThreeBond 2084B main agent + hardening agent, or equivalent), and insert the oversized sleeve before the filler hardens.
  - Install the oversized sleeve so that it covers the grooves, and make sure it does not extend to the tapered section.
  - Apply engine oil to the end section of the oversized sleeve when installing the oil seal.



Cross-sectional diagram of oversized sleeve

- Procedure for inserting oversized sleeve on camshaft
  1. Hold the camshaft with a vice.
  2. Apply ThreeBond 1215 to the oversized sleeve installation surface on the camshaft (no need to apply Three Bond 1215 if 2084B has been applied already), and insert the oversized sleeve, with the flange section facing the camshaft, onto the camshaft.
  3. Using the sleeve installer (special tool) and a drive tool, strike the oversized sleeve with a soft hammer.

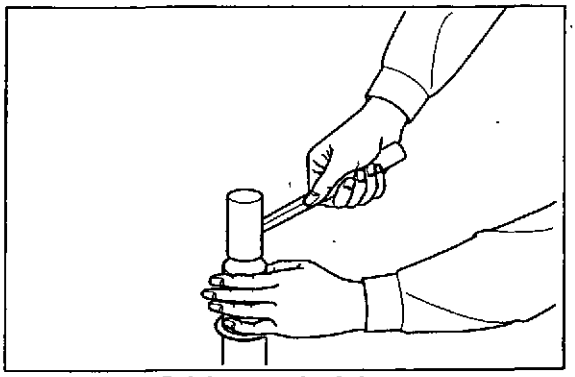


Driving jig and oversized sleeve

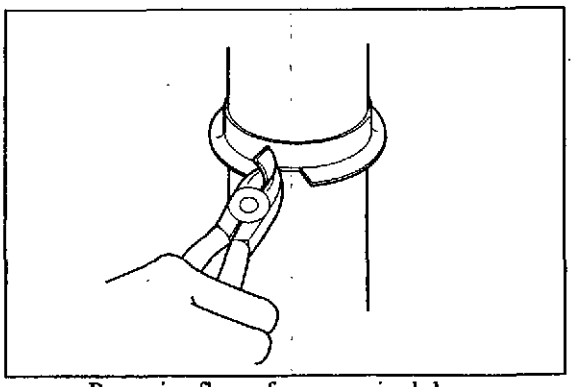
Name of special tool	Part No.
Sleeve installer	48202-09301

NOTE

Use a wooden hammer or soft hammer to strike the drive tool.


Driving oversized sleeve

4. After the installation, remove the flange section of the oversized sleeve at the cut line on the flange section.


Removing flange from oversized sleeve

(3) Installation of rear cover

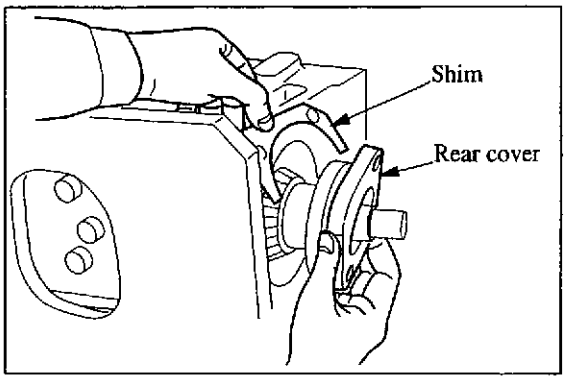
(a) Replace the oil seal of the rear cover with a new part.

NOTE

To prevent oil leakage, apply ThreeBond 1215 to the entire periphery of the metal ring before press-fitting the oil seal.

(b) Install the bearing outer race to the rear cover.

(c) Install the O-ring and shim to the rear cover, and mount the rear cover on the pump case. Be sure to apply engine oil or grease to the O-ring and oil seal lip. If the camshaft has been repaired with an oversize sleeve, apply engine oil or grease to the tip of the oversize sleeve.



Installing the rear cover

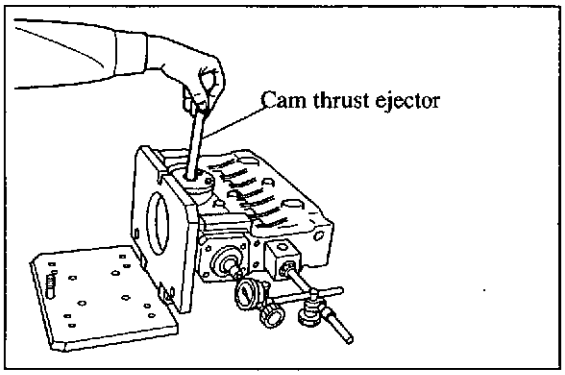
(4) Measuring camshaft thrust clearance

(a) Set a dial gage on the end surface of the camshaft, and measure clearance with the cam thrust ejector (special tool).

Name of special tool	Part No.
Cam thrust ejector	48291-00400

Unit: mm [in.]

Item	Assembly Standard
Camshaft thrust clearance	0.02 to 0.06 [0.0008 to 0.0024]



Measuring camshaft thrust clearance

(b) If the measured clearance deviates from the assembly standard, increase or decrease the shim thickness to make adjustment.

(c) Turn the camshaft to make sure it rotates smooth.

Shim thicknesses

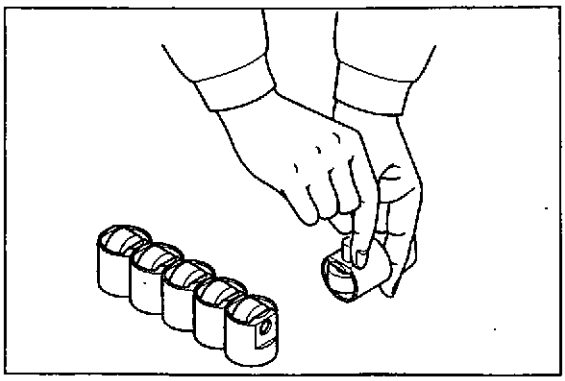
Part No.	Thickness (mm [in.])
48202-14100	0.5 [0.0197]
48202-14200	0.1 [0.0039]
48202-14300	0.15 [0.0059]
48202-14400	0.3 [0.0118]

(5) Installing tappets

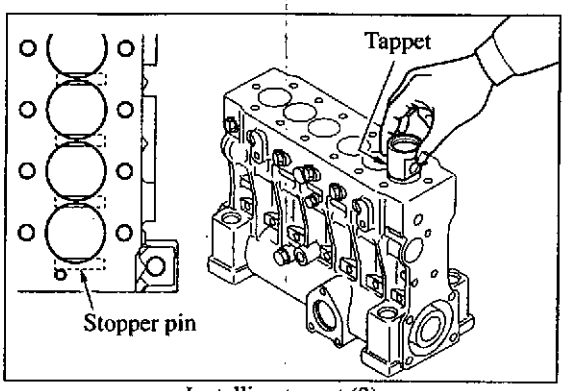
(a) Install the tappet roller and roller bearing in each tappet, and insert the tappet pin in each assembly.

(b) Apply lubricating oil to each part.

(c) After the assembly, make sure the roller rotates smoothly without sticking.


Installing tappet (1)

(d) Install tappets in the pump case by positioning each tappet so the flat section of each tappet engages securely with the stopper pin.



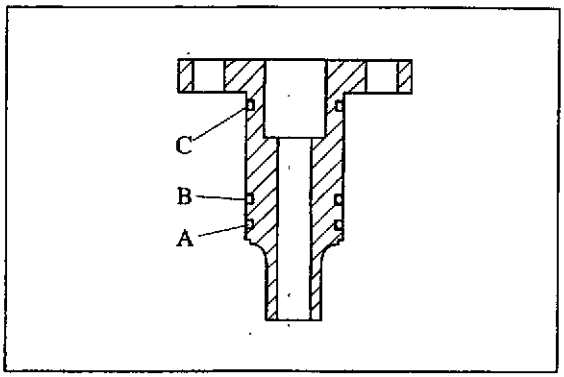
Installing tappet (2)

(6) Assembling plunger assemblies

(a) Install three O-rings on each barrel.

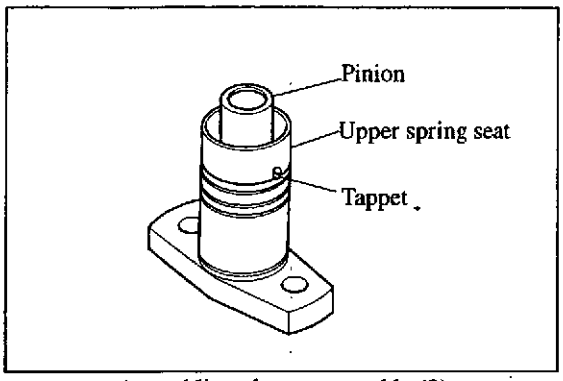
NOTE

(a) Wash each part with clean diesel fuel before assembly.
(b) Use new O-rings.
(c) Apply grease to the O-rings to prevent damage during assembly. Install the O-rings in the sequence of A, B and C.



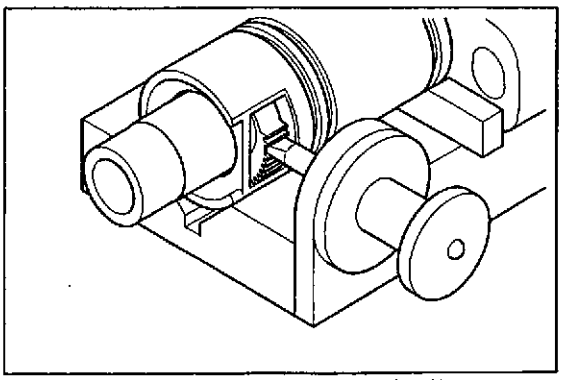
Assembling plunger assembly (1)

(b) Install the pinion and upper spring seat on each barrel by tapping with a hammer. Make sure the pin inserted in the barrel is aligned with the notch on the upper spring seat.

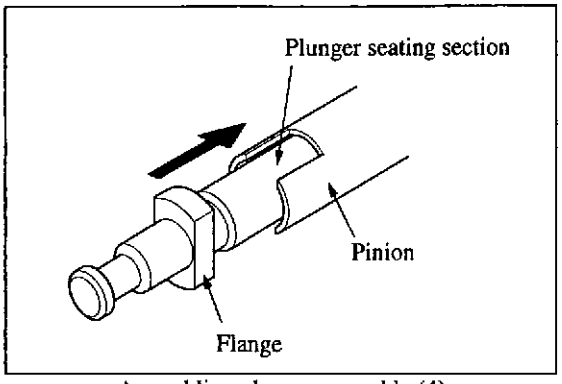


Assembling plunger assembly (2)

(c) Position the assembled barrel, pinion and upper spring seat securely on the plunger spring compression jig (48291-00200).
(d) Align the missing pinion tooth section (missing tooth prevents erroneous installation of the pinion to the rack) with the center of the inspection window on the upper spring seat.
(e) Insert the stopper of the jig into the missing pinion tooth section to secure the pinion in place.

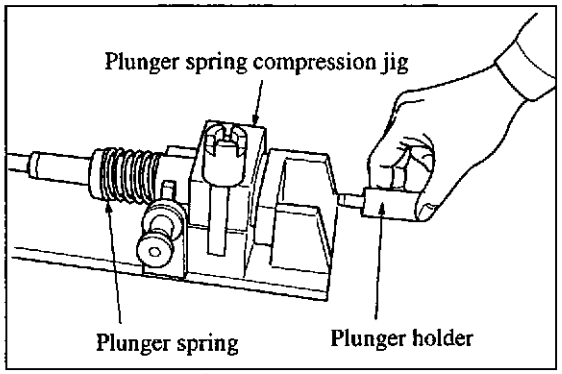

Assembling plunger assembly (3)

(f) Align the flange section of the plunger with the plunger seating section of the pinion by using a screwdriver.



Assembling plunger assembly (4)

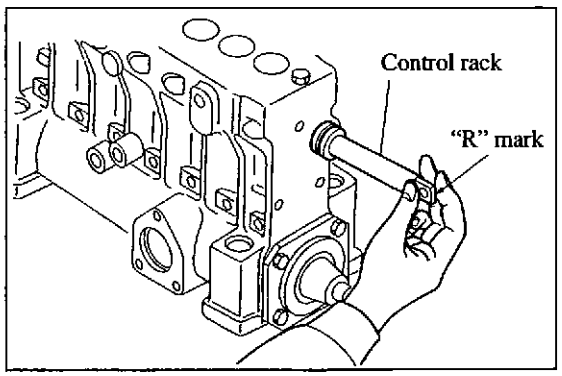
(g) Install the plunger, plunger spring and lower spring seat.
Press down the knob of the jig to insert the plunger into the plunger seating section, then screw the plunger holder (special tool) into the threaded hole in the plunger head.



