

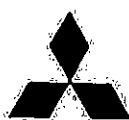
SERVICE MANUAL

**MITSUBISHI
DIESEL ENGINE**

S12R-Y1PTA

for Mitsubishi Engine North America, Inc.

April 2004



MITSUBISHI
HEAVY INDUSTRIES, LTD.

Foreword

This service manual describes the specifications and the maintenance and adjustment procedures of the S12R-YIPTA 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.

What This Manual Covers

This service manual covers standard specifications for the Mitsubishi S12R-Y1PTA Diesel Engines, and describes

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

Injection pump, governor and turbocharger are mentioned separately.

For non-standard models, like marine engines, also refer to the supplement.

In addition to the Summary of Manual Contents, a short summary of contents is found on the first page of each group 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*. Structure and function of the engine are described in the various training manuals.

How to Use This Manual

⚠ CAUTION

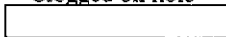
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

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.

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 chapter 2 of this manual.
4. The sequence in which parts are to be reassembled is summarized below each assembled view.
Such as:

⑤→②→④→③→①

5. Pay attention to;

Notes, Cautions, Warnings, and Dangers.

Particular marks which indicate notes, cautions, warnings, and dangers in this manual emphasizing important or critical instructions or advice.

-  Indicates the most serious specific potential hazard resulting in serious bodily injury or death.
-  Indicates a specific potential hazard resulting in bodily injury.
-  Indicates operating procedure, practice, etc., resulting in personal injury or damage to or destruction of engine.
-  An operating procedure, condition, etc. that will help you work more efficiently.

6. 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.

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 bleeding, fuel timing adjustment, bench testing, and performance tests.
6. Engine Auxiliaries Removal and Installation	Removal and installation of turbochargers, air coolers, fuel injection pumps, alternator, starter, etc.
7. Engine Main Parts	Disassembly, inspection, and reassembly of the engine main parts, to include cylinder heads, valve mechanisms, cylinder liners, pistons, connecting rods, flywheel, damper, timing gears, camshafts, crankcase, crankshaft and main bearings.
8. Inlet and Exhaust Systems	Disassembly, inspection, and reassembly of inlet and exhaust systems, to include air coolers, exhaust manifolds, pre-cleaner, and turbocharger.
9. Lubrication System	Disassembly, inspection, and reassembly of lubrication system, to include the oil pump, safety valve, oil cooler, oil filters, relief valve and oil filter alarm.
10. Cooling System	Disassembly, inspection, and reassembly of cooling system, to include water pump and thermostats.
11. Fuel System	Disassembly, inspection, and reassembly of the fuel system, to include fuel filters, fuel injection nozzles, fuel injection pump, fuel feed pump and pick-up.
12. Electrical System	Disassembly, inspection, and reassembly of electrical system, to include starters and alternator.
13. Workshop Tips	General precautions for disassembly and reassembly of parts: oil seals, O-rings, bearings, lock plates, and pins.

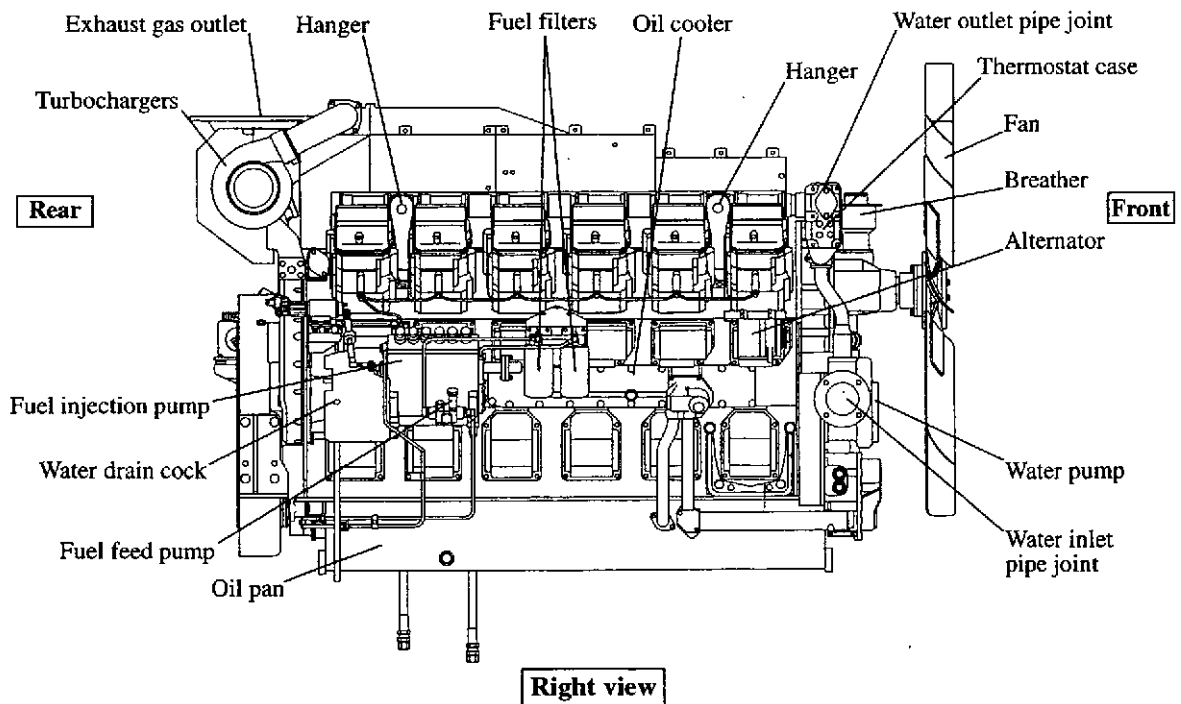
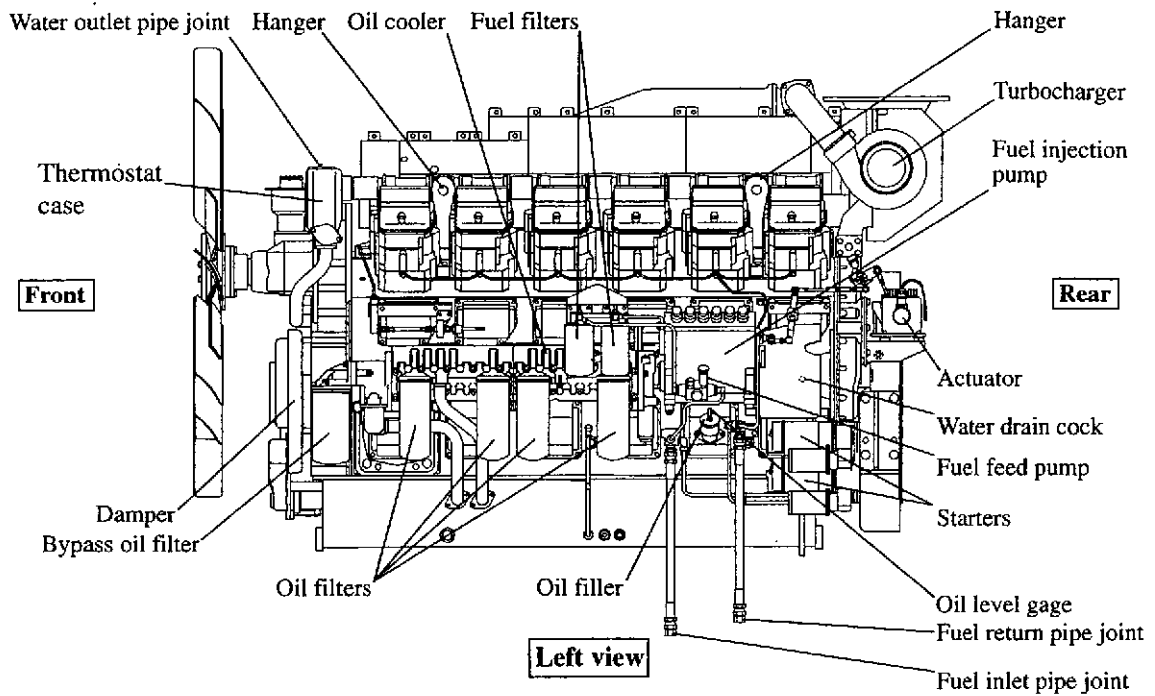
GENERAL

1. Outline	1-2
1.1 External View	1-2
1.2 Engine Serial Number Location	1-3
1.3 Engine Model and Application Codes	1-3
2. Specifications	1-4
3. Tips on Disassembly and Reassembly	1-7
3.1 Disassembly	1-7
3.2 Reassembly	1-7

GENERAL

1. Outline

1.1 External View

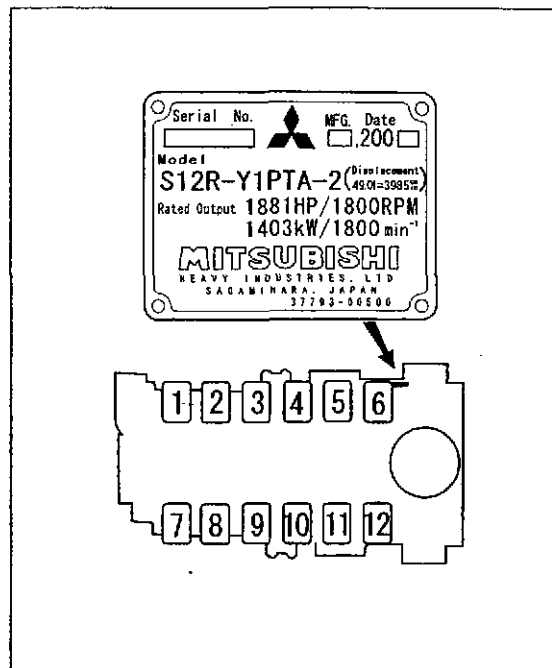


1.2 Engine Serial Number Location

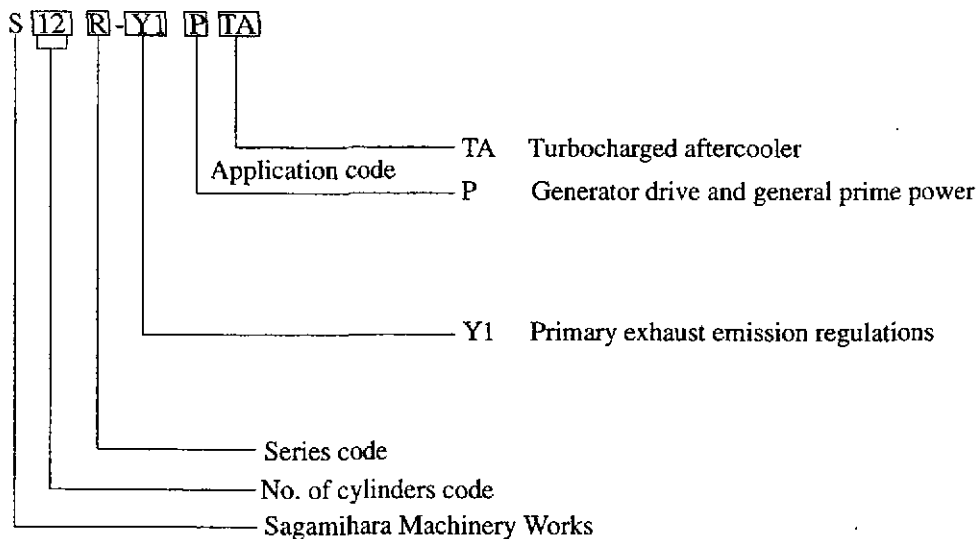
The engine serial number is stamped on the nameplate attached to the right rear side of the engine.

Example: Model Serial No.
 S12R-Y1PTA 11375

The rated output and speed are also stamped on the nameplate. Numbers in the illustration show cylinder numbers.



1.3 Engine Model and Application Codes



GENERAL

2. Specifications

Engine Type		S12R-Y1PTA		
Main specification	Model	Water-cooled, 4-stroke cycle, turbocharged diesel with aftercooler		
	No. of cylinders-arrangement	12-V		
	Combustion type	Direct injection		
	Valve mechanism	Overhead		
	Cylinder bore × Stroke	mm [in.]	170 × 180 [6.70 × 7.09]	
	Displacement	ℓ [U.S. gal]	49.0 [12.95]	
	Compression ratio	15.0:1		
	Fuel	Diesel fuel (ASTM, D975 No.1-D, No.2-D)		
	Firing order	1-12-5-8-3-10-6-7-2-11-4-9		
	Rotation direction	Counterclockwise as viewed from flywheel		
	Dimensions	Length	mm [in.]	2568 [101.1]
		Width	mm [in.]	1455 [57.3]
Height		mm [in.]	1592 [62.7]	
Weight (Dry)	kg [lb.]	4800 [10582]		
Engine main parts	Cylinder liner	Type	Wet type	
	Number of piston	Compression ring	2	
		Oil ring	1 (with expander)	
	Valve timing (when warm)	Inlet valve	Open	BTDC 53°
			Close	ABDC 44°
		Exhaust valve	Open	BBDC 57°
			Close	ATDC 40°
	Engine support method	4 point support		
Starting system	Electric-starter			
Inlet and exhaust system	Air cleaner	Type	Paper element type or pre-cleaner type	
	Turbocharger	Type	TF15	
		No. of units	2	
	Air cooler	Type	Multilayer fin-and-plate type	

Engine Type		S12R-YIPTA	
Lubrication system	Lubricating type	Forced circulation type (pressure feed by oil pump)	
	Engine oil	Standard	Class CD or CF oil (API service classification)
		Capacity (engine) ℓ [U.S. gal]	Approx. 180 [47.56]
	Oil pump	Type	Gear pump
		Delivery capacity ℓ [U.S. gal]/min	240 [63.4] (at 800 min ⁻¹ engine)
	Relief valve	Type	Piston valve type
		Valve opening pressure MPa (kgf/cm ²) [psi]	0.51±0.02 (5.2±0.2) [73.97±2.84]
	Oil cooler	Type	Water-cooled, multi-plate type (built-in in the crankcase)
		Element	10 stages
	Full-flow oil filter	Type	Spin on type with paper element
Bypass oil filter	Type	Spin on type with paper element	
Oil filter alarm	Type	Piston valve type, built-in electric contact points	
	Lamp lighting and valve opening pressure MPa (kgf/cm ²) [psi]	0.15 ^{+0.03} ₀ (1.5 ^{+0.3} ₀) [21.34 ^{+4.27} ₀]	
Oil thermostat	Type	Wax type	
	Valve opening temperature °C [°F]	80 to 84 [176 to 183.2]	
Cooling system	Cooling type	Water-cooled, forced circulation	
	Coolant capacity (Whole engine) ℓ [U.S. gal]	Approx. 125 [33]	
	Water pump	Type	Centrifugal
		Delivery capacity l [U.S. gal]/min.	1600 [422.7] (at 1800 min ⁻¹ engine)
	Thermostat	Type	Wax type
		Valve opening temperature °C [°F]	71±2 [159.8±35.6]
	Cooling fan	Type	Steel-blade, circular arc type
No. of blades		8	
Outside diameter mm [in.]		1524 [60]	
Fuel system	Fuel injection pump	Model	PS6 type
		Manufacturer	Mitsubishi Heavy Industry
		Plunger outside diameter mm [in.]	17 [0.67]
		Plunger lead mm [in.]	Both-side, 35 [1.38] lead
		Cam lift mm [in.]	15 [0.59]
	Fuel feed pump	Model	Bosch KD22Z type
		Manufacturer	Bosch Automotive Systems Corporation
		Cam lift mm [in.]	12 [0.47]
	Governor	Control system	Electric governor actuator Woodward Pro Act Model II
	Fuel injection nozzles	Type	Hole type
		Manufacturer	Bosch Automotive Systems Corporation
		No. of spray holes	10
		Spray hole diameter mm [in.] Spray angle	∅0.29 [0.011] - 160°
Injection pressure MPa (kgf/cm ²) [psi]		35.0 to 35.5 (350 to 355) [4979 to 5050]	
Fuel filter	Type	Spin on type with paper element	

GENERAL

Engine Type		S12R-YIPTA	
Electrical system	Voltage polarity		24V- Negative (-) ground
	Starter	Manufacturer	Nikko Electric Industry
		Pinion mesh type	Pinion shift (Reduction type)
		Output V-kW	24-7.5
		No. of starters	2
		No. of pinion tooth/ring gear tooth	15/193
	Alternator	Type	3-phase alternating generator, Internal IC regulator
		Manufacturer	Mitsubishi Electric
		Output V-A	24-30
		Rated output generated min ⁻¹ min ⁻¹	5000 (at 27V, 30A)
		Regulated voltage V	28.5±0.5
	Alternator drive belt	Model	Low edge cog belt C type
		Outside circumference mm [in.]	1000 [39.4]

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. Mark by yourself, if necessary, to ensure correct 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

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 section 3 of Group 2, "Maintenance Standards.")
- (4) Use torque wrenches to tighten parts when specified tightening torques are required. (Refer to section 2 of Group 2, "Maintenance Standards.")
- (5) Replace all gaskets and packing. Apply appropriate amount of adhesive or liquid to gaskets or packings when required.

CAUTION

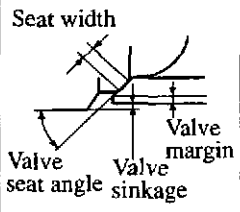
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MAINTENANCE STANDARDS

1. Maintenance Standards Table	2-2
2. Tightening Torque Table	2-16
2.1 Important Bolts and Nuts	2-16
2.2 Standard Bolts and Nuts	2-18
2.3 Standard Eyebolts	2-19
2.4 Standard Union Nuts	2-19
2.5 High-Pressure Fuel Injection Pipes	2-19
3. Sealants and Lubricants Table	2-20

1. Maintenance Standards Table

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
General	Maximum speed		5 to 10% higher than rated speed		Faulty if lower or 15% higher than rated speed		The rated speed is stamped on the nameplate. Check governor setting.
	Minimum speed		600 to 650 min ⁻¹				
	Compression pressure MPa (kgf/cm ²) [psi]		1.81 (18.5) [263] or more (at 120 min ⁻¹)		Faulty if 1.27 (13.0) [185] or less		Oil and water temperature 20 to 30°C [68 to 86°F]
	Lube oil pressure MPa (kgf/cm ²) [psi]		0.49 to 0.64 (5.0 to 6.5) [71 to 85.6] or more at rated speed		Faulty if 0.49 (5.0) [71] or less		Oil temperature 60 to 70°C [140 to 158°F]
			0.20 to 0.29 (2.0 to 3.0) [29 to 42] or more at idling		Faulty if 0.10 (1.0) [14.2] or less		
	Valve timing (with 2mm [0.079 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° ATDC 5.5° ±2° (crank angle)		Values are only for checking valve timing and are different from the actual ones.
	Valve clearance (cold)	Inlet valve		0.6 [0.024]			
Exhaust valve			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	Rocker	Rocker bushing inside diameter	ø36 [1.42]	36.000 to 36.040 [1.41732 to 1.41889]		36.090 [1.42086]	
		Rocker shaft diameter	ø36 [1.42]	35.966 to 35.991 [1.41598 to 1.41697]		35.940 [1.41496]	
	Valve	Valve stem diameter	ø10 [0.39]	9.940 to 9.960 [0.39134 to 0.39213]		9.910 [0.39016]	The same for both inlet and exhaust valves.
		Valve guide inside diameter	ø10 [0.39]	10.000 to 10.015 [0.39370 to 0.39429]		10.060 [0.39606]	The same for both inlet and exhaust valves.
	Valve seat and valve	Valve seat angle	30°				
		Valve sinkage	0	-0.2 to 0.2 [-0.008 to 0.008]	1.0 [0.039]		
Seat width		2.3 [0.091]	2.15 to 2.45 [0.0846 to 0.0965]	2.8 [0.110]			

MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark	
Engine main parts	Connecting rod	Big-end bore diameter	∅131 [5.16]	131.000 to 131.025 [5.15747 to 5.15845]		131.050 [5.15944]	To be measured in combination with caps. Roundness less than 0.1 mm [0.004 in.] - service limit.	
	Connecting rod bearing	Thick-ness of center	STD	3.000 [0.11811]	2.972 to 2.985 [0.11701 to 0.11752]		2.930 [0.11535]	Replace bearings if worn down to service limit. Re grind crank-pins and use undersize bearings if necessary.
			-0.25 [-0.0098]	3.125 [0.12303]	3.097 to 3.110 [0.12193 to 0.12244]		3.055 [0.11831]	
			-0.50 [-0.0197]	3.250 [0.12795]	3.222 to 3.235 [0.12685 to 0.12736]		3.180 [0.12520]	
			-0.75 [-0.0295]	3.375 [0.13287]	3.347 to 3.360 [0.13177 to 0.13228]		3.305 [0.13012]	
			-1.00 [-0.0394]	3.500 [0.13780]	3.472 to 3.485 [0.13669 to 0.13720]		3.430 [0.13504]	
	Flywheel	Face runout		0.336 [0.0132] or less				
		Circular runout		0.130 [0.0051] or less				
	Injection pump accessory drive	Bearing bore inside diameter	∅90 [3.54]	89.987 to 90.022 [3.54189 to 3.54417]				
			∅100 [3.94]	99.987 to 100.022 [3.93649 to 3.93701]				
		Bearing Outside diameter	∅90 [3.54]	89.985 to 90.000 [3.54272 to 3.54331]				
			∅100 [3.94]	99.985 to 100.000 [3.93642 to 3.93701]				
Bearing Inside diameter		∅45 [1.77]	44.988 to 45.000 [1.77118 to 1.77165]					
		∅50 [1.97]	49.988 to 50.000 [1.96803 to 1.96850]					


MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Engine main parts	Injection pump accessory drive	Drive shaft bearing outside diameter	ø45 [1.77]	45.002 to 45.013 [1.77173 to 1.77217]			
			ø50 [1.97]	50.002 to 50.013 [1.96858 to 1.96901]			
	Oil pump drive	Cover bearing bore inside diameter	ø110 [4.33]	110.000 to 110.035 [4.33070 to 4.33208]			
		Plate bearing bore inside diameter	ø110 [4.33]	109.987 to 110.022 [4.33019 to 4.33157]			
		Bearing	ø110 [4.33]	109.985 to 110.000 [4.33010 to 4.33071]			
		Outside diameter					
		Bearing	ø50 [1.97]	49.988 to 50.000 [1.96802 to 1.96850]			
	Inside diameter						
	Gear shaft bearing bore outside diameter	ø50 [1.97]	49.993 to 50.013 [1.96822 to 1.96901]				
	Damper	Circular runout (at periphery)		0.5 [0.020] or less		1.5 [0.059]	Replace at every 10,000 service hours.
		Face runout		0.5 [0.020] or less		1.5 [0.059]	
	Front gear	Backlash		(0.12 to 0.18) [(0.0047 to 0.0071)]	(0.30) [(0.0118)]	(0.50) [(0.020)]	Replace gears, if necessary.
		Idler bushing inside diameter	ø50 [1.97]	50.000 to 50.025 [1.96850 to 1.96948]		50.060 [1.97086]	Same as the front oil drive idler, front fan drive idler.
		Idler gear shaft diameter	ø50 [1.97]	49.950 to 49.975 [1.96653 to 1.96752]		49.900 [1.96456]	
		Front idler gear end play		(0.2 to 0.4) [(0.008 to 0.016)]		(0.6) [(0.024)]	
Fan drive idler gear end play			0.25 to 0.75 [0.0098 to 0.0295]		1.2 [0.047]		

MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark	
Engine main parts	Front gear	Fan drive idler bushing inside diameter	ø50 [1.97]	50.000 to 50.025 [1.96850 to 1.96948]		50.060 [1.97086]		
		Fan drive idler shaft outside diameter	ø50 [1.97]	49.950 to 49.975 [1.96653 to 1.96752]		49.900 [1.96456]		
	Timing gear	Backlash			(0.12 to 0.18) ([0.0047 to 0.0071])	(0.30) ([0.0118])	(0.50) ([0.020])	
		Rear idler bushing inside diameter	ø65 [2.56]	65.000 to 65.030 [2.55906 to 2.56024]		65.060 [2.56142]		
		Rear idler shaft diameter	ø65 [2.56]	64.951 to 64.970 [2.55713 to 2.55787]		64.900 [2.55512]		
		Idler gear end play			(0.3 to 0.6) ([0.012 to 0.024])		(1.0) ([0.039])	
	Camshaft	Cam lift (A-B)	9.247 [0.36405]	9.197 to 9.297 [0.36208 to 0.36602]		8.45 [0.3327]		
		Deflection		0.05 [0.0020] or less	0.08 [0.0031]		Deflection at center bushing measured with both ends supported. Repair or replace, if necessary.	
		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 [3.30708 to 3.30846]		84.10 [3.3110]	Replace bushings and ream them, if necessary.	
		End play	8 [0.31]	(0.10 to 0.25) ([0.0039 to 0.0098])		(0.40) ([0.0157])	Replace thrust plate, if necessary.	

MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection point	Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Engine main parts	Crankshaft	Crankpin diameter	∅125 [4.92]	124.930 to 124.950 [4.91724 to 4.91803]	124.890 [4.91567]	
		Crank journal diameter	∅170 [6.69]	169.920 to 169.940 [6.68685 to 6.68764]	169.890 [6.68567]	
		Center to center distance between journal and crankpin	90 [3.54]	89.90 to 90.10 [3.536 to 3.5444]		
		Parallelism between journal and crankpin		0.01 [0.0004] or less at pin length	0.03 [0.0012]	
		Circularity of journal and crankpin		0.01 [0.0004] or less in diameters	0.03 [0.0012]	
		Cylindricity of journals and crankpins		0.01 [0.0004] or less in diameters	0.03 [0.0012]	
		Fillet radius of crankpins	7R [0.28]	6.8 to 7.0 [0.268 to 0.276]		
		Fillet radius of journals	8.5R [0.33]	8.3 to 8.5 [0.327 to 0.335]		
		Hardness of journal and crankpin		Hv>590		
		Angularity		±0°20'		
		Deflection		0.04 [0.0016] or less	0.10 [0.004]	
End play (Journal width at thrust bearing)	67 [2.64]	(0.20 to 0.40) [(0.0079 to 0.0157)]		(0.50) [(0.0197)] +1.18 [+0.0465] for crankshaft width	Replace thrust bearings if worn to repair limit. Use oversize thrust bearings if worn beyond repair limit. +0.25 [+0.0098], +0.50 [0.0197], +0.75 [0.0295]	

MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark	
Engine main parts	Main bearings	Thick-ness at center	STD	4.500 [0.17717]	4.467 to 4.480 [0.17587 to 0.17638]	4.425 [0.17421]	Replace bearings if worn to service limit. Re grind crank journals and use undersize bearings if worn beyond service limit.	
			-0.25 [-0.0098]	4.625 [0.18209]	4.592 to 4.605 [0.18079 to 0.18130]	4.550 [0.17913]		
			-0.50 [-0.0197]	4.750 [0.18701]	4.717 to 4.730 [0.18571 to 0.18622]	4.675 [0.18405]		
-0.75 [-0.0295]			4.875 [0.19193]	4.842 to 4.855 [0.19063 to 0.19114]	4.800 [0.18898]			
-1.00 [-0.0394]			5.000 [0.19685]	4.967 to 4.980 [0.19555 to 0.19606]	4.925 [0.19390]			
Crankcase	Flatness of gasket surface			0.1 [0.004] or less	0.2 [0.008]		Reface if necessary.	
	Main bearing bore diameter		ø179 [7.05]	179.000 to 179.025 [7.04723 to 7.04821]		179.045 [7.04900]		
Inlet and exhaust system	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 & turbine wheel	Journal diameter	ø24 [0.9449]		23.996 [0.9447]		
			Shaft deflection			0.015 [0.0006]		
		Piston ring gap clearance			(0.05 to 0.25) [0.0020 to 0.0098]			
		Clearance between shaft & turbine wheel and turbine housing			(0.58 to 1.32) ([0.0228 to 0.0520])			
	Shaft & turbine wheel end play in axial direction			(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])				

MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark	
Lubrication system	Oil pump	Drive and driven gears backlash		(0.100 to 0.200) ([0.0039 to 0.0079])		(0.400) ([0.0157])		
		Clearance between drive and driven gears in case	ø60 [2.36]	(0.100 to 0.148) ([0.00394 to 0.00583])		Tip clearance (0.350) ([0.0138])		
		Pump gear end clearance	72.5 [2.85]	(0.040 to 0.116) ([0.00157 to 0.00457])		(0.21) ([0.0083])	Remove the cover packing (width of 0.04 [0.0016]) for measurement.	
		Shaft diameter	Drive shaft	ø30 [1.18]	29.887 to 29.900 [1.17665 to 1.17717]		29.840 [1.17480]	
			Driven shaft		29.947 to 29.960 [1.17902 to 1.17953]		29.900 [1.17795]	
		Bushing inside diameter	30.000 to 30.021 [1.18110 to 1.18193]			30.055 [1.18327]		
	Safety valve	Valve opening pressure MPa (kgf/cm ²) [psi]		1.27±0.13 (13.0±1.3) [184.9±18.50]				
		Spring set length/load mm [in.]/ N (kgf) [lbf]		65.8 [2.59] /359 (36.6) [520.6]		65.8 [2.59] /314 (32) [455.1]		
	Relief valve	Valve opening pressure MPa (kgf/cm ²) [psi]		0.51±0.02 (5.2±0.2) [71.1±2.84]				
	Oil thermostat	Valve opening temperature		80 to 84°C [176 to 183.2°F]				
		Temperature at which valve lift is more than 11 mm [0.43 in.]		95°C [203°F]				
	Oil filter alarm	Lamp lighting and valve opening pressure (differential pressure) MPa (kgf/cm ²) [psi]		0.15 to 0.18 (1.5 to 1.8) [21.3 to 35.3]			Changed oil pressure is 6.86 kPa (0.07 kgf/cm ²) [1.00 psi] with a low 1 mm [0.039 in.] shim.	

MAINTENANCE STANDARDS

Unit: mm [in.]

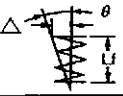
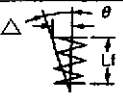
Group	Inspection point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark	
Lubrication system	Piston cooling nozzle	Valve opening pressure (differential pressure) MPa (kgf/cm ²) [psi]		0.26 to 0.32 (2.7 to 3.3) [38 to 47]				
Cooling system	Water pump	Bearing bore inside diameter	ø120 [4.72]	119.987 to 120.022 [4.72389 to 4.72527]			Same as the bearing cover.	
			ø110 [4.33]	110.005 to 110.040 [4.33090 to 4.33227]				
		Bearing Outside diameter	ø120 [4.72]	119.985 to 120.000 [4.72380 to 4.72441]				
			ø110 [4.33]	109.985 to 110.000 [4.33012 to 4.33071]				
		Bearing Inside diameter	ø55 [2.17]	54.985 to 55.000 [2.16476 to 2.16535]				
			ø50 [1.97]	49.988 to 50.000 [1.96802 to 1.96850]				
		Shaft bearing journal diameter	ø55 [2.17]	55.011 to 55.024 [2.16758 to 2.16629]				
			ø50 [1.97]	50.011 to 50.024 [1.96893 to 1.96944]				
		Vane front face clearance	1.04 [0.041]	(0.58 to 1.50) ([0.023 to 0.059])				
		Thermostat	Valve opening temperature		69 to 73°C [124.2 to 195.4°F]			
			Temperature at which valve lift is 11 mm [0.43 in.] or more		85°C [185°F]			Check at atmospheric pressure.

MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark	
Cooling system	Fan drive	Inside diameter of case in which bearing is installed	ø140 [5.51]	139.986 to 140.026 [5.51544 to 5.51702]				
			ø120 [4.72]	119.987 to 120.022 [4.72748 to 4.72886]				
		Bearing	Outside diameter	ø140 [5.51]	139.982 to 140.000 [5.51530 to 5.51600]			
				ø120 [4.72]	119.985 to 120.000 [4.72740 to 4.72800]			
		Inside diameter	ø55 [2.17]	54.985 to 55.000 [2.16640 to 2.16700]				
		Outside diameter of shaft on which bearing is installed	ø55 [2.17]	55.002 to 55.015 [2.16707 to 2.16760]				
Fuel system	Fuel injection nozzle	Valve opening pressure MPa (kgf/cm ²) [psi]	34.32 (350) [4979]	34.32 to 34.81 (350 to 355) [4977 to 5050]				
		Spray core 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 injection pump	Total clearance of taper roller section				0.2 [0.008]		
		Worn of tappet plunger contacting face				0.2 [0.008]		
		Outside diameter of camshaft oil seal	ø35 [1.38]	34.938 to 34.963 [1.3755 to 1.3765]		34.800 [1.37]		
		Camshaft deflection		0.05 [0.002]	0.15 [0.0059]			

Unit: mm [in.]

Group	Inspection point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark	
Fuel system	Perpendicularity of spring	Plunger spring				$\Delta = 1.8$ [0.071]	Lf=70.8 [2.79]	
		Delivery spring				$\Delta = 0.6$ [0.024]	Lf=18 [0.709]	
	Thrust clearance of camshaft			0.02 to 0.06 [0.0008 to 0.0024]				
	Sliding resistance of control rack			4.9 N (4.997 kgf) [1.1016 lbf] 500 g [1.102 lb.]			Ensure smooth rack operation, and set rack stroke to 36 mm [1.42 in.]	
	Injection interval			60±0.5°			Camshaft angle	
	Total stroke of control rack			36 [1.42]				
	Clearance between plunger and barrel			Replace plunger assembly if injection characteristics value exceeds -5% at 17mm [0.669 in.] rack position.				
	Air tightness test		There shall be no air leakage (air bubbles) from assembly.					Plug discharge port. Apply air pressure of 0.2 MPa (2 kgf/cm ²) [29 psi] to suction port and immerse in diesel fuel.
	Fuel feed pump	Oil feed pressure (pump at 100 min ⁻¹)			Discharge start time: 20 seconds or less			
		Suction capacity of priming pump			Discharge start: 30 strokes or less			
Oil feed rate (pump at 500 min ⁻¹)			Feed rate: 1100 cm ³ [67.126 cu in.] 15 sec. or more					
Electrical system	Starter	Commutator	Outside diameter	ø43 [1.69]		ø42 [1.65]		
			Deflection		0.06 [0.0024] or less	0.10 [0.0039]		
			Mica depth		0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]		
		Height of brushes			21 to 22 [0.83 to 0.87]		13 [0.51]	
		Tension of brush springs N (kgf) [lbf]		44.13 (4.5) [9.92]	39.23 to 49.03 (4.0 to 5.0) [9 to 11]		39.23 (4.0) [9]	


MAINTENANCE STANDARDS

Unit: mm [in.]

Group	Inspection Point		Nominal Value	Assembly Standards (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Electrical system	Starter	Armature	Diameter of rear side shaft	ø14 [0.55]	13.941 to 13.968 [0.54886 to 0.54992]		
			Diameter of front side shaft	ø25 [0.98]	25.002 to 25.011 [0.98433 to 0.98468]		
			Shaft deflection (1/2 valve of measurement at center journal shaft when shaft is supported at both ends)		0.05 [0.00197]		1/2 value of runout
		Pinion shaft	Diameter of rear side shaft	ø30 [1.18]	30.002 to 30.011 [1.18118 to 1.18153]		
			Diameter of front side shaft	ø19 [0.75]	18.900 to 18.940 [0.74409 to 0.74567]		
		Bearing	Front bearing	ø19 [0.75]	19.000 to 19.033 [0.7480 to 0.7493]		0.25 [0.0098]
			Pinion	ø19 [0.75]	19.000 to 19.033 [0.7480 to 0.7493]		0.25 [0.0098]
		Armature end play			0.15 to 0.75 [0.0059 to 0.0259]		
		Pinion shaft end play			0.2 to 0.8 [0.008 to 0.031]		
		Alternator	Output current	Rotation speed	1500 min ⁻¹	18 A or more (at warm room temperature)	
	2500 min ⁻¹			26A or more (at warm room temperature)			
	5000 min ⁻¹			30 A or more (at warm room temperature)			

MAINTENANCE STANDARDS

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]	
		Height of brush	21.5 [0.85]			8.0 [0.31]	Up to wear limit
		Tension of brush spring 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]	
		Regulator adjusting voltage (alternator: 5000 min ⁻¹ , load: 5 A or higher)		28.5±0.5 V			
		Resistance of field coil (at 20 °C [68 °F])		3.8 to 4.5 Ω			
		Alternator drive belt tension		10 to 15 [0.4 to 0.6]			Deflection when pressed with thumb 98 to 147 N (10 to 15kgf) [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	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Camshaft thrust plate	12 × 1.25 [0.472 × 0.0492]	59	6	43	
Main bearing caps	24 × 3.0 [0.945 × 0.118]	588	60	434	[Wet] Note (b)
Main bearing cap side bolts	20 × 2.5 [0.788 × 0.0984]	392	40	289	[Wet] Note (b)
Hanger	12 × 1.25 [0.472 × 0.0492]	392	40	289	Note (c)
	16 × 1.5 [0.63 × 0.0591]	216	22	159	
Piston cooling nozzle	12 × 1.75 [0.472 × 0.0689]	34	3.5	25	
Timing gear case	16 × 1.5 [0.63 × 0.0591]	255	26	188	2 lower bolts of right side bracket
Rear plate	12 × 1.25 [0.472 × 0.0492]	108	11	80	
	16 × 1.5 [0.63 × 0.0591]	216	22	159	
Oil pan	12 × 1.25 [0.472 × 0.0492]	59	6	43	
Front mounting bracket	20 × 1.5 [0.788 × 0.0591]	392	40	289	
		245	25	181	
Center mounting bracket	20 × 1.5 [0.788 × 0.0591]	392	40	289	
Rear mounting bracket	20 × 1.5 [0.788 × 0.0591]	392	40	289	
Connecting rod bearing caps	22 × 1.5 [0.866 × 0.0591]	539	55	398	[Wet] 2-step tightening method Note (d)
Balance weight	22 × 1.5 [0.866 × 0.0591]	490	50	362	[Wet]
Flywheel	22 × 1.5 [0.866 × 0.0591]	588	60	434	[Wet]
Ring gears	10 × 1.25 [0.394 × 0.0492]	59	6	43	
Damper	22 × 1.5 [0.866 × 0.0591]	490	50	362	
Rear idler shaft	20 × 1.25 [0.788 × 0.0492]	392	40	289	
Rear idler shaft (nut)	18 × 1.5 [0.709 × 0.0492]	196	20	145	
Front gear case	12 × 1.25 [0.472 × 0.0492]	59	6	43	
	16 × 1.5 [0.63 × 0.0492]	216	22	159	
Front plate	12 × 1.25 [0.472 × 0.0492]	59	6	43	



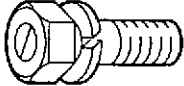

- Note: (a) To tighten cylinder head bolts according to the angle method, tighten snug torque to 294 N-m (30 kgf-m) [217 lbf-ft], then turn 60° more.
- (b) Make sure to tighten main bearing caps and main bearing cap side bolts according to the specified sequence.
- (1) Tighten the cap bolts to the specified torque.
 - (2) Tighten the side bolts on the right side of the engine.
 - (3) Tighten the side bolts on the left side of the engine.
- (c) 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.
- (d) 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±3° turn).
- (e) [Wet] indicates apply engine oil to the threads of the nuts and bolts.

Description	Thread Diameter × Pitch (M-thread) (mm [in.])	Torque			Remarks
		N-m	kgf-m	lbf-ft	
Front idler shaft	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Front idler gear 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	
Exhaust manifold mounting bolts	1/4 UNF: 28 [1.1024]	9	0.9	7	
Exhaust pipe V-clamp	10 × 1.5 [0.394 × 0.0591]	98	10	72	
Oil pump and water pump mounting plates	12 × 1.25 [0.472 × 0.0492]	59	6	43	
Bearing cover (oil pump and water pump)	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Injection pump drive case	12 × 1.25 [0.472 × 0.0492]	108	11	80	Tighten the slit part.
Injection pump gears (nuts)	30 × 1.5 [1.18 × 0.0591]	392	40	289	
Injection pump coupling shaft	14 × 1.5 [0.551 × 0.0591]	167 to 177	17 to 18	123 to 130	
Oil pump	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Oil pump cover	10 × 1.25 [0.394 × 0.0492]	33	3.4	25	
Oil pump safety valve	32 × 2.0 [1.26 × 0.0787]	74±10	7.5±1	54.6±0.74	
Oil pump safety valve (plug)	24 × 1.5 [0.945 × 0.0591]	88±10	9±1	64.9±0.74	
Water pump	12 × 1.25 [0.472 × 0.0492]	108	11	80	For alternator drive
Water pump shaft pulley (nuts)	30 × 1.5 [1.18 × 0.0591]	392	40	289	
Fuel filter air vent plug	—	8 to 10	0.8 to 1.0	5.8 to 7.2	
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 pump laminate plate	12 × 1.25 [0.472 × 0.0492]	103 to 113	10.5 to 11.5	76 to 83	
Injection pump flywheel (nuts)	24 × 1.5 [0.945 × 0.0591]	392	40	289	
Injection pump coupling shaft	14 × 1.5 [0.551 × 0.0591]	167 to 177	17 to 18	123 to 130	
Plunger assembly	12 × 1.25 [0.472 × 0.0492]	78 to 83	8 to 8.5	58 to 61	
Deliver valve holder	30 × 1.5 [1.18 × 0.0591]	235 to 255	24 to 26	174 to 188	
Injection nozzle gland (nuts)	14 × 1.5 [0.551 × 0.0591]	98	10	72	
Nozzle chip retaining nuts	28 × 1.5 [1.18 × 0.0591]	177 to 196	18 to 20	130 to 145	
Nozzle holder cap nuts	14 × 1.5 [0.551 × 0.0591]	69 to 78	7 to 8	51 to 58	
Nozzle holder set screw	10 × 1.5 [0.394 × 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 [0.708 × 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
Governor drive case	12 × 1.25 [0.472 × 0.0492]	108	11	80	
Starter	12 × 1.25 [0.472 × 0.0492]	59	6	43	T-bolt type Apply Moly Disulfide to thread. Note (a)
Air duct clamp	6 × 1.0 [0.236 × 0.0394]	4.9	0.5	3.6	
Turbocharger compressor wheel (nuts)	11 × 1.0 [0.433 × 0.0394]	—	—	—	
Turbocharger V-clamp	—	7.8 to 9.8	0.8 to 1.0	5.75 to 7.23	Apply Moly Disulfide to thread.