Assembling plunger assembly (5)

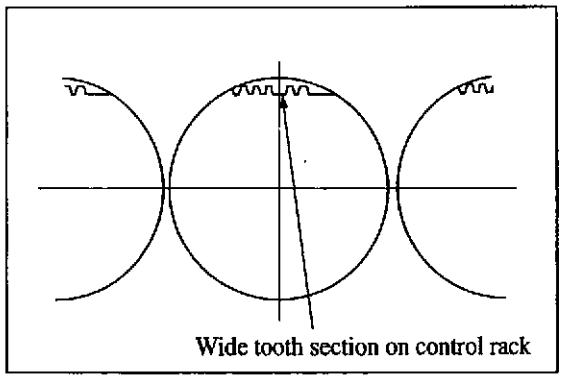
(7) Installing the control rack

(a) Insert the control rack in the pump case, making sure the "R" mark on the end surface or the threaded section is positioned on the drive side, then tighten the set screw to 21 N·m (2.1 kgf·m) [15 lbf·ft].



Installing the control rack (1)

(b) Look through the cylinder from the upper side of the pump case, and move the control rack so the thick tooth (three times thicker than other teeth; designed for prevention of incorrect engagement with pinion) is positioned at the center of the cylinder in the pump case.



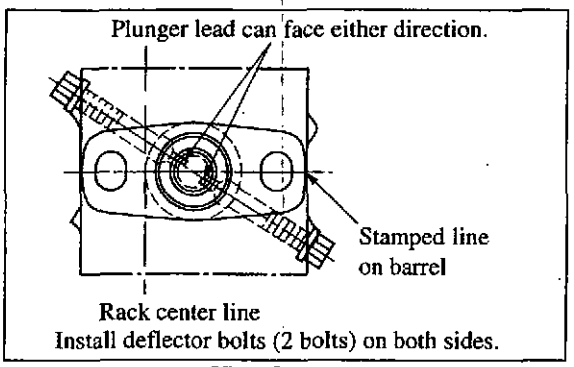
Installing the control rack (2)

(8) Positional relationship of plungers and barrels

⚠CAUTION

Install the plunger and barrel, making sure the lead and pinion teeth are positioned as shown in the right diagram.

[Installation of plunger with both-side lead]



View from top

(9) Installing plunger assemblies

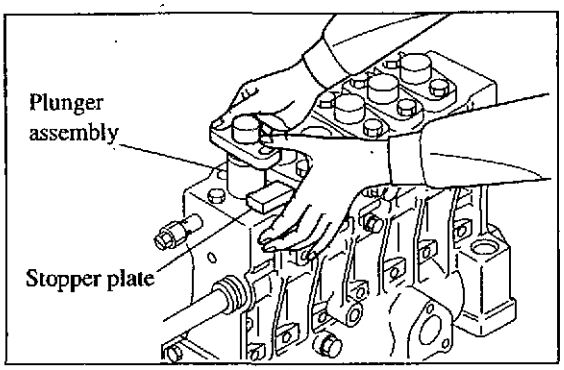
⚠CAUTION

Do not place fingers on the stopper plate during installation to prevent fingers from getting caught between the plunger assembly and stopper plate.

(a) Position the cam at the bottom dead center in the cylinder to which the plunger assembly is installed.

(b) Place the stopper plate (special tool) on top of the pump case to prevent damage to the pinion and control rack during the installation of the plunger assembly.

Name of special tool	Part No.
Stopper plate	48291-00500



Installing plunger assembly (1)

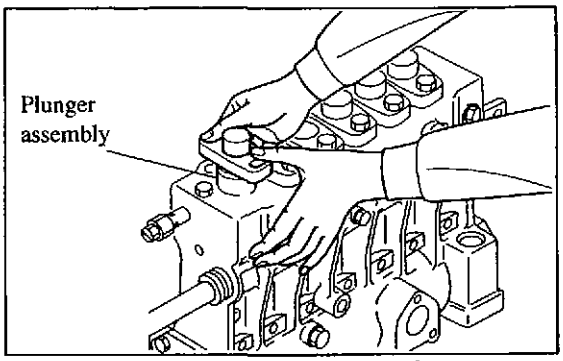
NOTE

If the stopper plate is not used during plunger assembly installation, the teeth on the pinion hit the teeth on the rack, causing rough edges that hinder smooth rack movement.

(c) Hold both sides of the flange of the barrel with two hands and press down the plunger assembly until the bottom side of the flange contacts the stopper plate.

(d) Remove the stopper plate, and lower the plunger assembly slowly. Do not apply excessive force to press down the plunger assembly. If the plunger assembly is jammed, turn the flange by jiggling it back and forth, then press down again.

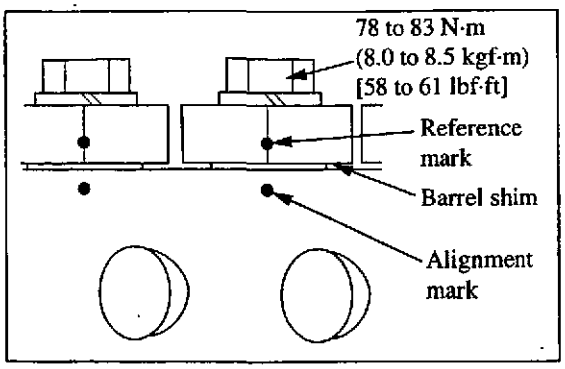
(e) Insert a standard barrel shim (thickness: 1.0 mm [0.04 in.]) under each barrel flange, and align the reference mark on the barrel flange with the alignment mark (small hole with diameter of 1.5 mm [0.06 in.]) on the pump case.



Installing plunger assembly (2)

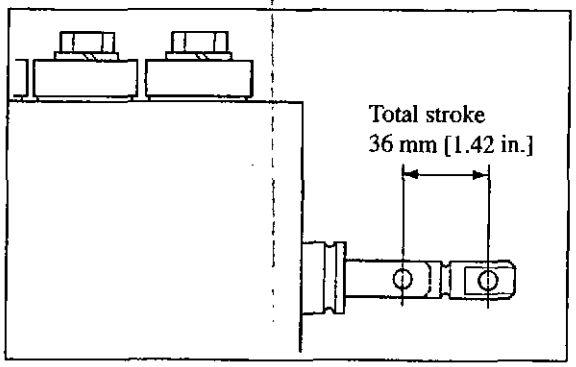
⚠CAUTION

In each cylinder, insert barrel shims of the same thickness, one in front and one in back. (Do not use two or more shims at one location.) If the shim thickness varies in the front and back of a cylinder, the rack may not move smoothly, causing hunting and other problems.



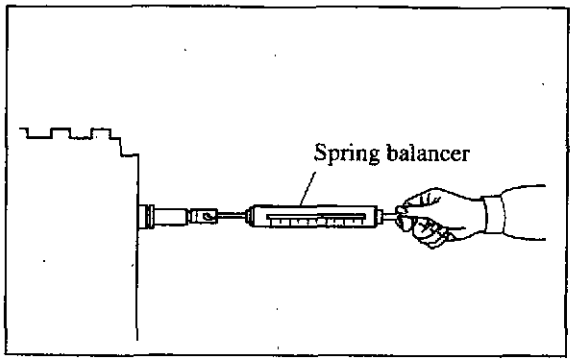
(f) Insert washers on the barrel bolts, and screw the bolts snug. Then, using a torque wrench, tighten the bolts alternately and evenly to 78 to 83 N·m (8.0 to 8.5 kgf·m) [58 to 61 lbf·ft].

(g) Remove the plunger holder (special tool), and check to make sure the control rack slides and strokes smoothly.



(10) Measuring control rack sliding resistance

(a) After the pump assembly is completed, attach a spring balancer to the control rack and make sure the control rack moves smoothly over the entire stroke.



Unit: N (gf) [lbf]

Item	Assembly Standard
Control rack sliding resistance	4.9 (500) [1.10] or less

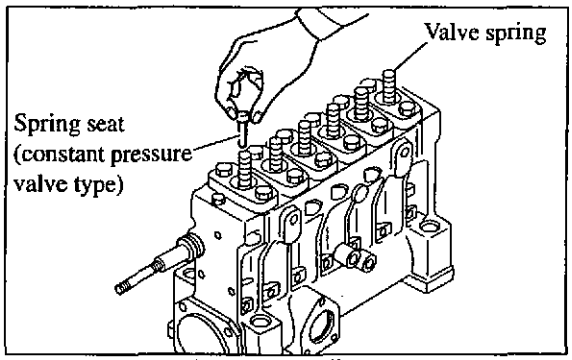
(b) After making sure the rack sliding resistance is lower than the standard value, install the deflector bolts on the pump case to 41 N·m (4.2 kgf·m) [30 lbf·ft].

(11) Assembling CPV delivery valves

(a) In each barrel, install spring seat and valve holder in that order.

(b) Install a new O-ring on the valve holder. Be sure to apply grease to the O-ring to prevent damage during installation.

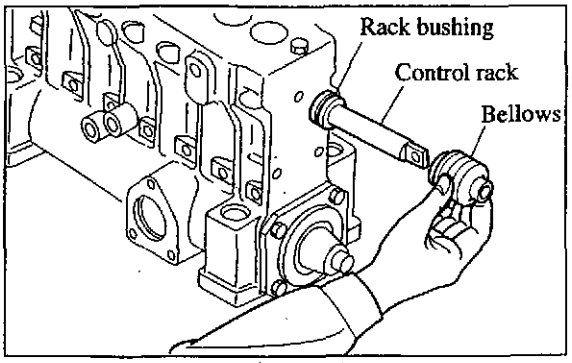
(c) Tighten the valve holder to 235 to 255 N·m (24 to 26 kgf·m) [174 to 188 lbf·ft]. Then, loosen the valve holder completely, and tighten again to the same torque.



Assembling CPV delivery valve

(12) Installing the bellows

(a) Insert the protrusions on the bellows into the grooves on the control rack and rack bushing, and install the bellows.
When installing, apply engine oil or grease to the inside of the bellows in order to avoid damaging the bellows.



Installing the bellows

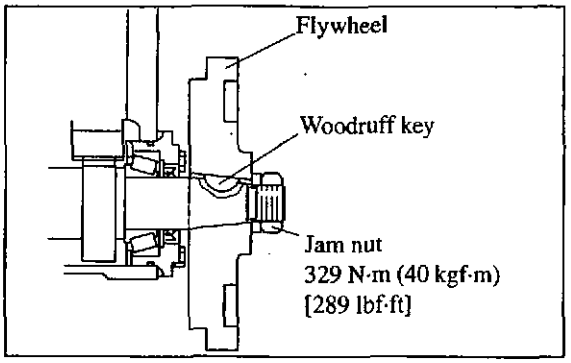
(13) Installing the flywheel

(a) Press-fit the woodruff key.

NOTE

The woodruff key may not stay in position depending on the size of the key groove on the camshaft. When this happens, adjust the shape of the side wall of the woodruff key using a punch before press-fitting (so that it fits tightly and does not fall off).

(b) Install the flywheel by aligning it with the woodruff key on the camshaft, and tighten the jam nut to the specified torque.



Installing the flywheel

(14) Installing the coupling assembly

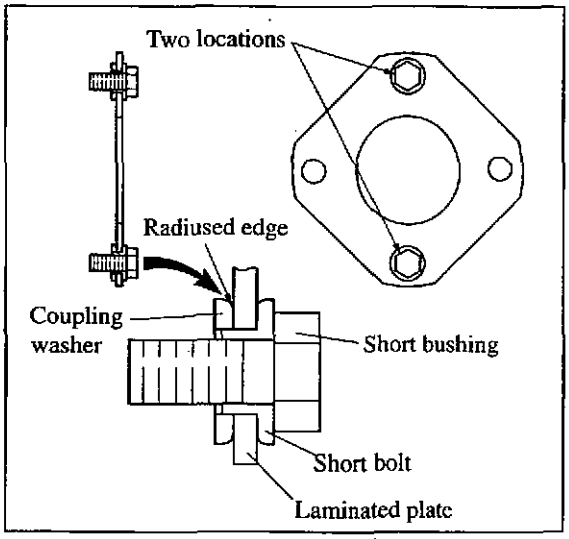
(a) Install sets of short bushings, short bolts and coupling washers in two diagonally located holes in the laminated plate.

NOTE

Set the side of the coupling washer with a radiused outer edge on the laminated plate.

⚠ CAUTION

If the coupling washer is installed in the wrong direction, the laminated plate can break.
When the laminated plate breaks, bolt damage occurs and can result in a serious accident.

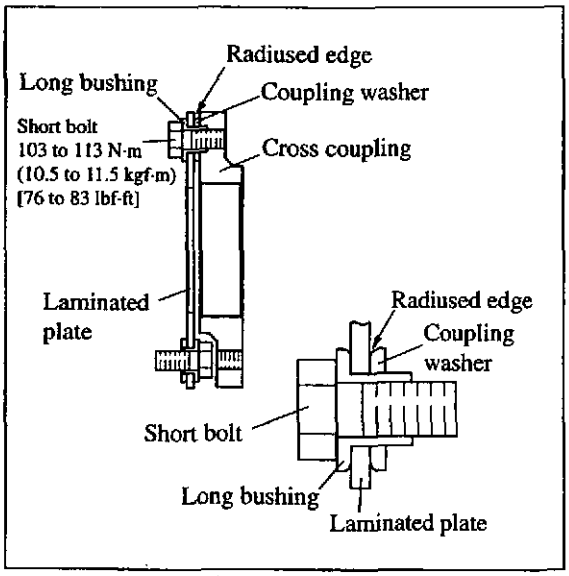


Installing the coupling assembly (1)

(b) While making sure that the short bolts and coupling washers installed on the laminated plate remain in place, install the laminated plate to the cross coupling by screwing short bolts with long bushings and coupling washers in the remaining two holes in the laminated plate from the opposite side. Tighten the short bolts to 103 to 113 N·m (10.5 to 11.5 kgf·m) [76 to 83 lbf·ft].