Note: (a) Tighten the lock nut to 69 N·m (7 kgf-m) [51 lbf-ft], then loosen. Tighten again to 9.8 N·m (1 kgf-m) [7.21 lbf-ft], then further turn 90 ± 3°.

MAINTENANCE STANDARDS

2.2 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).

2.3 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
M24 × 1.5 [(0.95 × 0.059)]	32 [1.26]	147±15	15.0±1.5	108.5±10.8
M27 × 1.5 [1.06 × 0.059]	—	226±20	23.0±2.0	166.3±14.5

(Dry)

2.4 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%)

2.5 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)

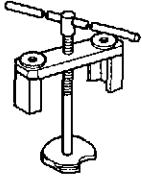
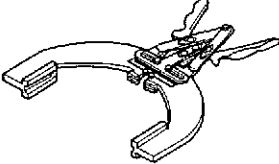
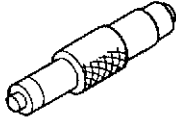
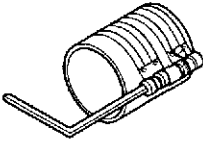
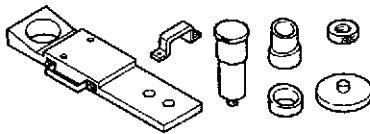
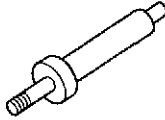
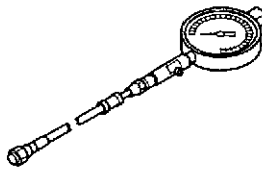

3. Sealants and Lubricants Table

Group	Application point		Sealant or lubricant	How to use
Engine main parts	Cylinder head sealing caps		Hermeseal S-2	Coat holes in crankcase
	Water outlet connectors (Rocker case)		Grease	Grease O-ring joint
	Cylinder liners		Engine oil	Grease O-ring joint
	Front plate, gear case, 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 ThreeBond)	Apply to tapered threads
	Oil pan and crankcase		Herdite	Coat joint portions only on both sides of packing
	Oil seals		Engine oil	Coat lip of each oil seal
	Front plate, front gear case, rear plate and timing gear case		ThreeBond 1212	Coat both sides of packing
	Drive case		ThreeBond 1212	Apply to flange surface
	Cylinder head gasket		ThreeBond 1212	Apply to areas around tappet chambers
Lubrication system	Oil pump	Cover and case	ThreeBond 1215	Coat both sides of packing
Cooling system	Water pump	Oil seal	Engine oil	Coat lip (only inner seal) of floating seat
		Unit seal	LLC solution (antifreeze)	
	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	Tapered threads of tapered plugs and cocks not coated with Seal-lock (ThreeBond) or plating film.		Vulcanized seal tape	Wrap threads with 2 rounds of tape.

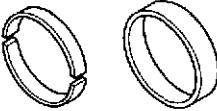
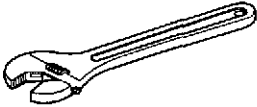
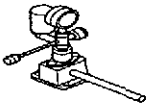
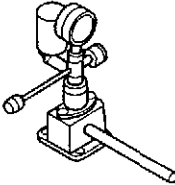
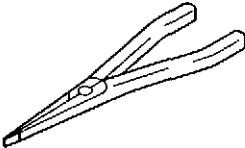
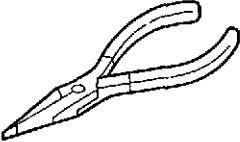
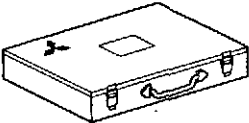
SPECIAL AND BASIC TOOLS

1. Special Tool List	3-2
2. Basic Tool List	3-8

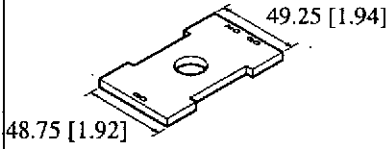
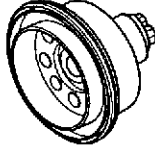
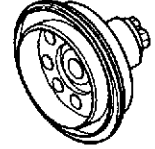
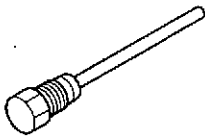


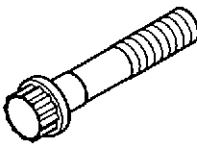
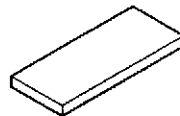
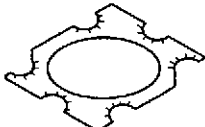
SPECIAL AND BASIC TOOLS

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.

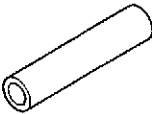
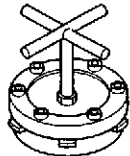
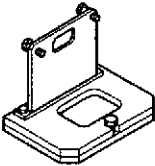
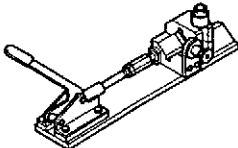
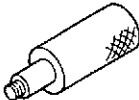
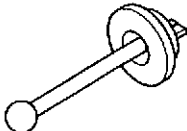
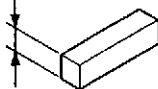
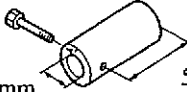
SPECIAL AND BASIC TOOLS

Tool name	Part No.	Shape	Use
Ring remover	37791-03400		Water pump unit seal ring removal
Adjustable wrench	F9611-15000		Width across flats 20 mm [0.79 in.] or less
Jack-bolt	64362-68500	 M12 x 1.25 (0.47 x 0.049) - 95 (3.74) Unit: mm [in.]	Oil pump and water pump plate removal, flywheel removal
Nozzle tester	83091-03301		Nozzle opening pressure measurement
Pliers	49160-90101		Snap ring (49162-23200) - removal/installation
Pliers	49160-90201		Snap ring (49181-22300) removal/installation
Tool box	49160-90501		75x203x360 mm [2.95x7.99x14.17 in.]

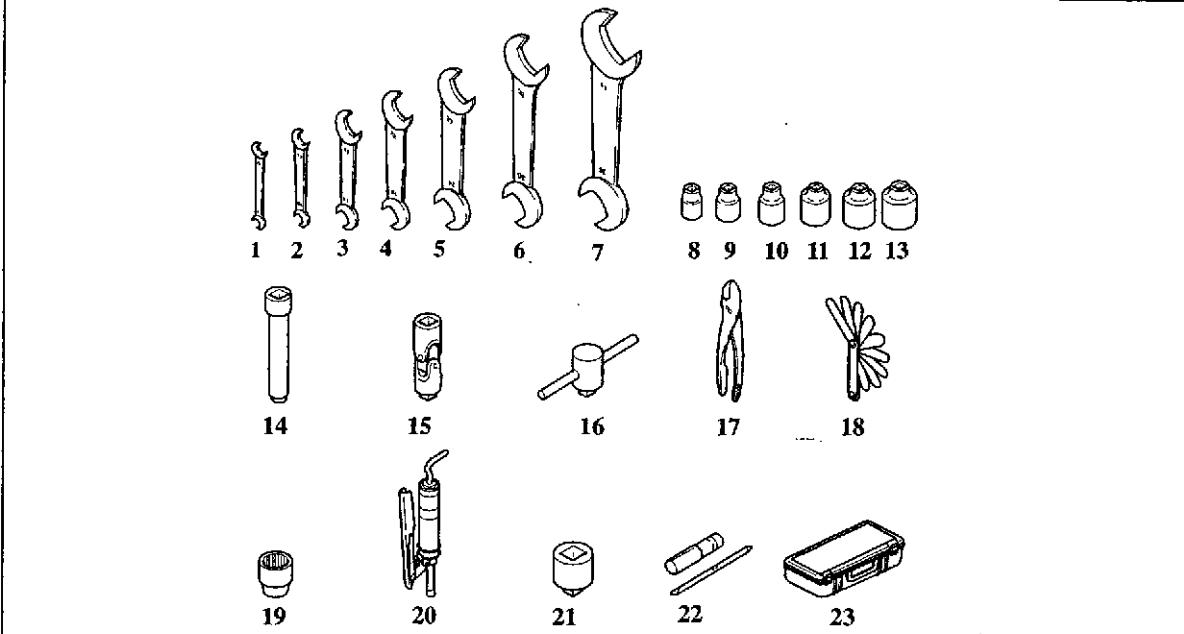
SPECIAL AND BASIC TOOLS

Tool name	Part No.	Shape	Use
Injection coupling gage	37591-06100	 <p>49.25 [1.94] 48.75 [1.92]</p>	Injection pump coupling connection
Front seal installer assembly	37591-05010		Front oil seal installation
Rear seal installer assembly	37791-06010		Rear oil seal installation
Valve seat cutter shaft	37591-06400		Valve seat contact surface adjustment
Valve seat cutter	37591-06430		
Liner pusher	37591-06200		Liner retainment
Bolt	37591-06300		
Projection plate	37598-09201		Crankcase counter bore depth measurement
Head bolt plate	37598-08900		Head-bolt tightening through an angle

SPECIAL AND BASIC TOOLS

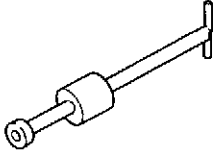
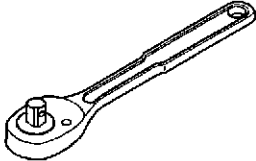
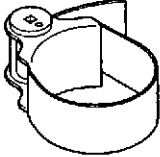
Tool name	Part No.	Shape	Use
Head bolt spacer	37598-09100		Spacer used for tightening liner pusher with head bolt
Cylinder grinder	37591-07010		For correction of right/left depth of liner shelf in crankcase
Pump assembly stand	48291-00100		For disassembly and reassembly of pump
Plunger spring compression 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	<p data-bbox="732 1329 992 1356">Square = 11 mm [0.43 in.]</p> 	For prevention of damage to pinion and rack during barrel installation
Rack setting jig	48291-00600	<p data-bbox="764 1514 1000 1541">M8 mm [0.315 in.] bolt</p>  <p data-bbox="659 1619 764 1675">ø 18 mm [0.709 in.]</p> <p data-bbox="894 1608 1000 1665">57 mm [2.244 in.]</p>	

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. gal]
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

SPECIAL AND BASIC TOOLS

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

SPECIAL AND BASIC TOOLS

OVERHAUL INSTRUCTIONS

1. Determination of Overhaul Timing 4-2
2. Testing the Compression Pressure 4-3

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 the necessity of engine overhaul are as follows:

- (a) Decreased 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 poor setting of the inlet and the exhaust 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. Of the items listed above some are not directly related to the necessity of engine overhaul. Items (b) and (f) are more likely to be affected substantially by

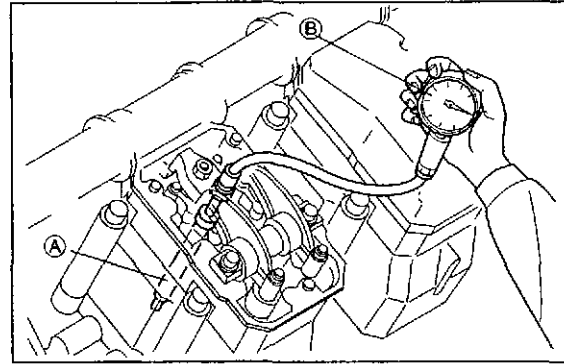
- Injection volume of the fuel injection pump
- Fuel injection timing
- Wear of injection pump
- Fitting of the injection nozzle
- Condition of electrical equipment: battery, starter, or alternator.

Item (d) above, however, requires special consideration because decreased pressure due to wear 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 decision 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 head where the compression pressure is to be measured.
- (2) Attach the compression gage adapter (A) (37591-02200) to the adapter and connect the compression gage (B) (33391-02100).
- (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.



Testing the compression pressure

CAUTION

- (a) Measure the compression pressure on all cylinders. It is not a good practice to measure the compression pressure on only few cylinders, and presume the compression on the remaining cylinders.
- (b) Compression pressure varies with changes in engine speed.
Check engine speed when measuring the compression pressure.

Unit: MPa (kgf/cm²) [psi]

Item	Assembly Standard	Repair Limit
Compression pressure	1.81 (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.

OVERHAUL INSTRUCTIONS

ADJUSTMENTS, BENCH TESTING, AND PERFORMANCE TESTS

1. Adjustments	5-2
1.1 Valve Clearance	5-2
1.2 Fuel System Bleeding	5-5
1.3 Fuel Injection Timing Adjustment	5-7
1.4 Idling Speed and Maximum Speed Setting Inspection and Adjustment	5-9
1.5 Alternator Drive Belt Inspection and Adjustment	5-9
2. Bench Testing	5-10
2.1 Starting Up	5-10
2.2 Inspection After Starting Up	5-10
2.3 Bench Testing (Dynamometer) Conditions	5-10
2.4 Inspection and Adjustments After Bench Testing	5-10
3. Performance Tests	5-11
3.1 Engine Equipment Condition	5-11
3.2 Tests and Their Purposes	5-11
3.3 Other Inspections	5-11
3.4 Engine Output Adjustment	5-11

1. Adjustments

1.1 Valve Clearance

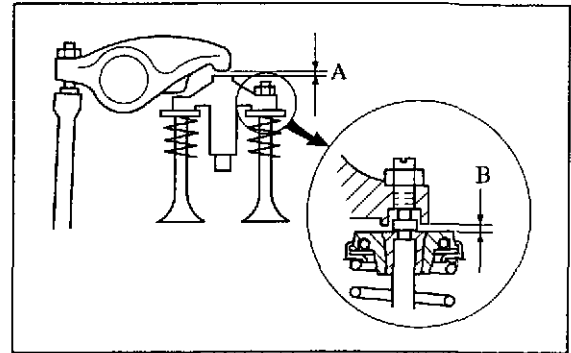
Valve clearance should be inspected and adjusted when the engine is cold.

Unit: mm [in.]

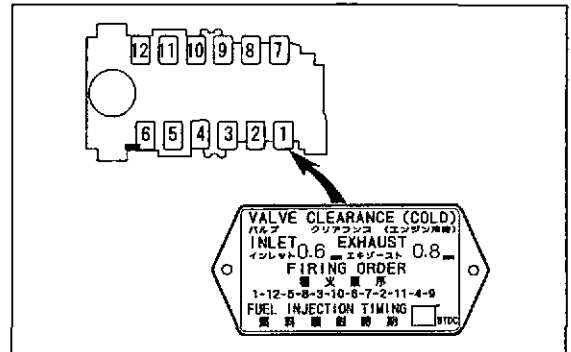
Item		Assembly Standard
Valve clearance (Cold)	Inlet valves	0.6 [0.024]
	Exhaust valves	0.8 [0.031]

NOTE

- 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.
- Looking toward the cylinder head, the inlet valves are on the left, the exhaust valves on the right.
- The specified clearances for the valves are indicated on the caution plate fitted to the No.1 cylinder rocker cover.



Inspecting and adjusting valve clearance (1)



Inspecting and adjusting valve clearance (2)

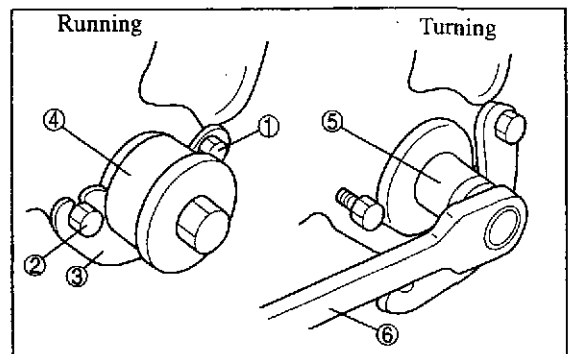
(1) Inspecting valve clearance

- Inspect the valve clearance in the firing order by turning the crankshaft (60°) in the direction of normal rotation to bring the piston to top dead center of the compression stroke.

Firing order: 1-12-5-8-3-10-6-7-2-11-4-9

Using the turning gear

- 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.
- Make the shaft ④ turn by rotating it with the socket ⑤ and the ratchet handle ⑥. Push down the ratchet handle ⑥ to turn the crankshaft in the normal direction.



Using the turning gear

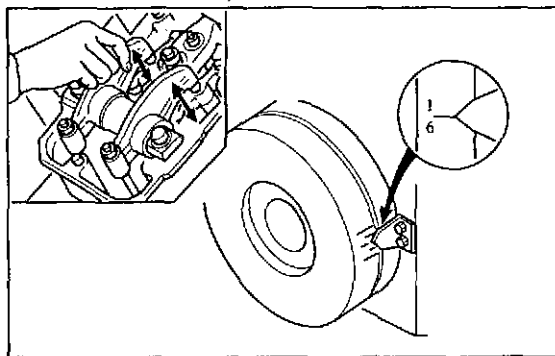
Injection start interval	0° -60° -90° -150° -180° -240° -270°
	-330° -360° -420° -450° -510° -540°
	-600° -630° -690°

- (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.

CAUTION

Make sure that the turning gear is at the running position before you start the engine.

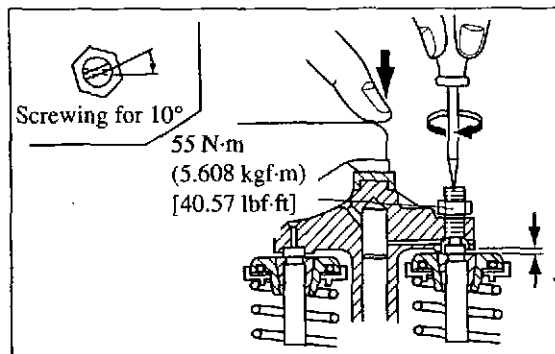
- (b) The top dead center on the compression stroke of the piston is identified by the timing mark (provided on the damper), aligned with the pointer. With the piston so located, the inlet and exhaust valve rocker arms are not pushed up by their push rods.
- (c) Insert feeler gages in between the rocker arm and bridge cap, and inspect the valve clearance.



Checking the top dead center on the compression stroke for No. 1 cylinder

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

- (a) Before adjusting the valve clearance, adjust the bridge to the front and rear valve tops with the bridge adjusting screw (bring the bridge into contact with the valves). If the valve seats are worn, valve heights will differ, causing gap between stem top and bridge.
- (b) To adjust valve height, loosen the lock nut, then back off the adjusting screw.
- (c) Push down the rocker arm with your fingers, and slowly screw in the adjusting screw until it touches the valve stem top. After looking into the inspection hole of the bridge to check that the screw is in contact with the stem top, turn the screw about 10° more, and tighten the lock nut.



Adjusting front and rear valve heights by the valve bridge

CAUTION

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 specified value or more.

(3) Tightening priming pump cap

- (a) Tighten the priming pump cap ① 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 $90^\circ \pm 10^\circ$ using a wrench.

NOTE

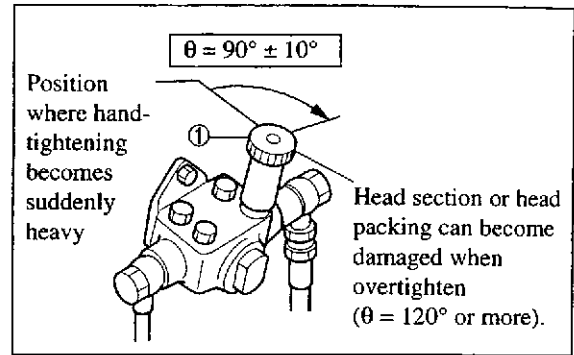
After tightening the priming pump cap, check that the priming pump head packing is not projecting.

CAUTION

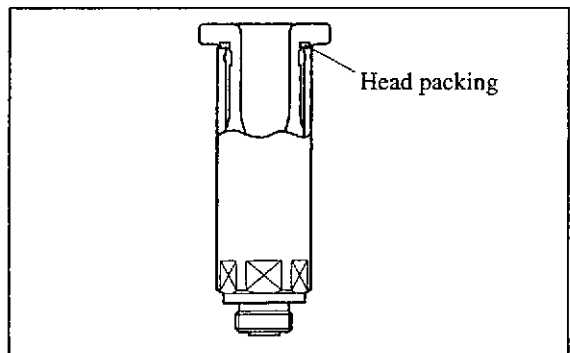
Be sure to tighten the priming pump cap according to the specified angle ($\theta = 90^\circ \pm 10^\circ$). If the priming pump cap is not tightened firmly, engine operations can result in the wear of internal threads. This can cause the priming pump cap to eject and fuel to flow out. If the priming pump cap is tightened with excessive force ($\theta = 240^\circ$ or more), the head section of the priming pump can be 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.



Tightening priming pump cap



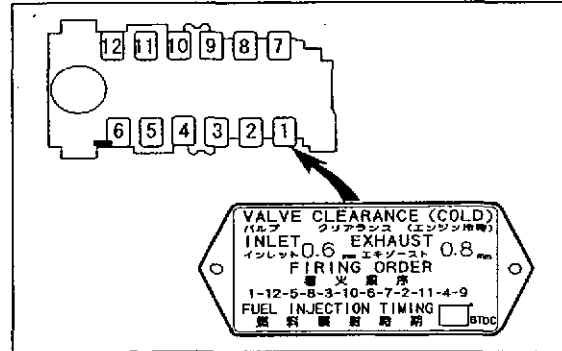
Cross section of priming pump

1.3 Fuel Injection Timing Adjustment

Right-hand Injection Pump

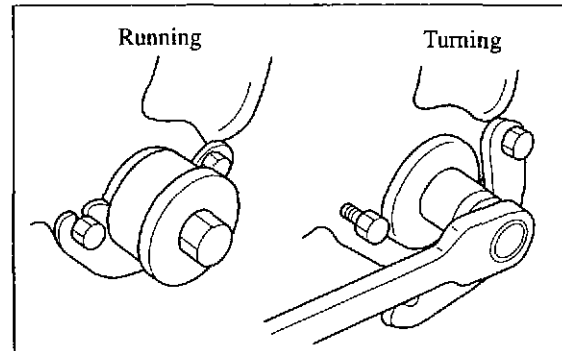
(1) Fuel injection timing and indication

The injection timing is stamped on the caution plate fitted 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.

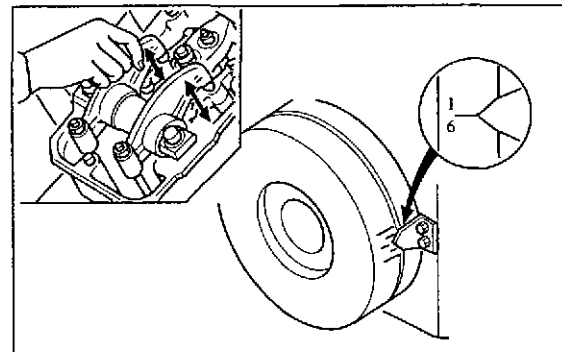


(2) Confirming No. 1 cylinder top dead center on the compression stroke

- (a) Use the ratchet handle to turn the crankshaft. Push down the ratchet handle to turn in the normal direction.



- (b) Stop turning when the timing mark "1•6" on the 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.

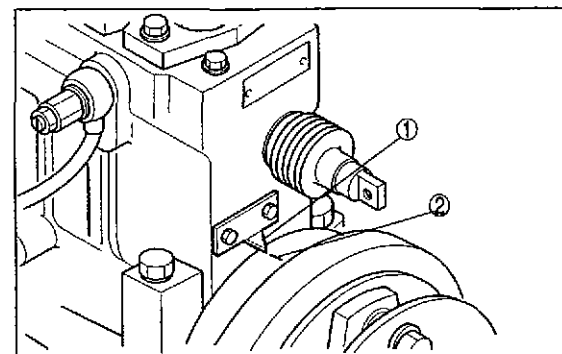


CAUTION

Do not confuse the top dead center on the compression stroke for No. 1 cylinder with that for the No. 8 cylinder.

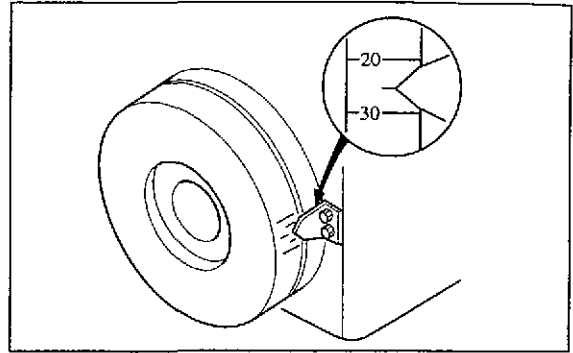
(3) Inspecting fuel injection timing

- (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 flywheel with the pointer ① on the pump case.



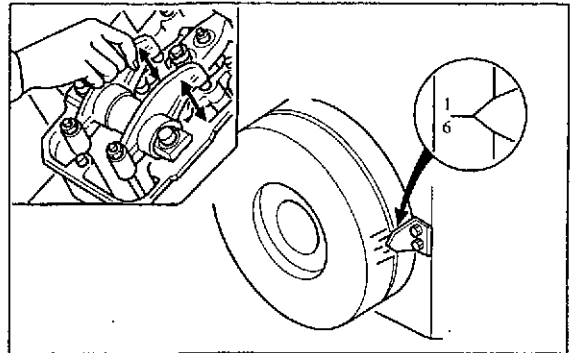
ADJUSTMENTS, BENCH TESTING, AND PERFORMANCE TESTS

- (b) Read the degree of an angle (injection timing) scale on the damper, indicated by the pointer minus (-) mark on the scale. BTDC on the caution plate means "Before Top Dead Center."

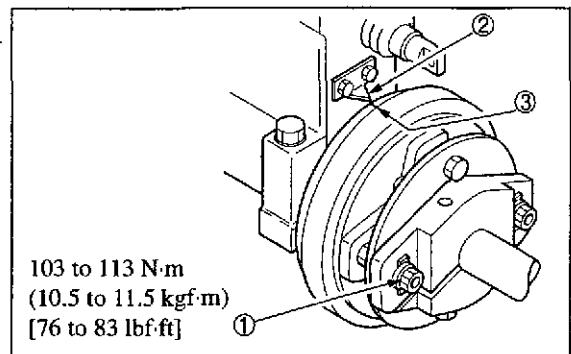


(4) Adjusting fuel injection timing

- (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.



Left-hand Fuel Injection Pump

On this pump, the position where the pointer is aligned with the index numbers "9-16" on the damper is top dead center on the compression stroke of the No. 9 cylinder piston. At this position, both inlet and exhaust valves of that cylinder should have the specified clearance.

For subsequent steps, follow the same procedure outlined for the right-hand injection pump.

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 Alternator Drive Belt Inspection and Adjustment

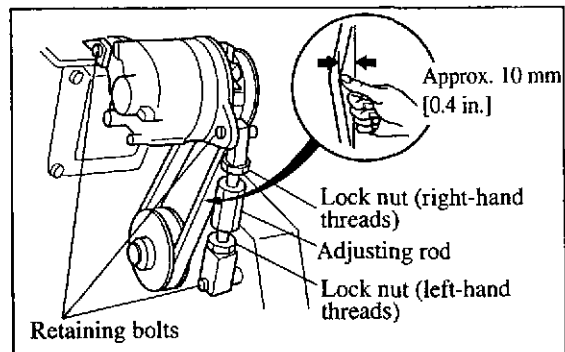
With your thumb apply pressure approx. 98 to 147 N (10 to 15 kgf) [22 to 33 lbf] to the belt midway between the pulleys to inspect the belt tension. If the tension is incorrect, adjust it with the adjusting rod.

Unit: mm [in.]

Item	Assembly Standard
Belt tension	10 to 15 [0.4 to 0.6]

CAUTION

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) Crank the engine with the starter for about 10 seconds to permit lubricating oil to circulate through the engine.
- (3) Move the speed control lever slightly in the direction of increasing fuel injection, then turn the starter switch to START to start the engine. Do not move the control lever to the full "fuel injection" position.
- (4) After the engine starts, let it idle under no load by operating the speed control lever.

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 0.64 MPa (5 to 6.5 kgf/cm²) [71 to 92 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)
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

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 Engine Output Adjustment

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]

ADJUSTMENTS, BENCH TESTING, AND PERFORMANCE TESTS

(2) Calculation of corrected power

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

$$\text{Corrected output} = \text{Correction factor } (\alpha_c) \times \text{Measured brake power}$$

• 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)

$$\alpha_c = (f_a)^{f_m} \quad f_a: \text{Atmospheric factor} \quad f_m: \text{Engine factor}$$

(a) Calculation of atmospheric factor (fa)

① Natural aspiration engine and engine with mechanically driven air charger

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

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

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

③ Turbocharged engine with air-to-liquid cooler

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

(b) Calculation of engine factor (fm)

$$f_m = 0.036 q_c - 1.14$$

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

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

$$z = 120000 \text{ (4-cycle engine)}$$

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)

$$37.2 \leq q_c \leq 65 \text{ mg}/(\ell\text{-cycle})$$

$$\bullet q_c \leq 37.2 \text{ mg}/(\ell\text{-cycle}) : f_m = 0.2 \text{ (Constant)}$$

$$\bullet 65 \text{ mg}/(\ell\text{-cycle}) \leq q_c : f_m = 1.2 \text{ (Constant)}$$

(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 AUXILIARIES REMOVAL AND INSTALLATION

1. Preparation	6-2
2. Engine Auxiliaries Removal	6-2
3. Engine Auxiliaries Installation	6-17
3.1 General	6-17
3.2 Installation of Fuel Injection Pump (Right)	6-18
3.3 Installation of Fuel Injection Pump (Left)	6-21
3.4 Adjustment of Run-on Solenoid	6-22
4. Adjusting Governor Controller	6-23
4.1 Wiring Controller	6-23
4.2 Initial Settings of Controller	6-23
4.3 Adjusting Governor during Idling	6-24

ENGINE AUXILIARIES REMOVAL AND INSTALLATION

This section explains procedures and tips for removal and installation of the auxiliaries, the preliminary procedures before overhauling the engine.

1. Preparation

- (a) Shut off the fuel supply and disconnect the starting system from the engine.
- (b) Loosen the drain plugs on both sides of the crankcase and drain the coolant.
- (c) Loosen the oil drain plug, and drain the engine oil.

Oil capacity: approx. 180 liters [47.56 U.S. gal]

⚠ WARNING

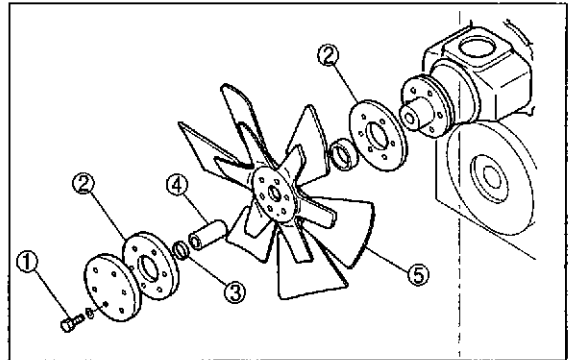
Hot engine oil can cause personal injury if it contacts the skin. Be cautious when you drain the oil.

2. Engine Auxiliaries Removal

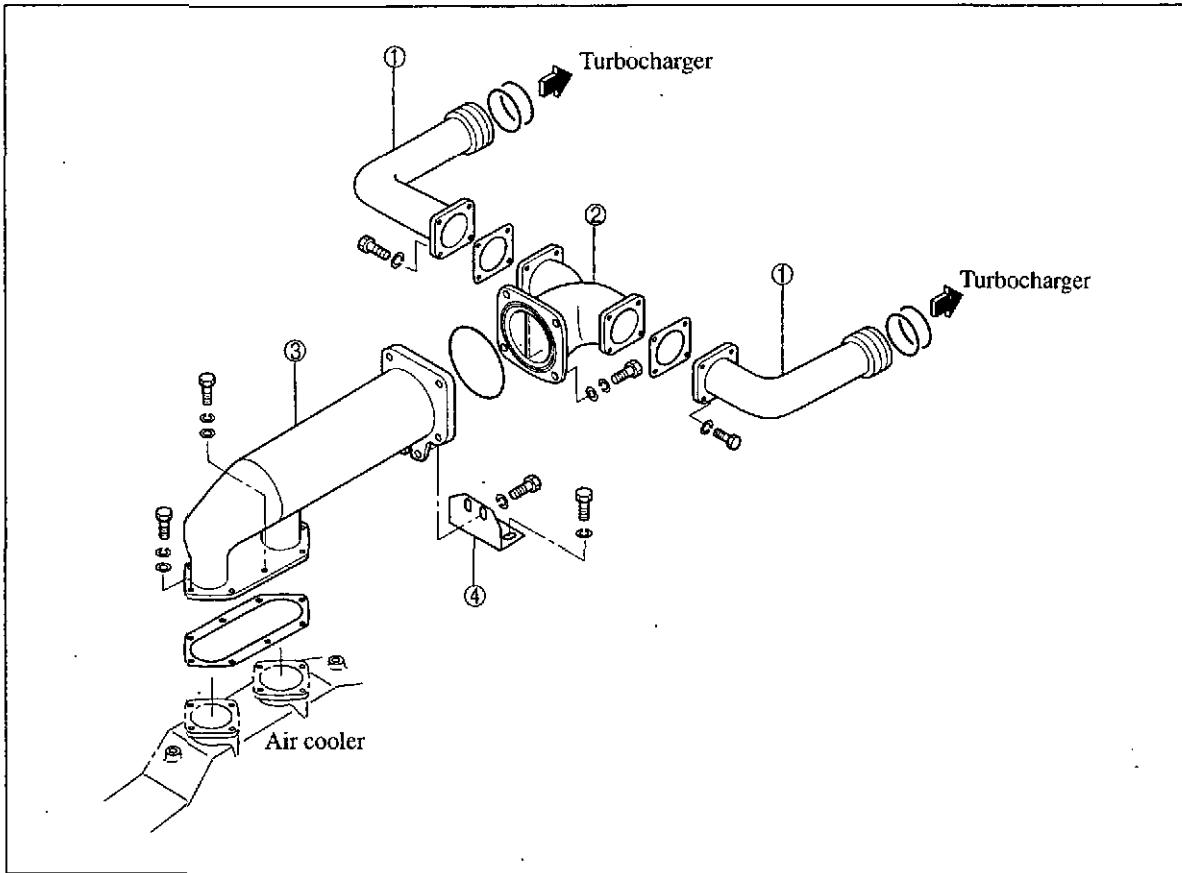
(1) Removing fan

Remove the plate attaching bolts①, and remove the friction rubbers ②, grommet③, spacer④ and fan⑤.

Weight: approx. 40 kg [88 lb.]



(2) Removing air duct (between turbocharger and air cooler)

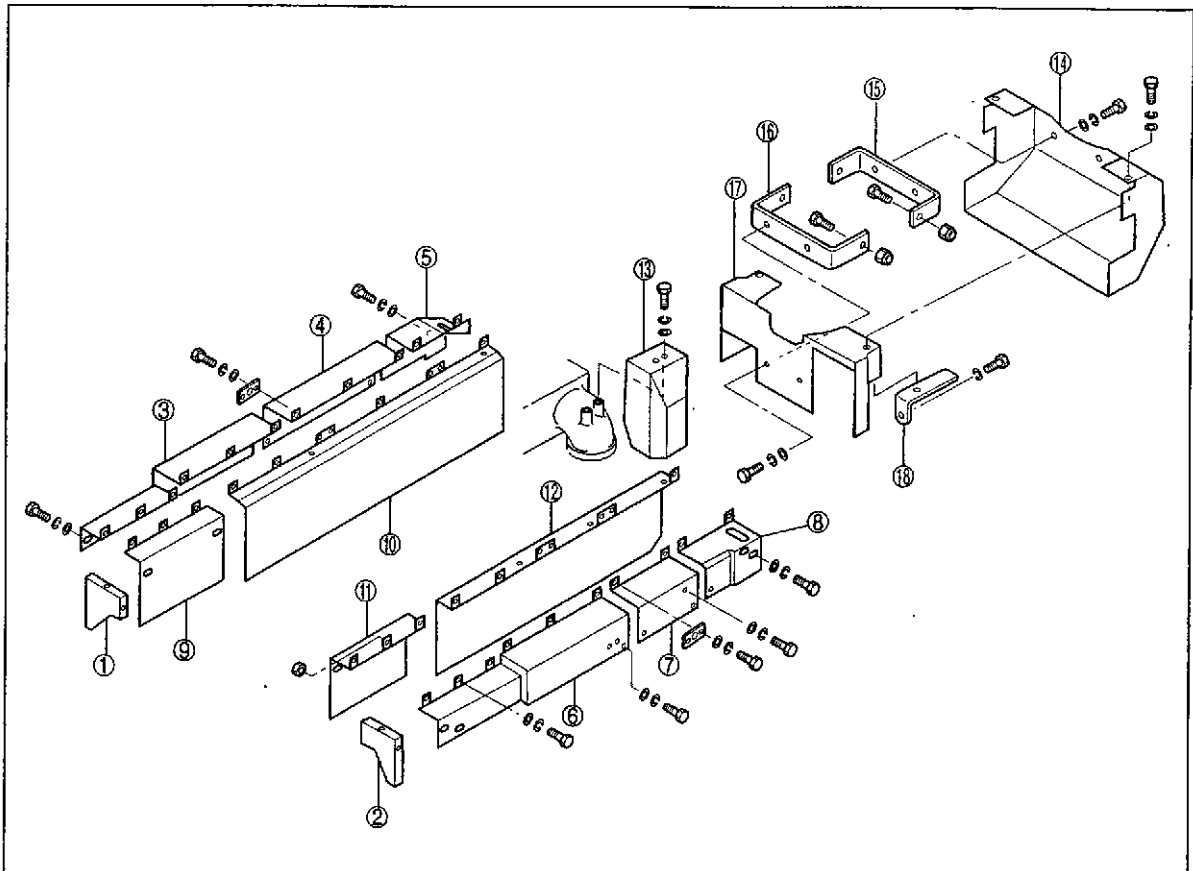


- ① Air duct
- ② Air duct

- ③ Air duct
- ④ Duct stay

ENGINE AUXILIARIES REMOVAL AND INSTALLATION

(3) Removing insulator (between exhaust manifold and turbocharger)



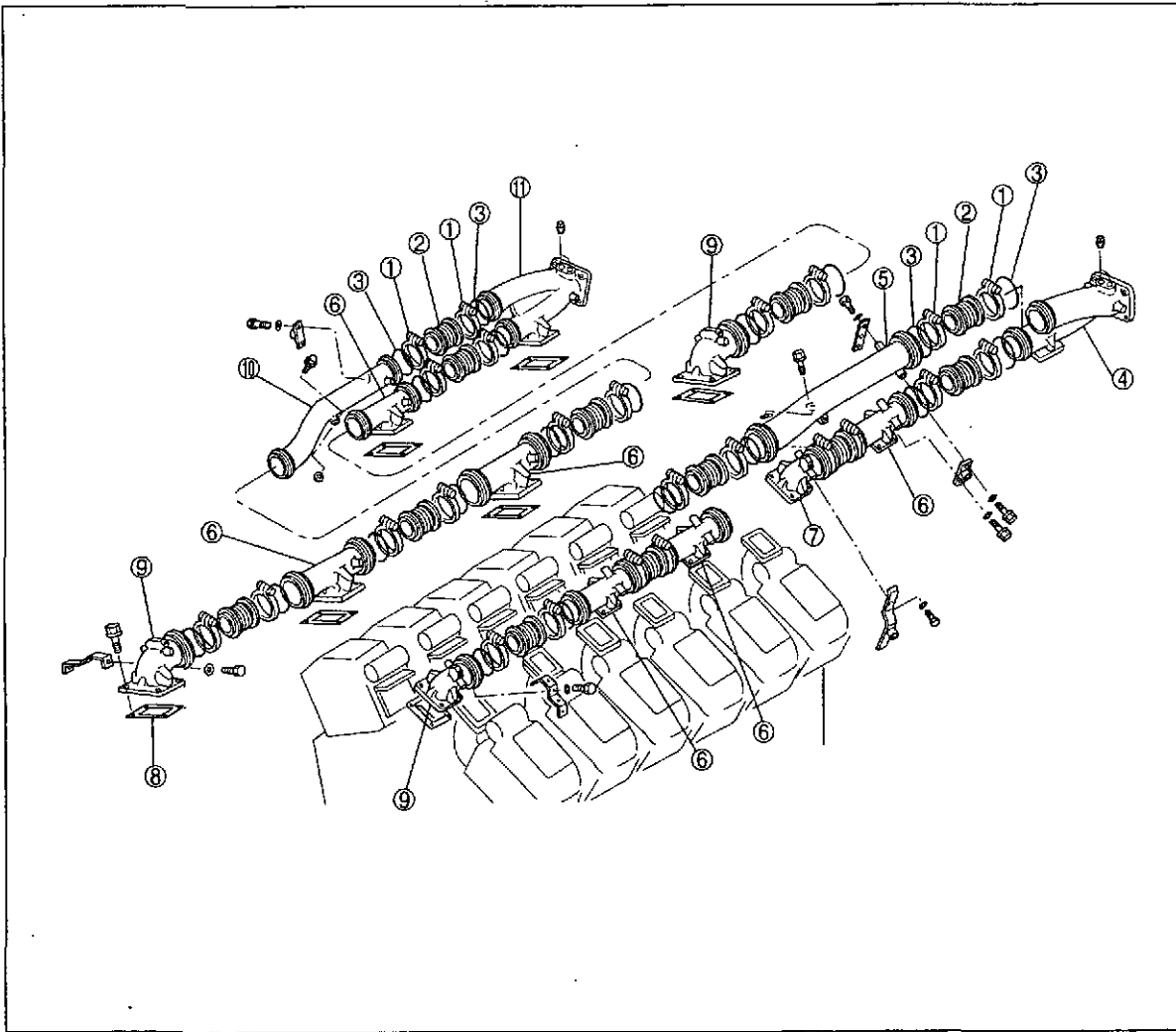
(a) Remove insulator from exhaust manifold.

(b) Remove insulator from turbocharger.

- ① Front cover (right)
- ② Front cover (left)
- ③ Insulator (right)
- ④ Insulator (right)
- ⑤ Insulator (right)
- ⑥ Insulator (left)
- ⑦ Insulator (left)
- ⑧ Insulator (left)
- ⑨ Front insulator (right)
- ⑩ Insulator (right)
- ⑪ Front insulator (left)
- ⑫ Insulator (left)

- ⑬ Insulator
- ⑭ Rear insulator
- ⑮ Stay
- ⑯ Front insulator
- ⑰ Stay
- ⑱ Plate

(4) Removing exhaust manifold

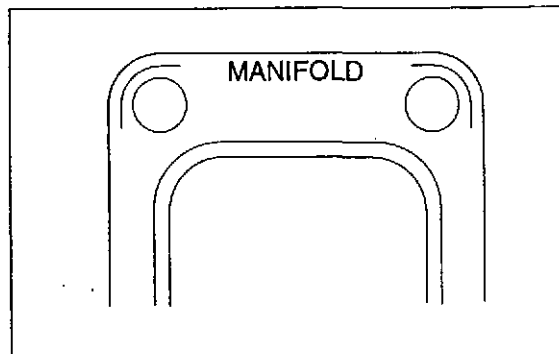


- ① Coupling
- ② Flexible joint
- ③ Joint gasket
- ④ Exhaust manifold
- ⑤ Exhaust manifold
- ⑥ Exhaust manifold

- ⑦ Exhaust manifold
- ⑧ Exhaust gasket
- ⑨ Exhaust manifold
- ⑩ Exhaust manifold
- ⑪ Exhaust manifold

NOTE

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

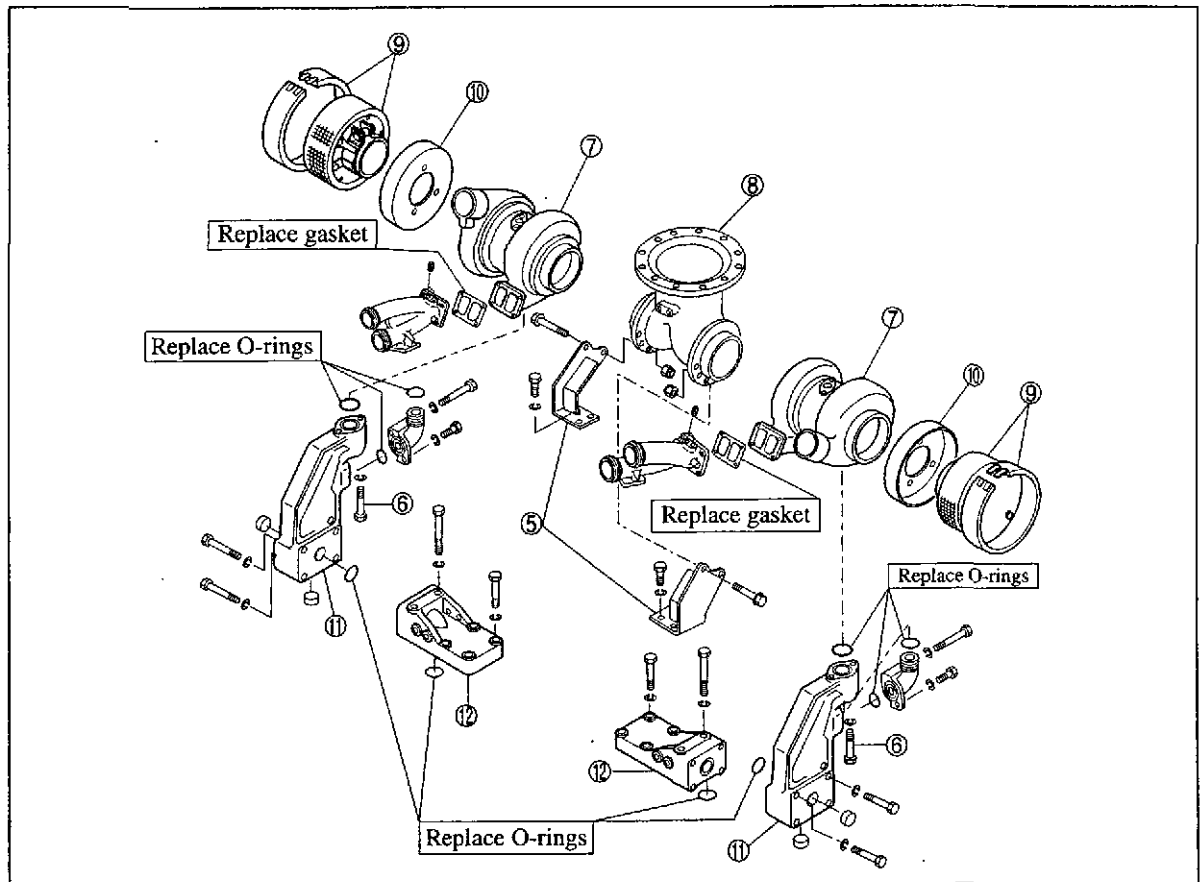
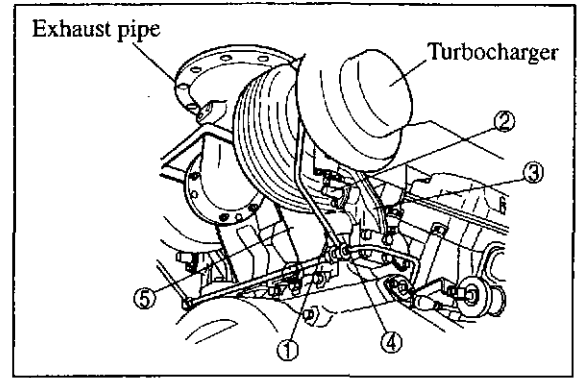


Manifold gasket

ENGINE AUXILIARIES REMOVAL AND INSTALLATION

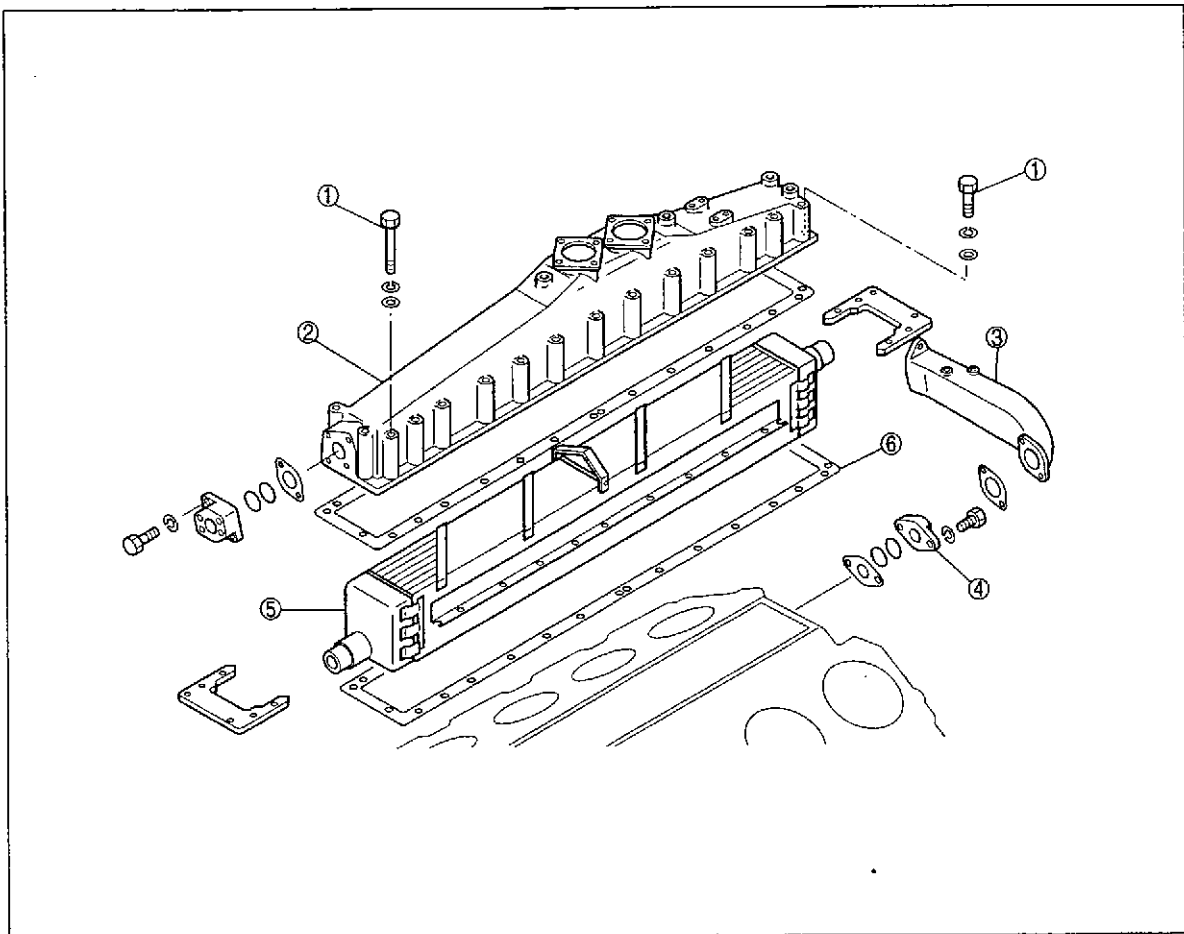
(5) Removing turbocharger and exhaust pipe

- ① Oil pipe
- ② Connector
- ③ Brackets
- ④ Brackets
- ⑤ Exhaust pipe stay



- ⑥ Bolt
- ⑦ Turbocharger
- ⑧ Exhaust pipe
- ⑨ Silencer assembly
- ⑩ Silencer cover
- ⑪ Bracket
- ⑫ Turbocharger bracket

(6) Removing air cooler



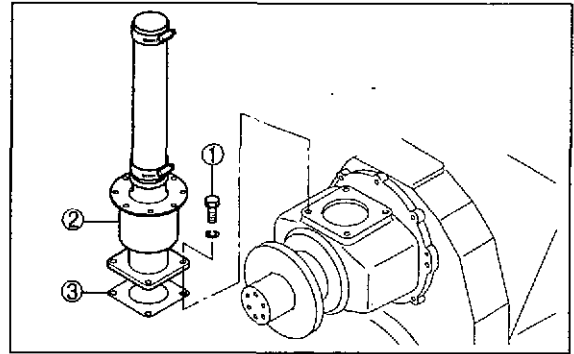
Disassembly sequence

- | | |
|--------------------|----------------------|
| ① Bolt | ④ Connector |
| ② Air cooler cover | ⑤ Air cooler element |
| ③ Water connector | ⑥ Gasket |

ENGINE AUXILIARIES REMOVAL AND INSTALLATION

(7) Removing breather

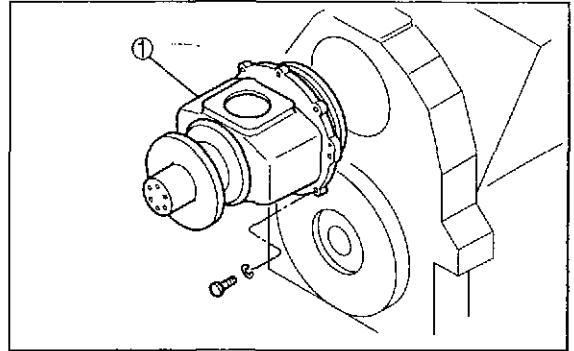
- (a) Remove the bolt ① and breather assembly ②.
- (b) Remove the packing ③.



(8) Removing fandrive

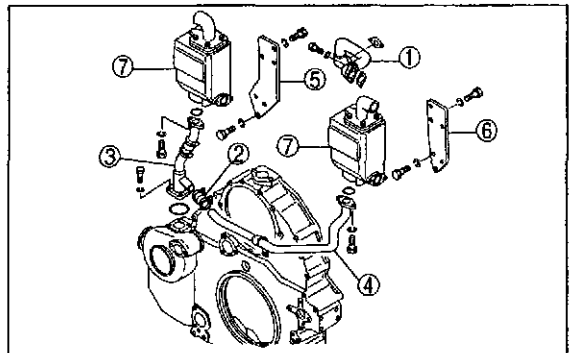
- (a) Remove the fan drive attaching bolts and fan drive ①.

Weight: approx. 45kg [99 lb.]



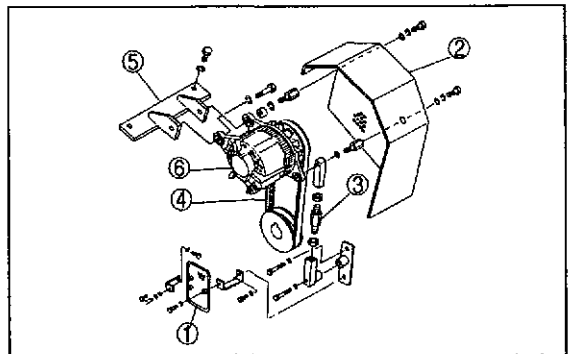
(9) Removing thermostat

- (a) Remove the water pipe ①.
- (b) Remove coupling ② and remove bypass pipe ③ and ④.
- (c) Remove thermostat bracket ⑤ and ⑥, then remove the thermostat ⑦.



(10) Removing alternator

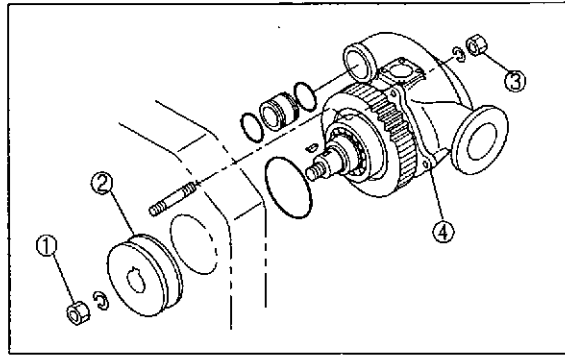
- (a) Remove the belt cover ① and ②.
- (b) Loosen the belt adjust turn buckle ③. Remove the V-belt ④.
- (c) Remove the bracket ⑤. Remove the alternator ⑥.



(11) Removing water pump

- (a) Remove the nut ① of the water pump shaft. Remove the alternator driving pulley ②.
- (b) Remove the water pump ④ by unscrewing the nuts ③ and stud.

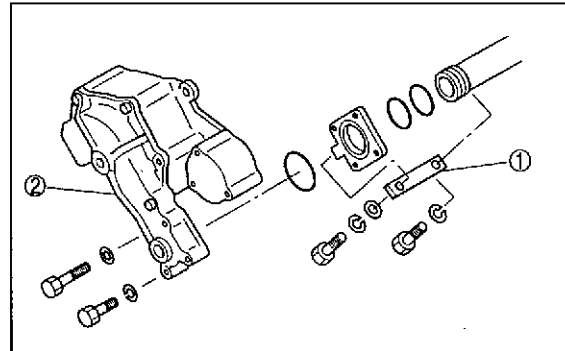
Weight: approx. 33 kg [73 lb.]



(12) Removing oil pump

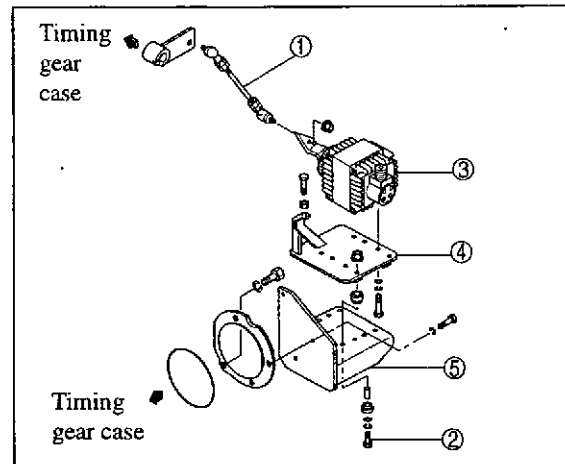
- (a) Remove the connection stay ① from the oil pipe located under the oil pump.
- (b) Unscrew the oil pump mounting bolts, then remove the oil pump ②.

Weight: approx. 22 kg [48.4 lb.]



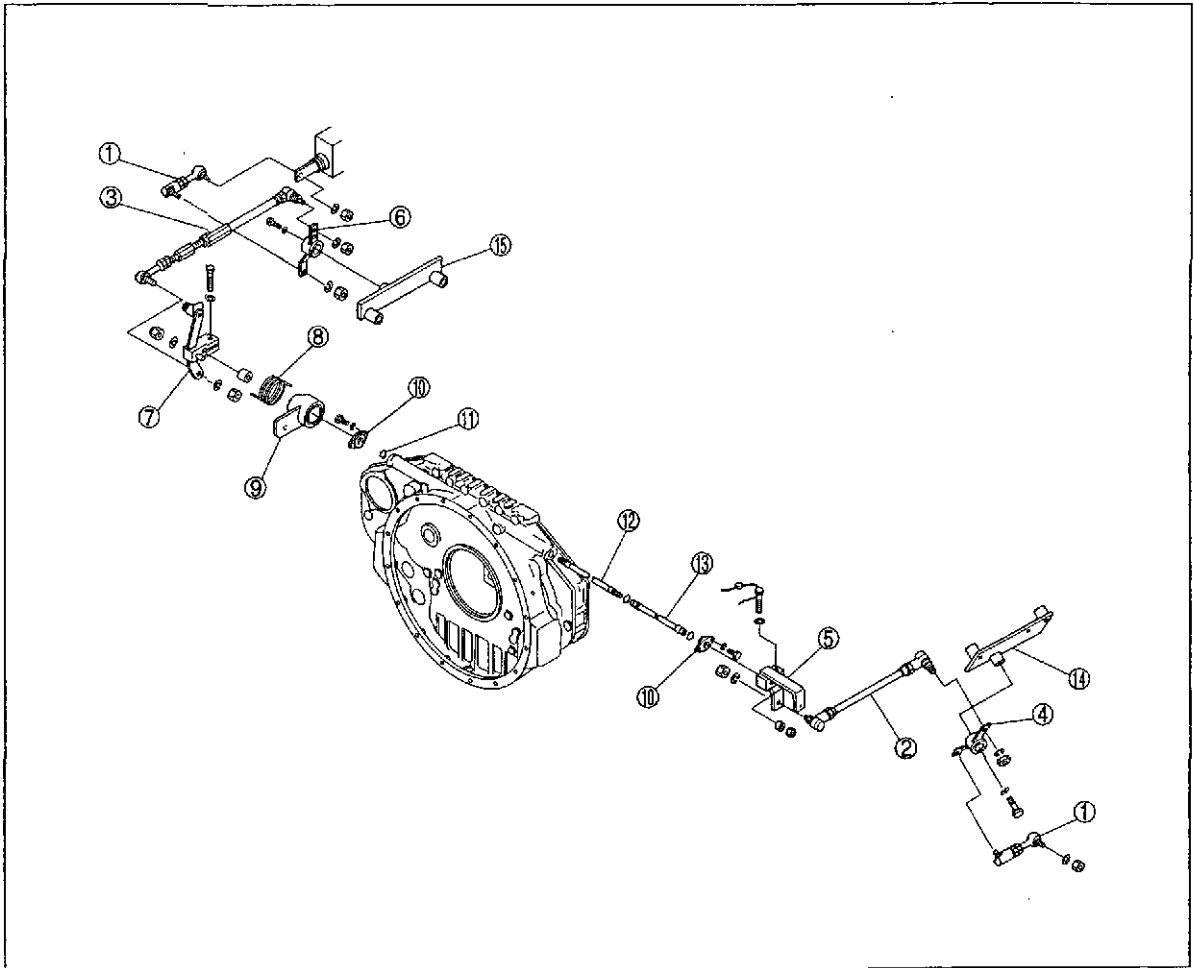
(13) Removing actuator

- (a) Disconnect the ball joint ① of the fuel controller.
- (b) Remove the bolts ②, and detach the actuator ③ and the actuator plate ④.
- (c) Remove actuator bracket ⑤.



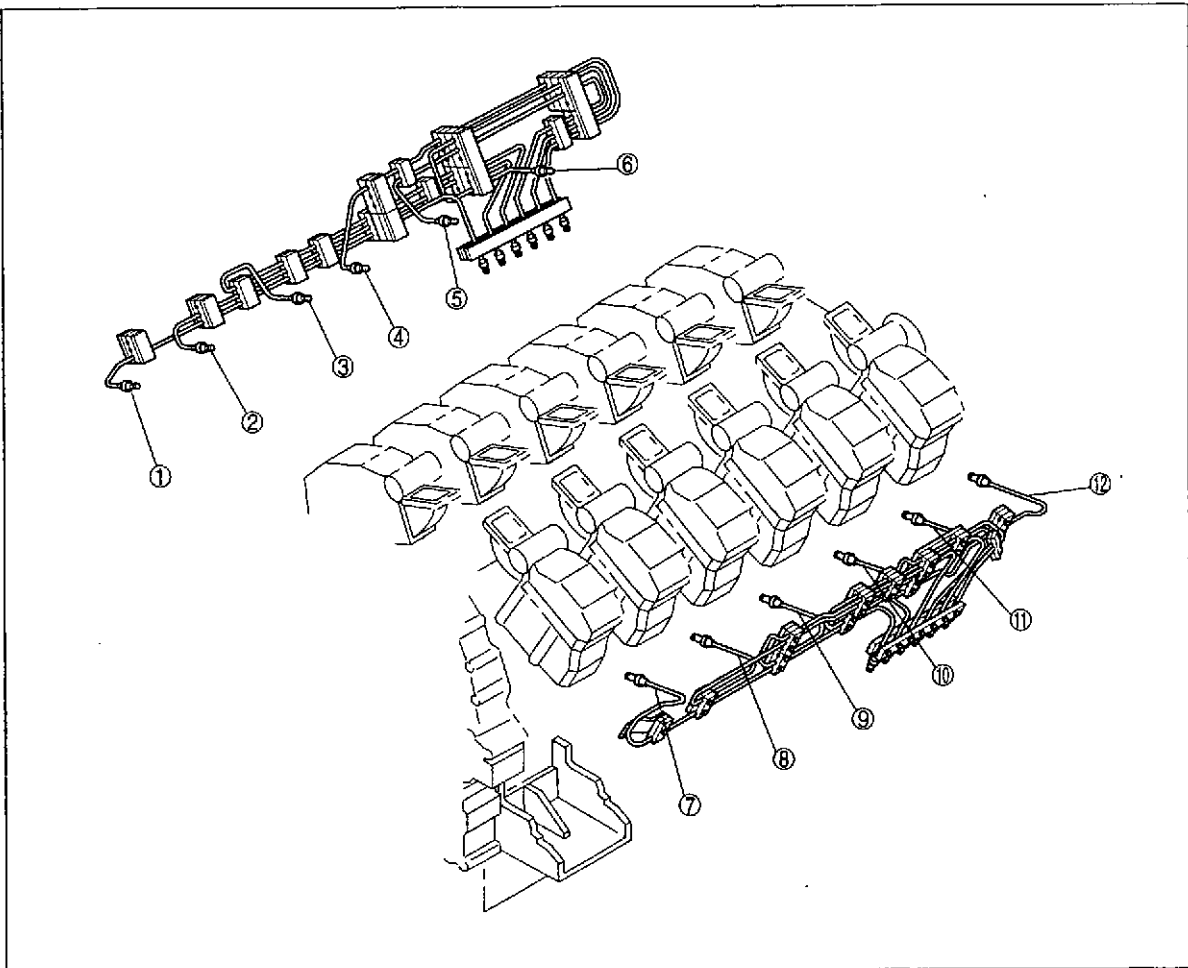
ENGINE AUXILIARIES REMOVAL AND INSTALLATION

(14) Removing fuel control linkage



- (a) Remove each control link ① from the right- and left-hand injection pumps.
- (b) Remove the R.H. link ② and the L.H. link ③.
- (c) Remove the link lever ④ and the R.H. lever ⑤ on the right side.
- (d) Remove the link lever ⑥ and the L.H. lever ⑦ on the left side.
- (e) Remove the spring ⑧ and the L.H. lever ⑨.
- (f) Remove each bearing cover ⑩ on both right- and left-side.
- (g) Remove the snap ring ⑪, the pipe ⑫, and the control shaft ⑬.
- (h) Remove the R.H. lever bracket ⑭ and the L.H. lever bracket ⑮.

(15) Removing fuel injection pipes



- ① No. 1 fuel injection pipe
- ② No. 2 fuel injection pipe
- ③ No. 3 fuel injection pipe
- ④ No. 4 fuel injection pipe
- ⑤ No. 5 fuel injection pipe
- ⑥ No. 6 fuel injection pipe

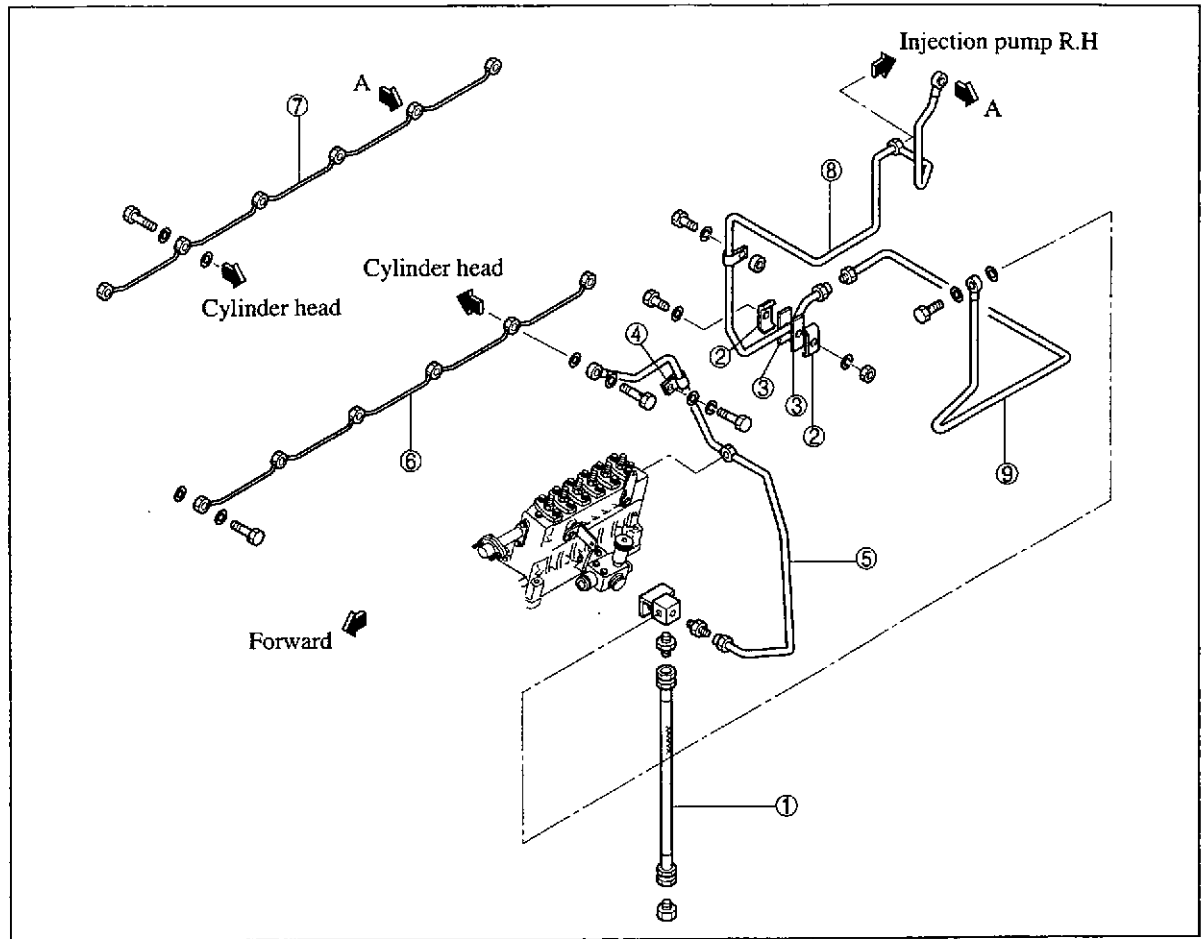
- ⑦ No. 7 fuel injection pipe
- ⑧ No. 8 fuel injection pipe
- ⑨ No. 9 fuel injection pipe
- ⑩ No. 10 fuel injection pipe
- ⑪ No. 11 fuel injection pipe
- ⑫ No. 12 fuel injection pipe

CAUTION

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

ENGINE AUXILIARIES REMOVAL AND INSTALLATION

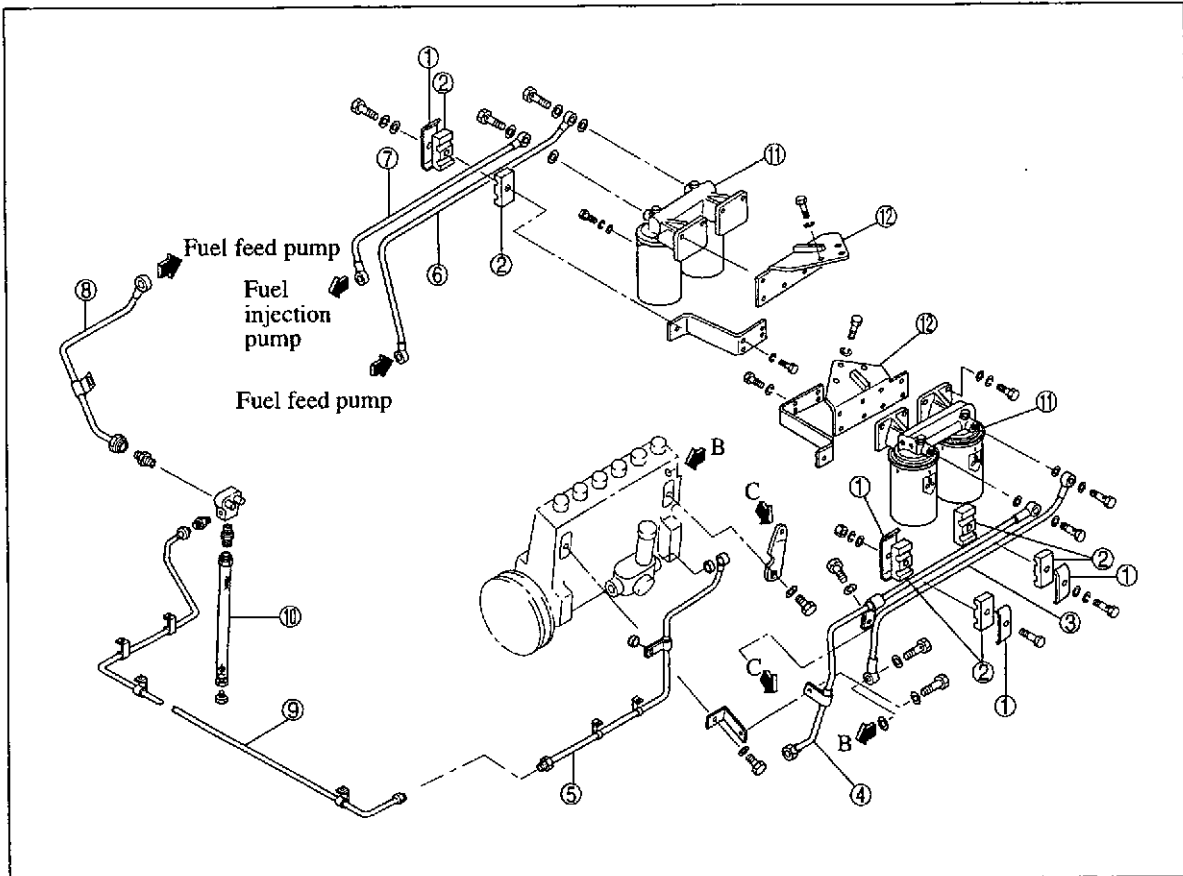
(16) Removing fuel leak-off pipes



(a) Untighten the clip to remove fuel leak-off pipe.

- | | | |
|-----------------|----------------------|----------------------|
| ① Flexible pipe | ④ Clamp | ⑦ Fuel leak-off pipe |
| ② Clamp | ⑤ Fuel pipe | ⑧ Fuel pipe |
| ③ Seat | ⑥ Fuel leak-off pipe | ⑨ Leak pipe |

(17) Removing fuel filter and the fuel pipes



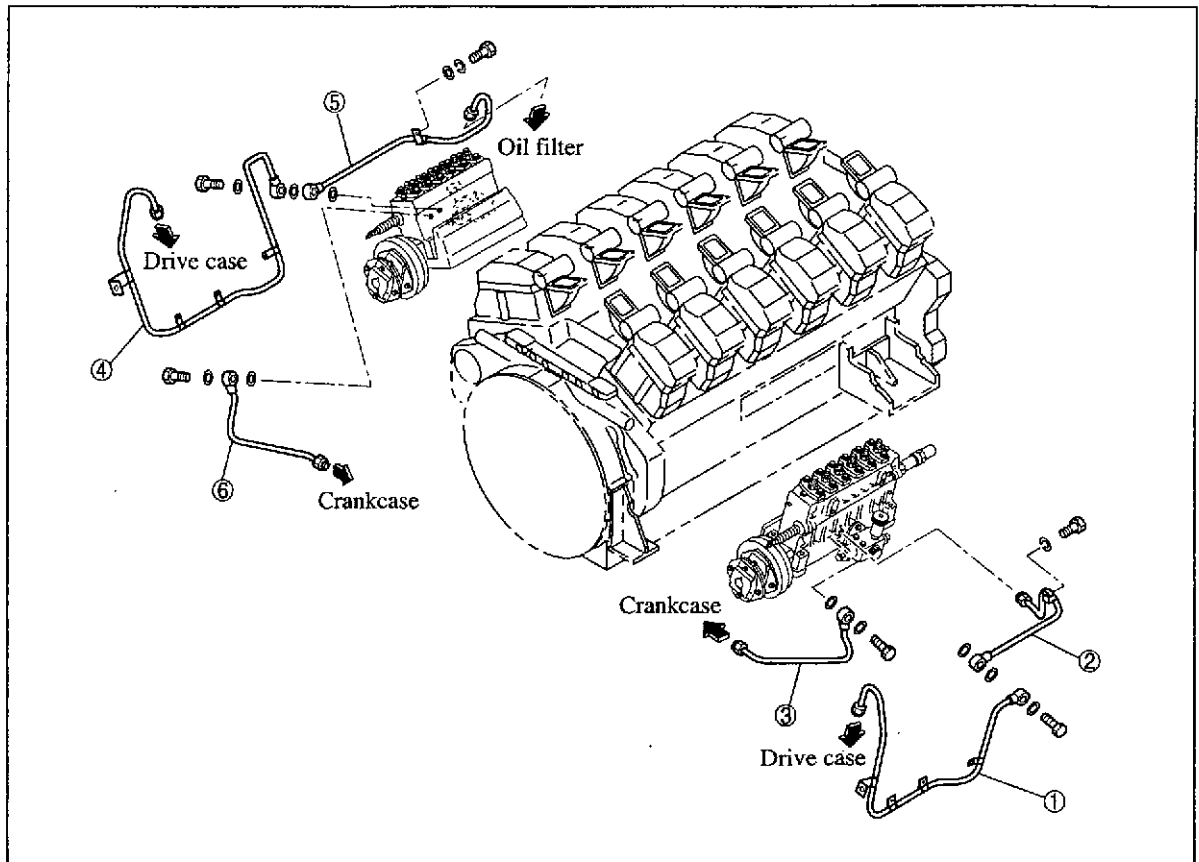
(a) Untighten the clip and clamp to remove fuel pipe.

- ① Clamp
- ② Seat
- ③ Fuel pipe
- ④ Fuel pipe
- ⑤ Fuel pipe
- ⑥ Fuel pipe
- ⑦ Fuel pipe
- ⑧ Fuel pipe
- ⑨ Fuel pipe
- ⑩ Flexible pipe

(b) Remove the fuel filter ⑪ and remove the fuel filter bracket ⑫.

ENGINE AUXILIARIES REMOVAL AND INSTALLATION

(18) Removing oil pipe (for fuel injection pump)



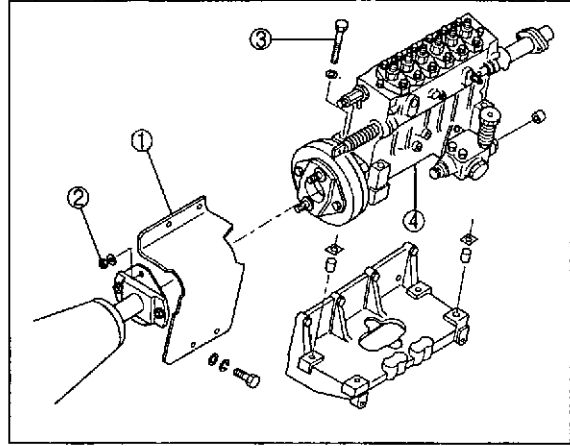
(a) Untighten the clip to remove the oil pipe.

- ① Oil pipe
- ② Oil pipe
- ③ Drain pipe
- ④ Oil pipe
- ⑤ Oil pipe
- ⑥ Drain pipe

(19) Removing left and right fuel injection pumps

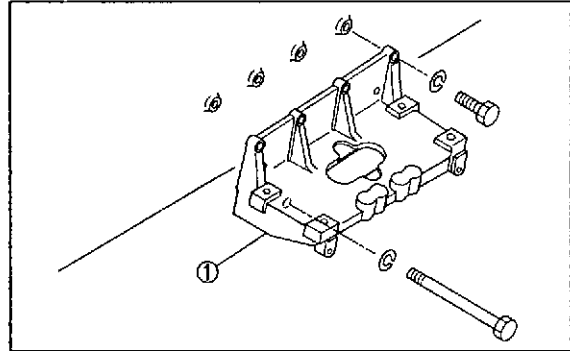
- (a) Remove the coupling cover ①.
- (b) Unscrew the two coupling nuts ②.
- (c) Remove the pump mounting bolts ③. Remove the injection pump ④, complete with the coupling by lifting it up. Leave the laminate plate on the drive shaft.

Weight: approx. 57 kg [126 lb.]



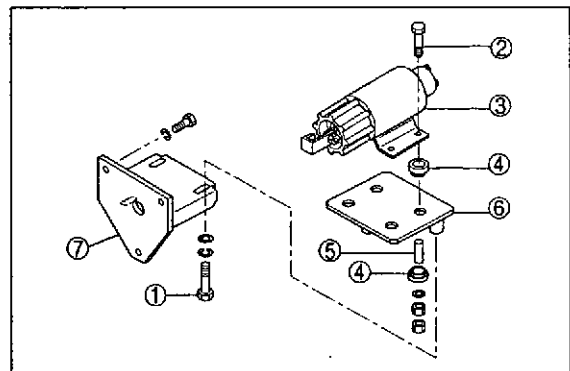
(20) Removing injection pump bracket

- (a) Unscrew the bracket mounting bolts, and remove bracket ①.



(21) Removing stop solenoid

- (a) Remove bolt ①, and dismount stop solenoid ③ and solenoid plate ⑥.
- (b) Remove bolt ②, and detach stop solenoid ③ from solenoid plate ⑥.
- (c) Remove cushion rubber ④ and spacer ⑤.
- (d) Dismount solenoid bracket ⑦.

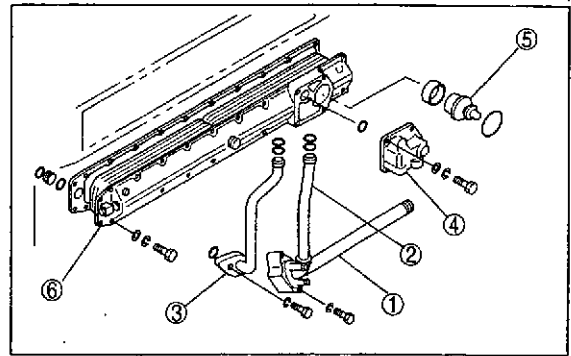


ENGINE AUXILIARIES REMOVAL AND INSTALLATION

(22) Removing right oil cooler

- (a) Disconnect the oil pipes ①, ② and ③ from the oil pan and oil cooler inlet connector.
- (b) Untighten the clip and remove oil pipe ③.
- (c) After unscrewing the oil cooler inlet connector mounting bolt, disconnect connector ④.
- (d) Pull out the oil thermostat ⑤ from the oil cooler ⑥.
- (e) Unscrew the oil cooler mounting bolts, then remove the oil cooler ⑥.

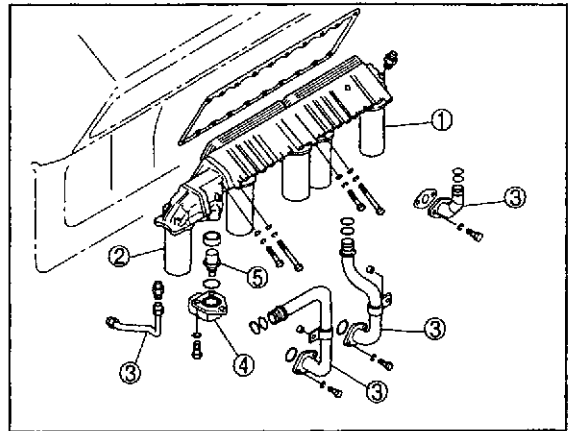
Weight: approx. 20 kg [44 lb.]



(23) Removing left oil filter and oil cooler

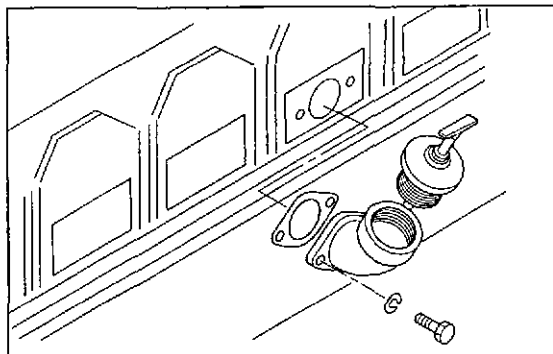
- (a) Remove the four oil filter elements ① and the bypass filter element ②.
- (b) Disconnect the oil pipes ③.
- (c) Unscrew the oil cooler inlet connector mounting bolts, and disconnect the connector ④.
- (d) Remove the oil thermostat ⑤.
- (e) After unscrewing the oil filter bracket mounting bolts, remove the filter bracket ⑥ complete with the oil cooler.

Weight: approx. 45 kg [99 lb.]



(24) Removing oil filler

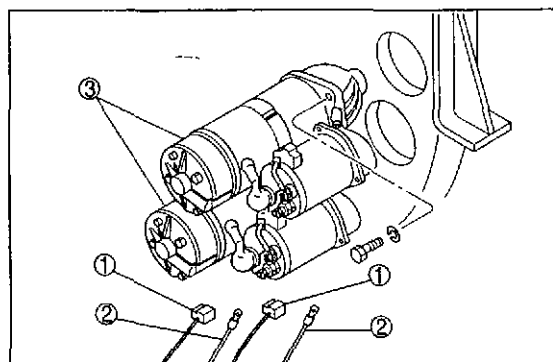
Unscrew the oil filler mounting bolts, then remove the oil filler ①.