NOTE

(a) Set the side of the coupling washer with a radiused outer edge on the laminated plate.
(b) Use a spanner-type torque wrench to tighten the short bolts.



Installing the coupling assembly (2)

(c) Tighten the two remaining short bolts on the laminated plate mounted with the cross coupling to install the laminated plate securely to the flywheel. Tighten the bolts to 103 to 113 N·m (10.5 to 11.5 kgf·m) [76 to 83 lbf·ft].

NOTE

When tightening the short bolts, be sure not to drop the coupling washers.

(d) Install a set of short bushing, long bolt and coupling washer at each of the positions (2 locations) on the other laminate plate that are diagonal to each other, then loosely tighten the flange nuts to prevent them from detaching.

NOTE

Set the side of the coupling washer with a radiused outer edge on the laminated plate.

(e) Install the laminated plate to the coupling on the drive side using the wide coupling washers. Tighten the flange nuts to 103 to 113 N·m (10.5 to 11.5 kgf·m) [76 to 83 lbf·ft].

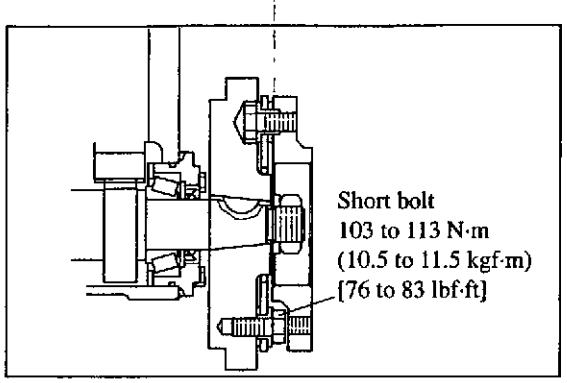
(f) Install sets of long bushings and coupling washers to the laminated plate, and install the laminated plate to the cross coupling with short bolts.
Tighten the short bolts to 103 to 113 N·m (10.5 to 11.5 kgf·m) [76 to 83 lbf·ft].

NOTE

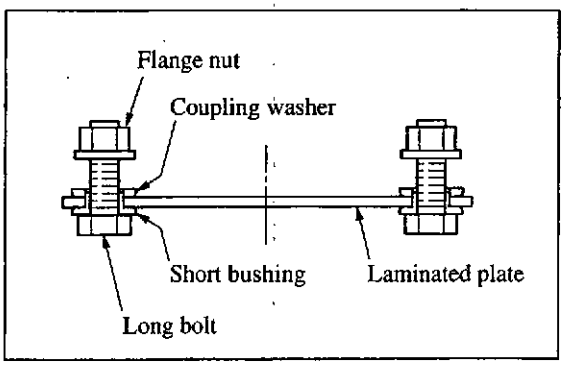
(a) Set the side of the coupling washer with a radiused outer edge on the laminated plate.

⚠ CAUTION

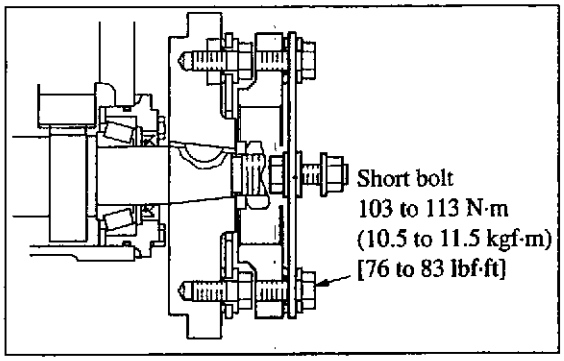
Make sure that the "S" mark on the camshaft end and the key groove on the coupling are positioned as shown in the diagram in installation.
Since the coupling can fit into position even if it is turned 180° from the correct installation position, be sure to inspect carefully to prevent injection timing deviation.



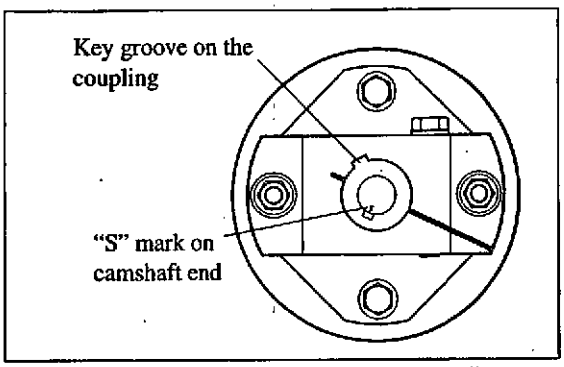
Installing the coupling assembly (3)



Installing the coupling assembly (4)



Installing the coupling assembly (5)



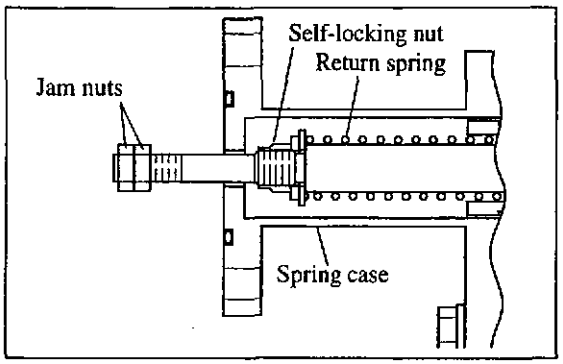
Assembly positions of camshaft and coupling
(View from rear end of drive side)

(15) Installing control rack return spring

(a) Install the return spring, plain washer, and spring washer to the control rack, and install and tighten a new self-locking nut.

NOTE

After tightening the self-locking nut, flatten the cylinder section.



Installing control rack return spring

(b) Install the spring case.

⚠ CAUTION

The two jam nuts installed at the end of the control rack hold the control rack at the maximum injection position. Perform a bench test and properly adjust the fuel injection pump after it has been installed on the engine.
Be sure to install the fuel injection pump on the engine in the specified manner. Otherwise, it will fail to function.

4.4 Adjustment

After the pump reassembly, mount the pump on the injection pump tester and make the following adjustments.

Adjustment of fuel injection timing

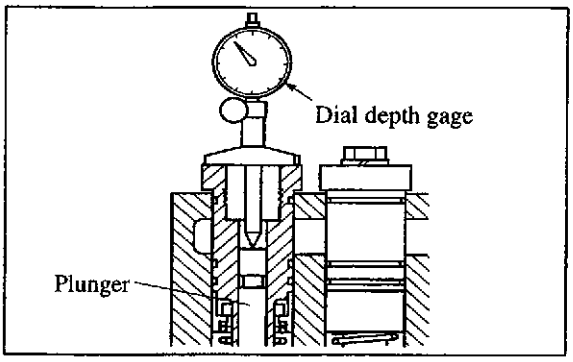
(1) Prestroke adjustment

(a) Unscrew all deflector bolts from the pump case.

(b) Remove the valve holder from cylinder No. 1 (driven side), and remove the spring seat, valve spring and delivery valve.

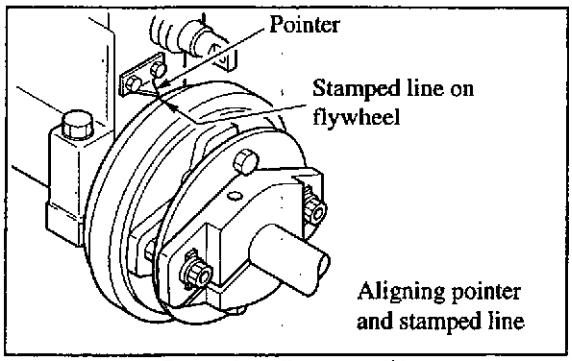
(c) Set a dial depth gage on the plunger head, rotate the camshaft by hand to bring the plunger to the bottom dead center while reading the gage indication, and set the dial depth gage indicator to "0."

(d) Rotate the camshaft in the forward direction. When the dial depth gage indicates "5 mm [0.20 in.]," secure the camshaft in position.



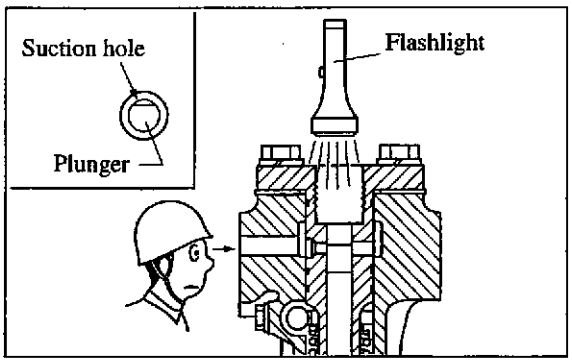
Prestroke adjustment (1)

(e) With the camshaft in that position, check to make sure the pointer on the end face of the pump case is aligned with the stamped mark on the flywheel. If they are not aligned, put a new mark on the flywheel at the pointer position.



Prestroke adjustment (2)

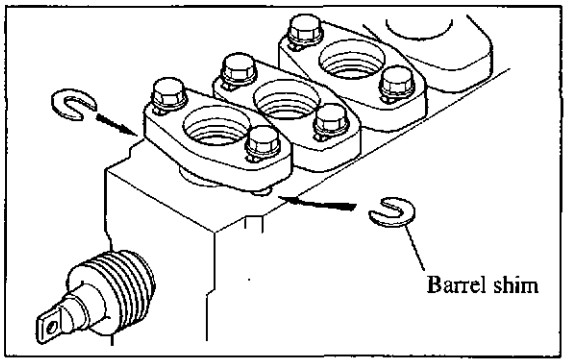
(f) Using a flashlight, check the position of the top surface of the plunger head by looking through the deflector bolt hole.



(g) Rotate the camshaft to adjust the position of the top surface of the plunger head so the barrel suction holes are closed. In this position, if the pointer aligns with the stamped line on the flywheel, there is no need to change the shims. If they do not align, change the shims so that the pointer and the stamped line on the flywheel align.
Increase of shim thickness → Retards injection timing
Decrease of shim thickness → Advances injection timing

⚠CAUTION

In each cylinder, install shims of the same thickness, one in front and one in back. (Do not use two or more shims at one location.)



(2) Adjustment of injection intervals
(a) Using the injection start timing of cylinder No. 1 as the reference point, measure the injection start intervals of cylinder No. 2 and subsequent cylinders in the injection sequence by reading the angle scale of the pump tester.
(b) If the injection start intervals deviate from the specification, make adjustment by changing the shim thickness in the same way as for prestroke adjustment.

Item	PS6
Injection start interval	60 ± 0.5°

Injection sequence

6 cylinders	1-5-3-6-2-4

Barrel shim thicknesses

Part No.	Thickness (mm [in.])
48202-04500	0.8±0.02 [0.031±0.00079]
48202-04600	0.9±0.02 [0.035±0.00079]
48202-04700	1.0±0.02 [0.039±0.00079]
48202-04800	1.1±0.02 [0.043±0.00079]
48202-04900	1.2±0.02 [0.047±0.00079]

Adjustment of fuel injection rate

> **⚠CAUTION**
> Keep flames away when using diesel fuel.

(1) Install the fuel hose and designated injection pipe to the fuel injection pump.
(2) Make adjustment in the following conditions.
- Test fuel: JIS class No. 2 diesel fuel
- Test fuel temperature: 40±10°C (104±18°F)

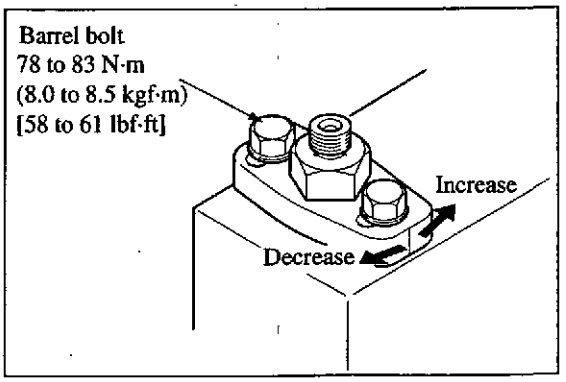
> **⚠ CAUTION**
> Do not attempt to adjust the injection volume without proper equipment. The injection volume must be adjusted by our company or a Mitsubishi dealer equipped with proper instruments.