(25) Removing starter

- (a) Remove the connectors ① and ②.
- (b) Remove the starter ③ by unscrewing the starter mounting bolts.

Weight: approx. 19 kg [42 lb.]



3. Engine Auxiliaries Installation

3.1 General

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, follow the removal procedures in reverse. After installation, service them as follows:

- (1) Refill the engine with the recommended oil up to the specified level.
- (2) Refill the cooling system with coolant.
- (3) Check each pipe connection for oil or coolant leaks.
- (4) Prime the fuel system.
- (5) Installation of the fuel injection pump is described below. After installing the fuel injection pump, be sure to inspect and adjust the injection timing. (Refer to Section 1.3 of Group 5, "Adjustments, Bench Testing, and Performance Tests"

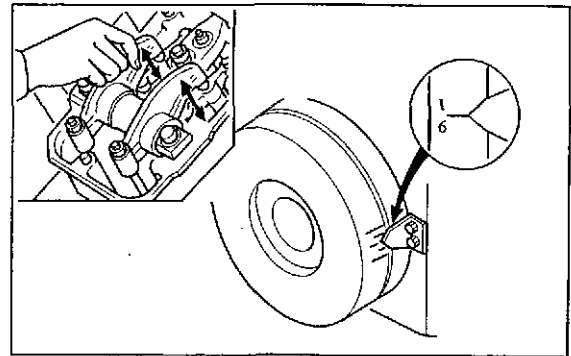
3.2 Installation of Fuel Injection Pump (Right)

- (1) To install, follow the removal sequence in reverse.
- (2) Tighten the injection pipe to the specified torque (58.8 ± 9.8 N·m (6 ± 1.0 kgf·m) [43.40 ± 7.23 lbf·ft]).
- (3) Install the fuel injection pump (right).
 - (a) Turn the crankshaft until the No. 1 cylinder injection start timing mark on the damper aligns with the pointer on the engine, and make sure that the No. 1 piston is at the top dead center in compression stroke.

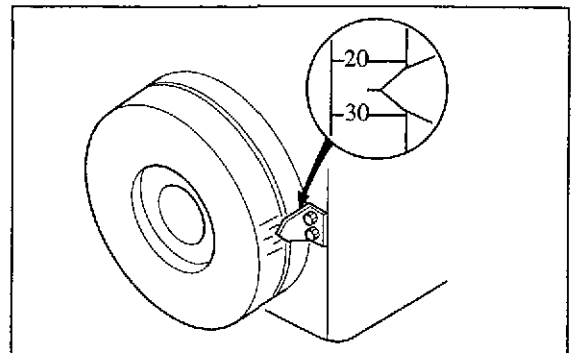
Be sure to observe the injection start timing position specified for the engine.

CAUTION

Using a clean cloth, wipe dust from the contact faces of the coupling and laminate plate and the washers and bolts located around them. If dust adheres on the contact faces, the coupling can slip, causing injection timing deviation and coupling damage.



Confirmation of No. 1 cylinder top dead center in compression stroke

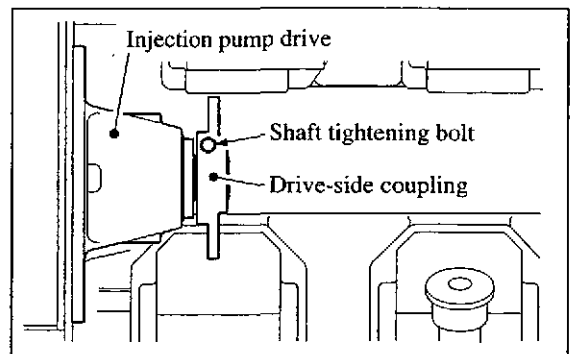


Inspection of fuel injection timing

- (b) Install the drive-side coupling of the fuel injection pump to the drive shaft of the fuel injection pump drive. Keep the shaft tightening bolt loose in this step.

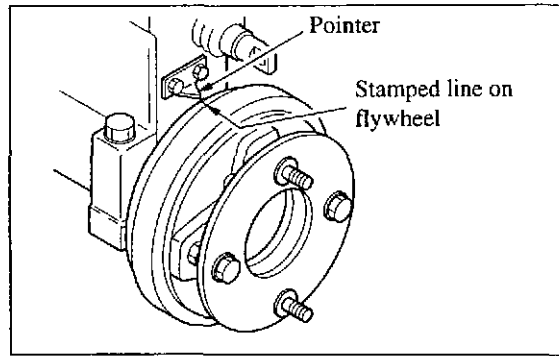
NOTE

Keep the shaft tightening bolt loose even if the pump drive-side coupling is not removed from the injection pump drive.



Installation of drive-side coupling

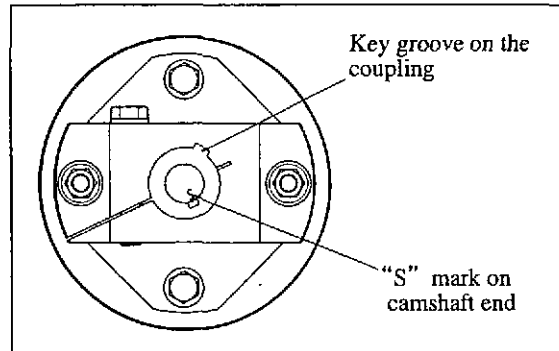
- (c) Before installing the fuel injection pump to the engine, align the stamped line on the flywheel with the pointer located on the end surface.



Aligning pointer and stamped line

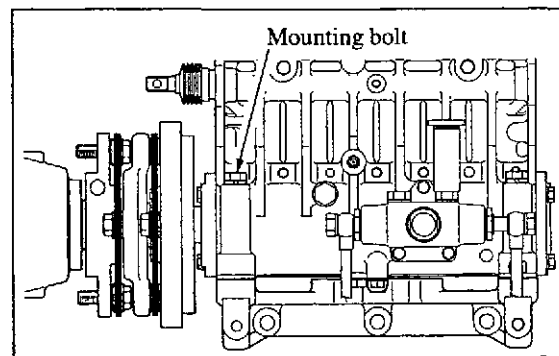
CAUTION

Make sure that the drive-side coupling and the "S" mark on the pump camshaft end are positioned as shown in the right diagram. If they are positioned as specified, correct. Be sure to conduct this inspection. If the drive-side coupling is installed 180° away from the proper position, injection timing deviation results.



Assembly positions of camshaft and coupling
(View from rear end of drive side)

- (d) Lower the fuel injection pump onto the bracket, then temporarily tighten the four mounting bolts.
- (e) After adjusting the centering of the shafts (refer to the following section), tighten the four mounting bolts.



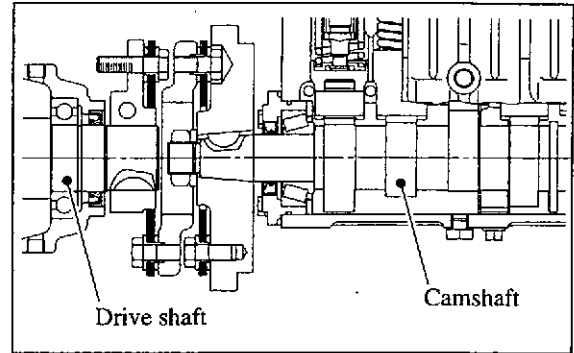
Installation of pump

Adjustment of shaft centering

Adjust the centering of the camshaft and drive shaft within $\varnothing 0.5$ TIR (Total Indicator Reading).

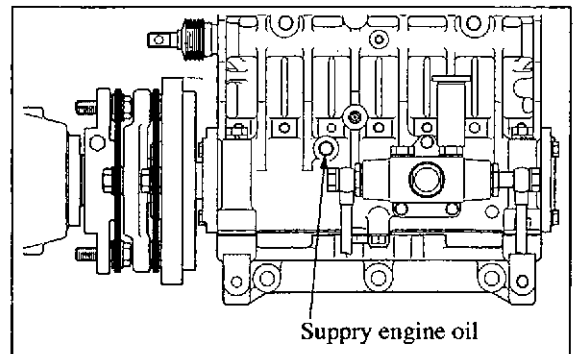
CAUTION

If the centering deviates more than $\varnothing 0.5$ TIR, damage can occur in the coupling and laminate plate, and broken pieces of the parts can cause personal injury.



Adjustment of shaft centering

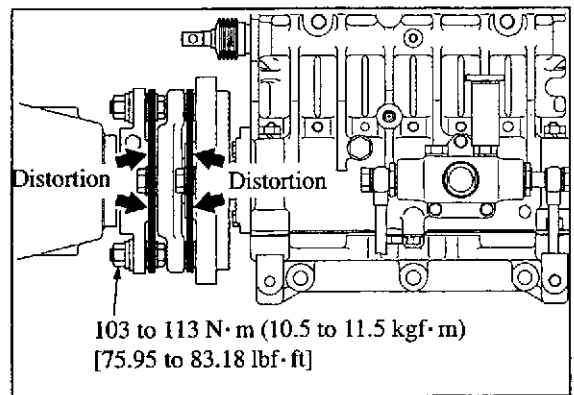
- (f) Connect the pipe of the fuel system to the injection oil supply pipe.
- (g) Pour the specified engine oil into the mounting hole on the injection oil drain pipe. When the oil surface reaches the bottom of the mounting hole, stop pouring oil and install the oil drain pipe.
- (h) Attach the coupling washers and flange nuts to the connecting bolts (2 locations), and tighten to the specified torque.



Supplying engine oil (oil drain pipe mounting hole)

CAUTION

Tighten the flange nuts (2 locations) on the connecting bolts to the specified torque, loosen them, then retighten to the specified torque. If the laminate plate is distorted after the nuts are tightened, loosen the nuts and retighten.

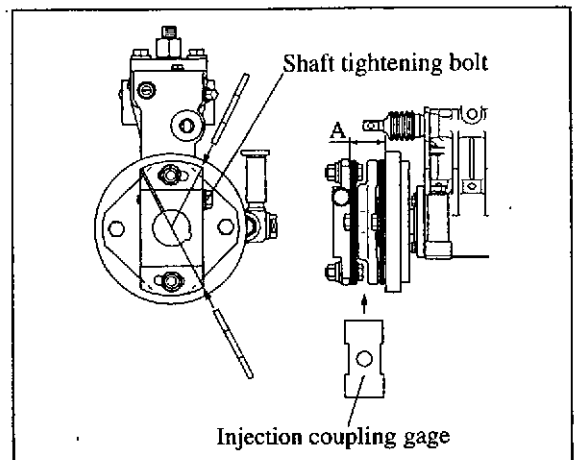


Tightening of connecting bolts

- (i) Using the injection coupling gage (37591-06100), adjust the clearance between the flywheel and coupling.
 - Insert the side of the gage with a "GO" mark into the gap, and adjust clearance (A) between the flywheel and coupling.
 - Tighten the shaft tightening bolt.
 - Make sure the side of the gage with a "NO GO" mark does not go into the gap, but only the side with a "GO" mark can be inserted.

In this condition, clearance (A) between the flywheel and coupling is as specified (49 ± 0.25 mm [1.93 ± 0.01 in.]).

 - If the clearance measured with the gage is not as described above (clearance is not 49 ± 0.25 mm [1.93 ± 0.01 in.]), repeat from step (h). Loosen the shaft tightening bolt, and readjust the clearance.



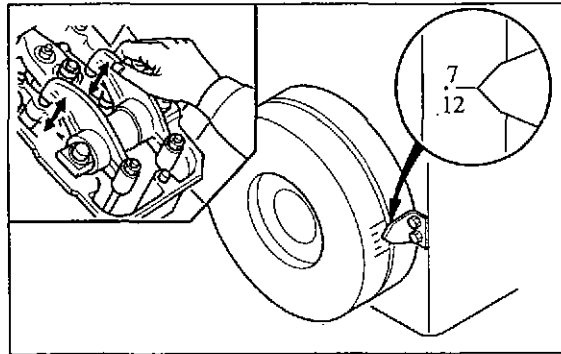
Installing fuel injection pump

CAUTION

- Be sure to tighten the coupling bolts evenly, and observe the specified tightening torque.
- Keep the contact surfaces clean. Dust and oil adhered on the contact surfaces can cause instable axial force.
- Excessive or insufficient tightening torque can cause parts damage and injection timing deviation.

3.3 Installation of Fuel Injection Pump (Left)

- To install the left fuel injection pump, align the No. 7•12 mark on the damper with the pointer. Check the inlet and exhaust valves for cylinder No. 7 to make sure that the piston in cylinder No. 5 is at the top dead center in compression stroke.
- Adjust the injection timing by following the same procedure as for the right fuel injection pump, and install the injection pump, then attach the pipes and control link.

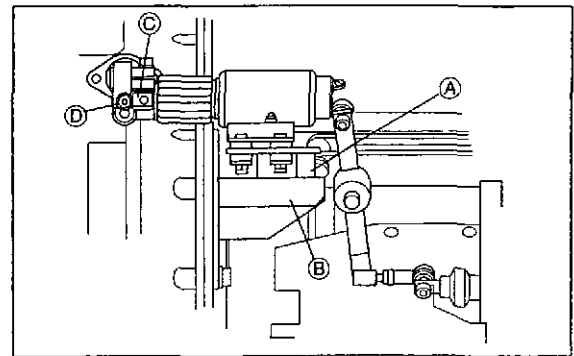


3.4 Adjustment of Run-on Solenoid

- (a) Before adjusting the solenoid, complete the adjustment of the governor linkage.
- (b) Install the solenoid to the plate (A).
- (c) Temporarily mount the plate (A) on the bracket (B).

NOTE

The bracket has elongated bolt holes so that the plate position can be adjusted in the forward and backward directions.



Run-on solenoid adjustment

- (d) With the governor turned off and no current supplied to the solenoid, adjust the position of the plate so that there is a clearance (note (2)) of 0.5 mm [0.02 in.] or more between the adapter (C) attached to the solenoid and the follower (D) installed to the lever, then secure the plate in that installation position.

NOTE

- (1) When the governor is turned off, the fuel racks of the fuel injection pumps are in the non-injection position (engine in non-operation).
- (2) If there is no clearance, the stopper of the governor actuator can break due to contacting force when the solenoid turns off.

- (e) Turn on the solenoid (solenoid in full-stroke operation), and move the output lever of the governor in the fuel increase direction until it contacts the maximum fuel set. In this process, check to make sure the follower (D) of the lever does not contact the adapter (C) of the solenoid.

NOTE

If the racks of the fuel injection pumps cannot be moved to the maximum fuel set positions, the engine may not produce the maximum output.

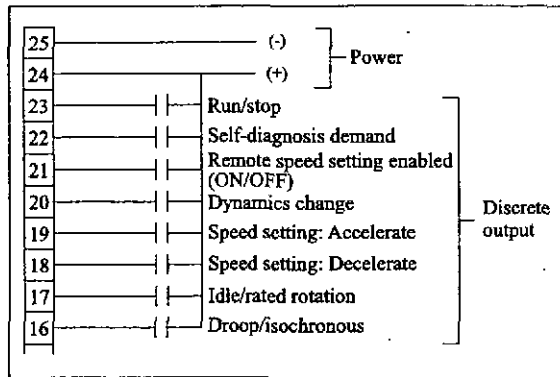
4. Adjusting Governor Controller

CAUTION

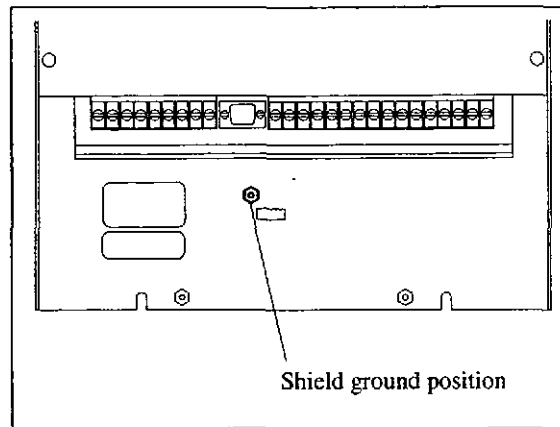
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.
Work related to the exhaust emission regulations can be conducted only at our designated service factories.

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



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

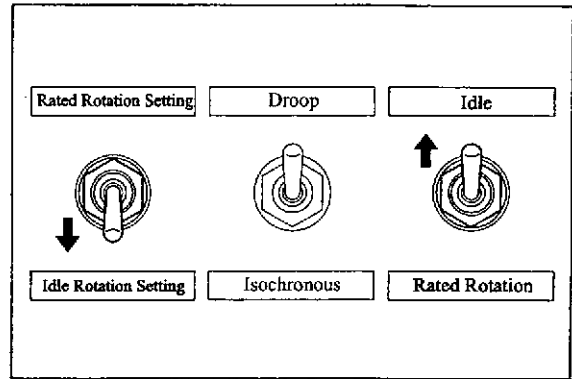


4.2 Initial Settings of Controller

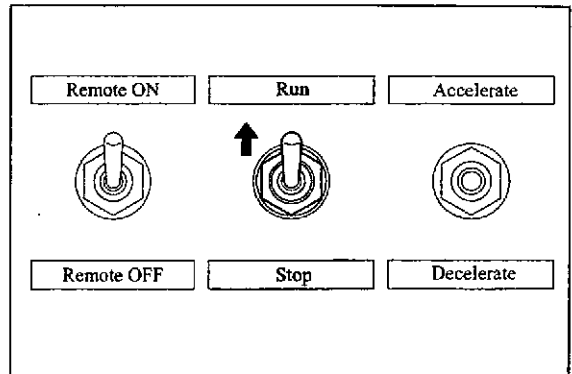
Do not change the initial set values unless otherwise required.

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.

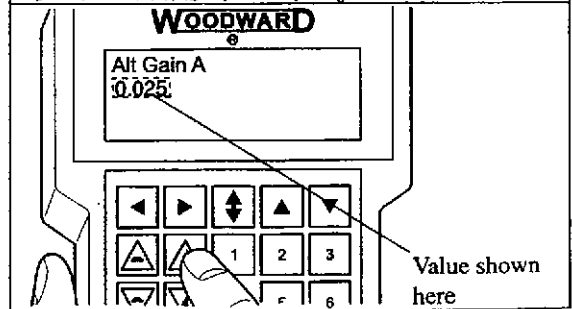
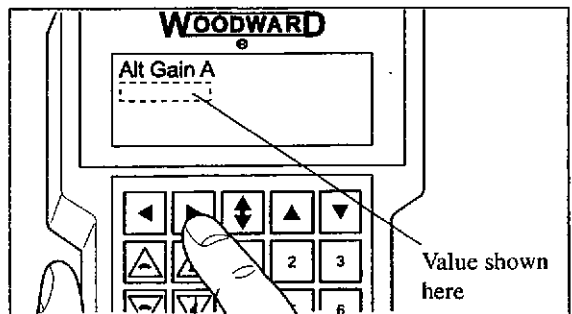
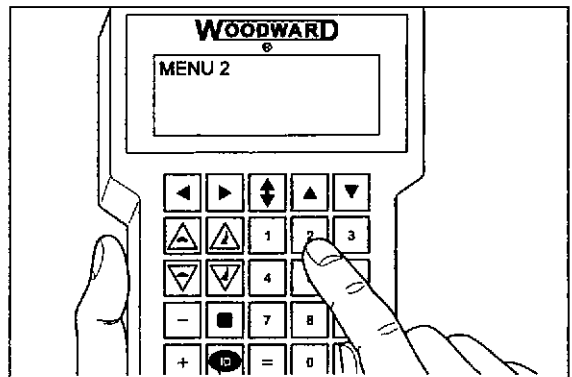
Key ▲ : Value slowly increases in small increments

Key ▼ : Value slowly decreases in small increments

Key ▲ (large) : Value rapidly increases in large increments

Key ▼ (large) : Value rapidly decreases in large increments

Set "Alt Gain A" to 0.025.

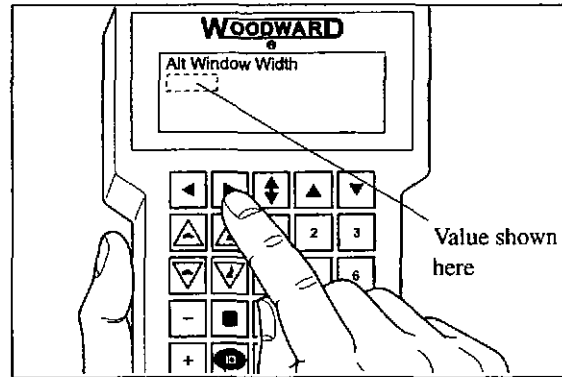


The value of "Alt Gain A" is related to hunting and rotational fluctuation as follows:
 When the value of "Alt Gain A" is large, hunting increases, and rotational fluctuation decreases.

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".



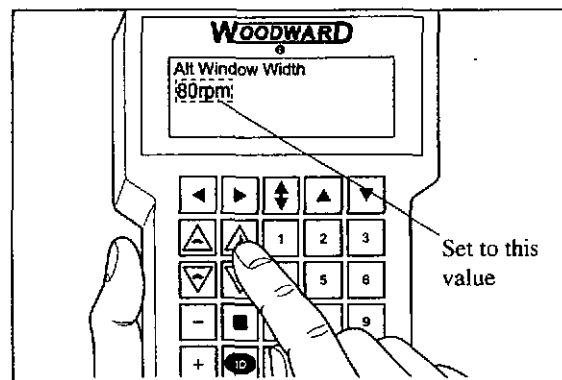
- (b) Adjust with the key ▲ or ▼.

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.

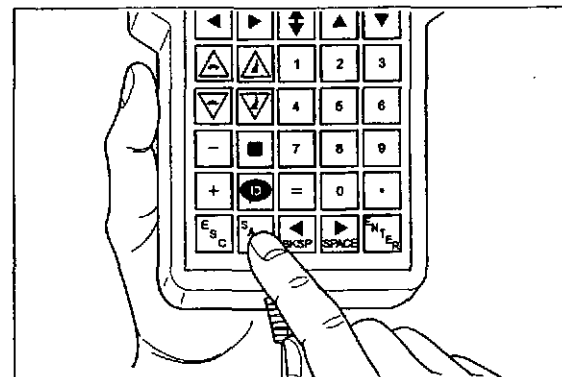


NOTE

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.



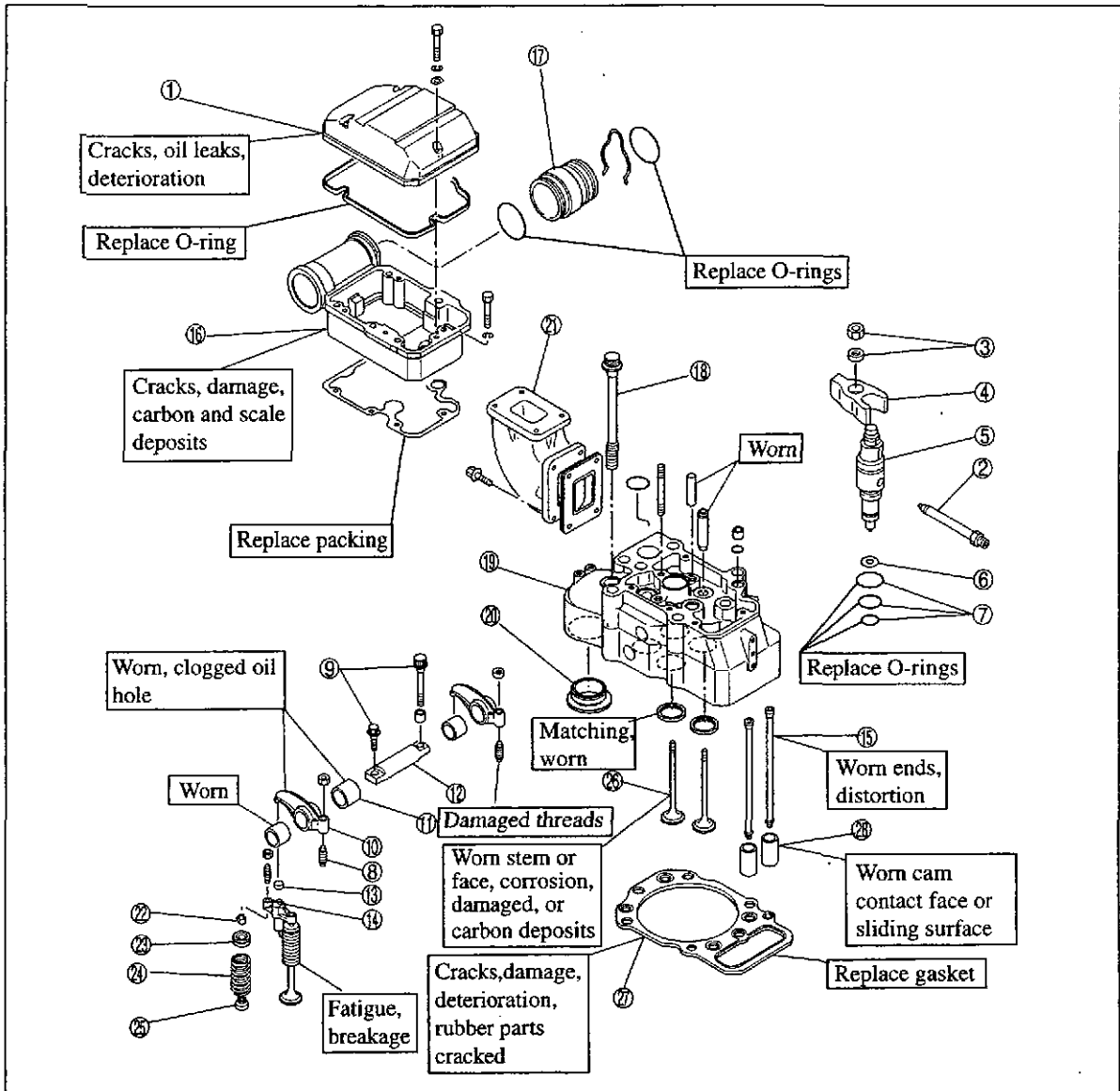
ENGINE AUXILIARIES REMOVAL AND INSTALLATION

ENGINE MAIN PARTS

1. Cylinder Heads and Valve Mechanism	7-2
1.1 Disassembly	7-2
1.2 Inspection and Repair	7-5
1.3 Reassembly	7-13
2. Cylinder Liners, Pistons, and Connecting Rods	7-18
2.1 Disassembly	7-18
2.2 Inspection and Repair	7-22
2.3 Reassembly	7-34
3. Damper and Front Gears	7-40
3.1 Disassembly	7-40
3.2 Inspection and Repair	7-44
3.3 Reassembly	7-47
4. Flywheel, Timing Gears, and Camshafts	7-50
4.1 Disassembly	7-50
4.2 Inspection and Repair	7-54
4.3 Reassembly	7-59
5. Crankcase, Crankshaft, and Main Bearings	7-65
5.1 Disassembly	7-65
5.2 Inspection and Repair	7-67
5.3 Reassembly	7-75

1. Cylinder Heads and Valve Mechanism

1.1 Disassembly



Disassembly sequence

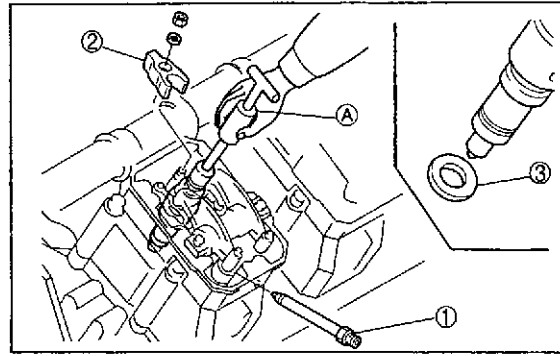
- | | | |
|-------------------------------|--------------------------|------------------------|
| ① Rocker cover | ⑪ Spacer | ⑳ Inlet port packing |
| ② Fuel inlet connector | ⑫ Rockershaft | ㉑ Exhaust connector |
| ③ Nut, washer | ⑬ Bridge cap | ㉒ Valve cotter |
| ④ Fuel injection nozzle gland | ⑭ Valve bridge | ㉓ Valve rotator |
| ⑤ Fuel injection nozzle | ⑮ Push rod | ㉔ Valve spring |
| ⑥ Gasket | ⑯ Rocker case | ㉕ Stem seal |
| ⑦ O-ring | ⑰ Water outlet connector | ㉖ Valve |
| ⑧ Adjusting screw | ⑱ Cylinder head bolt | ㉗ Cylinder head gasket |
| ⑨ Bolt | ⑲ Cylinder head | ㉘ Tappet |
| ⑩ Rocker | | |

⚠ CAUTION

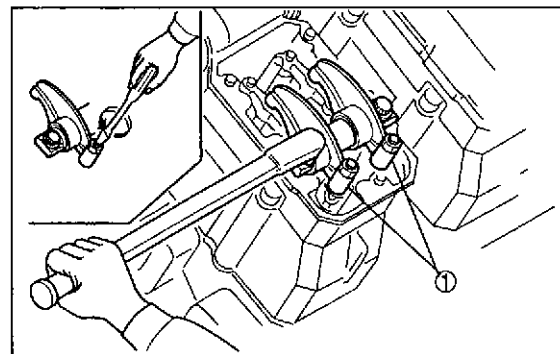
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(1) Removing fuel injection nozzle

- (a) Remove the fuel inlet connector ① and the nozzle gland ②.
- (b) Use the nozzle remover ④ (33591-10101), to remove the nozzle assembly. Take out the gasket ③ if it is left behind in the cylinder head.
- (c) Store the nozzle and the inlet connector as a set to avoid swapping. Pay attention not to damage the nozzle tip.

**(2) Removing rockershaft assemblies**

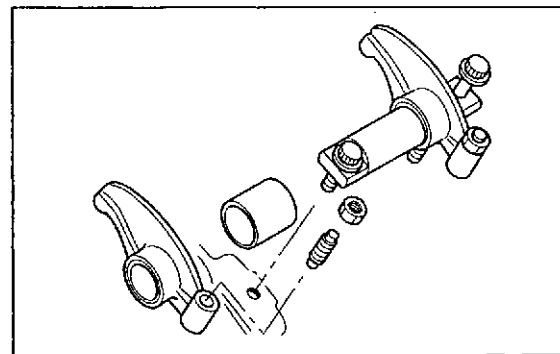
- (a) First loosen the adjusting screw ① of each rocker.
- (b) Remove the rockershaft assembly, then store the shaft assembly and mounting bolts together as a set.

**(3) Disassembling rockershaft assemblies**

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

(4) Removing valve bridge

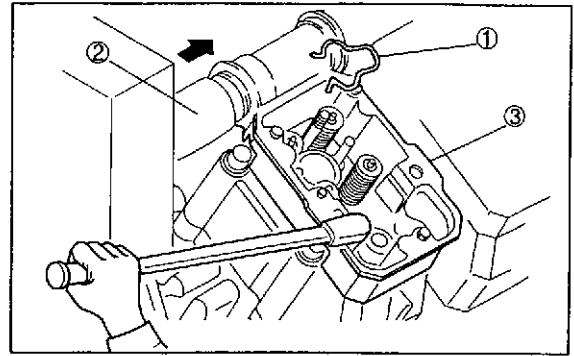
Remove the valve bridge and bridge cap. Do not drop the bridge cap or other parts into the crankcase through the pushrod hole.



ENGINE MAIN PARTS

(5) Removing rocker cases

- (a) Remove the snap ring ① of the water outlet connector. Slide the connector ② towards the snap ring.
- (b) Unscrew the rocker case mounting bolts, then remove the rocker case ③ from the cylinder head.

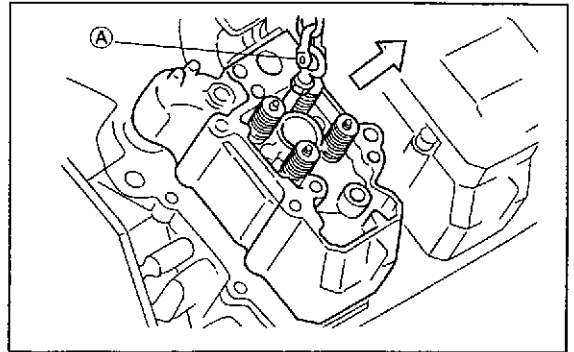


(6) Removing cylinder head assemblies

- (a) Each cylinder head is located relative to the crankcase with dowel pins. Use the eye nut ① (37591-02400) to lift the head off the crankcase at a slant.

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

- (b) Remove the cylinder head gasket.



CAUTION

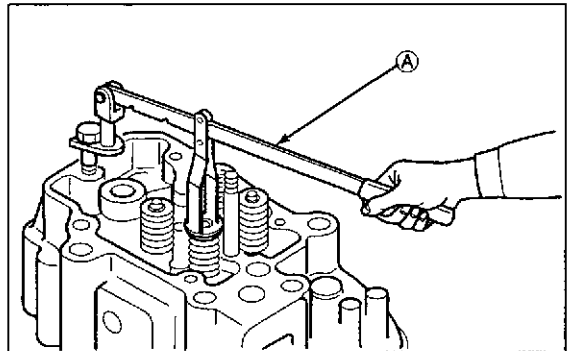
Do not damage the cylinder head or crankcase surfaces when you remove the gasket with a screwdriver or other tool.

(7) Removing valves and valve springs

Use the valve spring pusher ① (33591-04500) to compress the valve spring squarely, then remove the valve cotters.

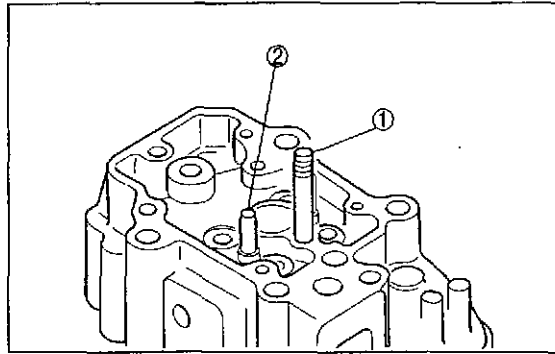
NOTE

If the valves are to be used, do not change the combination of the valve seat and valve guide.



(8) Removing studs and guides

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 adhesive to the threads when installing it or a new part to the cylinder head.



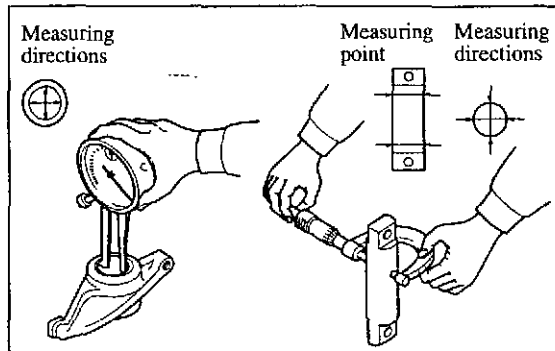
1.2 Inspection and Repair

(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 outside diameter	Ø36 [1.42]	35.966 to 35.991 [1.41598 to 1.41697]	35.940 [1.41496]



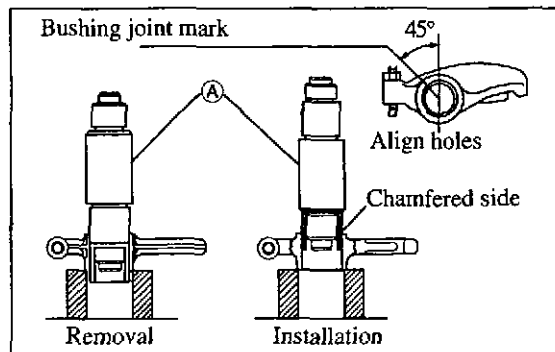
Measuring rocker bushing and rockershaft

(2) Replacing rocker bushings

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

NOTE

- Press a new bushing into the rocker from the internally chamfered side of the bore.
- Align the oil holes in the bushing and rocker.
- After installing the bushing, measure its inside diameter to make sure that it is $\phi 36^{+0.04}_0$ mm [$1.42^{+0.002}_0$ in.]. If the diameter is not within this tolerance, refinish to standard tolerance by reaming ($\phi 36^{+0.04}_0$ mm [$1.42^{+0.002}_0$ in.] 0.8 Ra).



Replacing the rocker bushing

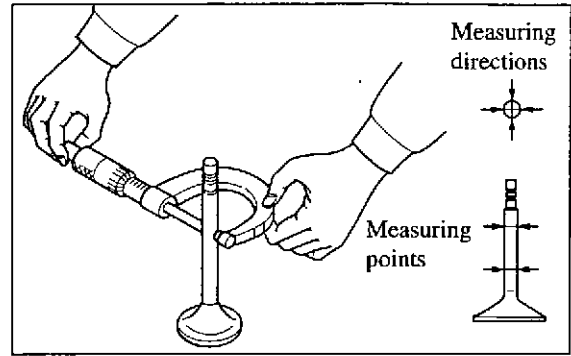
ENGINE MAIN PARTS

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

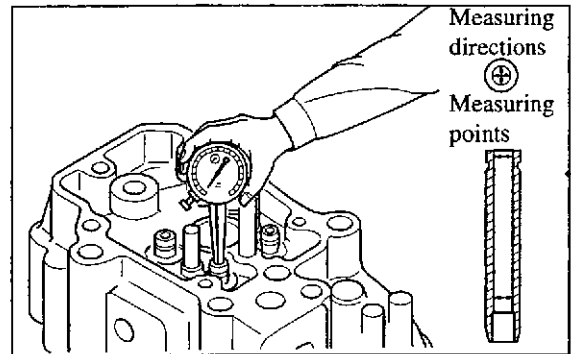
The valve guide wears more rapidly at its ends than at any other location. Measure the inside diameter of the guide at its ends in two directions. If the service limit is exceeded, replace the guide.

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]



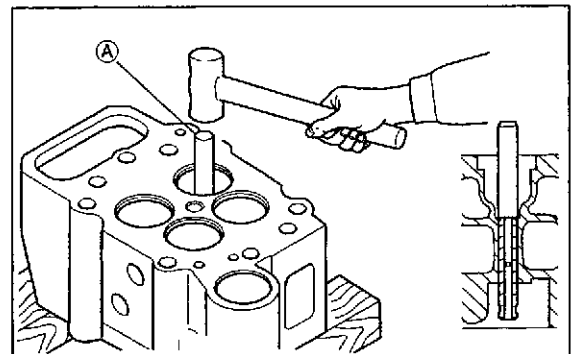
Measuring valve stems



Measuring valve guide inside diameter

(4) Replacing valve guides and stem seals

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

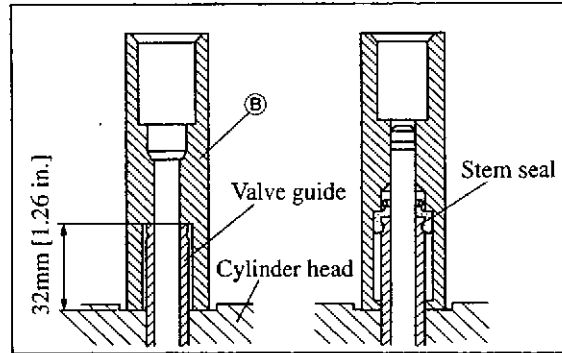


Removing valve guide

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

⚠ 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.



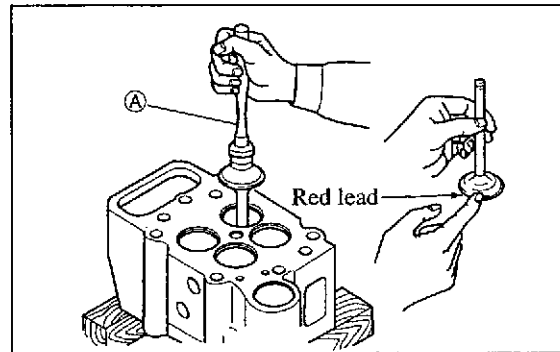
Installing valve guide and stem seal

(5) Inspecting valve face

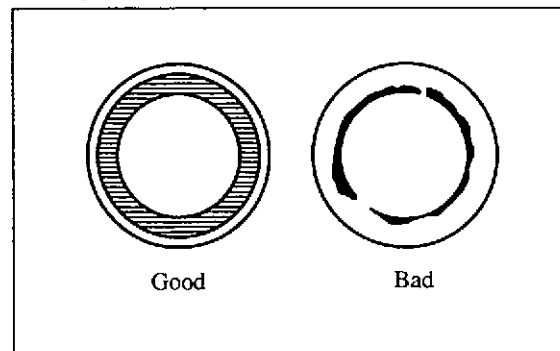
Coat the valve face lightly with red lead. Use the valve lapper **Ⓐ** (30091-08800) to inspect the valve contact with its seat. If the contact is not uniform, or if the valve is defective, or if the repair limit is exceeded, repair or replace the valve and valve seat.

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.



Inspecting valve face

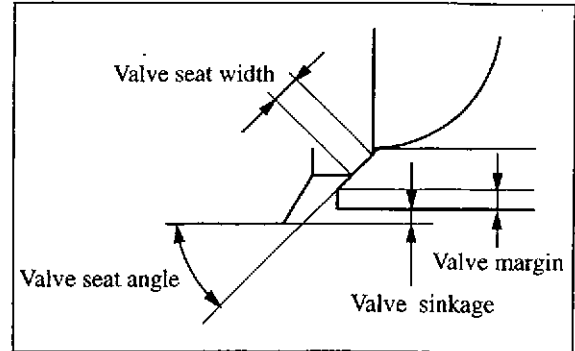


Valve contact with its seat (1)

ENGINE MAIN PARTS

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Repair Limit
Valve seat	Angle	30°	
	Valve sinkage		-0.2 to 0.2 [-0.008 to 0.008]
	Width	2.3 [0.0906]	2.15 to 2.45 [0.0846 to 0.0965]
Valve margin	3.0 [0.1181]	2.8 to 3.2 [0.110 to 0.126]	2.5 [0.098] by refacing



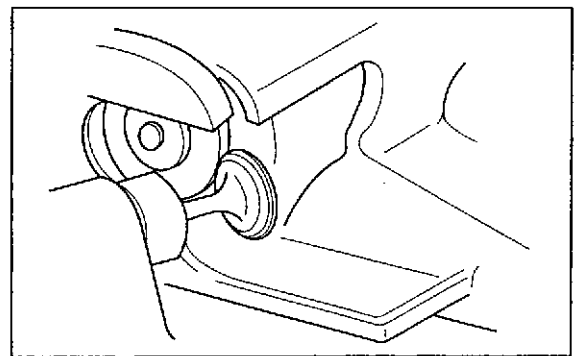
Valve contact with its seat (2)

(6) Refacing valve face

If the valve face is excessively worn, reface it with a valve refacer.

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 valve face

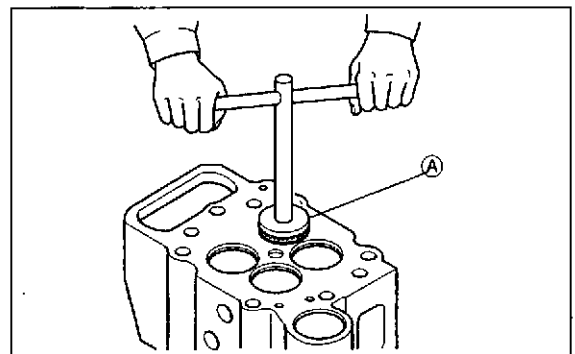
(7) Refacing valve seats

- (a) Use the valve seat cutter (A) (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.

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.



Refacing valve seats

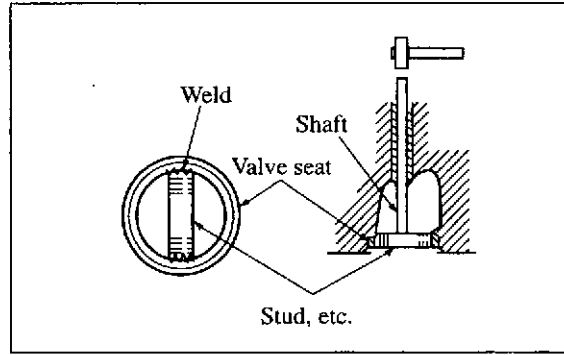
(8) Replacing valve seats

- (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.

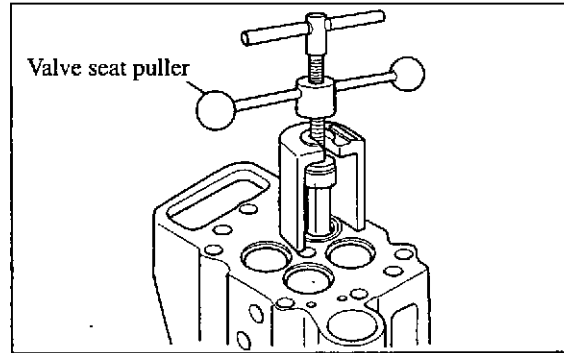
NOTE

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 valve seat

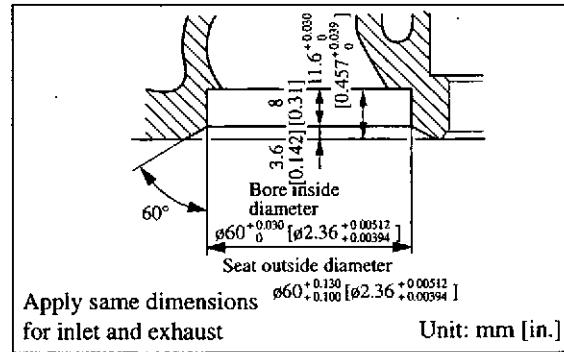


Removing valve seat (Using valve seat puller)

- (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	$\phi 60$ [2.36]	-0.070 to -0.130 [-0.00276 to -0.00512]

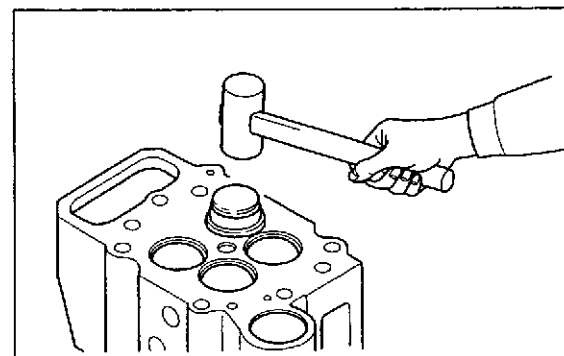


Valve seat dimensions

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.



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

ENGINE MAIN PARTS

(9) Lapping valves in valve seats

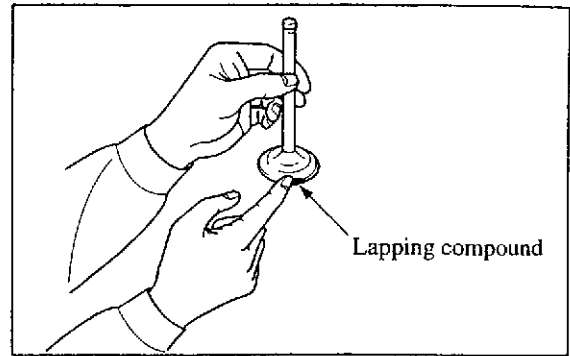
Be sure to lap the valves in the valve seats after the seats have been replaced.

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

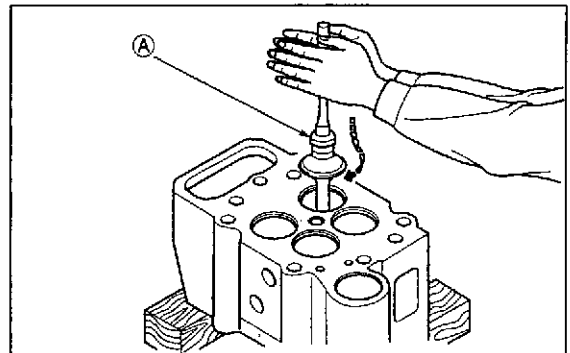
NOTE

- (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.

- (b) Use the valve lapper **A** (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.



Coating valve with lapping compound

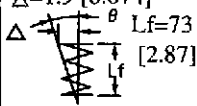


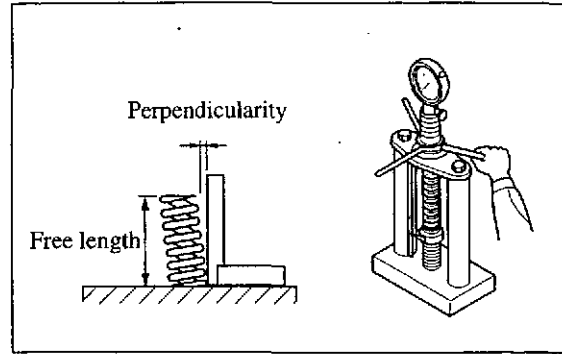
Lapping valve in its valve seat

(10) 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.]

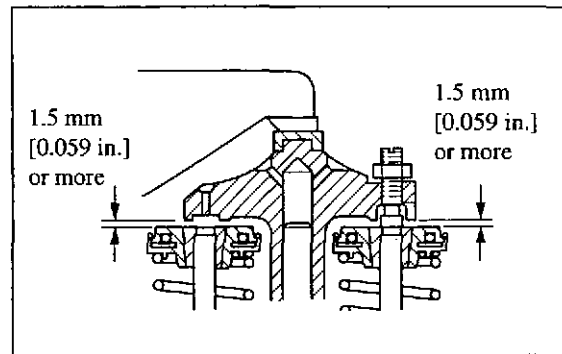
Item	Assembly Standard	Service Limit
Free length	73 [2.87]	71 [2.80]
Perpendicularity	$\theta=1.5$ [0.059] $\Delta=1.9$ [0.074] 	$\Delta=2.2$ [0.087] at the end
Set length/set force	66.0 [2.6]/ 289 to 319	
mm [in.]/ N (kgf) [lbf]	(29.45 to 32.55) [64.9 to 71.8]	



Measuring valve spring perpendicularity and free length

(11) Checking clearance between bridge with cotter and rotator, bridge and rotator

- (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.

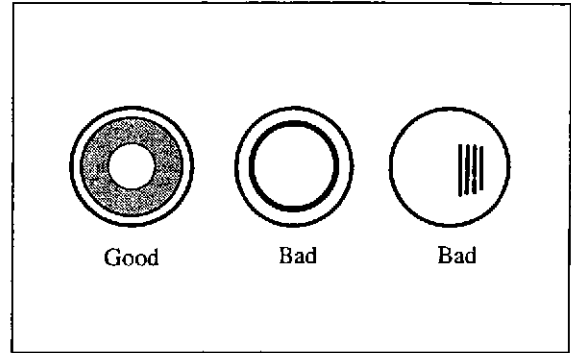


Checking clearance between bridge with cotter and rotator, bridge and rotator

ENGINE MAIN PARTS

(12) Inspecting cam contact faces of tappets

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



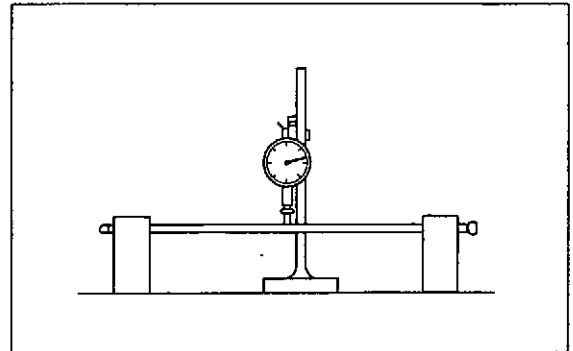
Tappet cam contact face

(13) Measuring valve pushrods deflection

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

Unit: mm [in.]

Item	Assembly Standard
Pushrod deflection	0.5 [0.020] or less



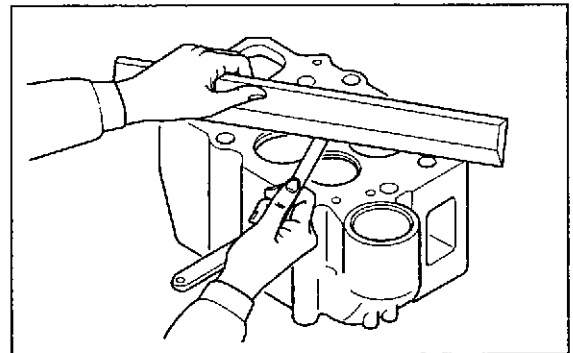
Measuring valve pushrod deflection

(14) 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 of gasket surface	0.03 [0.0012] or less	0.07 [0.0028]	0.50 [0.0200]



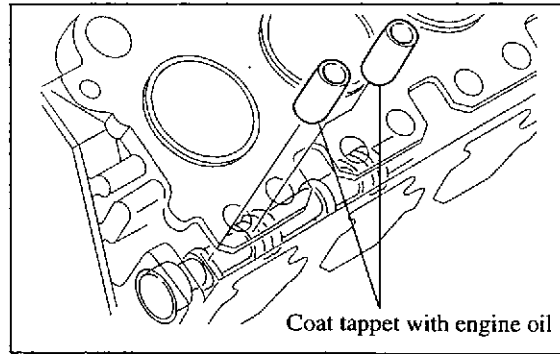
Measuring head gasket flatness of surface

1.3 Reassembly

To reassemble, follow the reverse of disassembly.

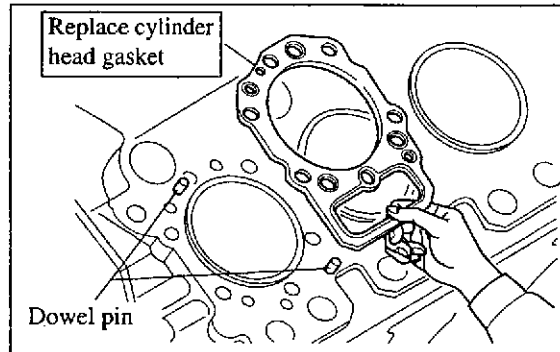
(1) Installing tappets

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 gasket 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.



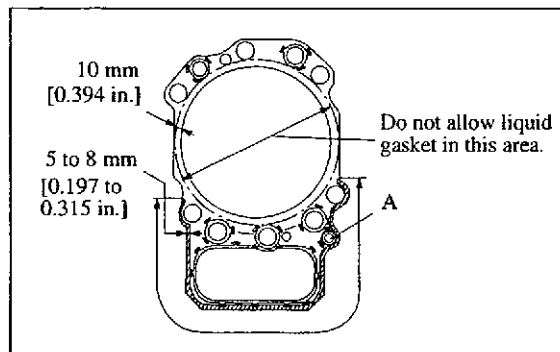
• Application of liquid gasket

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.

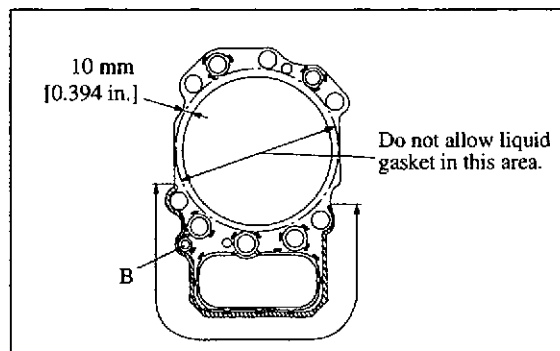
Do not apply an excessive amount of liquid gasket, since it can press the head gasket O-ring and cause deformation. Do not allow liquid gasket to adhere around the bore; otherwise, gas leakage can occur.

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, and make sure they are clean.

The drawing on the right shows 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

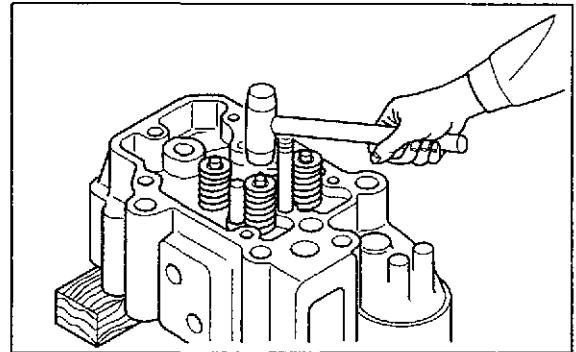
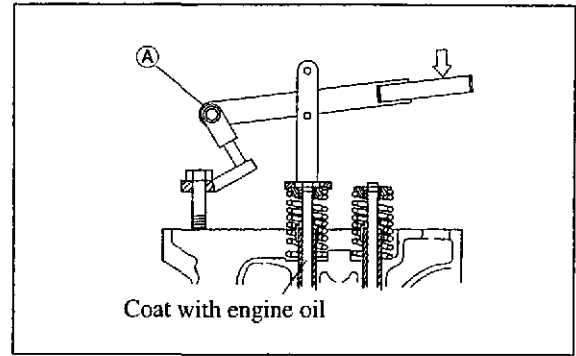
- (a) Apply liquid gasket (37594-01300) to areas 5 to 8 mm [0.197 to 0.315 in.] from the periphery of the head gasket.
- (b) Liquid gasket should be applied to areas indicated in the drawing on the right.
- (c) Apply liquid gasket to both sides of the head gasket. Spread the liquid gasket with a finger to a thickness of 0.2 to 0.5 mm. [0.008 to 0.020 in.]
- (d) Sections (A) and (B) are very close to O-rings. Make sure that 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.

ENGINE MAIN PARTS

(3) Reassembling 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 **A** (33591-04500), then install the valve cotters on the valve stem.
- (c) Lightly tap on the top of each valve stem with a soft-face mallet to make sure that the valve spring and cotters are properly installed.

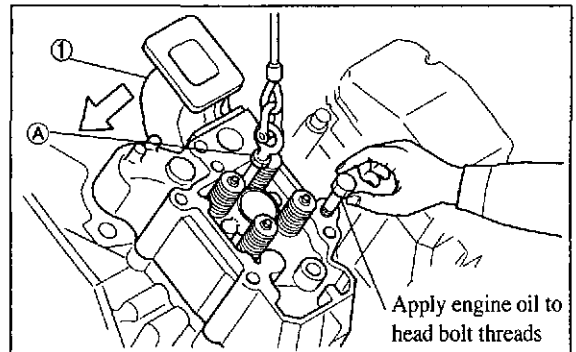


(4) Installing cylinder head assembly

- (a) Install the exhaust connector **1** to the cylinder head. To properly position the exhaust manifold at the center, move the exhaust manifold connector down as much as the play at the bolt holes allows.

NOTE

Place the gasket so its "MANIFOLD" printed side aligns with the connector side.



- (b) Install the eye nut **A** (37591-02400) to the stud bolt. Connecting a shackle and wire rope, lift up the cylinder head assembly. Locate the head aligning its holes with the dowel pins, and keep the head being slightly separated from the cylinder. Apply engine oil to the threads and bolt seat, then tighten head bolts.

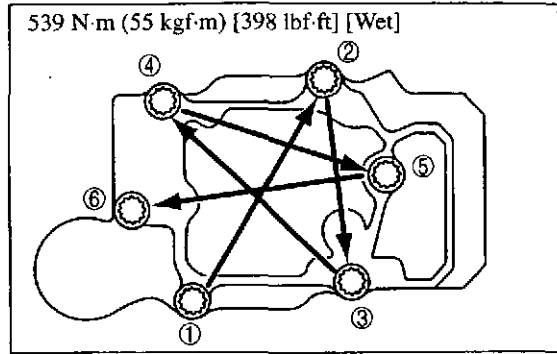
- (c) Tighten the cylinder head bolts with the specified torque in the sequence shown in the drawing.

• **Tightening cylinder head bolts by angle of turn method**

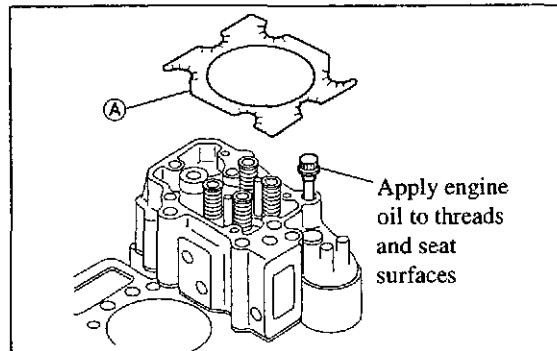
- Place the head bolt plate (A) (37598-08900) on the cylinder head.
- Tighten the cylinder head bolts to a snug torque (initial torque) of 294 ± 14.7 N·m (30 ± 1.5 kgf·m) [217 ± 10.8 lbf·ft] according to the tightening sequence.
- The head bolt plate has angle scales graduated in 30 degrees. Mark a reference point on the cylinder head bolts.
- Tighten the cylinder head bolts by the first $30^\circ \pm 1.5^\circ$ and then by another $30^\circ \pm 1.5^\circ$ (total tightening angle of $60^\circ \pm 3^\circ$) according to the tightening sequence.
- Loosen all bolts, and then tighten them by the angle of turn method (double tightening).

CAUTION

- The cylinder head bolts should be screwed down after wiping off the applied engine oil.
- Before installing the cylinder head assembly, measure the protrusion of each piston. Make sure the protrusion is correct.



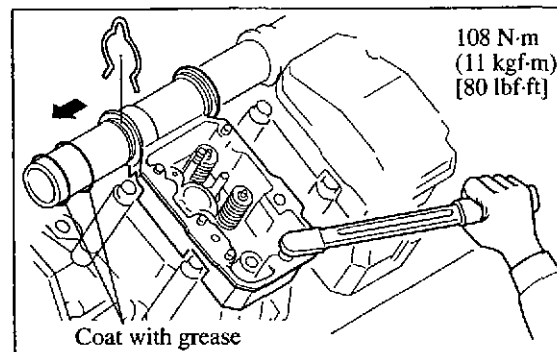
Head bolt tightening sequence



Tightening cylinder head bolts by angle of turn method

(5) Installing rocker case

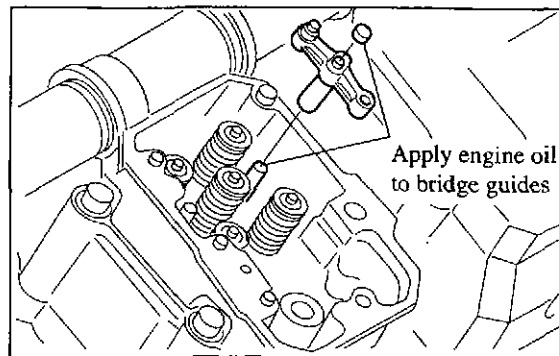
- Insert the water outlet connector fully into the rocker case.
- Install the rocker case so that it meets the dowel pins.
- Tighten the rocker case mounting bolts to the specified torque.
- Before installing the water outlet connector, coat the O-ring with grease, then align it to the flange by shifting away from the adjacent rocker case, and tighten the bolts.



ENGINE MAIN PARTS

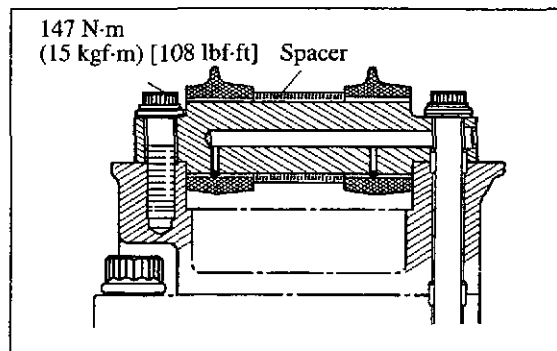
(6) Installing bridge and bridge cap

- (a) Apply engine oil to the bridge guides, then install the bridges to the guides with the adjusting screws positioned on the exhaust manifold side.
- (b) Apply engine oil to the bridge contact face of the bridge caps. Install the caps in position, being careful not to let them fall into the crankcase through the pushrod holes.



(7) Installing rockershaft assembly

- (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.

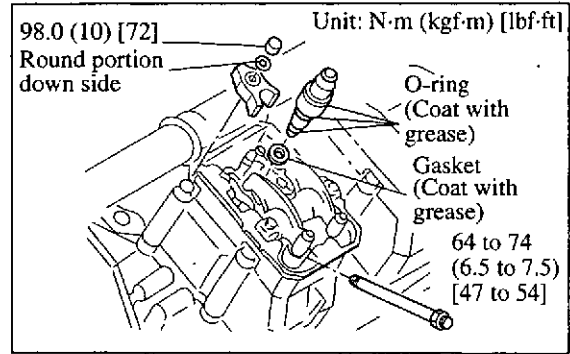


CAUTION

- (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 that 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 fuel injection nozzle assembly

- (a) Disconnect the fuel inlet connector from the nozzle assembly.
- (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. Align its connector hole with the rocker case hole.
- (d) Tighten the fuel inlet connector to the specified torque.
- (e) Tighten nozzle gland mounting nut to the specified torque.

**NOTE**

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

CAUTION

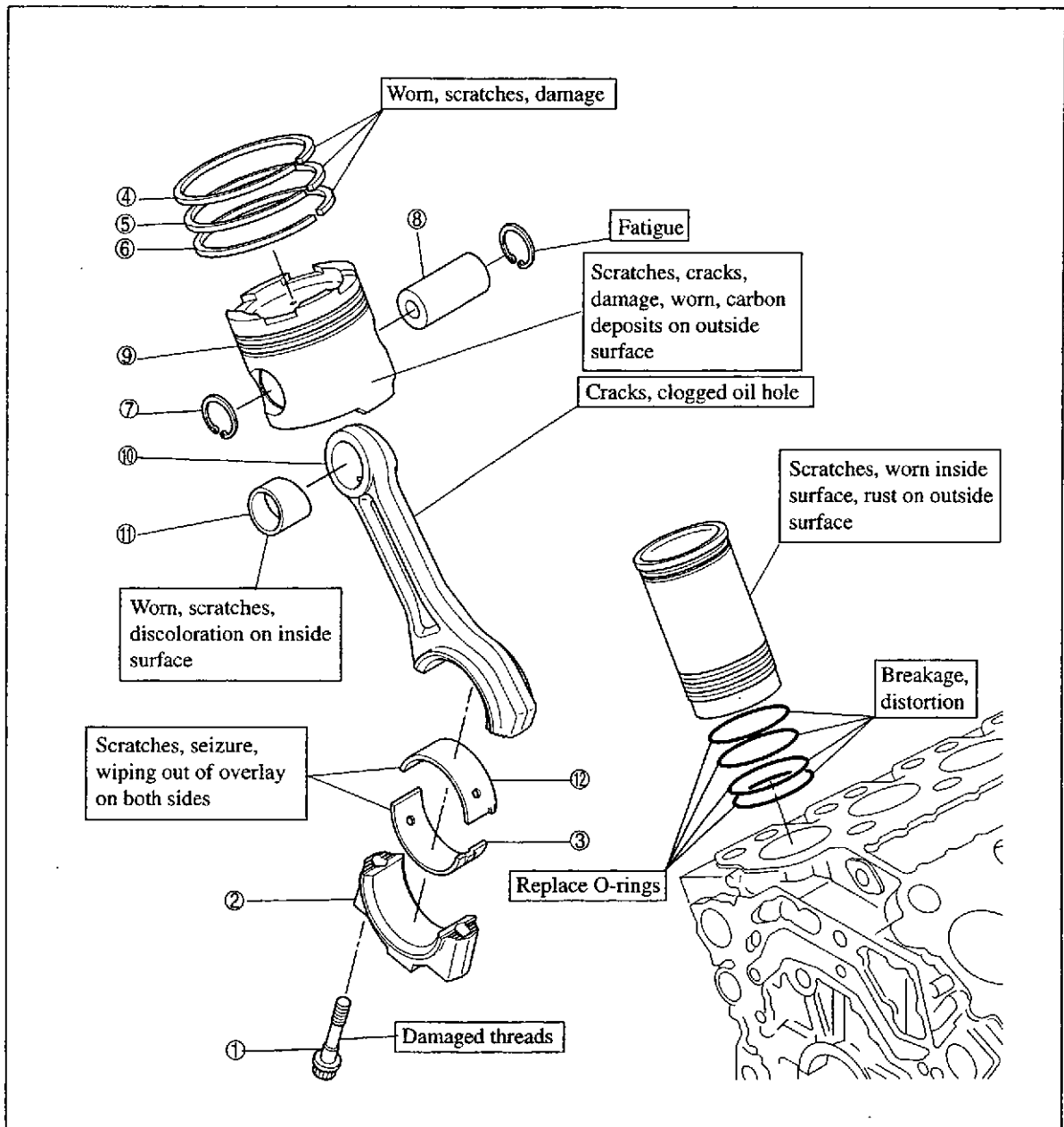
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(9) Adjusting valve clearance

Refer to section 1.1, Group 5, "Adjustments, Bench Testing, and Performance Tests."

2. Cylinder Liners, Pistons, and Connecting Rods

2.1 Disassembly



Disassembly sequence

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

CAUTION

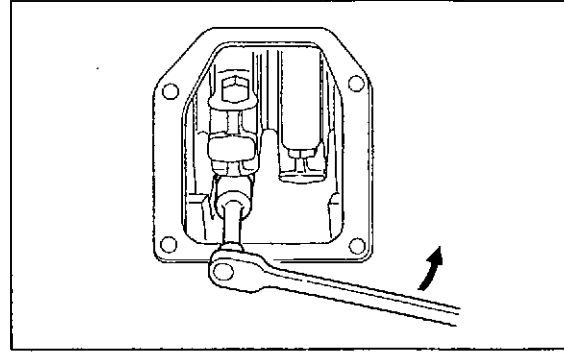
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(1) Removing connecting rod caps

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

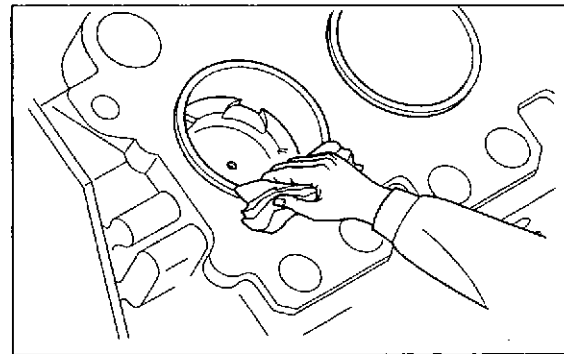
NOTE

- (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.



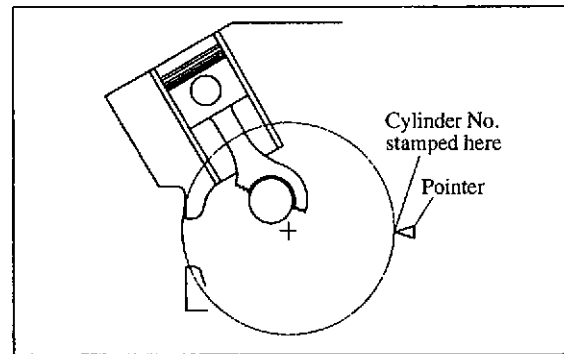
(2) Preparation before removing pistons

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.

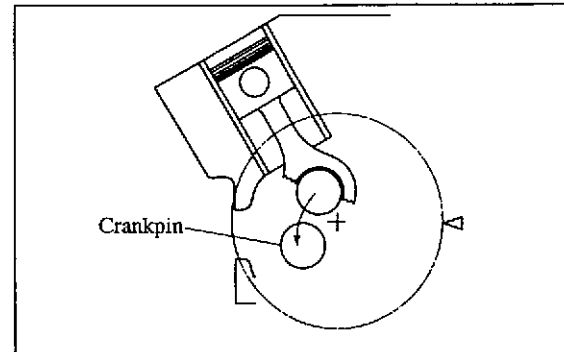


(3) Removing pistons for right bank cylinders

- (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 reverse until the crank pin comes off the connecting rod and the bolt hole of the rod is visible through the inspection window on the side of the crankcase.

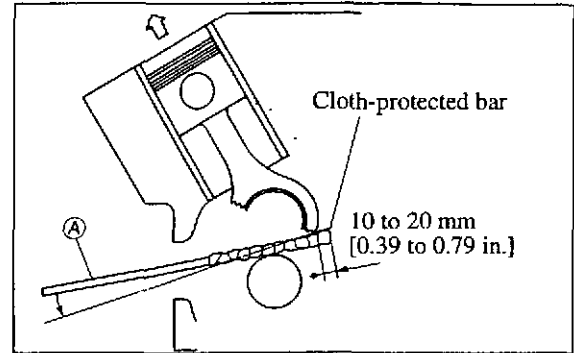


ENGINE MAIN PARTS

- (c) Cover a bar (A) with a cloth for protection. 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. Make use of the crankpin as a fulcrum.

NOTE

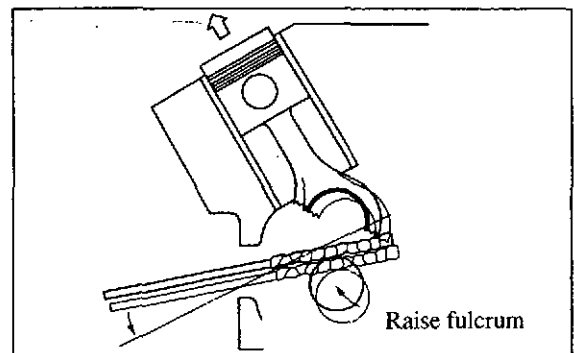
Inserting the bar too much, the piston assembly cannot be pried up. Insert the bar so that it protrudes about 10 to 20 mm [0.39 to 0.79 in.] from the bottom end of the big-end.



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

NOTE

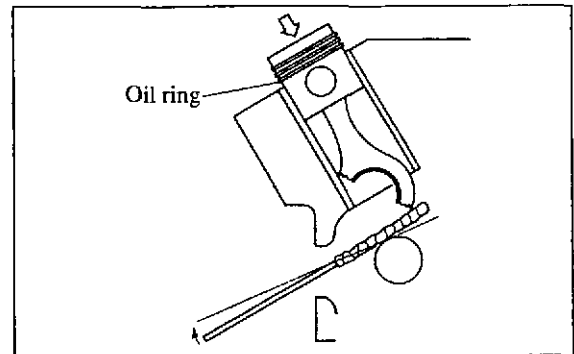
Raise the piston assembly carefully so that the connecting rod will not interfere with the oil jet nozzle for piston cooling.



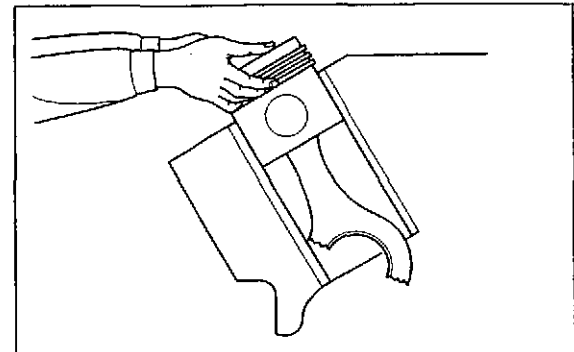
- (e) When the oil ring of the piston comes out of the cylinder liner, lower the piston a little and carefully rest the oil ring on the edge of the liner.

CAUTION

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

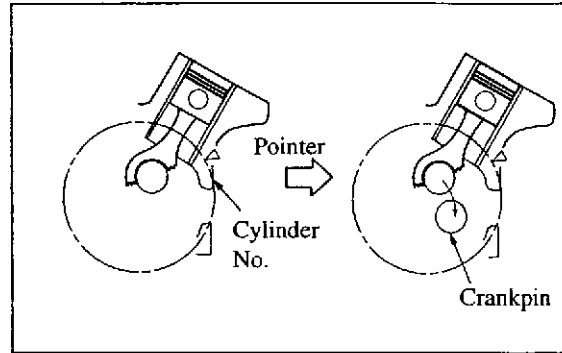


- (f) While holding the compression ring portion of the piston with your hands, carefully pull the piston from the cylinder liner, then rest its skirt on the top of the crankcase.
- (g) With your hands hold the piston pin portion of the piston, and lift the piston assembly off the liner.



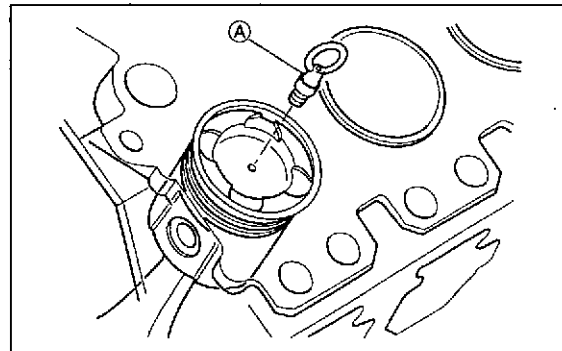
(4) Removing pistons for left bank cylinders

Removal procedure is the same as that for removing pistons in right bank cylinders. The only difference is that the position of the crankpin and the direction of the crankshaft rotation for removal are reversed.



(5) Using piston remover

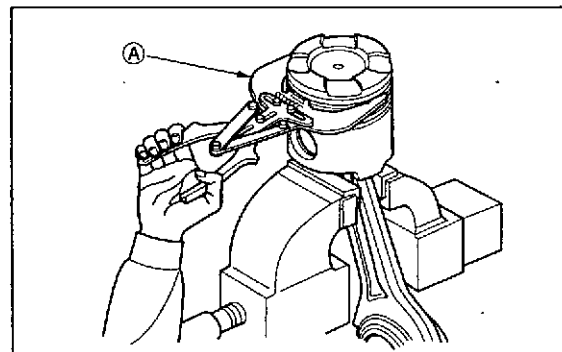
- Turn the crankshaft to bring the piston assembly to be removed to 50° after top dead center for the right bank.
- Attach the piston remover (A) (MM321420) to the top of the piston. Grip the handle of the remover, then lift the piston and the connecting rod off the liner.

**CAUTION**

- Do not damage the piston when you pull it out from the cylinder liner. Do not let it hit the connecting rod with its skirt.
- Support the connecting rod, to protect the cylinder liner bore from scratching.

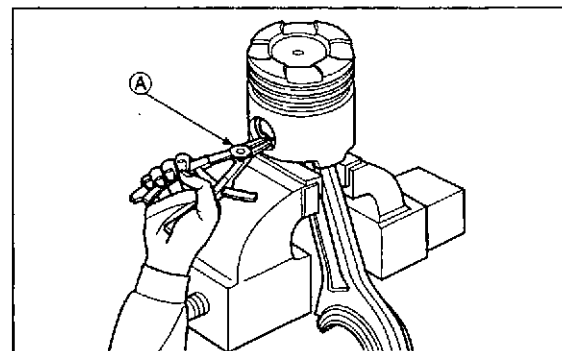
(6) Removing piston ring

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



(7) Removing piston pins

- Use the ring pliers (A) (45191-08400) to remove the snap rings.
- Remove the piston pin to separate the piston from the connecting rod.
- 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.



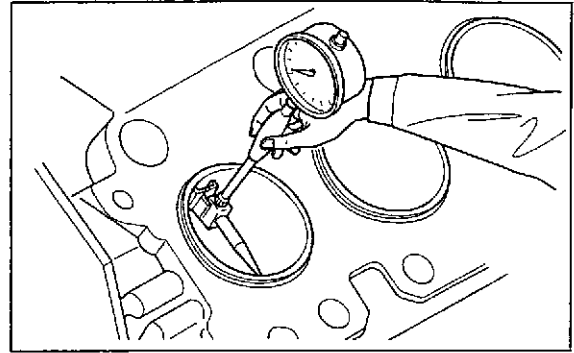
2.2 Inspection and Repair

(1) Measuring cylinder liner inside diameter

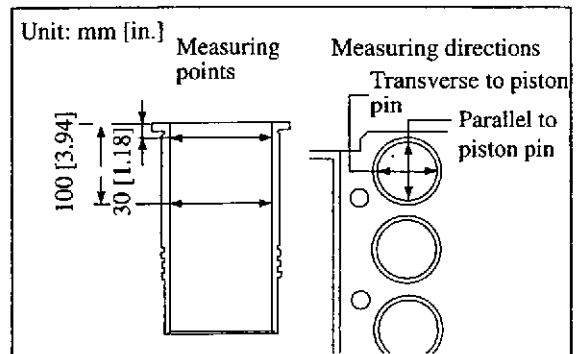
Measure the inside diameter of each liner in two directions, parallel and transverse to the piston pin, at three positions, top (worn position), middle and low. If measurements exceed the service limit, replace the liner.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Cylinder liner inside diameter	∅170 [∅6.69]	170.000 to 170.040 [6.69291 to 6.69447]	170.500 [6.71770]



Measuring cylinder liner inside diameter



Cylinder liner measuring diagram

(2) Measuring cylinder liner protrusion

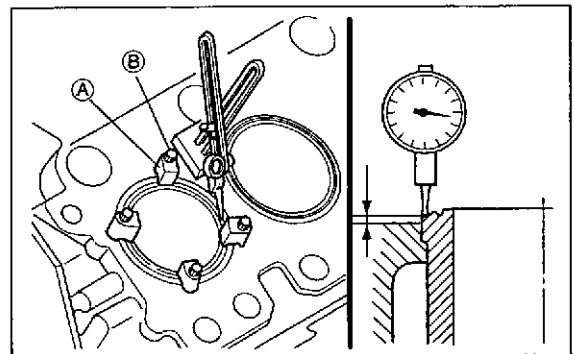
Measure the protrusion of each liner at its flange with dial gage as shown.

NOTE

The method of measuring the protrusion of a used liner differs from that of newly installed one.

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 (1)

CAUTION

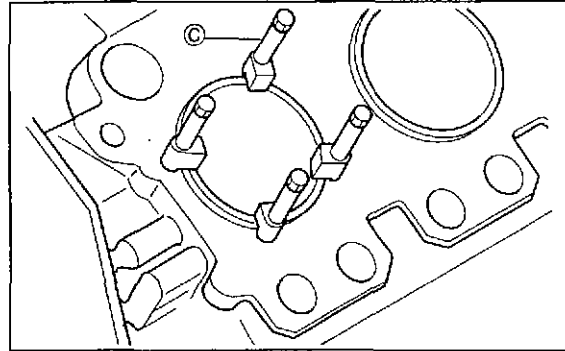
If the protrusion is less than the assembly standard, the gasket will fail to seal the bore, causing gas leakage.

- When cylinder head has just been removed
 - (a) Clean the gasket surface of the crankcase and the top of the liners.
 - (b) Secure the top of the liner uniformly at four places with the liner pusher **(A)** (37591-06200) and the bolts **(B)** (37591-06300).

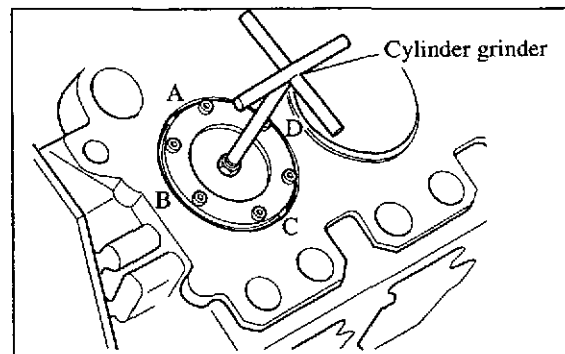
NOTE

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

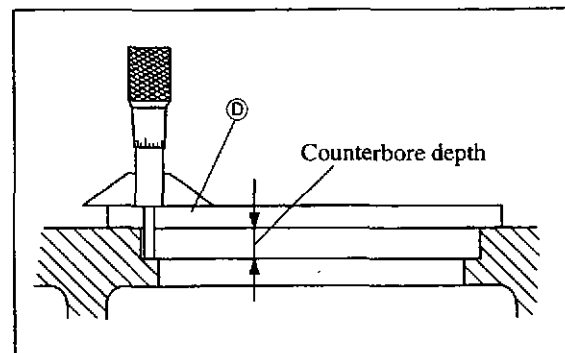
- (c) Set up the dial gage at the top face of the crankcase, then set the gage pointer to 0 (zero).
 - (d) Measure the protrusion at four places at the flange of the liner. Take the average of the four measurements.
 - (e) If the average is less than the assembly standard, insert a shim under the collar of the cylinder liner.
- When cylinder liner is to be replaced (See section (3).)
 - (a) Remove the cylinder liner, and observe the cylinder liner contacting surface to the crankcase.
 - (b) If the cylinder liner contacts the crankcase only on one side, use the cylinder grinder (37591-07101) 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 counterbore depth of the crankcase. Since the top surface of the crankcase may be slightly distorted, use the projection plate **(D)** (37598-09201) to obtain accurate measurements.
 - (d) Measure at four locations A, B, C and D, and obtain the average.



Measuring cylinder liner protrusion (2)



Measuring cylinder liner protrusion (3)



Measuring crankcase counterbore depth

ENGINE MAIN PARTS

- (e) Measure the thickness (standard value: 15 mm [0.59 in.]) of the projection plate using a micrometer. Subtract the projection plate thickness from the measured counterbore depth to obtain the actual counterbore depth from the top surface of the crankcase.