Nozzle assembly part No. (No. of nozzles – Nozzle diameter (mm [in.])	37560-05000 (10 – φ0.29 [φ0.0114])
Nozzle valve opening pressure MPa (kgf/cm²) [psi]	35.0 to 35.5 (350 to 355) [4979 to 5050]
Feed pressure MPa (kgf/cm²) [psi]	0.3 ± 0.05 (3 ± 0.5) [43 ± 7]
Injection pipe part No. (Outside diameter (mm [in.]) × Inside diameter (mm [in.]) – Length (mm [in.])	37561-37700 (φ7 × φ2.8 – 1286) [φ0.276 × φ0.110 – 50.63]
Fuel pressure at pump inlet MPa (kgf/cm²) [psi]	0.3 ± 0.05 (3 ± 0.5) [42.7 ± 0.7]
Lubrication oil pressure at pump inlet MPa (kgf/cm²) [psi]	0.5 ± 0.05 (5 ± 0.5) [71.1 ± 0.7]

- Injection amount adjustment specifications

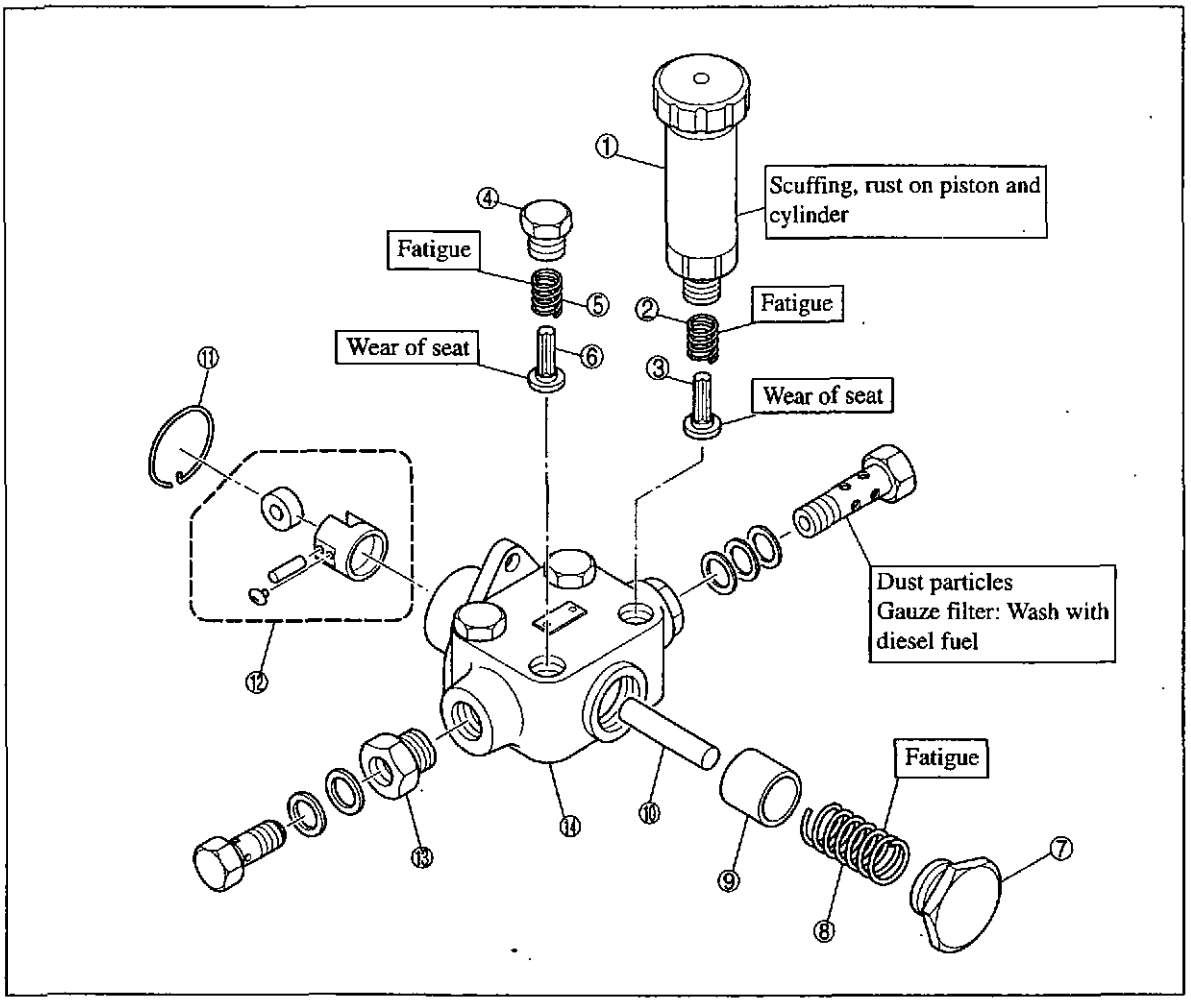
Item	Rack position / pump rotation speed	Average injection amount / number of strokes
Adjustment point 1	17 mm / 900 min⁻¹ [0.67 in.]	72 ± 3g / 200 st [2.54 ± 0.11 oz.]

(3) To adjust the injection rate, loosen the barrel bolts and slowly turn the barrel.
(4) After the adjustment, tighten the barrel bolts alternately to the specified torque.



5. Fuel Feed Pump

5.1 Disassembly and Inspection



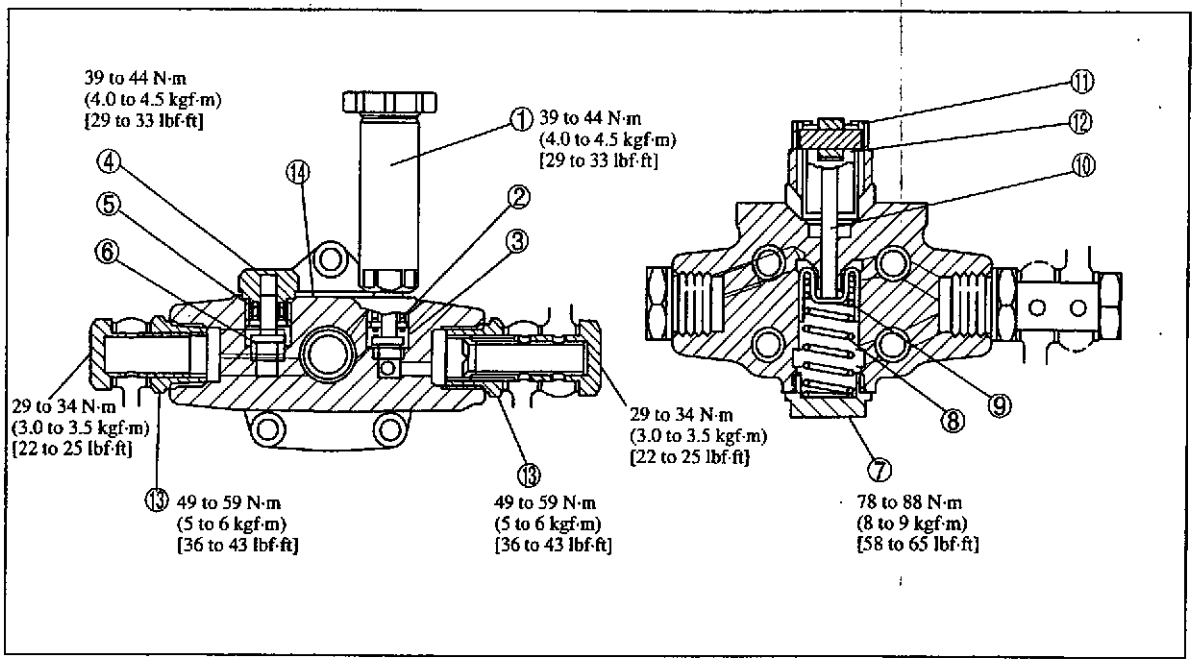
Disassembly sequence

① Priming pump
② Spring
③ Valve
④ Plug
⑤ Spring
⑥ Valve
⑦ Plug
⑧ Spring
⑨ Piston
⑩ Push rod
⑪ Snap ring
⑫ Tappet
⑬ Adapter
⑭ Pump housing

⚠CAUTION

- Keep flames away when using diesel fuel.
- Do not remove the gauze filter if it is clogged; otherwise the filter becomes twisted and damage results. Remove as much dust as possible through small holes, then remove the gauze filter with a screw driver.

5.2 Reassembly



Reassembly sequence

⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

(1) Tightening priming cap

(a) Tighten the priming cap lightly by hand until you feel a sudden increase of resistance.

NOTE

Mark the priming cap in this condition to facilitate the subsequent procedure.

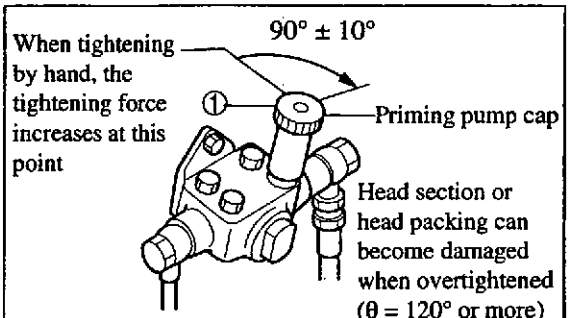
(b) After the priming cap is tightened as described in step (a), tighten it further by 90° ± 10° with a wrench.

NOTE

After tightening the priming pump cap, check that the priming pump head packing is not projecting.

⚠CAUTION

- If the priming cap is loose, engine vibrations can result in rapid wear of the internal threads of the priming cap, thus causing the cap to eject and fuel to flow out.
- If the priming cap is tightened excessively (120° or more after tightened by hand), the head section of the priming cap can be damaged.



Method for tightening the priming pump cap

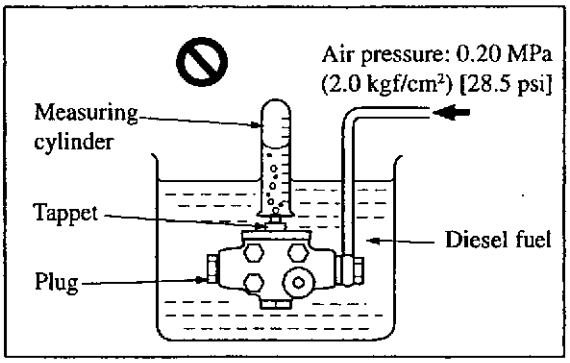
5.3 Testing

⚠CAUTION

Keep flames away when using diesel fuel.

(1) Airtightness test

Plug the discharge port. Apply air pressure of 0.20 MPa (2.0 kgf/cm²) [28.5 psi] to the suction port, immerse the pump in diesel fuel, and check for air leakage (air bubbles).



Airtightness test

(2) Feed pressure test

Testing conditions

Suction pipe: Outside diameter 15 mm [0.59 in.], Inside diameter 13 mm [0.51 in.], Length 2000 mm [78.7 in.].

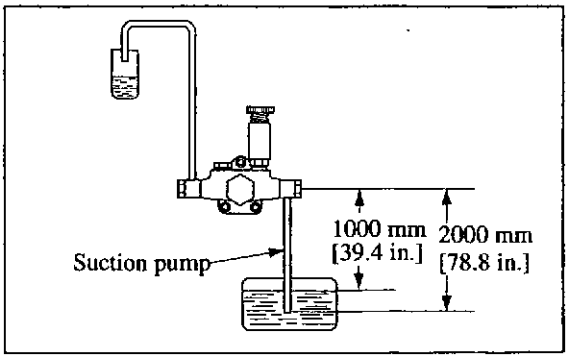
Suction height: 1000 mm [39.4 in.]

Cam lift: 12 mm [0.47 in.]/revolution

Drive the pump in the above testing conditions, and measure the discharge start time.

Unit: sec

Item	Assembly Standard
Feed pressure (pump at 100 min⁻¹)	Discharge start time: 20 sec or less



Feed pressure test

(3) Priming pump suction capacity test

Discharge fuel completely from the feed pump in the testing conditions described in (2). Then, operate the priming pump at a rate of 60 to 100 strokes per minute, and count the number of pumping operations required for fuel to reach the pump.

Unit: st/min

Item	Assembly Standard
Priming pump discharge start	No. of pumping operations: 30 strokes or less

(4) Feed rate test

Open the valve on the discharge side in the testing conditions described in (2). Then, operate the pump and measure the amount of fuel fed during the first 15 seconds.