Unit: mm [in.]

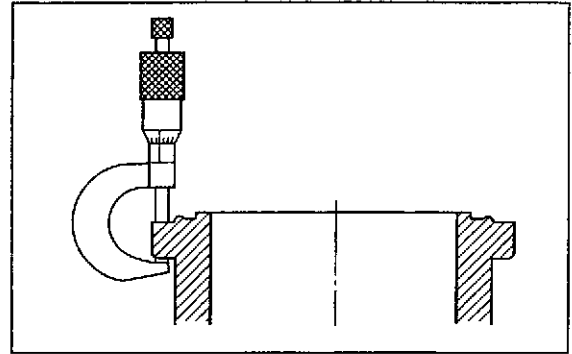
Item	Assembly Standard
Crankcase counterbore depth	$14^{+0.05}_0$ [$0.55^{+0.0020}_0$]

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

Unit: mm [in.]

Item	Assembly Standard
Thickness of cylinder liner collar	$14^{+0.20}_{+0.16}$ [$0.55^{+0.0079}_{+0.0063}$]

- (g) Subtract the crankcase counterbore depth from the cylinder liner collar thickness. This value is the cylinder liner protrusion.
- (h) If the value is less than the assembly standard, insert a shim under the collar of the cylinder liner.



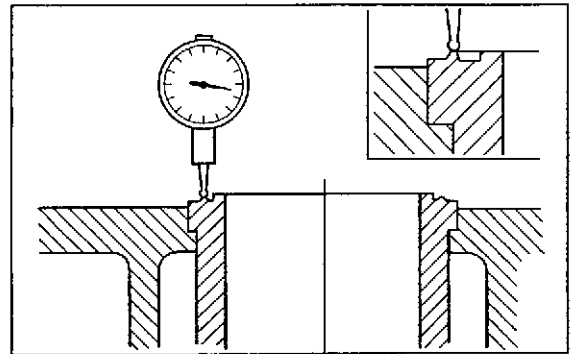
Measuring thickness of cylinder liner collar

• 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 step as shown at four locations, and obtain the average.

Unit: mm [in.]

Item	Assembly Standard
Cylinder liner step height	0.2 ± 0.04 [0.008 ± 0.002]



Measuring height of liner collar

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

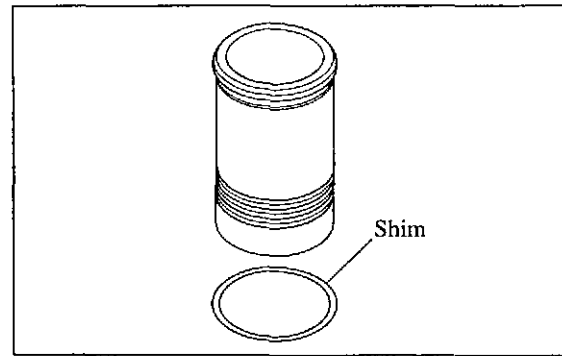
- Inserting cylinder liner shim

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

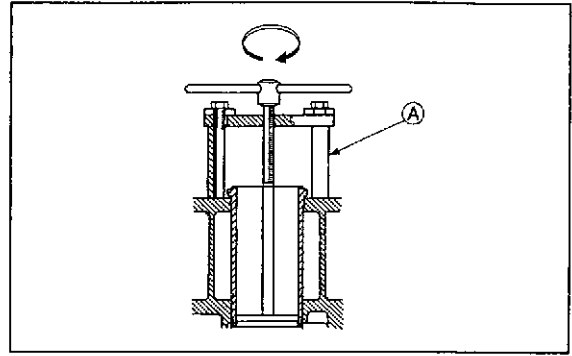


Inserting cylinder liner shim

ENGINE MAIN PARTS

(3) Replacing cylinder liners

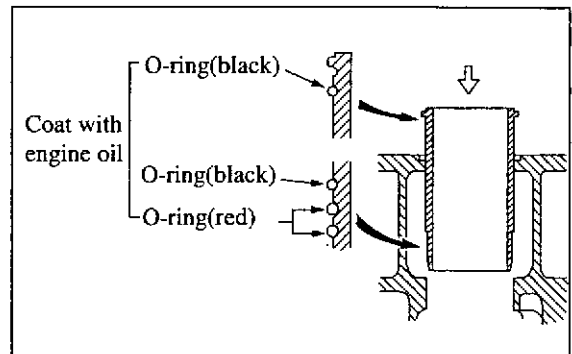
- (a) Use the cylinder liner remover **A** (37591-04100) to remove the cylinder liner from the crankcase for replacement.



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

CAUTION

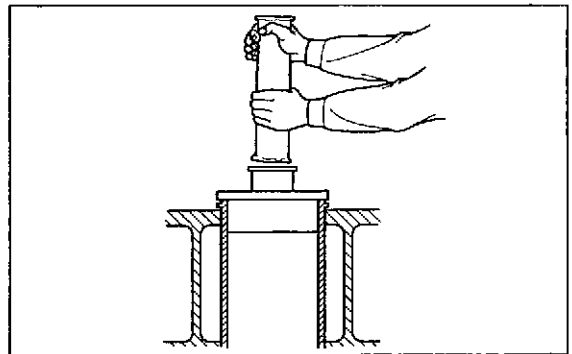
Before inserting the liner, coat the O-rings with engine oil to prevent them from twisting.



- (c) After inserting the liner into the bore, lightly tap it on the top with the Installer so that it rests on its flange on 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 fitting for water tightness by applying water under pressure.
(b) Check each liner to be sure its protrusion is within assembly standards.

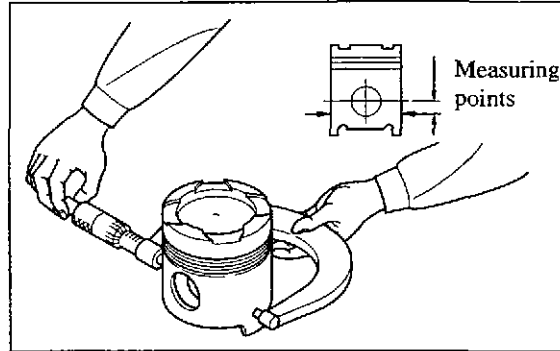


(4) Inspecting piston outside surfaces

Check the combustion surfaces and inside surfaces of the pin 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.



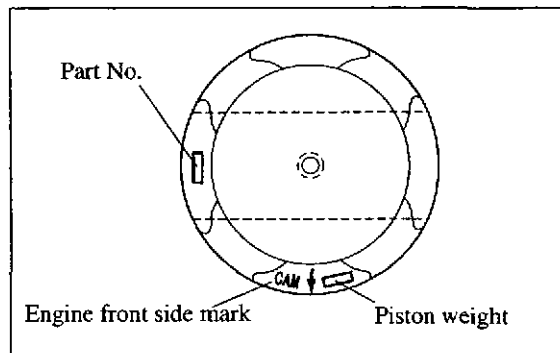
Measuring piston diameter

(5) Measuring piston diameter

- (a) Using a micrometer, measure the diameter of each piston perpendicular 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 that the weight difference in an engine is within assembly standards.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Outside diameter	ø170 [ø6.69]	169.76 to 169.80 [6.6835 to 6.6850]	169.66 [6.6795]
Weight difference in one engine		±10 g [±0.02 lb] or less	

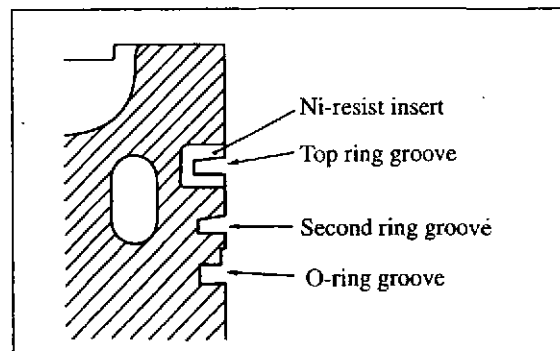


Piston weight stamp location

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

(6) Inspecting piston ring grooves

Check the piston ring grooves for wear and damage, then replace the piston if necessary.



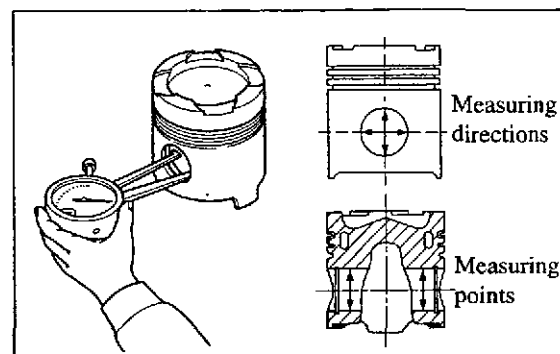
Inspecting piston ring grooves

(7) 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
Inside diameter of piston pin bore	ø 70 [2.76]	70.002 to 70.015 [2.75598 to 2.75649]	70.040 [2.75747]



Measuring piston bore diameter

ENGINE MAIN PARTS

(8) 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 zero (0).
- (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	0.06 to 0.65 [0.0023 to 0.0256]
Thickness when tightened (cylinder head gasket)	1.77 to 1.83 [0.0697 to 0.0720]
Clearance between piston top and cylinder head	1.22 to 1.95 [0.0480 to 0.0768]

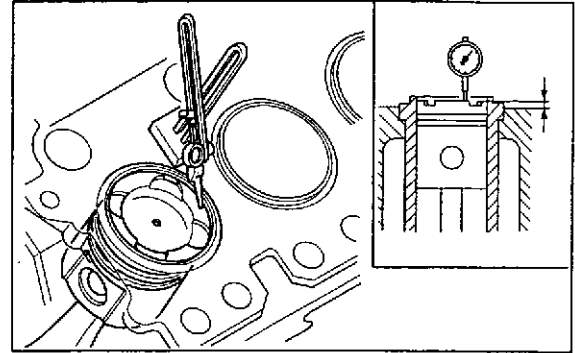
CAUTION

Keep the piston protrusion within the assembly standard range to maintain high engine performance and to prevent the valves from stamping on the piston.

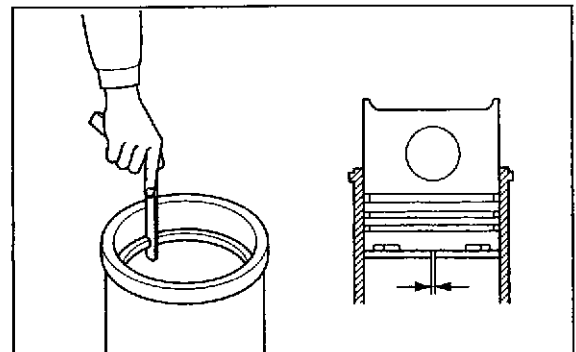
(9) Measuring piston ring gap

Place the rings in the new or 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
[6.69 ± 0 in.]



Measuring piston protrusion



Measuring piston ring gap

NOTE

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

Unit: mm [in.]

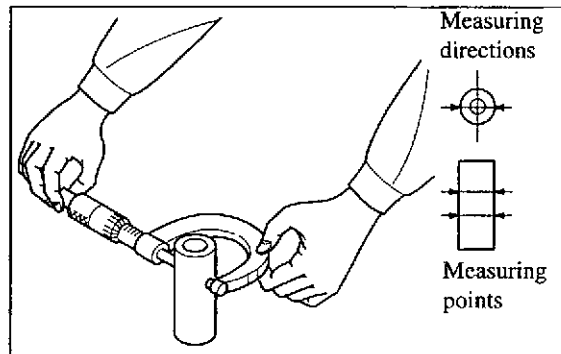
Item		Standard Clearance	Service Limit
Piston ring gap	Top	0.6 to 0.8 [0.024 to 0.031]	2.0 [0.079]
	Second	0.6 to 0.8 [0.024 to 0.031]	
	Oil	0.3 to 0.45 [0.012 to 0.018]	

(10) 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
Outside diameter of piston pin	ø70 [2.76]	69.987 to 70.000 [2.75539 to 2.75590]	69.970 [2.75472]



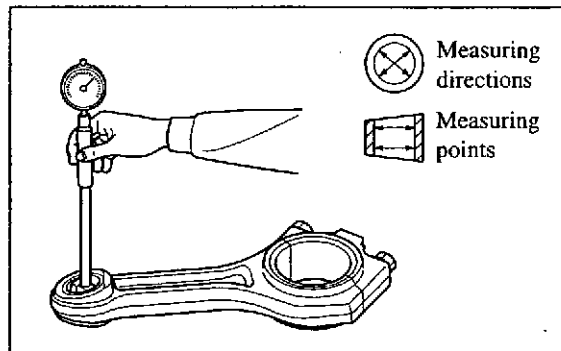
Measuring piston pin diameter

(11) Measuring connecting rod 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
Inside diameter of connecting rod bushing	ø70 [2.76]	70.020 to 70.040 [2.75669 to 2.75747]	70.070 [2.75866]

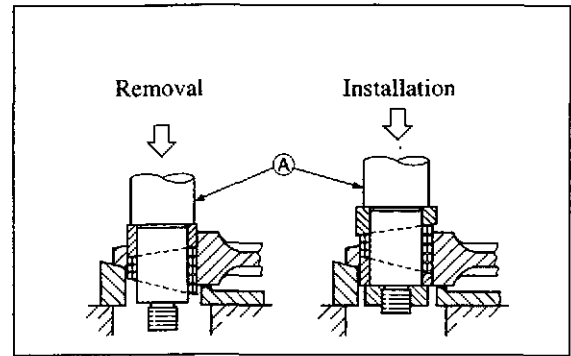


Measuring connecting rod bushing inside diameter

ENGINE MAIN PARTS

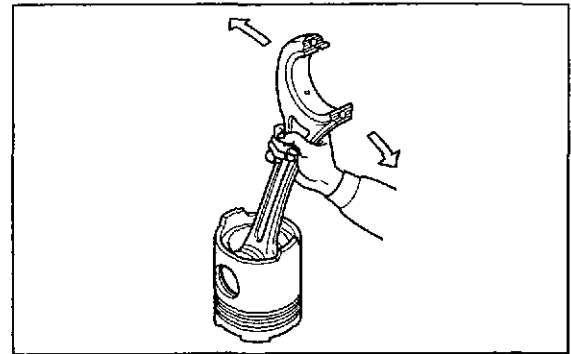
(12) Replacing connecting rod bushing

- (a) Use the connecting rod bushing installer (A) (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.



(13) Inspecting connecting rods for bend and twist

- (a) Measure C and l. If the measurement at C is larger than 0.05 mm per 100 mm [0.020 in. per 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.

Unit: mm [in.]

Connecting rod bend

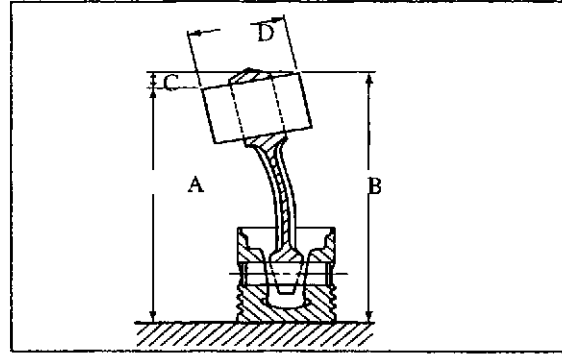
Connecting rod twist

Inspecting connecting rod for bend and twist

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

Unit: mm [in.]

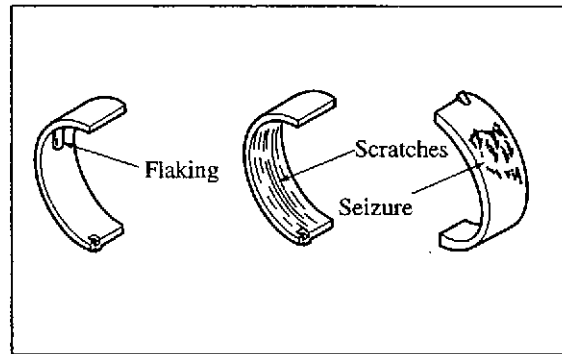
Item	Assembly Standard
Connecting rod bend and twist (C/D)	0.05/100 or less [0.020/3.9]



Inspecting connecting rod assembly with piston

(14) Inspecting connecting rod bearings

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

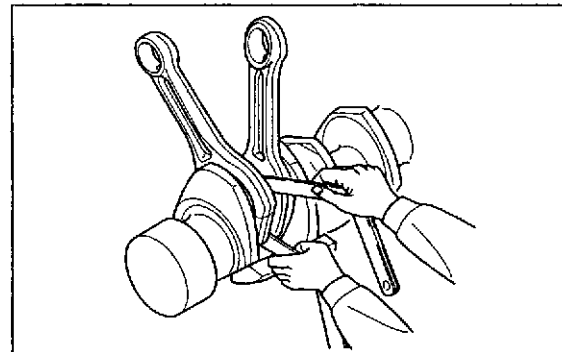


(15) Measuring connecting rod end play

Install the connecting rod to its crankpin, then tighten its cap bolts to the specified torque. Use feeler gages 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	Service Limit
Connecting rod end play*	60 × 2 [2.36 × 2]	0.4 to 0.9 [0.016 to 0.035]	1.4 [0.055]



Measuring connecting rod end play

*Widths of connecting rod and crankpin

ENGINE MAIN PARTS

- (16) Weight difference of connecting rods in one engine

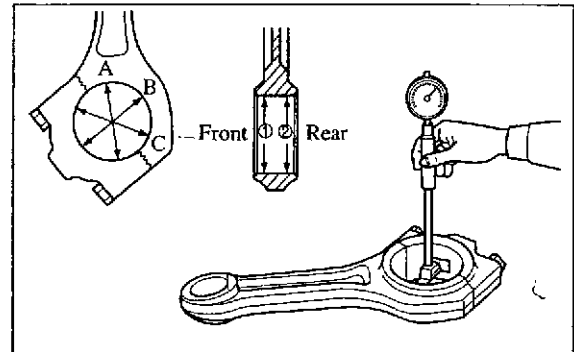
When replacing connecting rods, make sure that the weight difference of connecting rod assemblies in one engine is within the assembly standards below.

Item	Assembly Standard
Weight difference of connecting rod assemblies in one engine	±30 g [0.07 lb.] or less

- (17) Measuring connecting rod big-end bore diameter and roundness

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 drawing. To obtain the roundness value, subtract the smallest measured value from the largest measured value.

If the diameter exceeds the service limit, replace the connecting rod.



Measuring connecting rod big-end bore diameter

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Connecting rod big-end bore diameter	ø131 [5.16]	131.000 to 131.025 [5.15747 to 5.15845]	131.050 [5.15944]

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

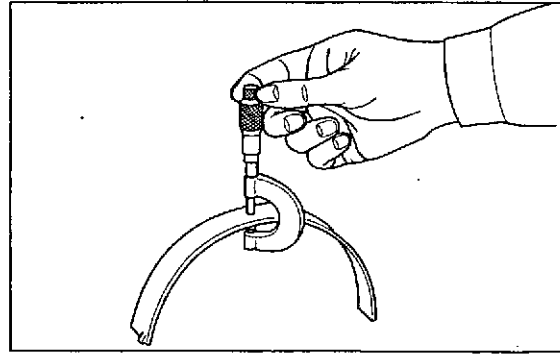
Inspect the serration on connecting rod big-end by conducting a Magnaflux (magnetic particle) test. If cracking or damage is found, replace the connecting rod.

(19) 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 [0.11811]	2.972 to 2.985 [0.11701 to 0.11752]	2.930 [0.11535]
	-0.25 [-0.0098]	3.125 [0.12303]	3.097 to 3.110 [0.12193 to 0.12244]	3.055 [0.12028]
	-0.50 [-0.0197]	3.250 [0.12795]	3.222 to 3.235 [0.12685 to 0.12736]	3.180 [0.12520]
	-0.75 [-0.0295]	3.375 [0.13287]	3.347 to 3.360 [0.13177 to 0.13228]	3.305 [0.13012]
	-1.00 [-0.0394]	3.500 [0.13780]	3.472 to 3.485 [0.13669 to 0.13720]	3.430 [0.13504]



Measuring connecting rod bearing thickness

NOTE

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

2.3 Reassembly

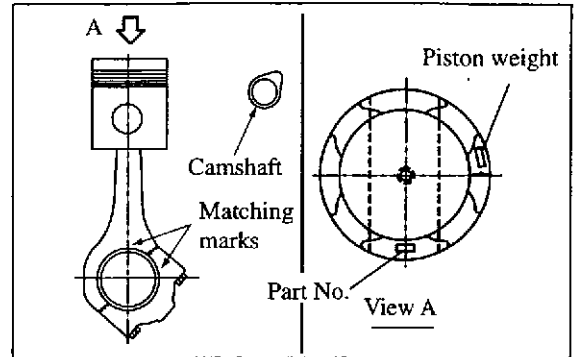
Reassembly is done in the reverse order of disassembly.

(1) Reassembling pistons on connecting rods

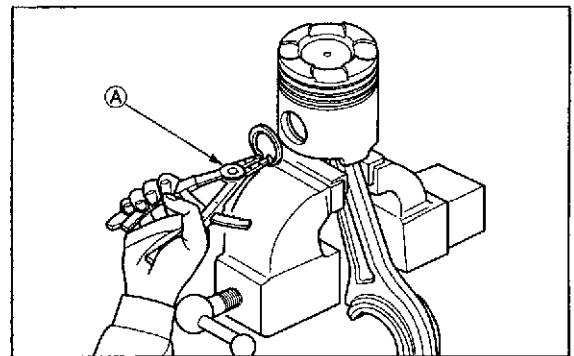
- (a) The piston pin is clearance-fitted to the piston. To facilitate pin insertion, heat the piston with a piston heater or in hot water.
- (b) Coat the piston pin with engine oil, then insert it in position through the connecting rod.
- (c) Install the connecting rod to the piston with the matching marks on the big-end on the camshaft side.
- (d) Use the ring pliers (A) (45191-08400) to install the snap rings in the grooves of the piston.

NOTE

Position the end gap of each snap ring at the bottom of the pin bore.



Matching marks on connecting rod

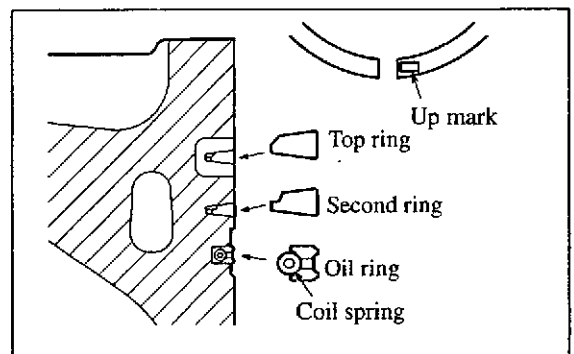


(2) Installing piston rings

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

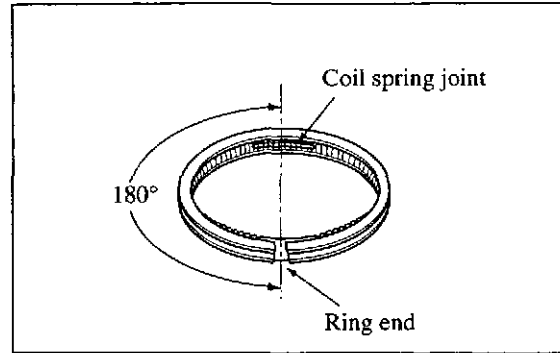
CAUTION

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. If not, excessive oil consumption and overheating will result.



Piston and piston ring arrangement

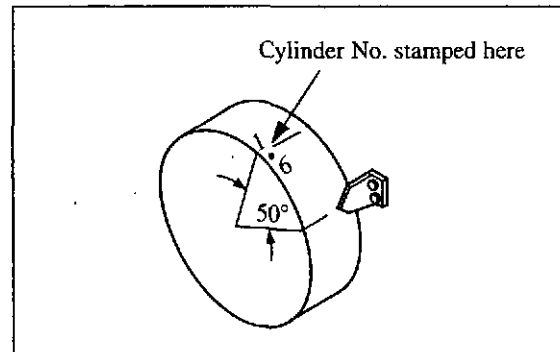
- (b) Install the oil ring with its end gap positioned at 180° to the coil spring joint.



(3) Preparation before installing pistons

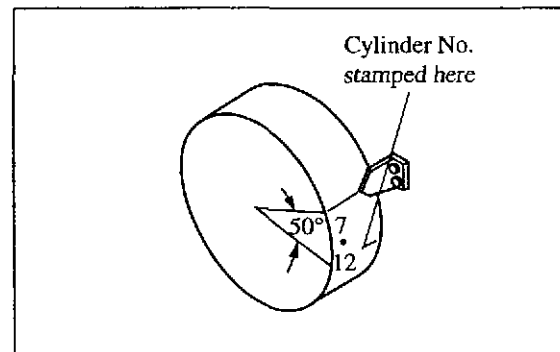
- (a) Pistons for right bank cylinders

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.

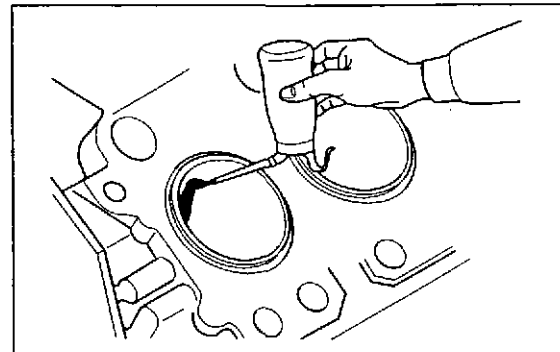


- (b) Pistons for left bank cylinders

Turn the crankshaft in the normal direction until the number of the cylinder to which the piston is to be installed is at the position of about 50° after top dead center.



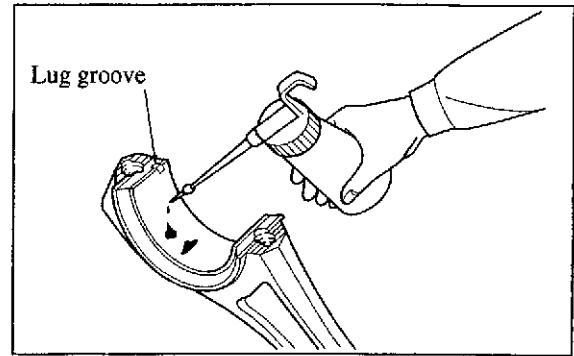
- (c) Clean the cylinder liner bore surface and crank pin by wiping with a cloth, then apply engine oil to it.



ENGINE MAIN PARTS

(4) Installing connecting rod bearing upper shells

Install the upper shell of the bearing in the rod by fitting its locating lug in the lug groove provided in the rod. Apply engine oil to the inside surface of the shell. Make sure the oil holes in the rod and bearing are aligned.



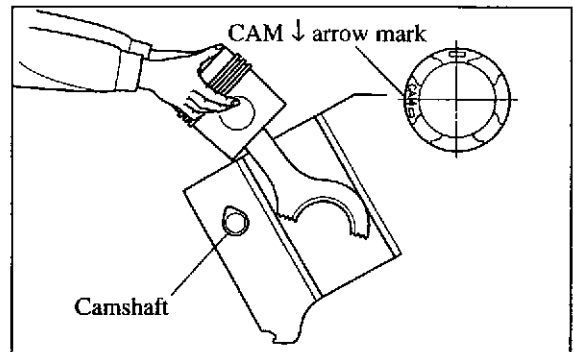
(5) Inserting pistons

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

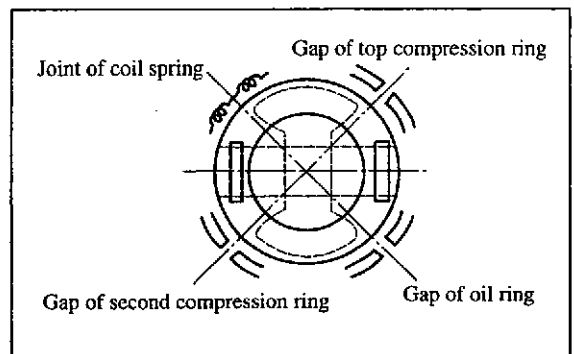
CAUTION

Make sure the arrow mark above the "CAM ↓ (arrow mark)" on top of the piston points camshaft side.

When placing the connecting rod in the liner, have another serviceman observe the rod through the inspection window to keep it away from the oil jet nozzle. Do not rotate the piston.



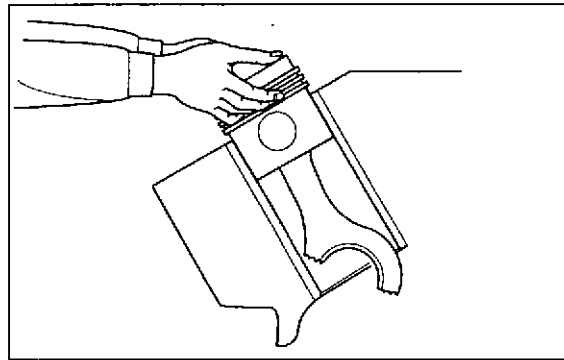
- (b) Apply engine oil to the piston rings, then move the piston rings so that the end gaps do not align with the pin direction, thrust directions or counter-thrust direction.



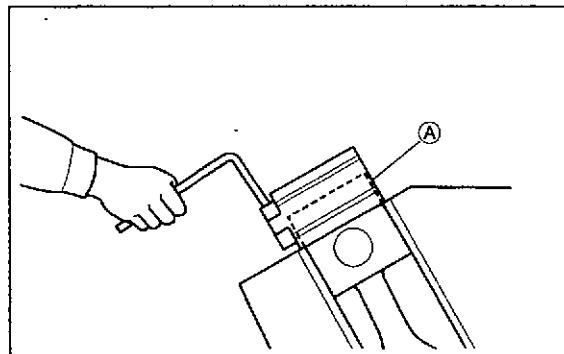
- (c) With your hands, hold the compression ring portion of the piston, then carefully insert the piston into the cylinder liner.

NOTE

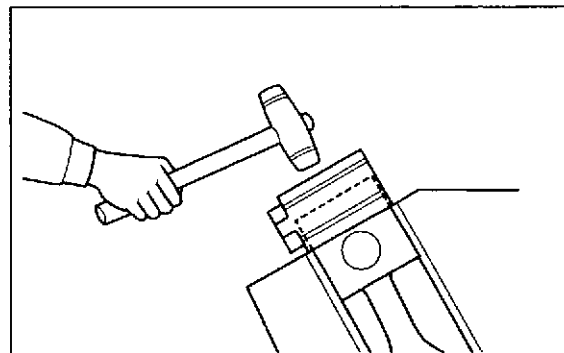
- (a) Do not pinch your finger between the oil ring and cylinder liner.
 (b) Slowly insert the piston to avoid damaging the oil ring.



- (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 (A) (37191-07100). At this time, apply engine oil to the inside surface of the installer.

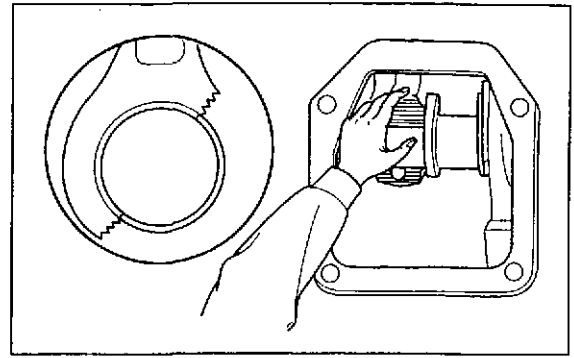


- (e) Lightly tap on the piston head with a soft-head mallet to insert the piston into the cylinder liner. If the piston will not go into the liner, move the big-end of the connecting rod back and forth through the crankcase inspection window.



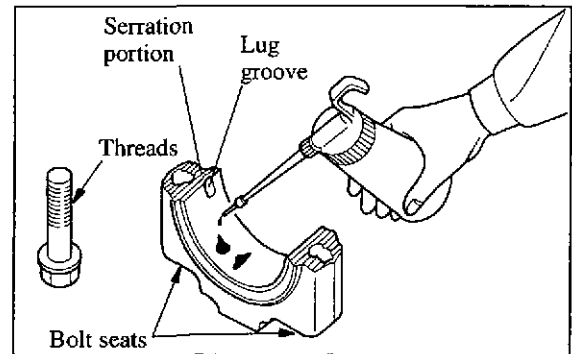
ENGINE MAIN PARTS

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

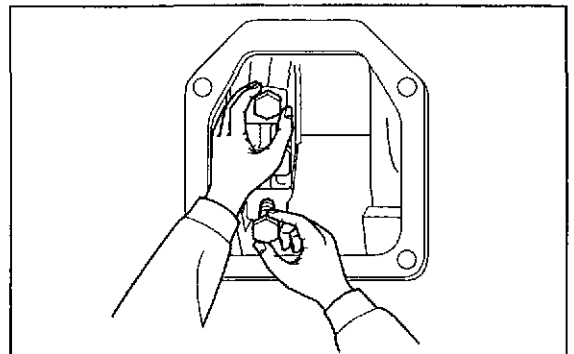


(6) Installing connecting rod cap

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



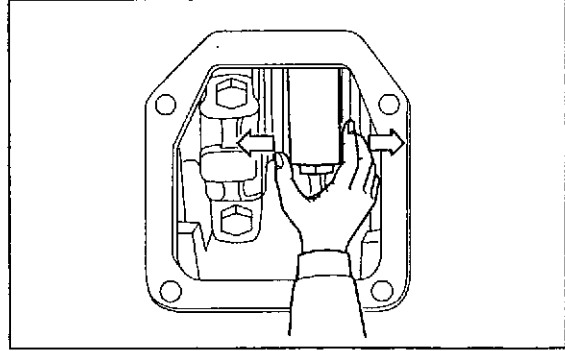
- (c) Install each cap in position. With your hand, hold the upper end of the cap, then tighten the bolt at the lower end first. This will help prevent the cap from dropping into the oil pan. Apply engine oil to the threads and bearing surfaces of the bolts, then tighten the bolts temporarily.
- (d) With the cap bolts tightened temporarily, touch the joint between the cap and rod. Make sure that the cap is fit 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 show the same number.

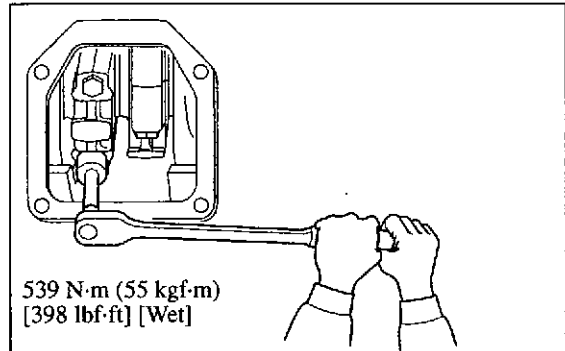
- (e) Install the other connecting rod to the crankpin. Temporarily tighten the cap bolts of the rod installed later, then press it squarely toward the rod already installed by tapping. Move the big-end of this rod in the thrust direction. Make sure that the rod has correct end play.



- (f) 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

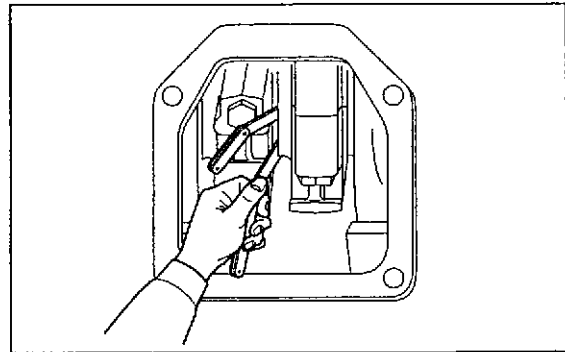
To tighten connecting rod cap bolts according to the angle method, tighten snug torque to 245 N·m (25 kgf·m) [181 lbf·ft], then turn each bolt by 30°. After tightening all the bolts, turn each bolt again by 30° (total of 60±3° turn).



- (g) Use feeler gages 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 crankpin.

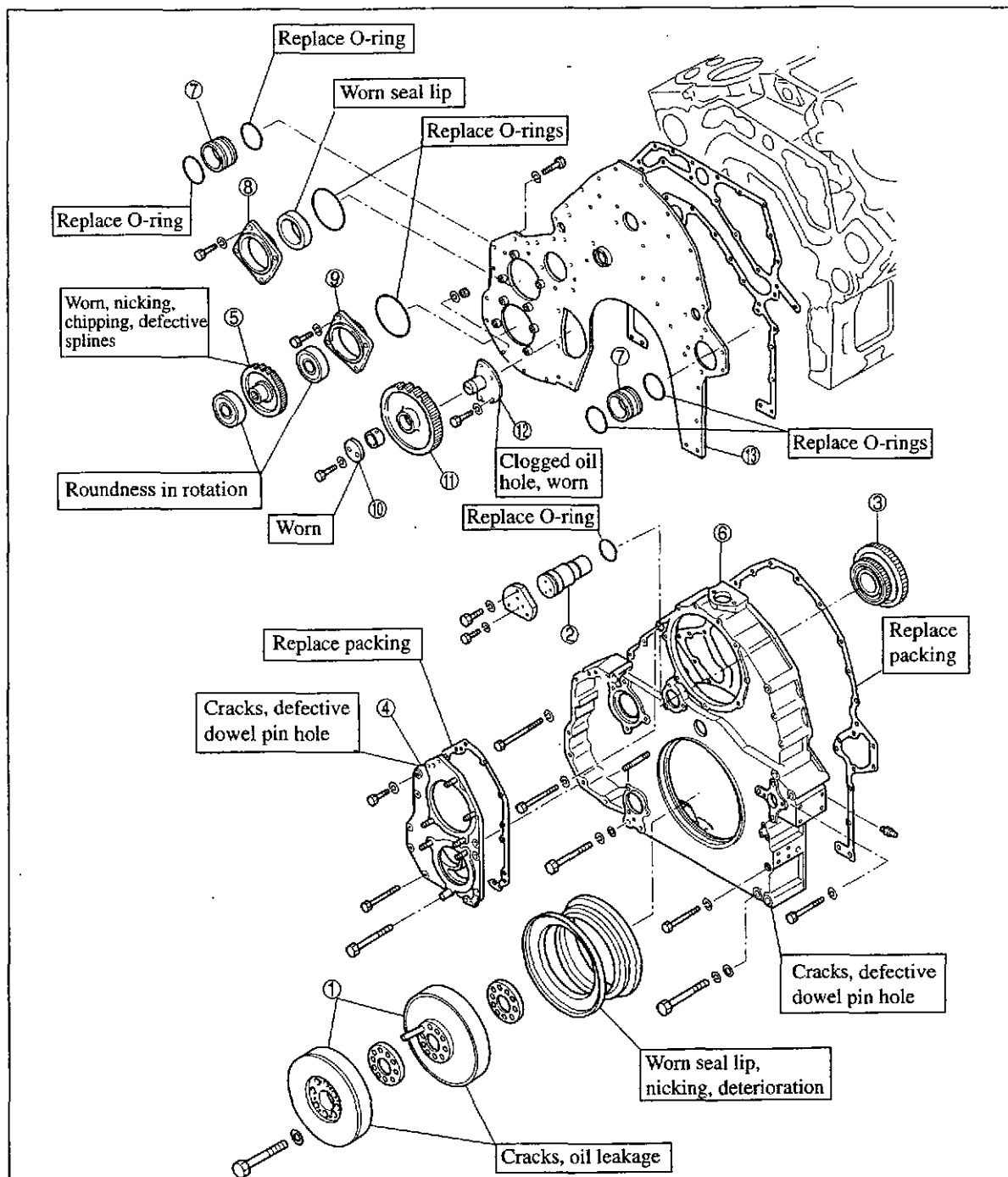
CAUTION

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



3. Damper and Front Gears

3.1 Disassembly



Disassembly sequence

- | | |
|-------------------------|----------------------------|
| ① Damper, damper spacer | ⑧ Water pump bearing cover |
| ② Idler shaft | ⑨ Oil pump bearing cover |
| ③ Idler gears | ⑩ Thrust plate |
| ④ Plate | ⑪ Idler gear |
| ⑤ Oil pump gear | ⑫ Idler shaft |
| ⑥ Front gear case | ⑬ Front plate |
| ⑦ Water coupling | |

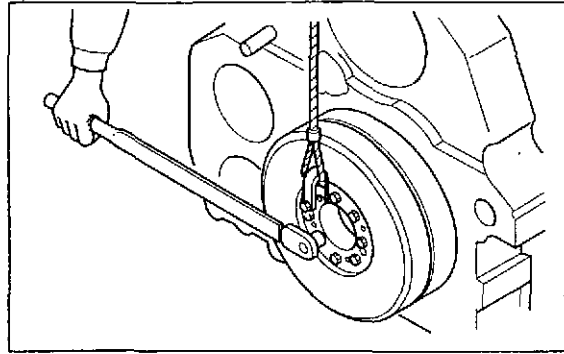
⚠ CAUTION

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 damper

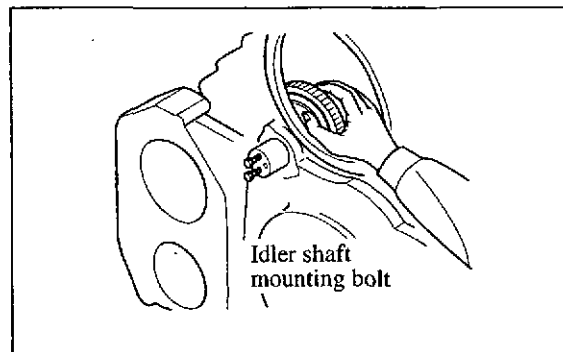
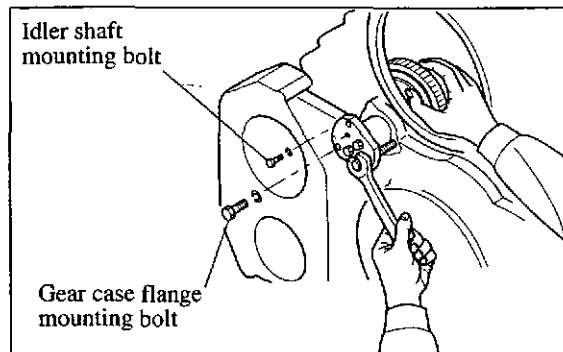
- (a) Attach a sling to the damper.
Unscrew the mounting bolts.
- (b) Screw the two jack-bolts (M14 × 1.5-40 mm [0.55 × 0.059-1.57 in.]) into the thread evenly, then remove the damper.

Weight of damper : approx. 50 kg [22.72 lb.]



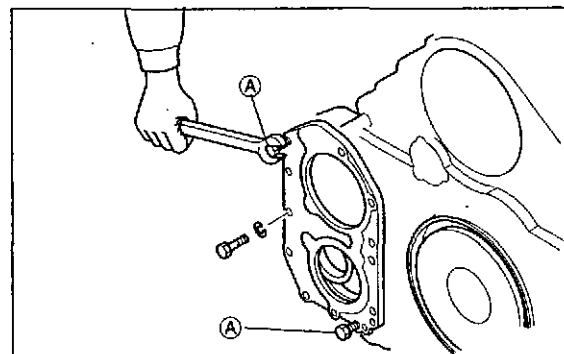
(2) Removing fan drive idler gears and idler shaft

- (a) Unscrew the three gear case flange mounting bolts and three idler shaft mounting bolts, and remove the gear case flange.
- (b) Screw the idler shaft mounting bolts into the idler shaft, and pull out the idler shaft by using the bolts. Reach through the fan drive mounting hole, and grab and hold the idler gears. After pulling out the idler shaft, remove the idler gears through the fan drive mounting hole.



(3) Removing oil pump and water pump mounting plate

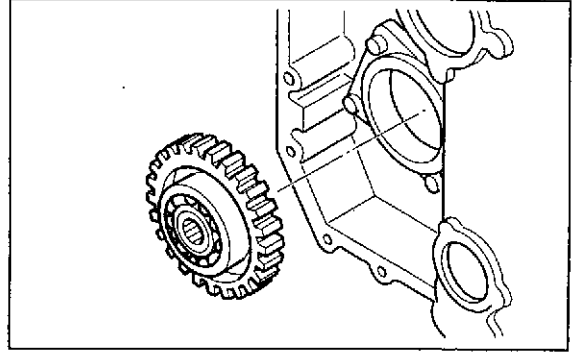
Unscrew the mounting bolts of the plate.
Remove the plate by screwing the two jack-bolts (A) (64362-68500: M12 × 1.25 mm [0.47 × 0.049 in.]) evenly into the plate.



ENGINE MAIN PARTS

(4) Removing oil pump gear

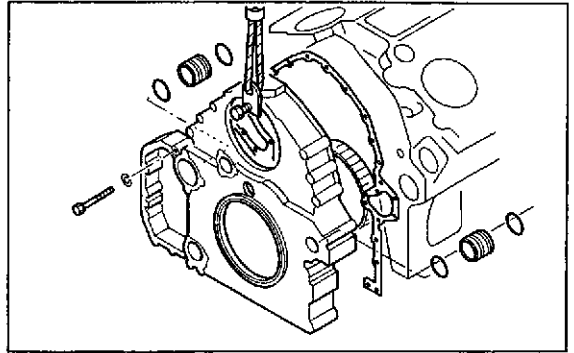
Remove the oil pump gear with the bearing.



(5) Removing front gear case

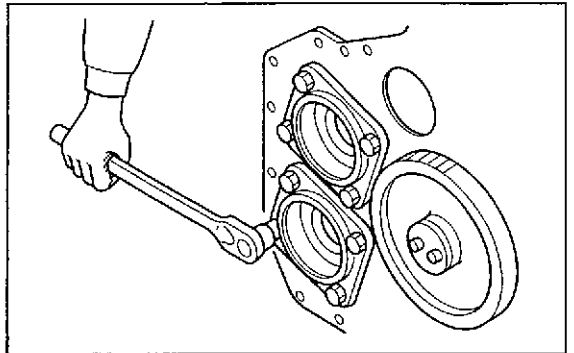
- (a) Attach a sling to the front gear case.
- (b) Unscrew the front gear case mounting bolts. Remove the lifted gear case by sliding it until the gear case comes apart from the positioning dowel pin. Be careful not to damage the oil seal, or bend the pointer by hitting it.

Weight: approx. 70 kg [154 lb.]



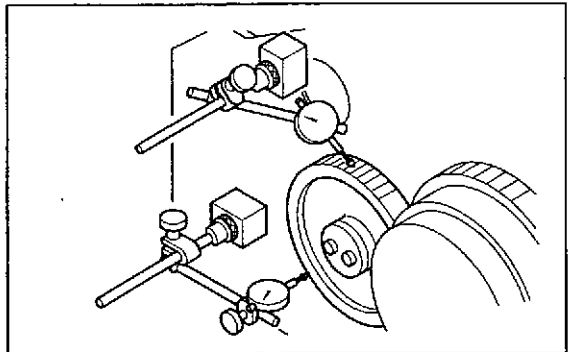
(6) Removing oil pump and water pump bearing cover

Unscrew the bearing cover mounting bolts, and remove the bearing cover.



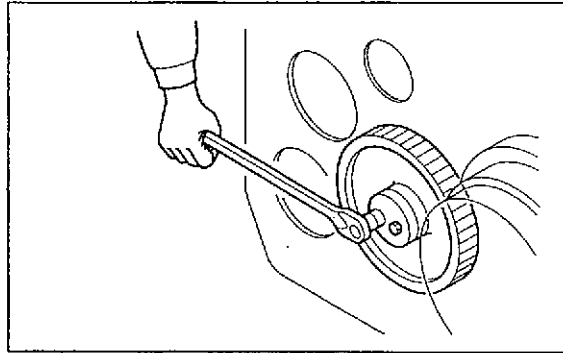
(7) Measuring backlash and end play of idler gear

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

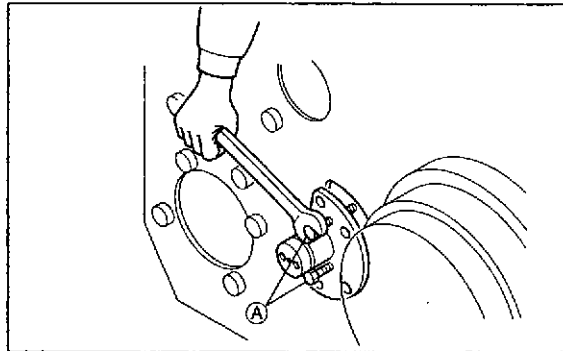


(8) Removing idler gear

Unscrew the thrust plate mounting bolt and remove the idler gear.

**(9) Removing idler shaft**

Do not remove the idler shaft unless it is needed. When needed, remove it by unscrewing the mounting bolts and screwing the two jack-bolts **A** (M10 × 1.25 mm [0.39 × 0.049 in.]) evenly.



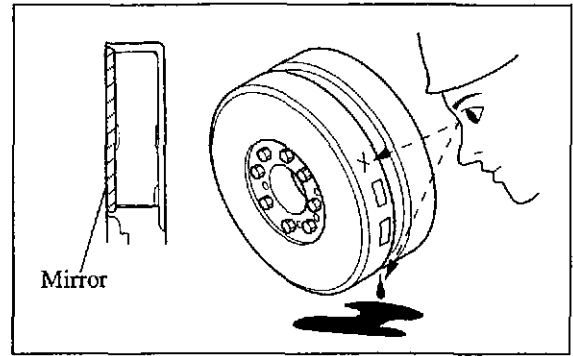
3.2 Inspection and Repair

(1) Damper inspection

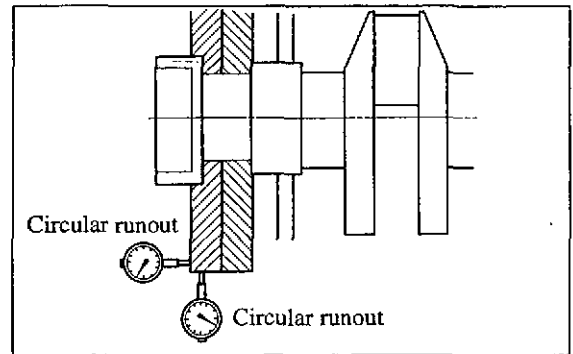
Check the damper for cracks, deformations or cracks in the mirror plate, leakage of silicone oil, discolored or peeling paint due to excessive heat. Replace it with a new one after 8000 hours of service, even when no defect is observed.

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]



Damper inspection



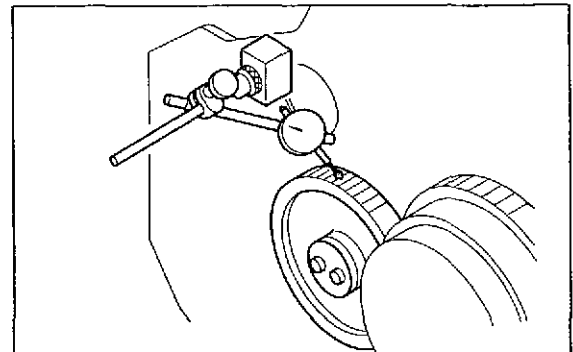
Measuring damper circular runout

(2) Measuring backlash

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

Unit: mm [in.]

Item	Standard Clearance	Service Limit
Backlash	0.12 to 0.18 [0.0047 to 0.0071]	0.50 [0.0200]



Measuring gear backlash

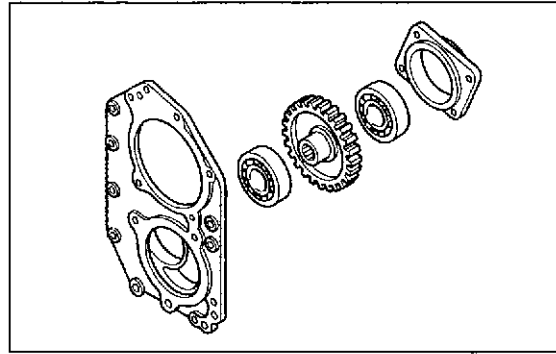
(3) Bearing bore diameters of oil pump drive

Rotate the bearing, and replace it if it is not smooth. Check the fittings of the following items and replace them if they show any evidence of excessive wear.

- Drive shaft and bearing
- Drive case and bearing
- Drive shaft and oil seal

Unit: mm [in.]

Item	Nominal Value	Assembly Standard
Cover bearing bore inside diameter	ø110 [4.33]	110.000 to 110.035 [4.33070 to 4.33208]
Plate bearing bore inside diameter	ø110 [4.33]	109.987 to 110.022 [4.32900 to 4.33157]
Bearing	Outside diameter	ø110 [4.33]
	Inside diameter	ø50 [1.97]
Gear shaft bearing bore outside diameter	ø50 [1.97]	49.993 to 50.013 [1.96822 to 1.96901]



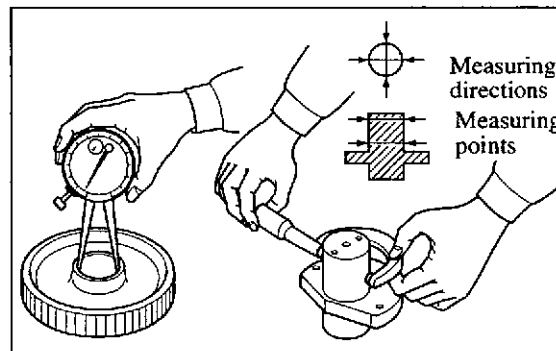
Bearing bore diameters of oil pump drive

(4) Measuring idler gear bushing inside diameter and idler gear shaft diameter

If the diameter exceeds the service limit, replace the bushing or shaft (whichever is worn).

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Idler bushing inside diameter	ø50 [1.97]	50.000 to 50.025 [1.96850 to 1.96948]	50.060 [1.97086]
Idler gear shaft diameter	ø50 [1.97]	49.950 to 49.975 [1.96653 to 1.96752]	49.900 [1.96456]



Measuring idler gear bushing inside diameter and shaft diameter

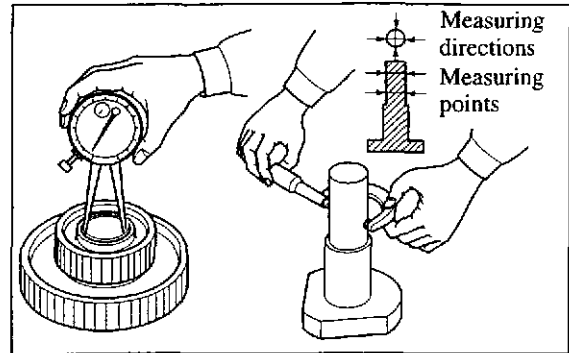
ENGINE MAIN PARTS

(5) Measuring fan drive idler bushing inside diameter and fan drive idler shaft outside diameter

Measure the fan drive idler bushing inside diameter and fan drive idler shaft outside diameter. If the diameter exceeds the service limit, replace the bushing or shaft.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Fan drive idler bushing diameter	$\phi 50$ [1.97]	50.000 to 50.025 [1.96850 to 1.96948]	50.060 [1.97086]
Fan drive idler shaft outside diameter	$\phi 50$ [1.97]	49.950 to 49.975 [1.96653 to 1.96752]	49.900 [1.96456]



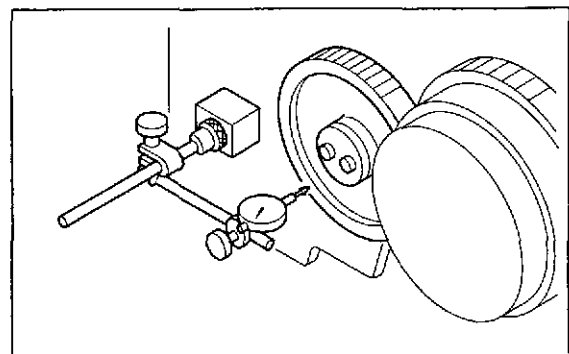
Measuring fan drive idler bushing inside diameter and fan drive idler shaft outside diameter

(6) Measuring idler gear end play

Measure the end play with a feeler gage or dial gage. If the idler gear end play exceeds the service limit, replace the thrust plate for the idler gear, or the front plate for the fan drive idler gear.

Unit: mm [in.]

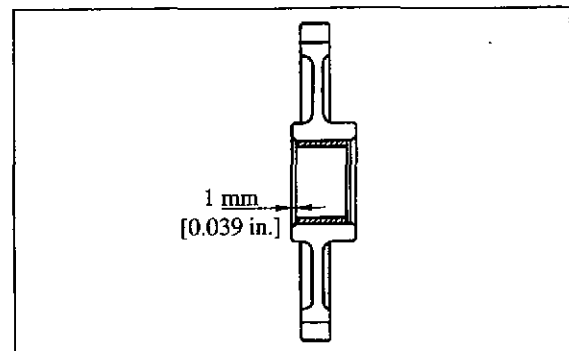
Item	Standard Clearance	Repair Limit
Front idler gear end play	0.2 to 0.4 [0.008 to 0.016]	0.6 [0.024]
Fan drive idler gear end play	0.25 to 0.75 [0.0098 to 0.0295]	1.2 [0.047]



Measuring idler gear end play

(7) Replacing idler bushing

- Use the idler bushing puller (32591-02500) to remove the bushing.
- Install a new bushing to the gear by pressing it until the end face of the bushing is 1 mm [0.039 in.] recessed from that of the gear boss.
- After installing the bushing, make sure that its inside diameter is within the assembly standard. If it is less than the standard, ream the bushing to the inside diameter of $\phi 50^{+0.025}_0$ mm [1.97^{+0.00098}₀ in.] 0.4 Ra.



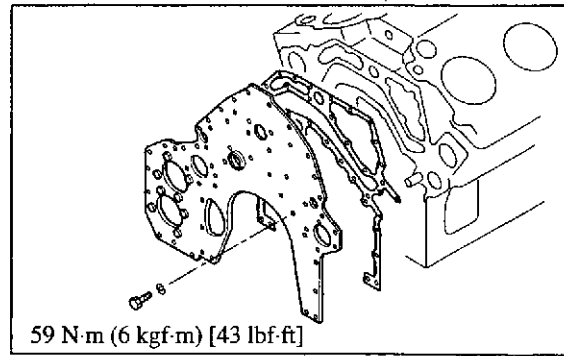
Replacing idler bushing

3.3 Reassembly

Reassembly is the reverse procedure of disassembly.

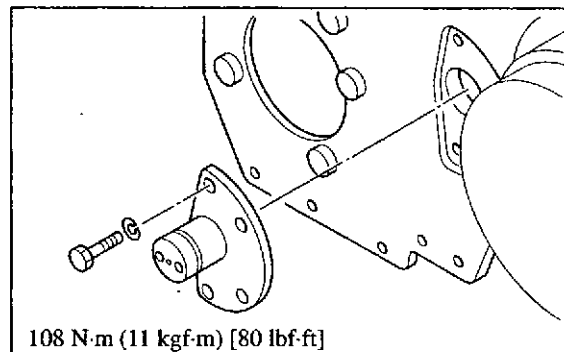
(1) Installing the front plate

- (a) Apply sealant (Heredite) to the front plate mounting surface of the crankcase, then place the packing in position. Apply the same sealant to the packing, then install the front plate.
- (b) Replace the dowel pins if worn, or if the front plate has been replaced.
- (c) Make sure that the lower end of the front plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



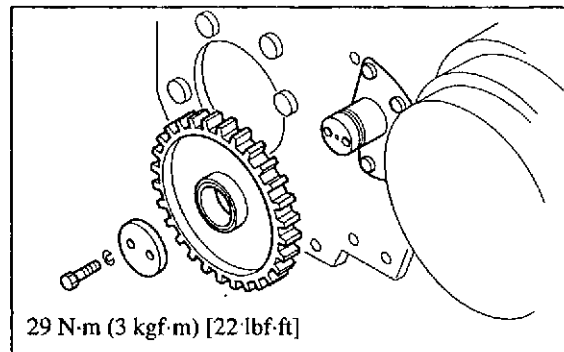
(2) Installing idler shaft

- (a) Insert the idler shaft with the guide bolts.
- (b) Tighten the shaft mounting bolts to the specified torque.



(3) Installing idler gear

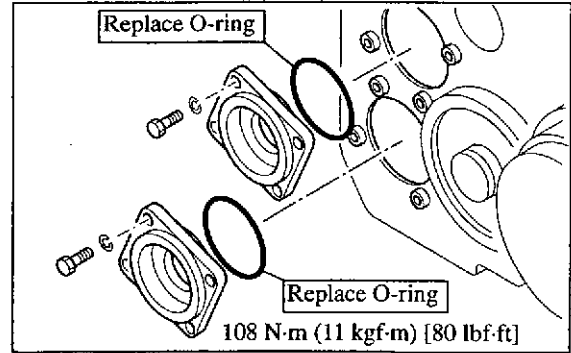
- (a) Insert the idler gear into the shaft, and install the thrust plate.
- (b) Install the thrust plate, then tighten the mounting bolts to the specified torque.



ENGINE MAIN PARTS

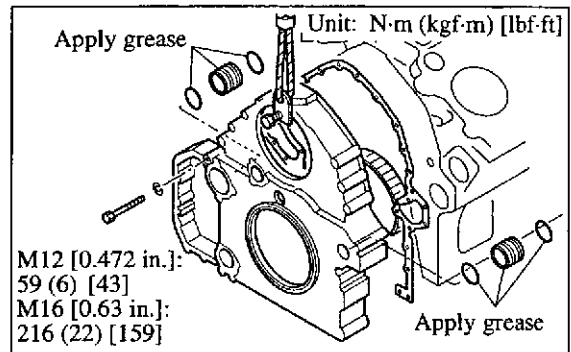
(4) Installing the oil pump and water pump drive bearing cover

- (a) Insert the bearing cover into the front plate, then tighten the cover mounting bolts to the specified torque.

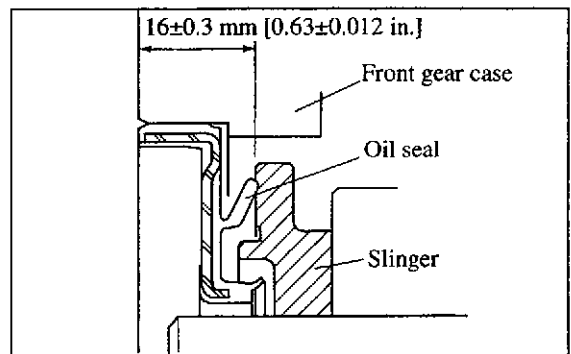


(5) Installing the front gear case and pointer

- (a) Apply a sealant (Heredite) to the front gear case packing mounting surface, then place the packing in position. Apply sealant in the same manner to the packing, then install the front gear case.
- (b) Now mount the water coupling of the crankcase and the gear case to the crankcase. Apply grease to the O-rings and O-ring grooves. Do not damage the O-rings when installing the gear case.

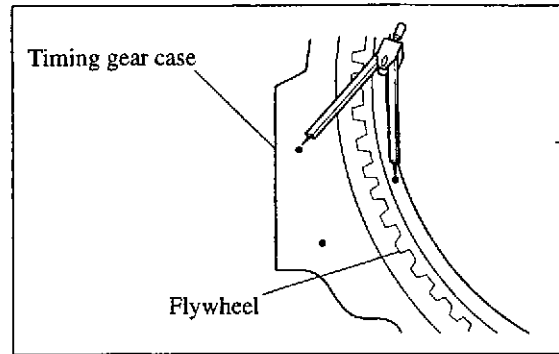


- (c) Replace the dowel pins if worn, or if the front cover has been replaced.
- (d) Tighten the case mounting bolts evenly to the specified torque.
- (e) Make sure that the lower end of the front gear case is flush with the bottom of the crankcase. Cut off the excess packing neatly along the edge of the cover.
- (f) Install the oil seal to the front gear case.
- (g) Apply engine oil to the lip of the oil seal.
- (h) Insert the oil seal to the slinger using the front seal installer assembly (37591-05010).



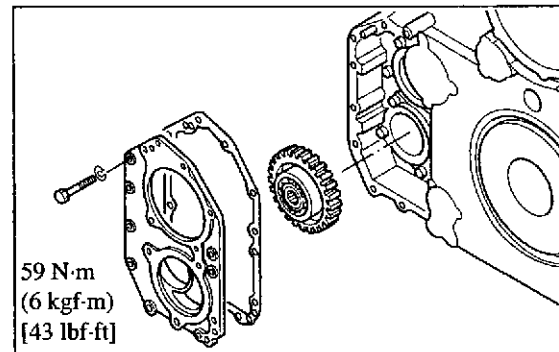
When the pointer is out of place

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 marks are positioned at the equal distance from one another, No. 1 and No. 8 pistons are at the top dead center.



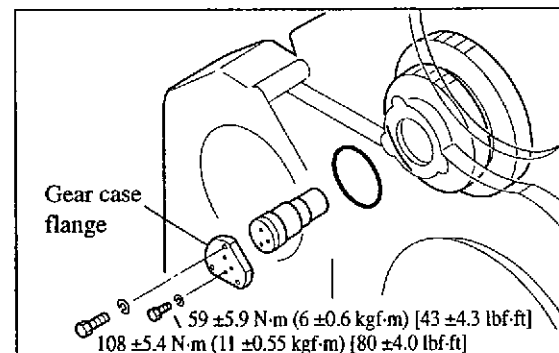
(6) Installing the oil pump gear and mounting plate for the oil pump and water pump

- (a) Insert the oil pump gear.
- (b) Install the plate, then tighten the bolts to the specified torque.



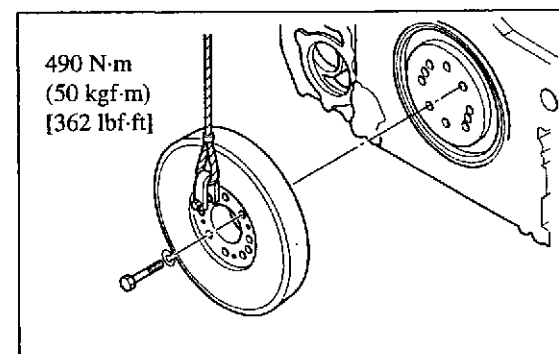
(7) Installing fan drive idler gears and idler shaft

- (a) Install the gear case flange to the idler shaft, and tighten the mounting bolts to the specified torque.
- (b) Place the fan drive idler gears through the fan drive mounting hole with the smaller gear in front.
- (c) Insert the idler shaft into the fan drive idler gears while holding them so that the gear center aligns with the idler shaft hole center.
- (d) Tighten the gear case flange mounting bolts to the specified torque.
- (e) Check that the fan drive idler gears have end play and backlash.



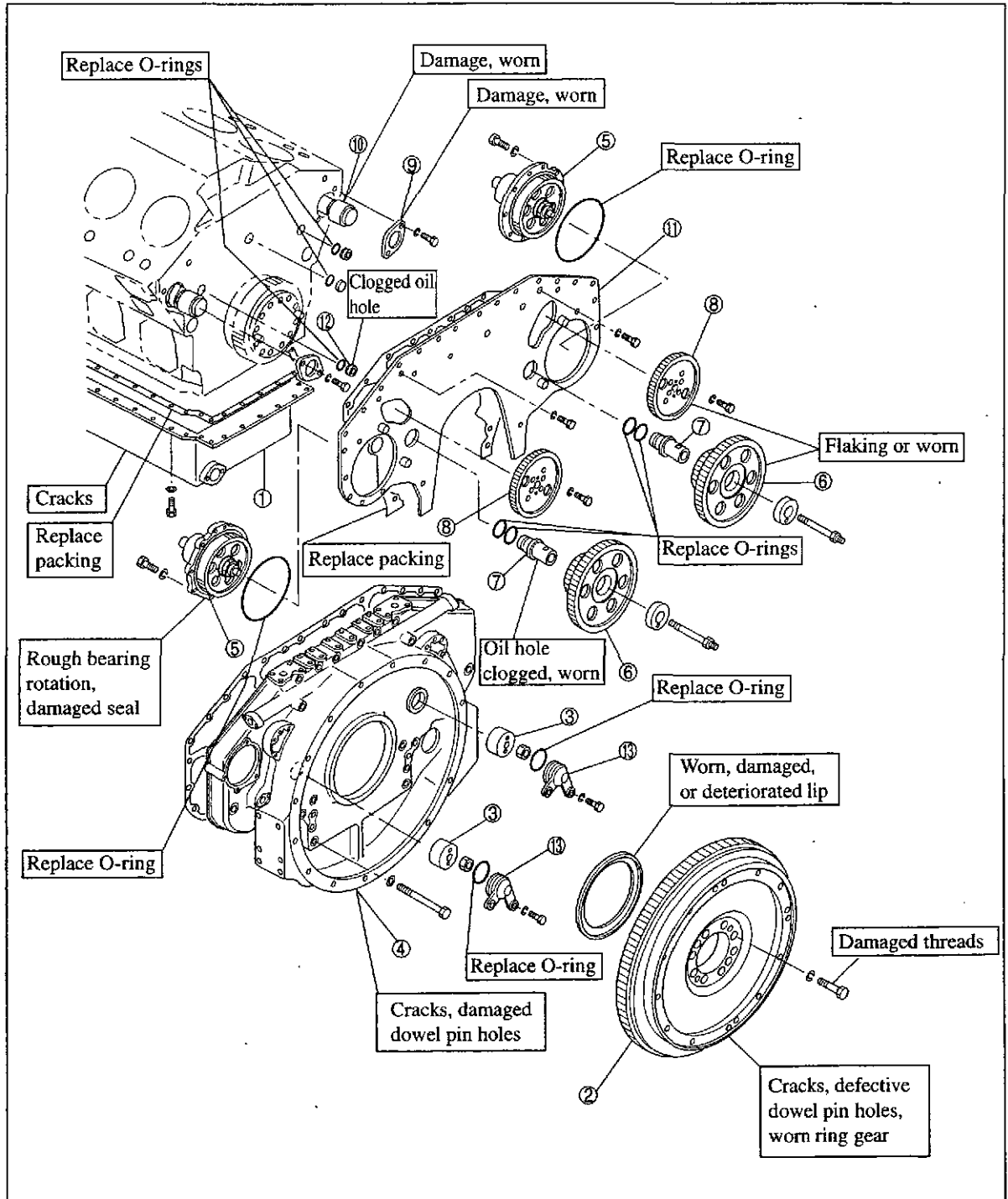
(8) Installing the damper

Tighten the damper mounting bolts to the specified torque.



4. Flywheel, Timing Gears, and Camshafts

4.1 Disassembly



Disassembly sequence

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

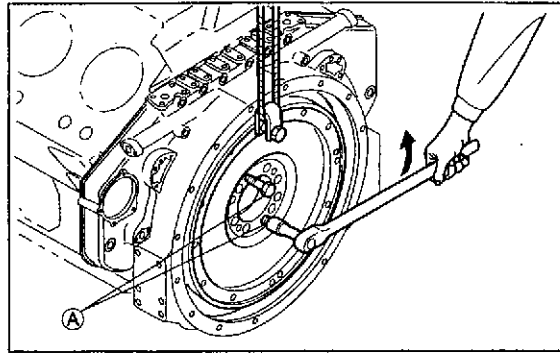
(1) Removing the flywheel

- (a) Attach a sling to the flywheel.
- (b) Unscrew the flywheel mounting bolts.
- (c) Install the two jack-bolts **A** (64362-68500: M12 × 1.25 mm [0.47 × 0.049 in.]) into the holes in the flywheel evenly, then screw the bolts to remove the flywheel.

Weight: approx. 138 kg [304 lb.]

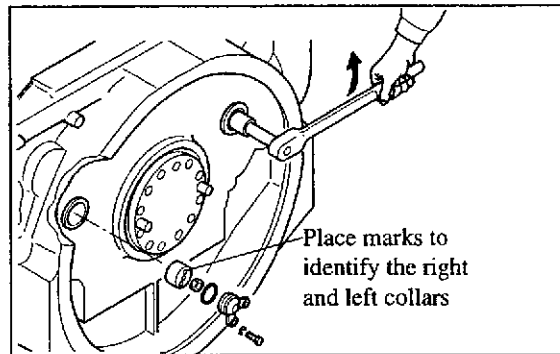
CAUTION

- (a) When you remove 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 the idler shaft thrust collar

- (a) Unscrew the cover mounting bolts, then remove the cover.
- (b) Unscrew the idler shaft thrust collar mounting bolts. Mark the collar at its position.
- (c) Screw the bolts (M6 × 1.0 mm [0.24 × 0.039 in.]) through the thrust collar removing bolt holes and pull the thrust collar from the gear case.

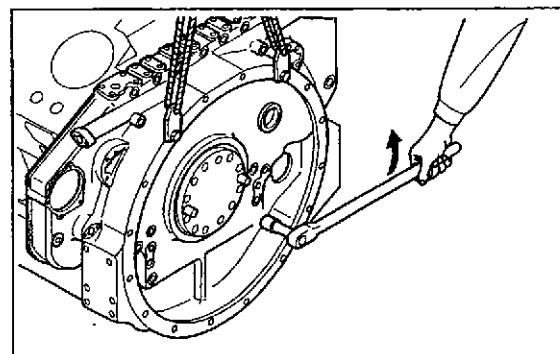
**NOTE**

Place marks to identify the right and left collars to ensure proper backlash and end play in reinstallation.

(3) Removing the 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.

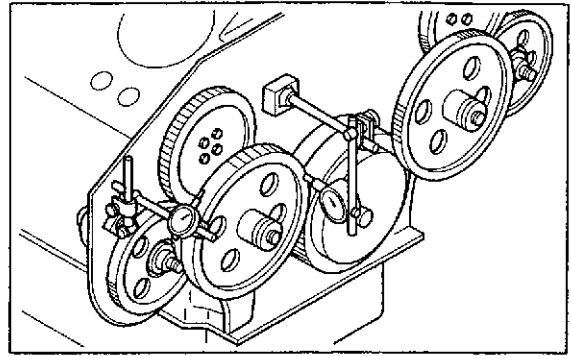
Weight approx. 150 kg [330 lb.]



ENGINE MAIN PARTS

(4) Measuring backlash and end play

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

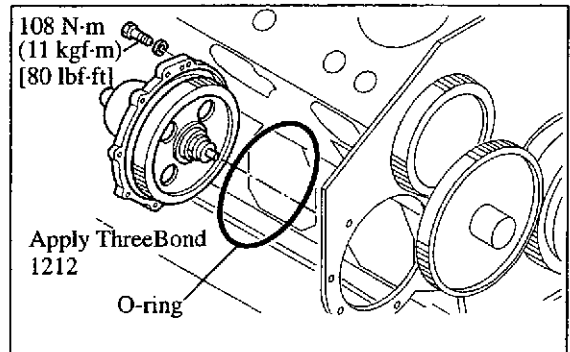


(5) Removing the fuel injection pump drive (left and right)

Unscrew the injection pump drive case mounting bolts, then remove the pump drive. Do not damage the gear teeth.

NOTE

Remove the No. 12 cylinder cam cover before removing the pump drive case of the left side.

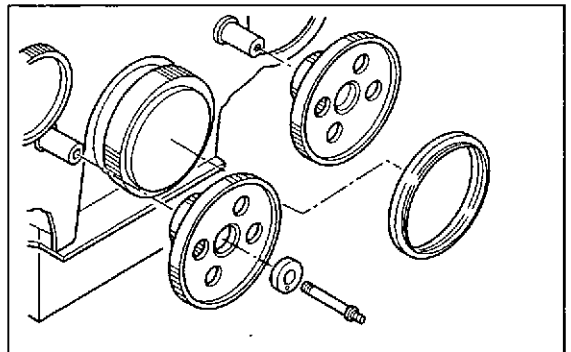


(6) Removing idler gears

- (a) Remove the slinger of the crankshaft.
- (b) Remove the idler gears (left and right).

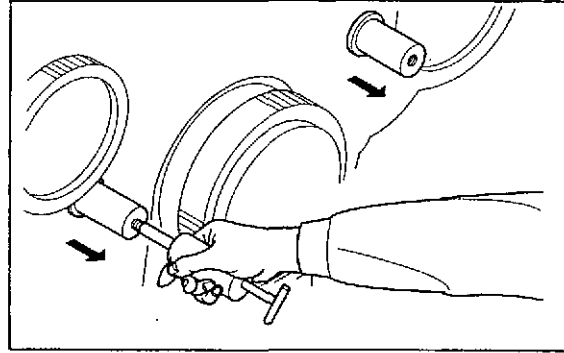
NOTE

If you want to remove the idler gear without removing the slinger, unscrew the assembly bolt of the idler gear.

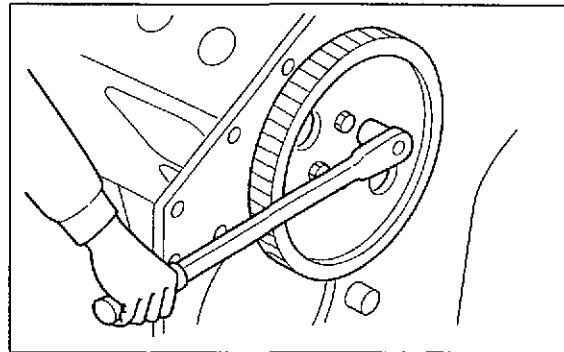


(7) Removing the idler shaft

Do not remove the idler shaft unless you need to repair it. To remove, install the sliding hammer to the idler shaft removing screw hole (M22 × 1.5 mm [0.87 × 0.059 in.]).

**(8) Removing the camshaft gear**

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

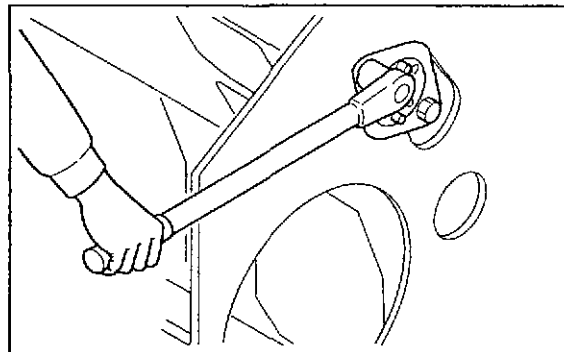
**(9) Removing camshafts**

Unscrew the thrust plate mounting bolts, then pull out the camshaft from the crankcase.

Weight: approx. 35 kg [77 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.



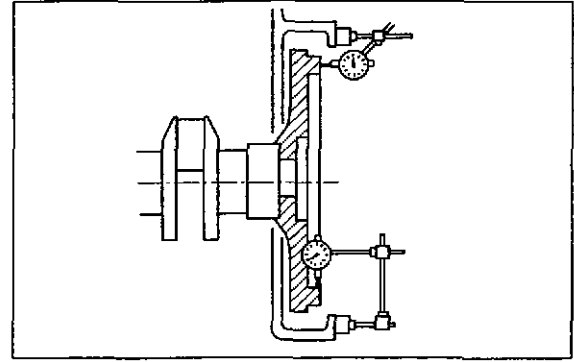
4.2 Inspection and Repair

(1) Measuring the flywheel face and circular runouts

Measure the runouts of 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.

Unit: mm [in.]

Item		Assembly Standard
Flywheel	Face runout	0.336 [0.0132] or less
	Circular runout	0.130 [0.0051] or less



Measuring flywheel runout

(2) Injection Pump Drive Diameter and Inside Diameter of Bearings

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

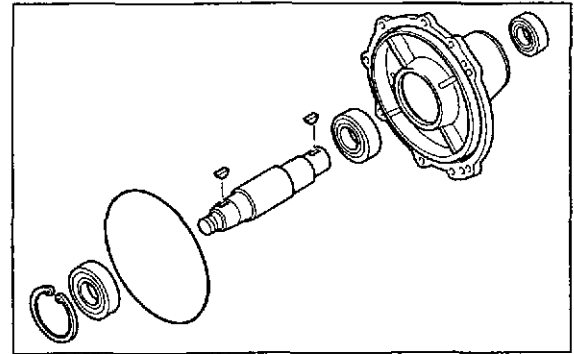
Inspect the fit of the bearing inner race on the drive shaft. Replace excessively worn parts.

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
Bearing bore inside diameter	ø90 [3.54]	89.987 to 90.022	[3.54189 to 3.54417]
	ø100 [3.94]	99.987 to 100.022	[3.93649 to 3.93701]
Bearing	Outside diameter	ø90 [3.54]	89.985 to 90.000
		ø100 [3.94]	99.985 to 100.000
	Inside diameter	ø45 [1.77]	44.988 to 45.000
		ø50 [1.97]	49.988 to 50.000
Drive shaft bearing outside diameter	ø45 [1.77]	45.002 to 45.013	[1.77173 to 1.77217]
	ø50 [1.97]	50.002 to 50.013	[1.96858 to 1.96901]

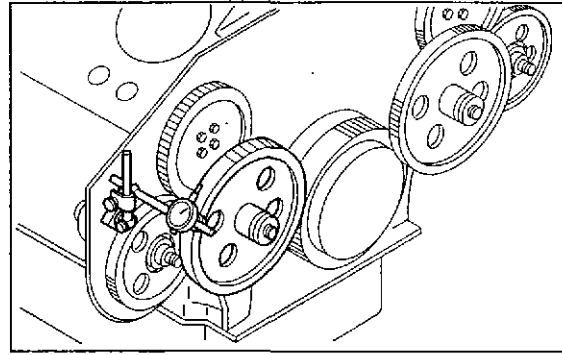


(3) Measuring gear backlash

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 feeler gages between the gear teeth. If the backlash exceeds the service limit, replace the worn gears.

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]



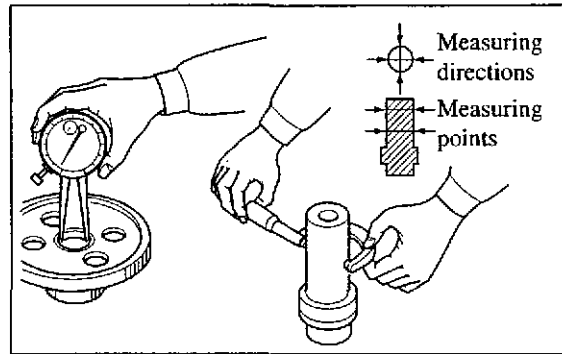
Measuring timing gear backlash

(4) 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	Nominal Value	Assembly Standard	Service Limit
Rear idler gear bushing inside diameter	ø65 [2.56]	65.000 to 65.030 [2.55906 to 2.56024]	65.060 [2.56142]
Rear idler gear shaft diameter	ø65. [2.56]	64.951 to 64.970 [2.55713 to 2.55787]	64.900 [2.55512]



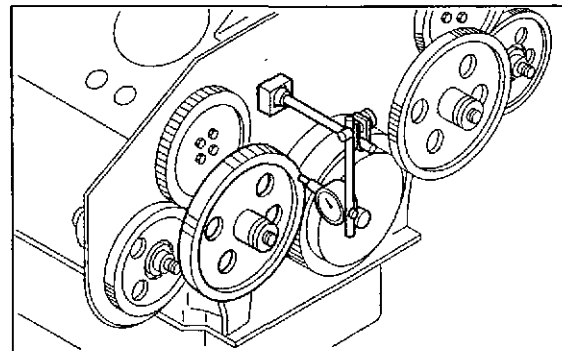
Measuring idler gear bushing inside diameter and shaft diameter

(5) 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 collar.

Unit: mm [in.]

Item	Standard Clearance	Repair Limit
Idler gear end play	0.3 to 0.6 [0.012 to 0.024]	1.0 [0.039]

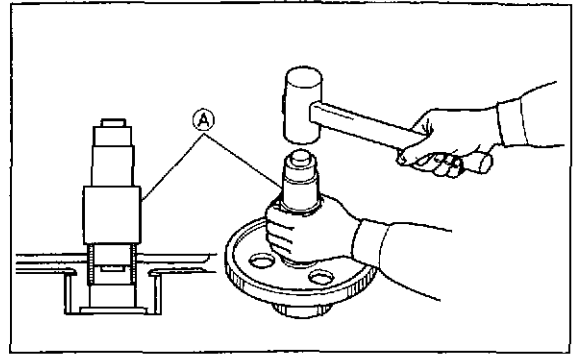


Measuring idler gear end play

ENGINE MAIN PARTS

(6) Replacing idler bushings

- (a) Use the idler bushing puller (A) to remove the bushing.
- (b) Install a new bushing to the gear by pressing it until the end face of the bushing 1 mm [0.04 in.] recessed from that of the gear boss.
- (c) After installing the bushing, make sure its *inside diameter is within the assembly standard*. If it is less than assembly standard, ream the bushing to the inside diameter of $\phi 65^{+0.030}_0$ mm [$2.56^{+0.001181}_0$ in.] 0.4 Ra.