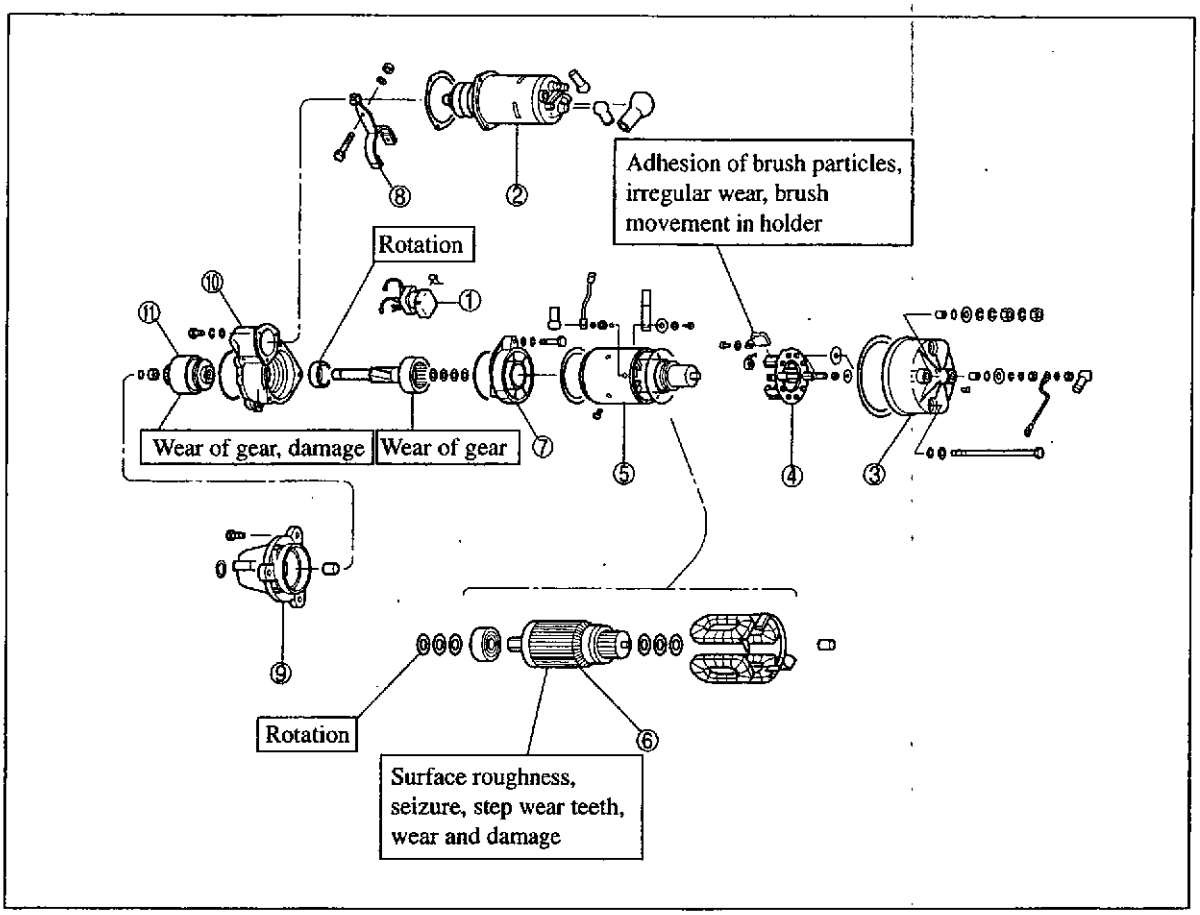
Unit: cm³ [cu.in.]/15 sec

Item	Assembly Standard
Feed pump feed rate (pump at 500 min⁻¹)	1100 [67]

ELECTRICAL SYSTEM

1. Starter

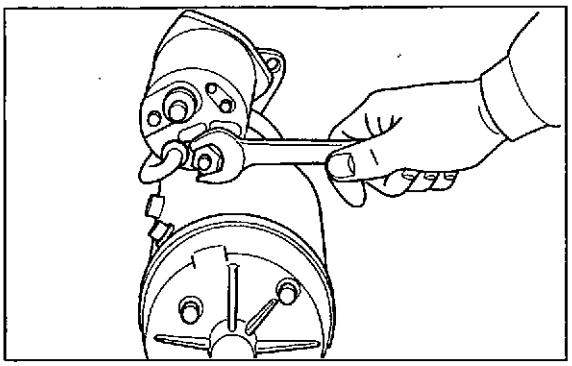
1.1 Disassembly



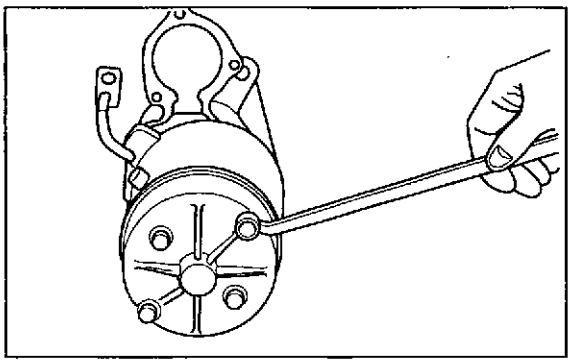
Disassembly sequence

① Safety magnetic switch
② Magnetic switch assembly
③ Rear bracket
④ Brush holder assembly
⑤ Yoke assembly
⑥ Armature assembly
⑦ Center bracket
⑧ Lever assembly
⑨ Front bracket
⑩ Pinion case
⑪ Pinion clutch assembly

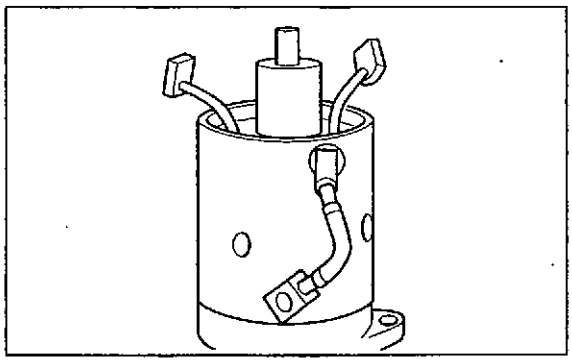
(1) After removing the safety switch, remove the lead wire, then the magnetic switch assembly.



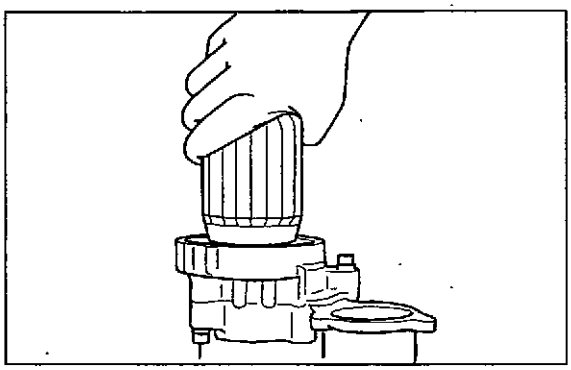
(2) Unscrew the through bolts and the brush holder mounting screws, then remove the rear bracket.



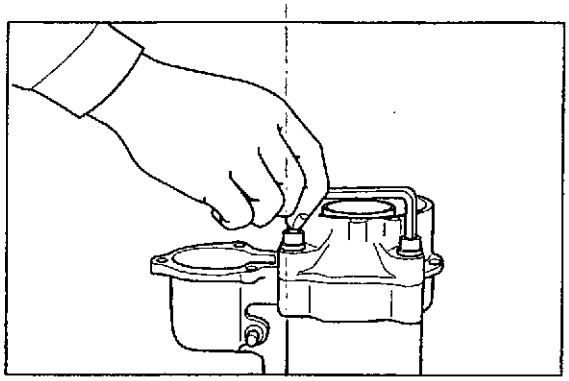
(3) Remove the brushes from the brush holder assembly, then remove the yoke.



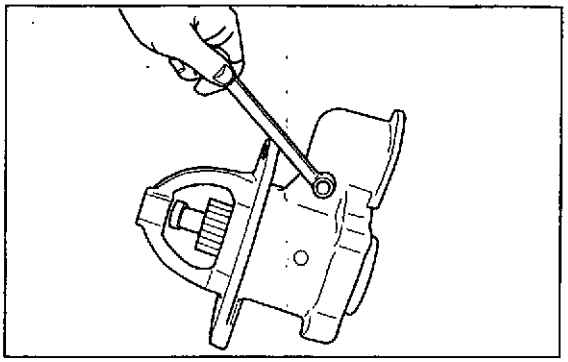
(4) Pull out the armature assembly.



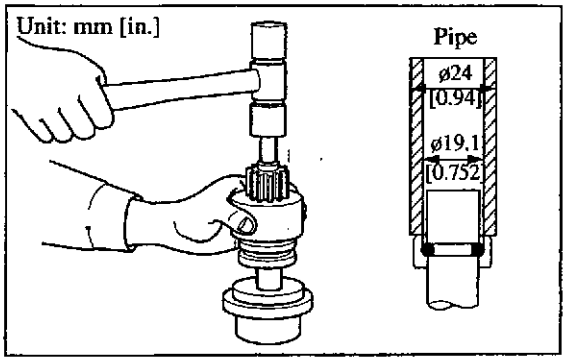
(5) Remove the center bracket.



(6) Remove the lever pin, inner housing, and shift lever from the pinion case.

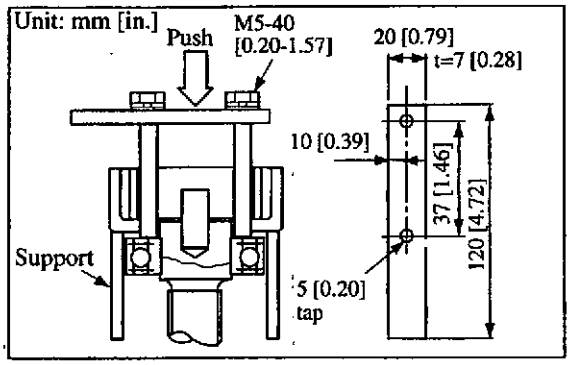


(7) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.



NOTE

To remove the shaft bearing for replacement, use a bearing puller as shown in the drawing.



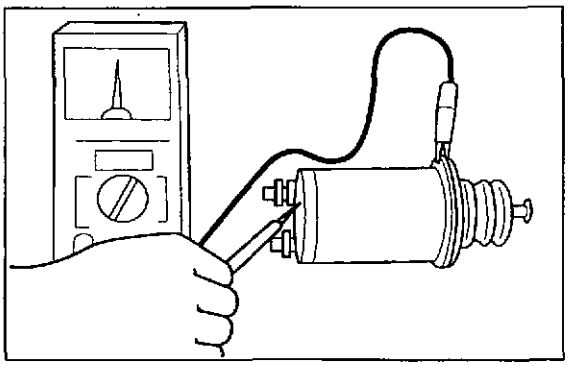
Pinion shaft bearing puller

1.2 Inspection and Repair

Magnetic Switch

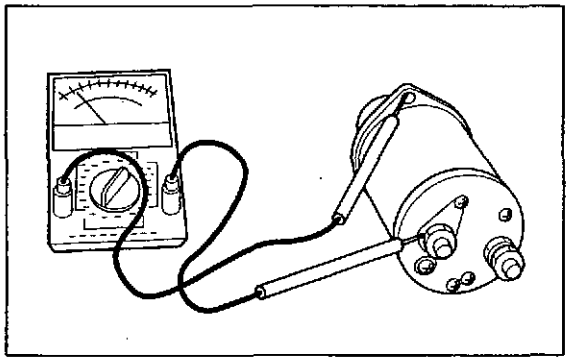
(1) Testing the magnetic switch coil

(a) Test the pressure coil and holding coil for an open circuit. The coils are open-circuited if there is no continuity between the M terminal of the magnetic switch and the case.



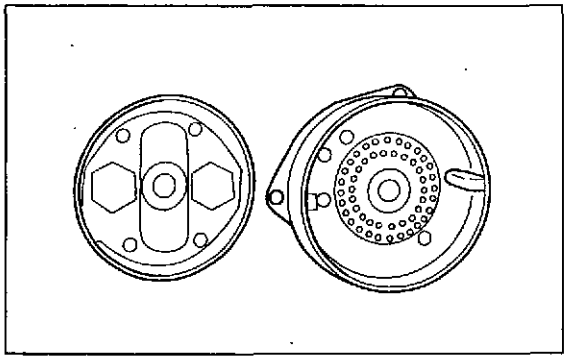
Resistance: approx 1.16 ohms

(b) Apply voltage of 24 volts between the M terminal of the magnetic switch and the case. Under this condition, push in the plunger by hand. When you release your hand, the plunger should not be attracted.



(2) Testing magnetic switch contact points

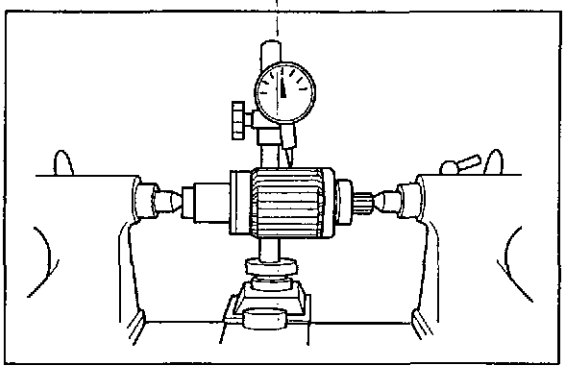
Measure the load current flowing through the starter. If the voltage drop between terminals B and M exceeds 0.3 volts per 100 amperes, clean or replace the contact points.
If the starter switch is turned to OFF during voltage measurement, the battery voltage is directly applied to the voltmeter. This can damage the voltmeter. Always turn the starter switch to ON before measuring the voltage, then turn it OFF after measuring the voltage.



⚠CAUTION

Do not apply 24 V on terminals to test the magnetic switch movement.

Armature

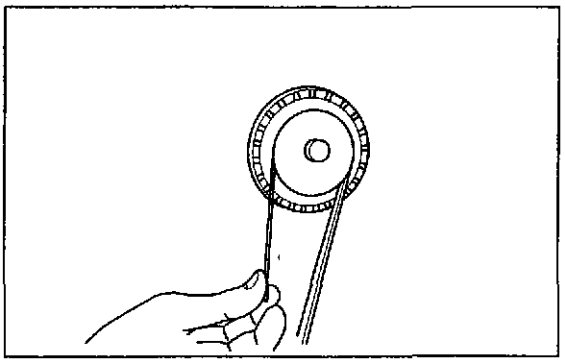


(1) Measuring the armature deflection

Measure the deflection with a dial gage. If the deflection exceeds the assembly standard, repair or replace the armature.

Unit: mm [in.]

Item	Assembly Standard
Armature deflection	0.05 [0.0020]

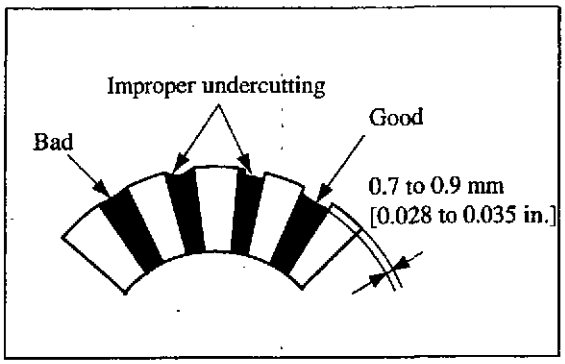


(2) Inspecting the commutator

(a) Check the condition of the commutator surface. If it is rough, polish it with #400 to #600 sandpaper.
Check the commutator for deflection with a dial gage. Replace the commutator if the deflection exceeds the service limit.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Commutator deflection	0.06 [0.0024] or less	0.10 [0.0039]



(b) Measuring the mica depth

Use a depth gage to measure the depth of each mica undercut. If the depth exceeds the repair limit, re-condition the mica.

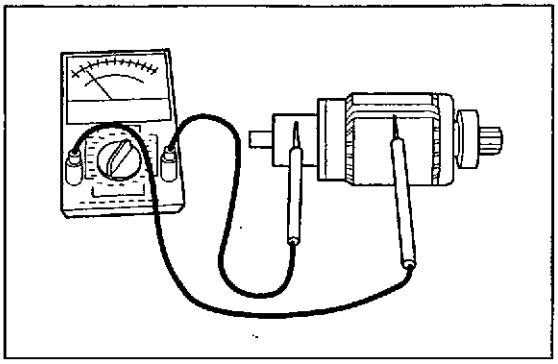
Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Commutator mica depth	0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]

(3) Testing the armature

(a) Use a growler to test the armature for short circuits. If the hacksaw blade vibrates against the core, replace the armature.

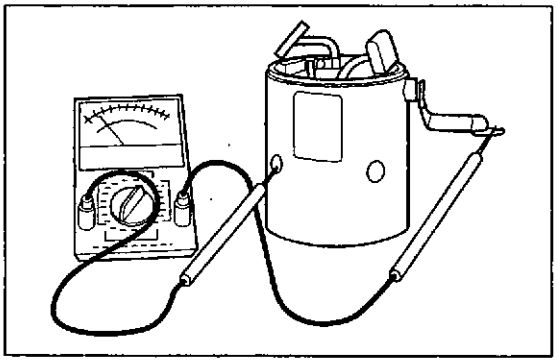
(b) If there is continuity between the commutator and shaft, replace the armature.



Field Coil

(1) Testing for open circuits

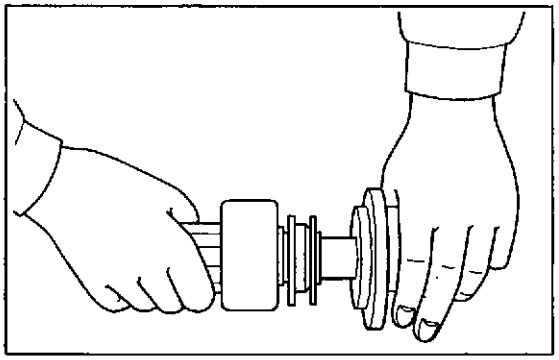
If there is no continuity between the M terminal of the field coil and the lead wire on the brush side, replace the field coil.



Overrunning Clutch

The clutch is in good condition if it rotates freely in one direction when turned by hand.

Check the pinion teeth for wear or damage. If they are damaged, replace the pinion.



⚠CAUTION

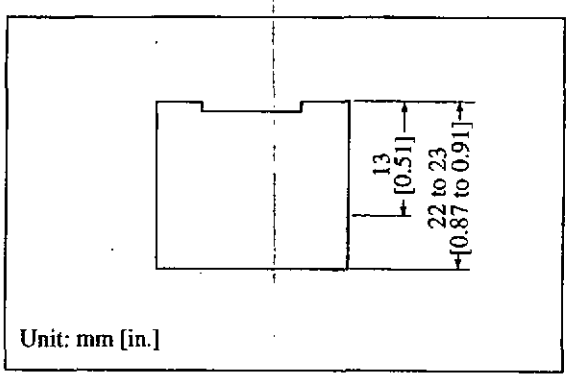
Do not immerse the overrunning clutch in cleaning solvent to clean it. Immersion in cleaning solvent will cause grease inside the clutch to run out, causing clutch parts to seize when operating.

Brushes

(1) Inspecting for wear

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Brush height	22 to 23 [0.87 to 0.91]	13 [0.51]



Unit: mm [in.]

(2) Testing brush spring tension

Unit: N (kgf) [lbf]

Item	Assembly Standard	Service Limit
Brush spring tension	39.23 to 49.03 (4.0 to 5.0) [9 to 11]	39.23 (4.0) [9]

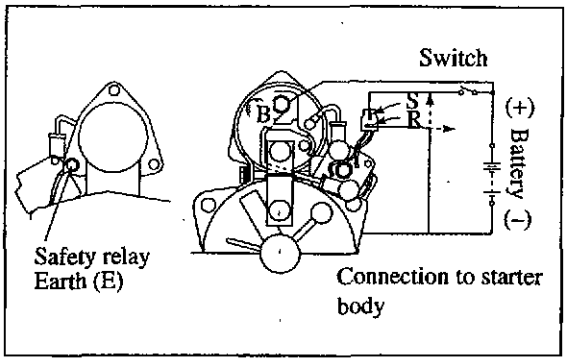
Safety Switch

Connect the safety switch as shown, and check the starter and safety switch operations.

(1) Connect the R terminal to the battery minus (–) side.

(2) Turn the switch on, and check that the starter turns.

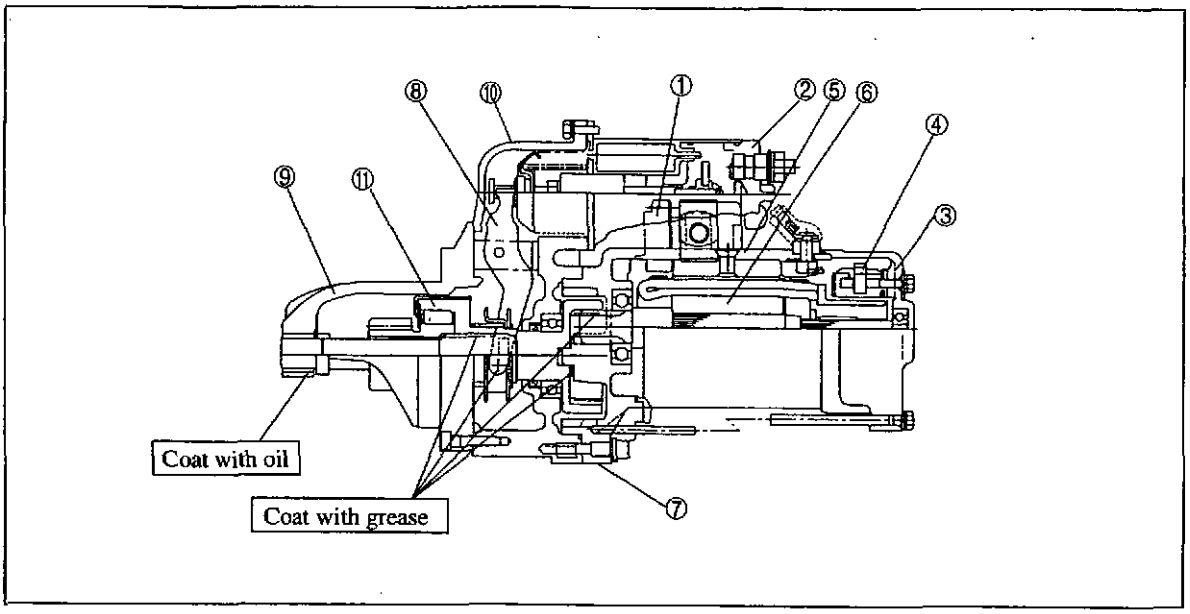
(3) After step (2) above is completed, if you remove the R terminal from the battery minus (–) side, or if you connect the terminal to the battery plus (+) side after removal, make sure you stop the starter operation.



⚠CAUTION

When you are making connections, pay special attention to the battery's polarity (+) (–).

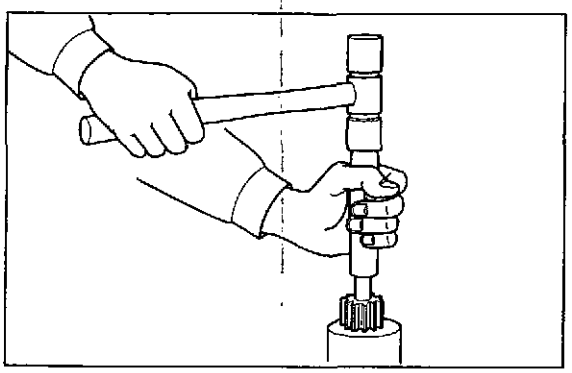
1.3 Reassembly



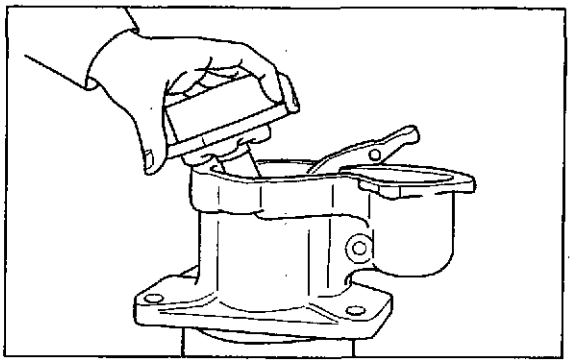
Reassembly sequence

⑩→⑨→⑪→⑧→⑦→⑥→⑤→④→③→②→①

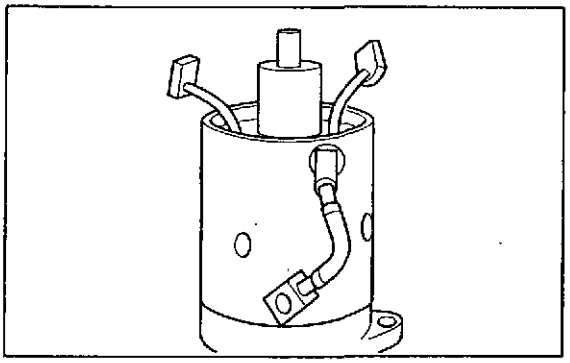
(1) Install the center bracket, overrunning clutch, and pinion stopper to the pinion shaft. Insert the shaft in position by tapping it with a soft-head mallet.



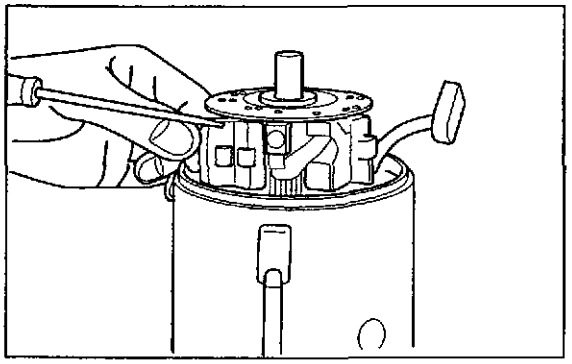
(2) Install the shift lever and pinion shaft to the front bracket by aligning the matching mark on the shift lever.



(3) Install the armature and yoke to the center bracket, making sure that the dowel pin enters its hole.

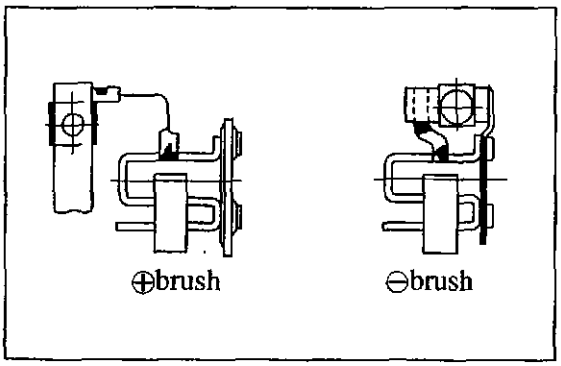


(4) Install the brushes and brush holders.

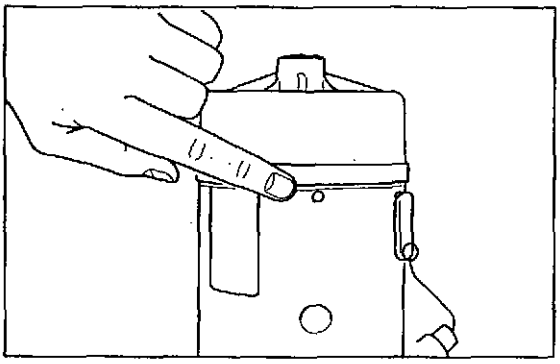


NOTE

Install the positive (+) side brush and negative (–) side brush as shown.



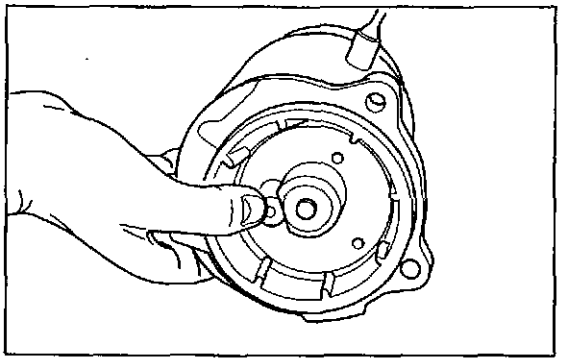
(5) Install the rear bracket to the yoke by aligning the matching marks. Secure the brush holders with bolts, then tighten the through bolts.



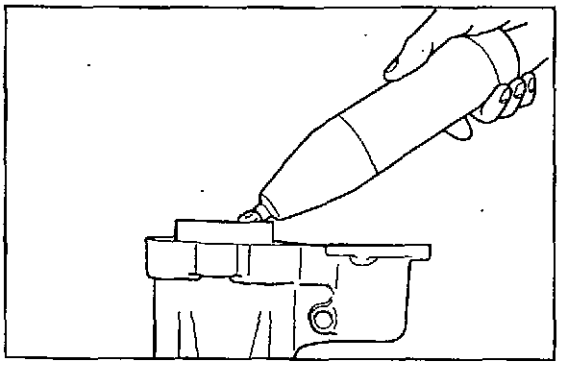
(6) Measure the end play of the armature. If the end play exceeds the assembly standard, adjust it on the rear side.

Unit: mm [in.]

Item	Assembly Standard
Armature end play	0.3 to 0.7 [0.012 to 0.028]



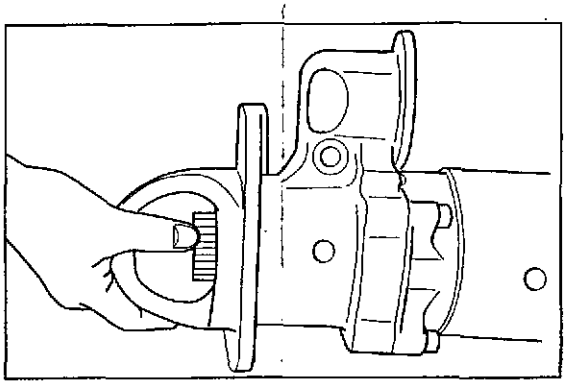
(7) Liberally coat the internal gear with grease, then install the pinion shaft to the gear.



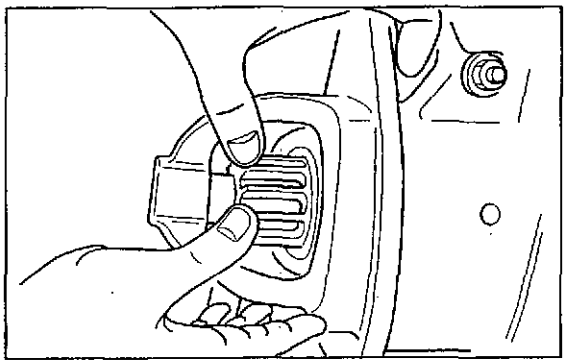
(8) Measure the end play of the pinion shaft. If the end play exceeds the assembly standard, adjust it on the internal gear side.

Unit: mm [in.]

Item	Assembly Standard
Pinion shaft end play	0.2 to 0.8 [0.008 to 0.031]

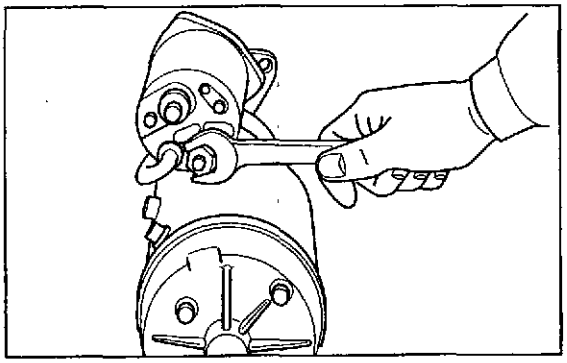


(9) Install the magnetic switch. Apply a voltage of 24 volts between the C and E terminals. Connect the lead wire and energize the circuit between the M and E terminals (within 1 second). After the pinion has shifted, measure retraction length of the pinion. If the measurement is not within 1.5 to 5 mm [0.06 to 0.20 in.], use the magnetic switch adjusting screw to make adjustments.



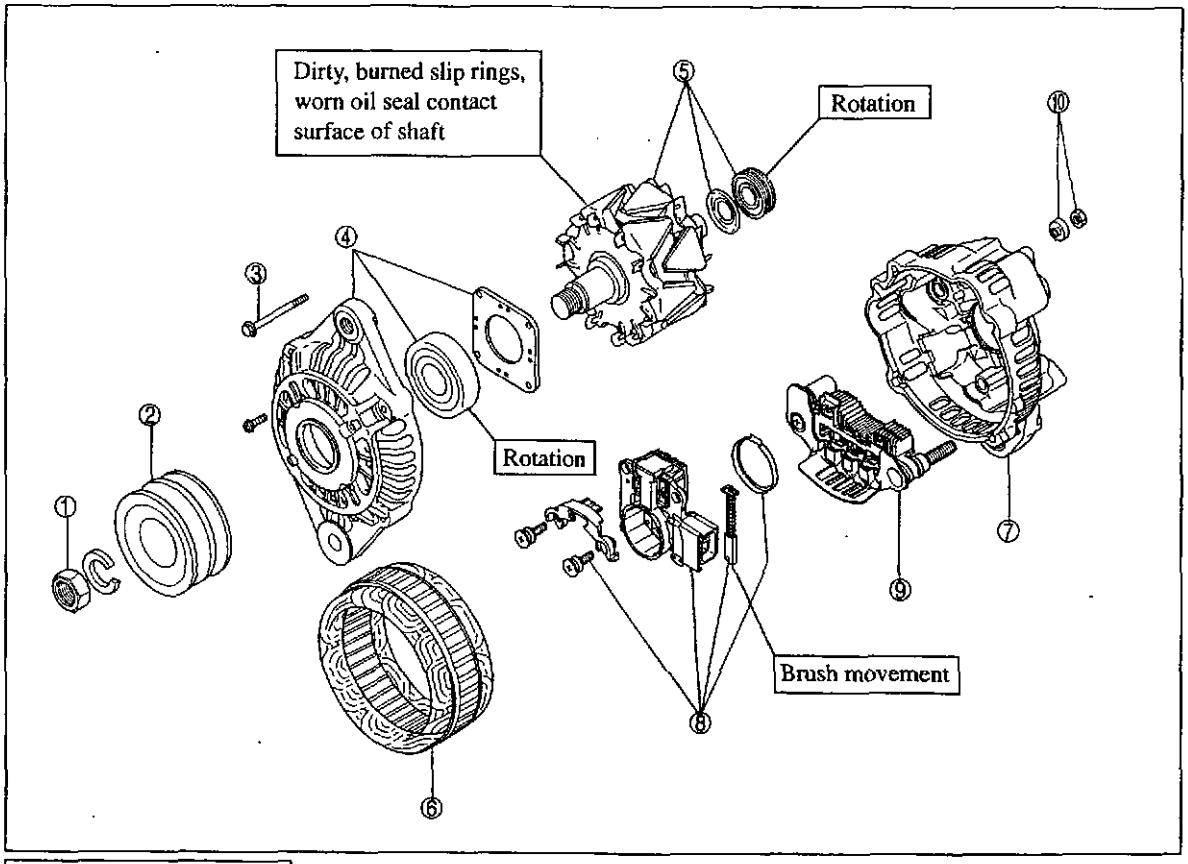
(10) Secure the lead wire.

(11) Install the safety switch.



2. Alternator

2.1 Disassembly



Disassembly sequence

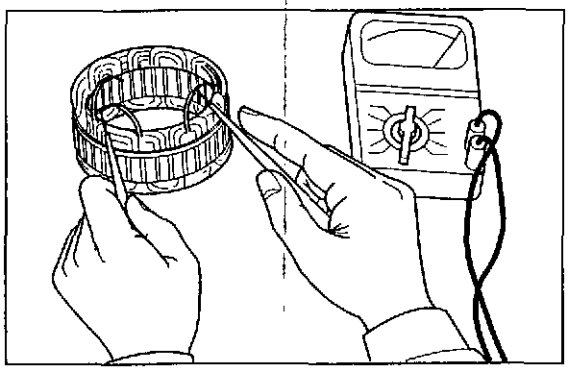
① Nut, washer
② Pulley
③ Set screw
④ Front bracket assembly
⑤ Rotor assembly
⑥ Stator
⑦ Rear bracket
⑧ Regulator assembly
⑨ Rectifier assembly
⑩ Nut set

2.2 Inspection and Repair

(1) Stator

(a) Testing the stator coil for open circuits

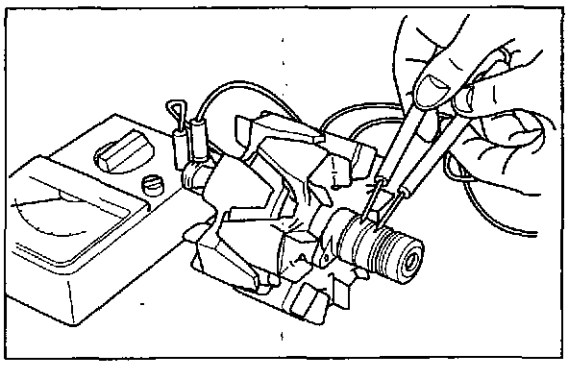
If there is no continuity among the four lead wires, replace the stator.



(b) Testing the stator coil for grounding

If there is continuity between the coil and core, replace the stator.

(2) Rotor



(a) Testing the rotor coil for open circuits

If there is no continuity between the slip rings, replace the rotor.

(b) Testing the rotor coil for grounding

If there is continuity between the slip rings and shaft (or core), replace the rotor.

(c) Measure the slip ring outside diameter

Using calipers, measure the outside diameter of each slip ring. If the diameter exceeds the service limit, replace the slip ring.

Unit: mm [in.]

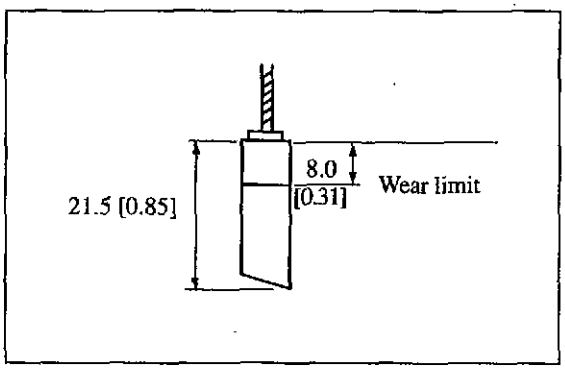
Item	Assembly Standard	Service Limit
Slip ring outside diameter	32.8 to 33.2 [1.291 to 1.307]	32.4 [1.276]

(3) Brushes and brush springs

(a) Brush wear

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Brush height	21.5 [0.85]	8.0 [0.31]



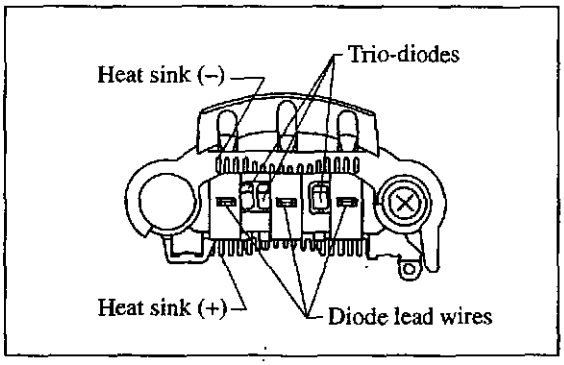
(b) Brush spring tension

Unit: N (gf) [lbf]

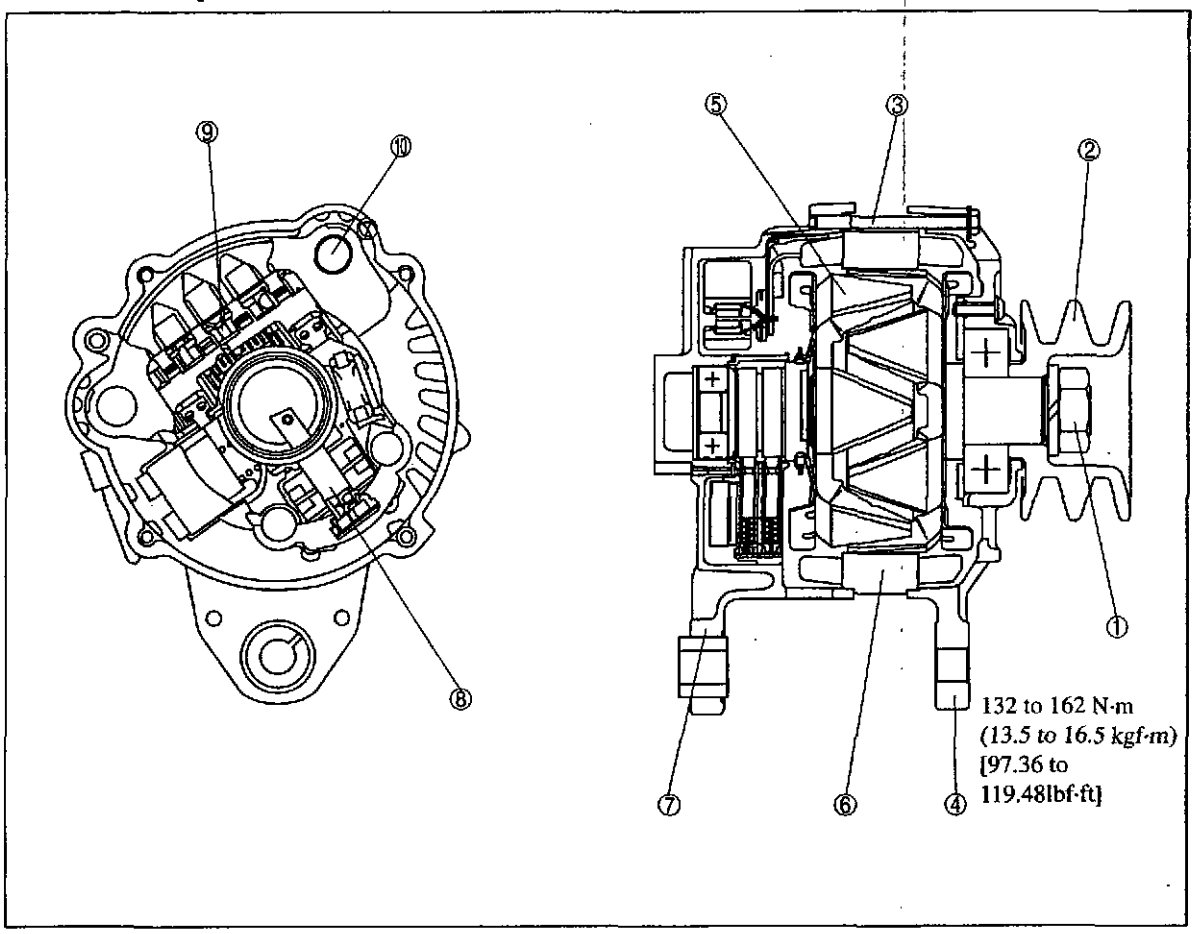
Item	Assembly Standard	Service Limit
Brush spring tension	3.1 to 4.3 (320 to 440) [0.70 to 0.97]	1.8 (180) [0.40]

(4) Inspecting rectifier

To check individual diodes, measure resistance between the diode lead wire and heat sink. Connect the positive (+) test lead wire to the diode and measure resistance. Then, connect the negative (–) test lead wire to the diode and measure resistance again. If both measured values are infinite, the diode circuit is open. If both measured values are close to 0 (zero), the circuit is shorted. If the diode has an open circuit or is shorted, it is defective, and the rectifier must be replaced.



2.3 Reassembly

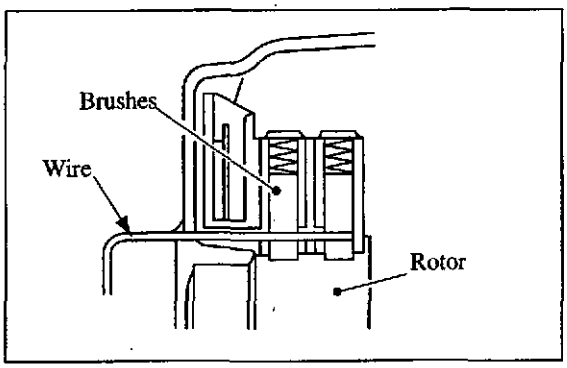


Reassembly sequence

④ → ⑤ → ② → ① → ⑦ → ⑨ → ⑩ → ⑧ → ⑥ → ③

(1) Installing the brushes

Use a push wire to install the brushes in the brush holder as shown in the right drawing. Install the rotor. Be sure to remove the push wire when you are finished.



WORKSHOP TIPS

1. Precautions for Disassembly and Reassembly

1.1 Oil Seals

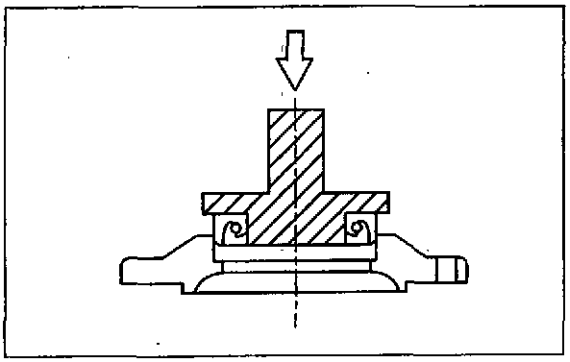
When installing oil seals, carefully observe the following points.

(1) Driving oil seals into housings

(a) Check the seal lip for damage, and make sure to position correctly in the housing.

(b) Apply a smear of grease to the surface of the oil seal to fit into the housing bore.

(c) Use an oil seal driver to guide the seal lip and drive the outer diameter squarely. To avoid damage to the oil seal and leaking, never hammer on it directly.

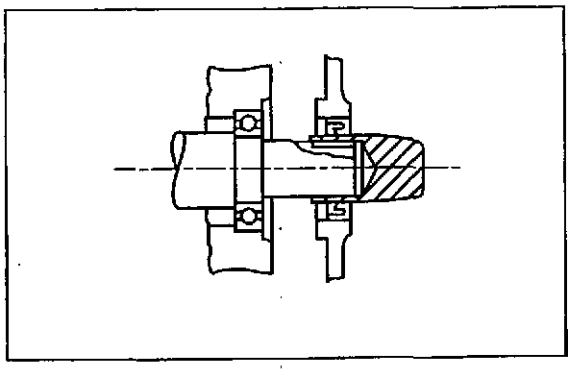


Oil seal driver

(2) Driving oil seals onto shafts

(a) Apply a smear of grease to the oil seal lip.

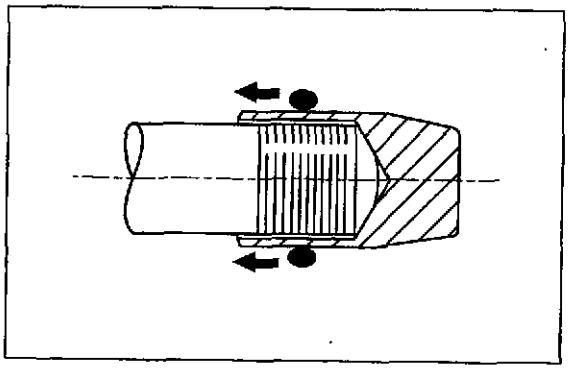
(b) Use an oil seal guide of the type shown when driving the oil seal over the stepped portion, splines, threads, or key way to prevent damage to the oil seal lip.



Oil seal guide

1.2 O-Rings

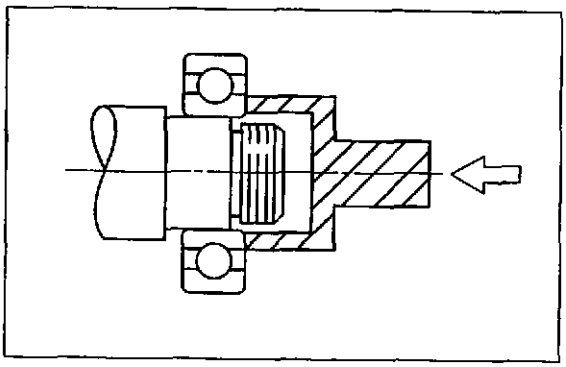
Use an O-ring guide to install an O-ring over stepped parts, splines, threads, or key way to prevent damage to the ring. Apply a smear of grease to the O-ring before installation.



O-ring guide

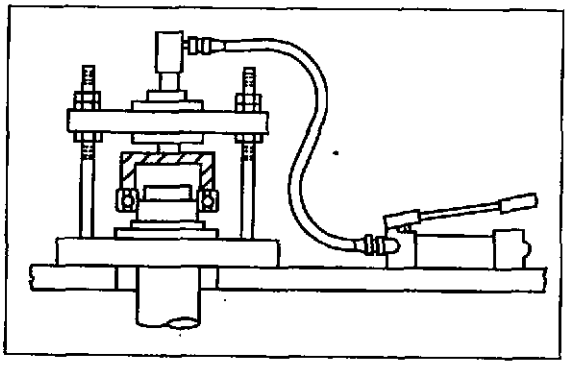
1.3 Bearings

(1) When installing a rolling bearing, be sure to push the inner or outer race by which the bearing is fitted. Be sure to use a bearing driver like the one shown in the drawing.



Bearing driver

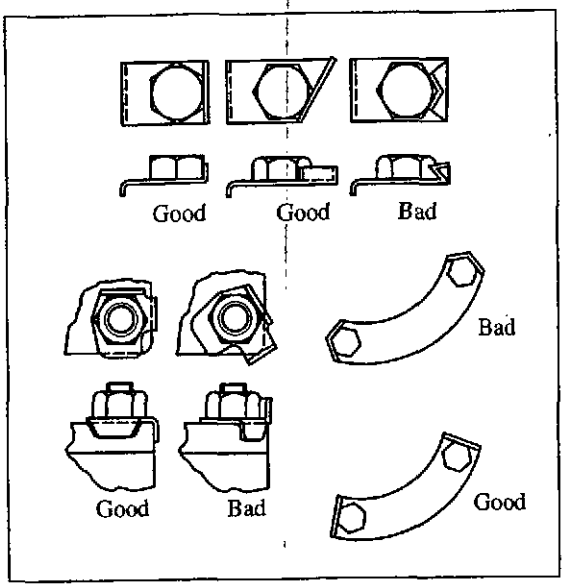
(2) Whenever possible, use a press to minimize shock to the bearing and to assure proper installation.



Bearing installation with a press

1.4 Lock Plates

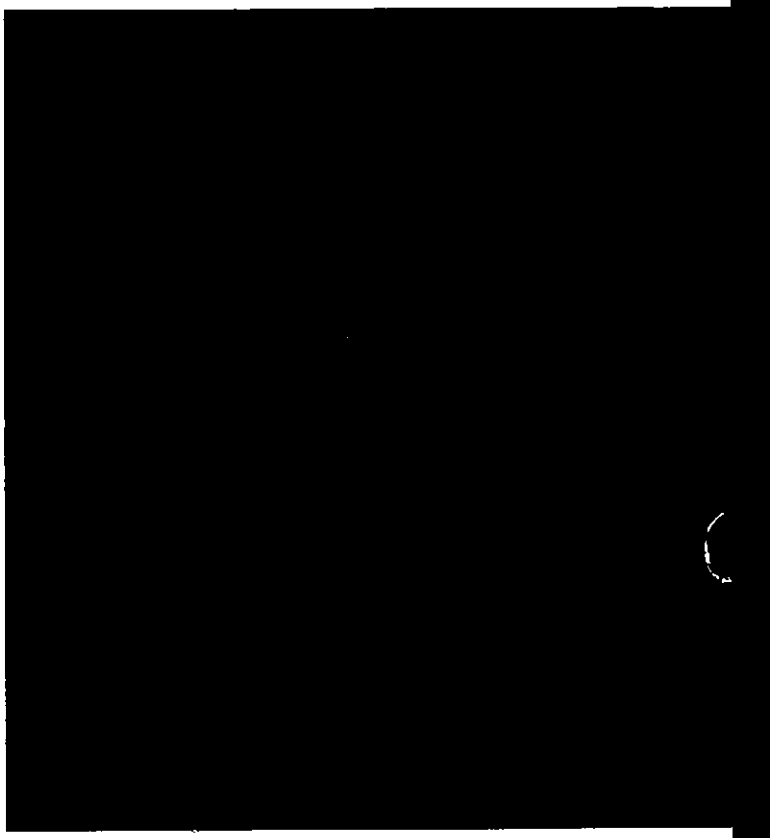
Bend lock plates against the flats of the nuts or bolt heads as shown.



Bending lock plate

1.5 Split Pins and Spring Pins

Generally, split pins are to be replaced at once disturbed. Insert the pin fully and spread it properly. Drive each spring pin into position to hold it in place after later installation of parts has been completed.



Printed in Japan

Pub. No. 99416-A1100