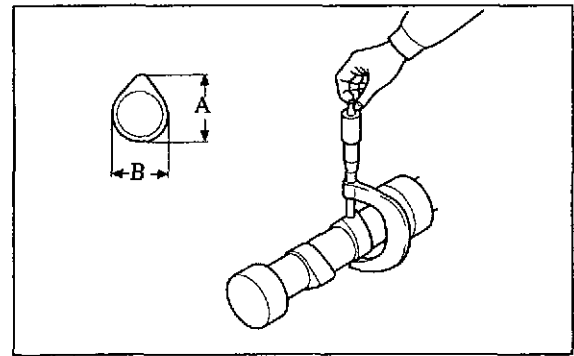
Replacing the idler gear bushing

(7) Measuring cam lift

Use a micrometer to measure the diameters of "A" and "B" on each cam to determine the reduction 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 [0.36209 to 0.36605]	8.45 [0.3327]



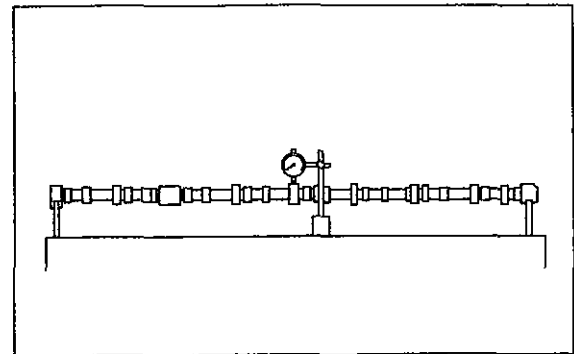
Measuring cam lift

(8) Measuring camshaft deflection

If the deflection 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.]

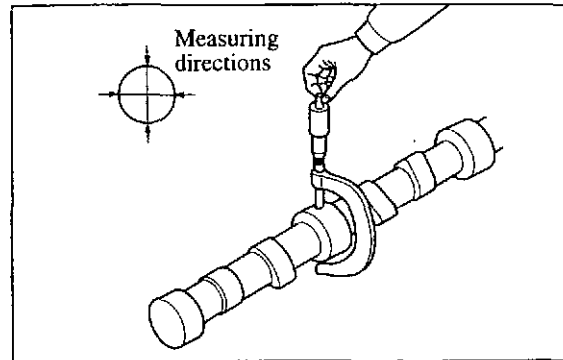
Item	Assembly Standard	Repair Limit
Camshaft deflection	0.05 [0.002] or less	0.08 [0.0031]

(9) Measuring camshaft journal diameters

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 [3.3020]



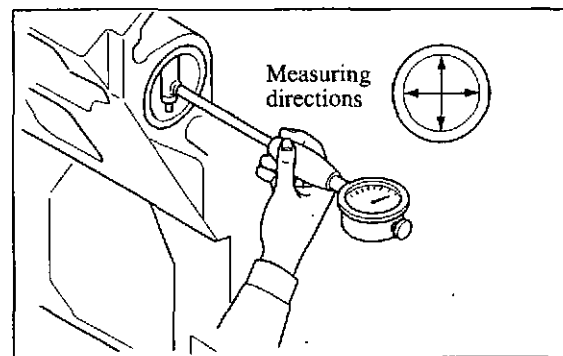
Measuring camshaft journal diameter

(10) 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 diameter	ø84 [3.31]	84.000 to 84.035 [3.30708 to 3.30846]	84.10 [3.31130]



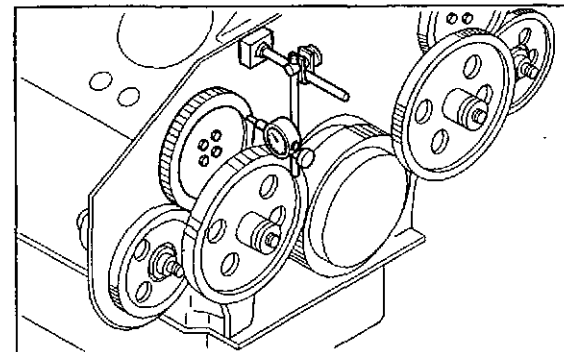
Measuring camshaft inside diameter

(11) 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	Nominal Value	Standard Clearance	Service Limit
Camshaft end play	8 [0.315]	0.10 to 0.25 [0.0039 to 0.0098]	0.40 [0.0157]



Measuring camshaft end play

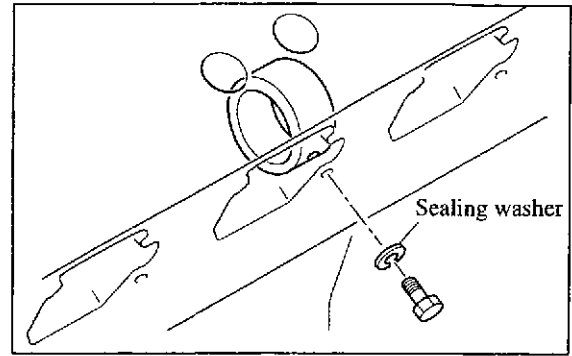
ENGINE MAIN PARTS

(12) Replacing camshaft bushing

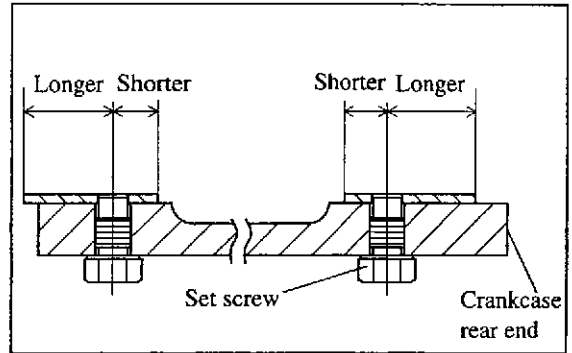
Install the bushings in the crankcase, then secure them in place with the set screws.

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.

Install the wide bushing at the rearmost journal correctly.



Replacing camshaft bushing (1)

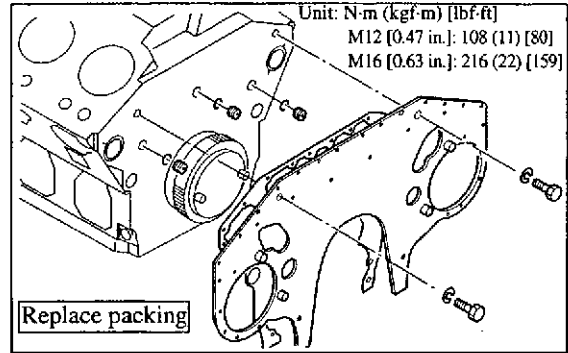


Replacing camshaft bushing (2)

4.3 Reassembly

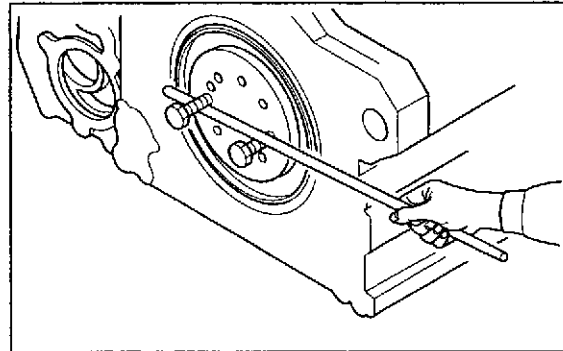
(1) Installing the rear plate

- (a) Apply sealant (Heredite) to the rear plate mounting surface of the 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 the rear plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



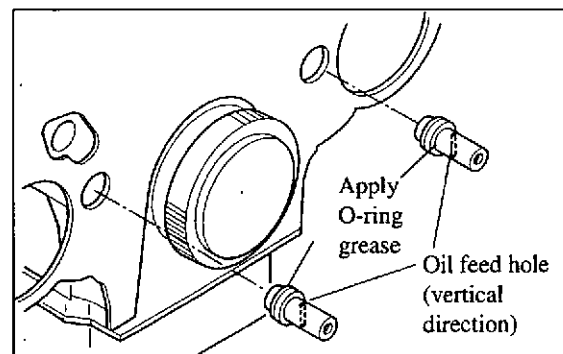
(2) Cranking engine

- (a) Install the bolts to the damper mounting holes (M22 × 1.5 mm [0.87 × 0.059 in.]).
- (b) Using these bolts, turn the crankshaft with a bar to bring the No. 1 cylinder piston to the top dead center.



(3) Installing idler gear shafts

Fit the O-ring to the idler shaft. Apply grease to the O-ring to insert the idler shaft into the crankcase. In this step, make sure the "TOP" mark on the shaft is located at the top (oil passage in vertical direction).



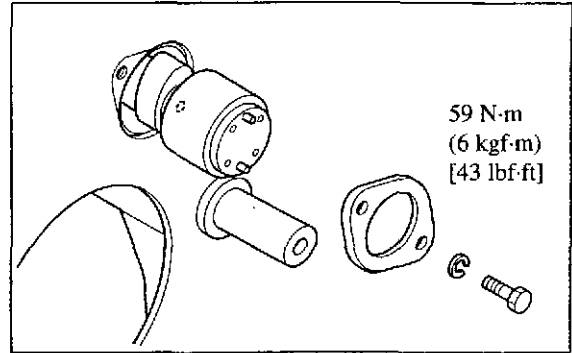
ENGINE MAIN PARTS

(4) Installing the camshafts (left and right)

- (a) Insert the camshaft into the crankcase, then install the thrust plate.
- (b) Tighten the thrust plate mounting bolt to the specified torque.
- (c) Check and make sure that the camshaft rotates smoothly.

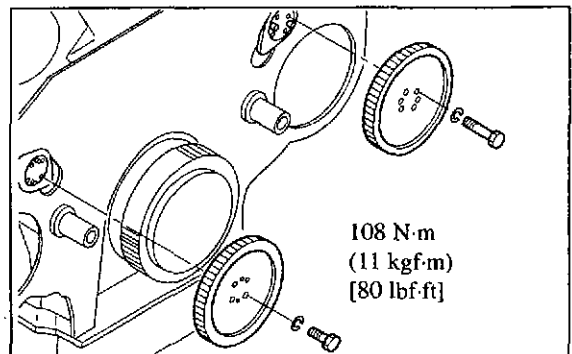
NOTE

Do not mix the two different camshafts when you reassemble the engine.



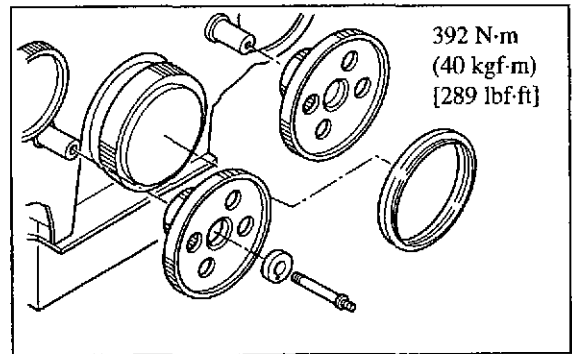
(5) Installing camshaft gears

- (a) Install the camshaft gears to meet the dowel pin.
- (b) Tighten the camshaft gear mounting bolts to the specified torque.
- (c) After installing the camshaft gear, check and make sure that the gear rotates smoothly.

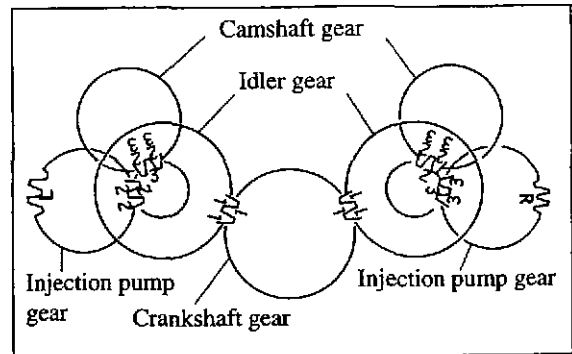


(6) Installing idler gears

- (a) Install the idler gear by aligning its matching mark with that on the crankshaft gear and camshaft gear.
- (b) Insert the slinger to the crankshaft.



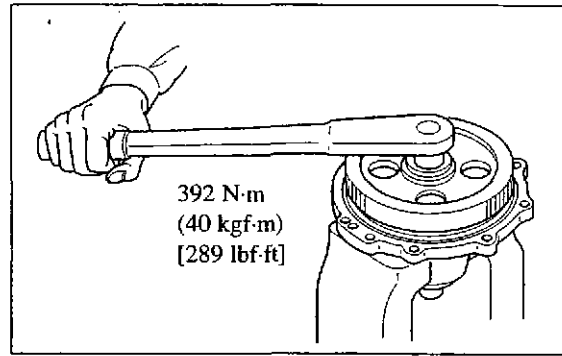
- (c) Confirm that the matching marks of the timing gears are as the drawing shown on the right.



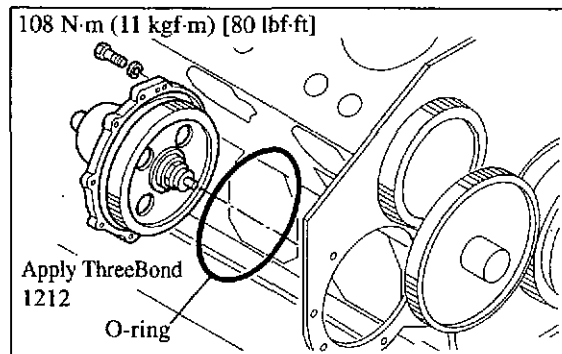
Timing gear train

(7) Installing the injection pump drive

- (a) Install the injection pump gear to the drive shaft, then tighten it to the specified torque.



- (b) Fit the O-ring to the installation surface of the drive case. Apply a small amount of Three Bond 1212 to the flange face.
- (c) Install the injection pump drive to the rear plate by aligning its matching mark to that of the idler gear.
- (d) Tighten the drive case mounting bolts to the specified torque.

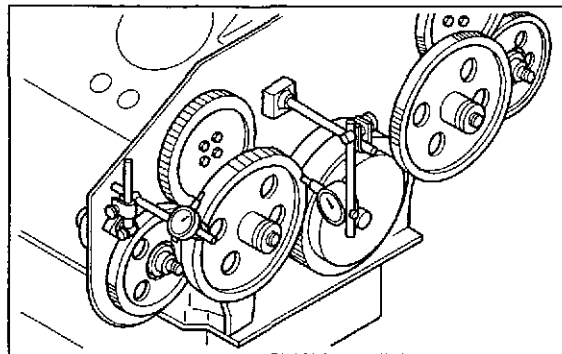


(8) Inspecting and adjusting timing gears after installation

After installing the timing gears, be sure to inspect and adjust the backlash and end play between each gear.

(Inspecting Timing Gear Backlash and End Play)

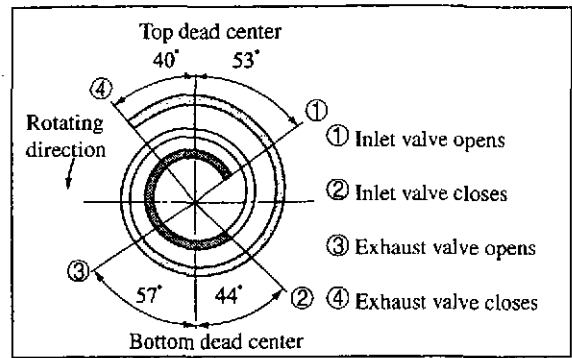
After installing the timing gears, inspect the backlash between the gears in mesh, and the end play of each gear. (Refer to section 4.2 of this chapter.)



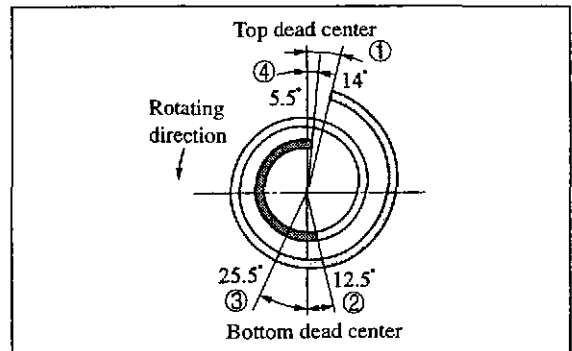
Inspecting Valve Timing

It is not necessary to inspect the valve timing, provided that all match 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 opening) and the position where the gage is released (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.



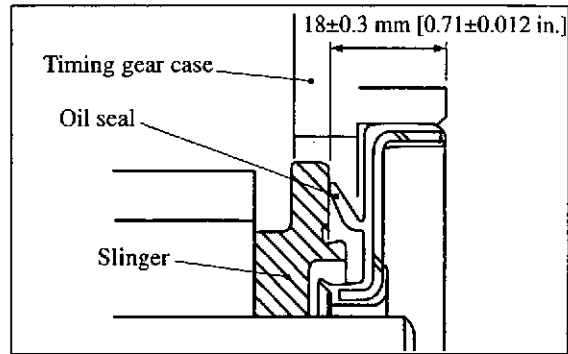
Valve timing diagram



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

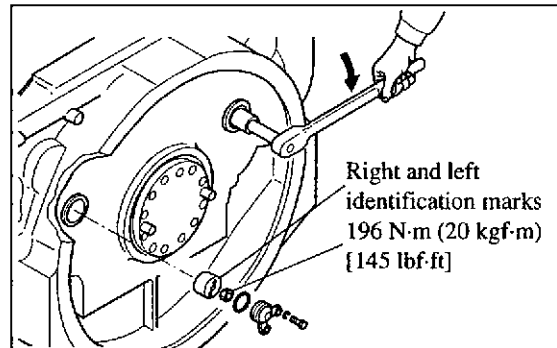
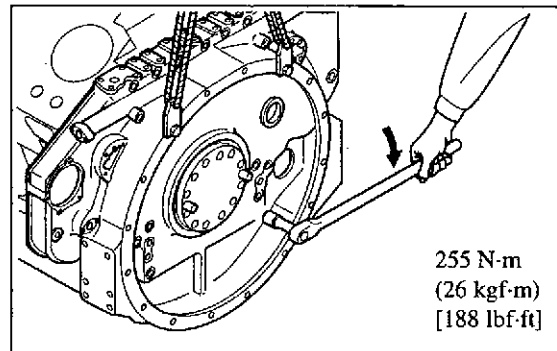
(9) Installing the timing gear case

- (a) Apply sealant (Heredite) 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.
- (b) Replace the dowel pins if worn, or if the gear case has been replaced.
- (c) Tighten the gear case mounting bolts evenly to the specified torque.
- (d) Apply engine oil to the oil seal lip. Insert the oil seal into the timing gear case.
- (e) Fit the oil seal to the slinger using the rear seal installer (37791-06010) in the position as shown.



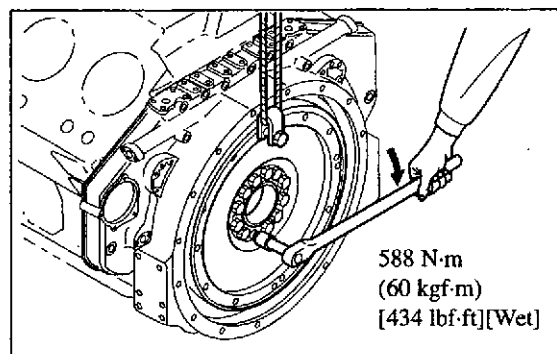
(10) Installing the idler shaft thrust collar

- (a) Apply grease to the thrust collars, and insert the collars in the timing gear case. In this step, make sure the "TOP" mark is located at the top and the right and left collars are installed in their original positions by checking the identification marks placed during removal.
- (b) Tighten the thrust collar mounting nuts to the specified torque.
- (c) Install the cover, and tighten the mounting bolts to the specified torque.



(11) Installing the flywheel

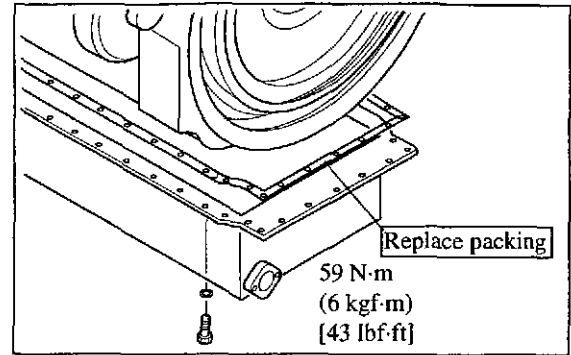
- (a) Install the flywheel. Check that all dowel pins enter their holes.
- (b) Coat the threads and the bolt bearing surface of the flywheel mounting bolts with engine oil, then tighten the bolts to the specified torque. Inspect the face and circular runouts of the flywheel.



ENGINE MAIN PARTS

(12) Installing oil pan

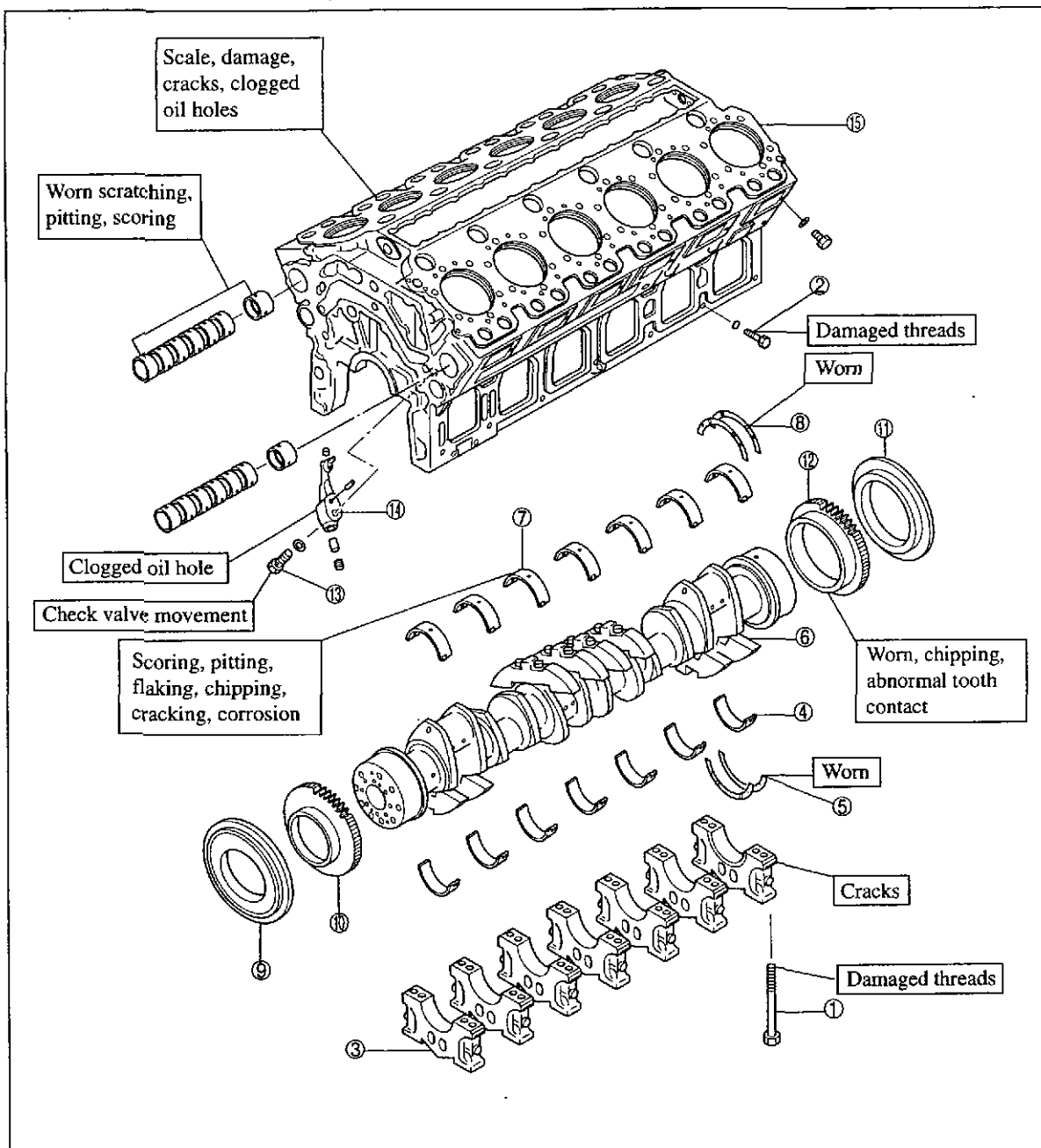
- (a) Fit the O-ring to the oil passage of the oil pan mounting surface.
- (b) Fit the packing to the oil pan by applying sealant (Hereditite) to the separated portions (4 locations).
- (c) Screw two guide bolts into the crankcase, then install the oil pan.
- (d) Tighten the oil pan mounting bolts evenly to the specified torque.



Installing oil pan

5. Crankcase, Crankshaft, and Main Bearings

5.1 Disassembly



Disassembly sequence

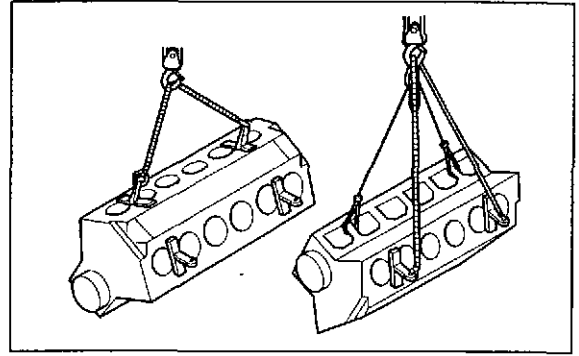
- | | | |
|-------------------------|---------------------------|--------------------------|
| ① Main bearing cap bolt | ⑥ Crankshaft | ⑪ Slinger (rear) |
| ② Side bolt | ⑦ Main bearing (upper) | ⑫ Crankshaft gear (rear) |
| ③ Main bearing cap | ⑧ Thrust bearing | ⑬ Check valve |
| ④ Main bearing (lower) | ⑨ Slinger (front) | ⑭ Piston cooling nozzle |
| ⑤ Thrust bearing | ⑩ Crankshaft gear (front) | ⑮ Crankcase |

ENGINE MAIN PARTS

(1) Turning the crankcase upside down

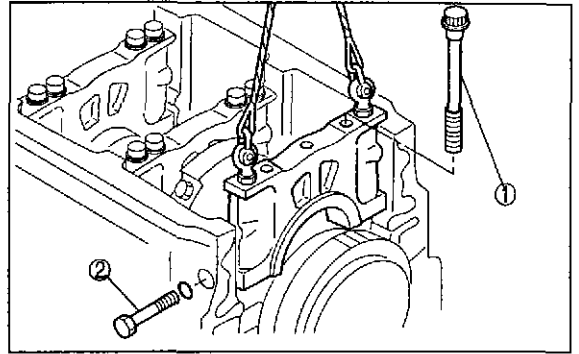
Use such lifting tools as a chain block and shackles to lay the crankcase on its side. Then add slings to the crankcase, and turn it upside down.

Crankcase and crankshaft weight: approx. 1850 kg
[4079 lb.]



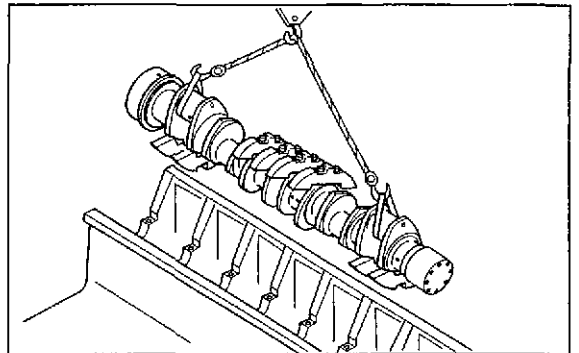
(2) Removing the main bearing caps

- (a) Unscrew the cap bolts ① and side bolts ②. Remove the main bearing cap using cap removers or a chain block (eye bolt M27 × 1.5 mm [1.06 × 0.059 in.]).
- (b) Remove the thrust bearings from the No. 9 bearing cap. Do not damage the thrust bearings.



(3) Removing the crankshaft

- (a) Remove the front upper halves of the thrust bearings by rotating them slowly.
- (b) Carefully lift the crankshaft off the crankcase, keeping it horizontal.
- (c) Remove the rear upper halves of the thrust bearings on the crankcase.



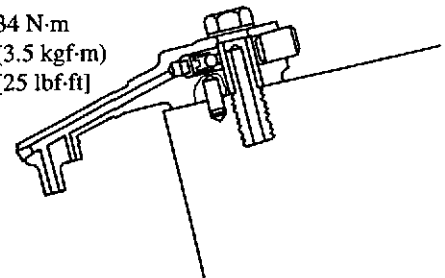
(4) Removing the piston cooling nozzles

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.

34 N·m
(3.5 kgf·m)
[25 lbf·ft]

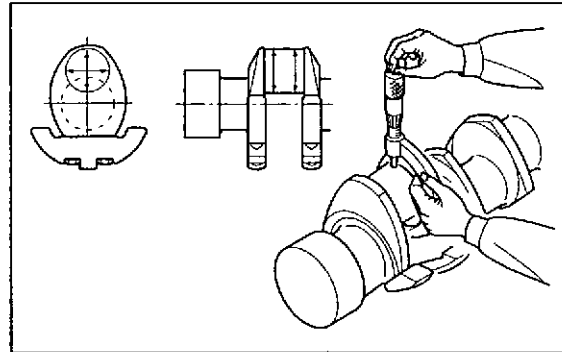


5.2 Inspection and Repair

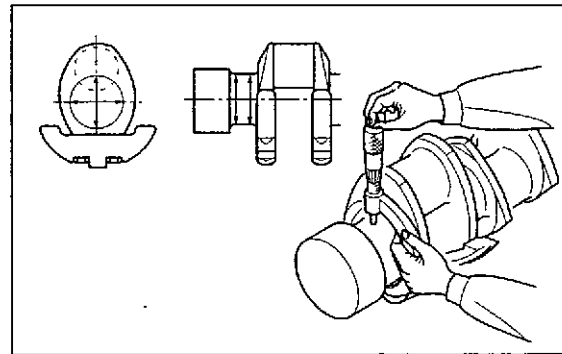
Crankshaft

(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, -0.50 mm, -0.75 mm, or -1.00 mm [-0.0098 in., -0.0197 in., -0.0295 in., -0.0394 in.].
- (b) Measure the crankpins and journals to determine the roundness and cylindricity.
- (c) If the -1.00 mm [-0.0394 in.] undersize journals and crankpins exceed the repair limit, replace the crankshaft.



Measuring crankpin diameter



Measuring crank journal diameter

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Repair Limit		
Crankpin diameter	ø125 [4.92]	124.930 to 124.950 [4.91724 to 4.91803]	124.890 [4.91567]		
Crank journal diameter	ø170 [6.69]	169.920 to 169.940 [6.68685 to 6.68764]	169.890 [6.68567]		
Center to center distance between journal and crankpin	90 [3.54]	89.90 to 90.10 [3.536 to 3.5444]			
Pin, journal	Parallelism		Runout over pin length 0.01 [0.0004] or less	0.03 [0.0012]	
	Roundness		Diameter difference 0.01 [0.0004] or less	0.03 [0.0012]	
	Cylindricity		Diameter difference 0.01 [0.0004] or less	0.03 [0.0012]	
	Fillet radius	Pin	7R [0.28]	6.8 to 7.0 [0.268 to 0.276]	
		Journal	8.5R [0.33]	8.3 to 8.5 [0.327 to 0.335]	
	Hardness		Hv >590		
Angle error between pins			±0° 20'		

ENGINE MAIN PARTS

Grinding dimensions for an undersize crankshaft

Unit: mm [in.]

Item	Under-size	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]		
Crank journal diameter	0.25 [0.0098]	169.67 to 169.69 [6.6799 to 6.6807]	Diameter difference 0.01 [0.0004] or less	Diameter difference 0.02 [0.0008] or less
	0.50 [0.0197]	169.42 to 169.44 [6.6701 to 6.6709]		
	0.75 [0.0295]	169.17 to 169.19 [6.6602 to 6.6610]		
	1.00 [0.0394]	168.92 to 168.94 [6.6504 to 6.6512]		

(2) Grinding the crankshaft

Refinish the crankshaft according to the dimensions of the undersize main bearing and connecting rod bearing.

When grinding the crankpins and journals, be sure to produce the same fillet radius as the original. They should have a hardness of 590 (Vickers Hardness Number). If necessary, re-harden the crankpins and journals, and inspect them for cracks by conducting a Magnaflux (magnetic particle) test. After grinding, finish the journals and crankpins to 0.2 Ra.

(3) Measuring crankshaft end play

- (a) Install the thrust bearings 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.

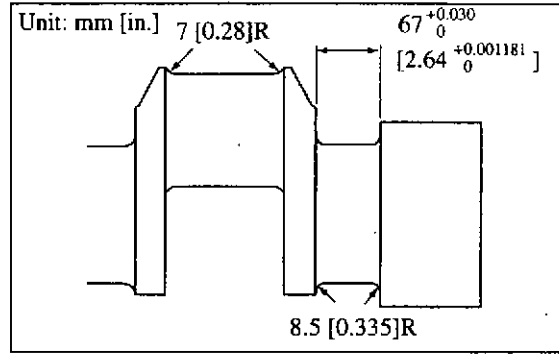
Unit: mm [in.]

Item	Nominal Value	Standard Clearance	Service Limit
Crankshaft end play	67 [2.6378]	0.20 to 0.40 [0.0079 to 0.0157]	0.50 [0.0197]

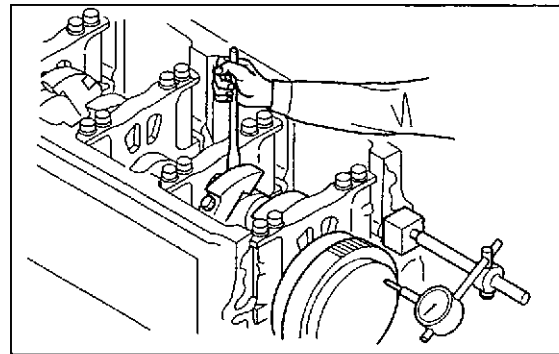
Crankshaft journal grinding dimensions for oversize thrust bearings

Unit: mm [in.]

Item	Oversizes for Journal or Thrust Bearings	Oversizes for Journal and Thrust Bearings	Tolerance
+0.25 [0.0098] O.S	67.25 [2.6476]	67.50 [2.6575]	+0.03 0 [+0.0012] 0
+0.50 [0.0197] O.S	67.50 [2.6575]	68.00 [2.6772]	
+0.75 [0.0295] O.S	67.75 [2.6673]	68.50 [2.6968]	



Measuring thrust bearing journal length



Measuring crankshaft end play

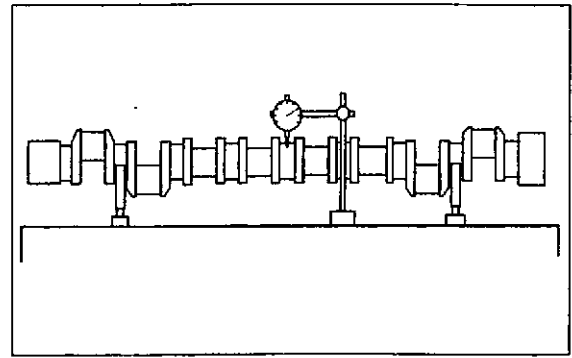
ENGINE MAIN PARTS

(4) Measuring crankshaft deflection

Support the crankshaft on its journals in V-blocks, then measure the deflection 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 deflection exceeds the repair limit, replace the crankshaft.

Unit: mm [in.]

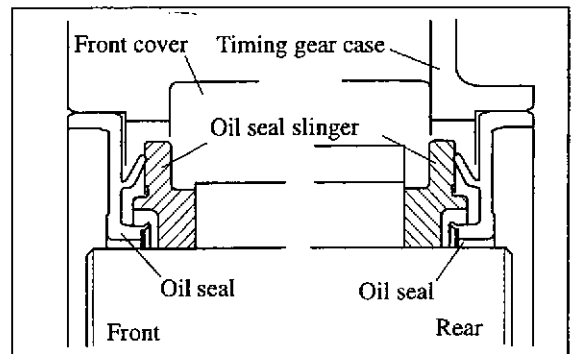
Item	Assembly Standard	Repair Limit
Crankshaft deflection	0.04 [0.0016] or less	0.10 [0.0040]



Measuring crankshaft deflection

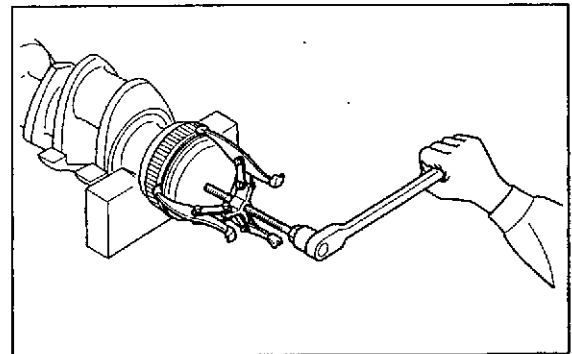
(5) Replacing the oil seal slinger

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



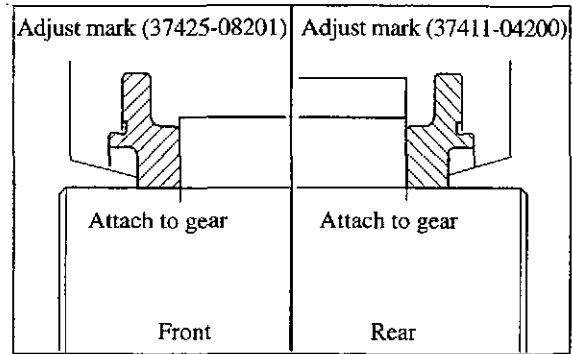
(a) Removing the Slinger

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



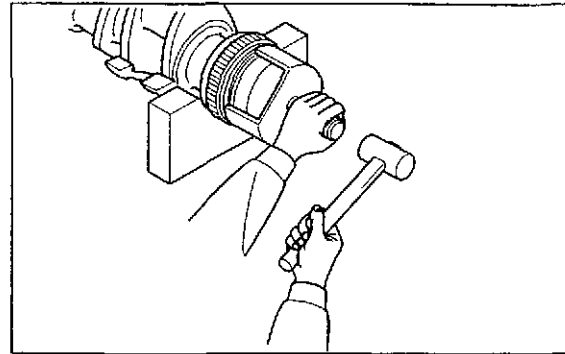
(b) Installing the slinger

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



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

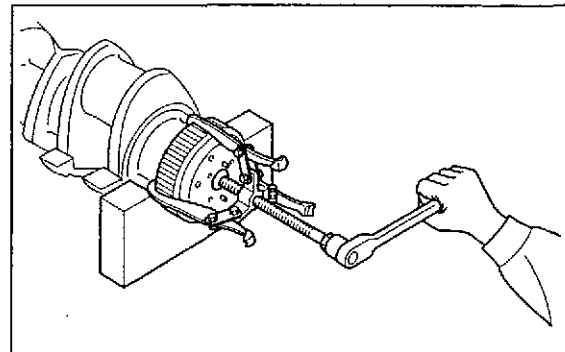
If the slinger has stopped before it contacts the gear, tap the center or shoulder of the installer with a copper hammer.



(6) Replacing the crankshaft gear

(a) Removing the gear

Use a gear puller to remove the gear from the crankshaft. Do not remove the gear by hitting it with a hammer.



ENGINE MAIN PARTS

(b) Installing gear

Before installing the crankshaft gear, measure the inside diameter of the crankshaft gear to be sure that the fit is within the specified value.

Front side: 0.106 to 0.171 mm [0.00417 to 0.00673 in.]
Rear side: 0.274 to 0.358 mm [0.01079 to 0.01410 in.]

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

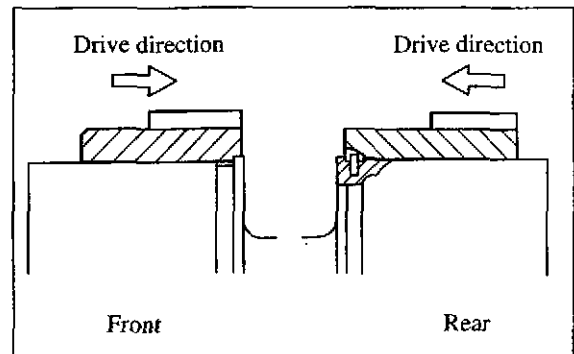
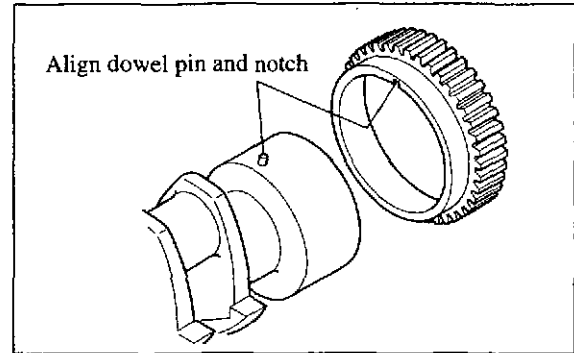
(Do not heat the gear above 200°C [392°F].)

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.

The rotational position of front gear is discretionary.

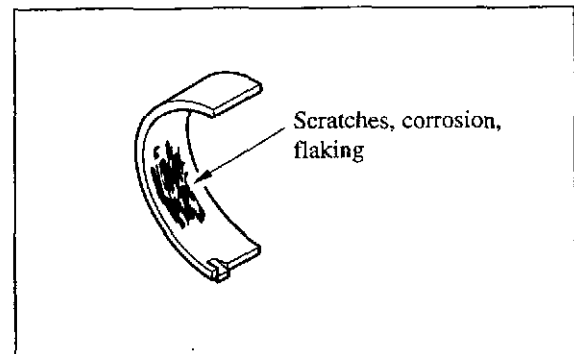
NOTE

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



(7) Inspecting main bearing shell

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

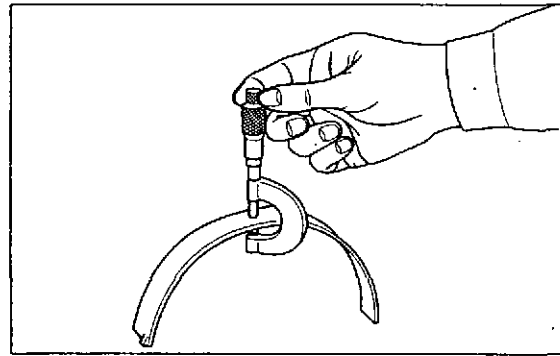


(8) Measuring bearing thickness

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 [0.177165]	4.500 [0.17587 to 0.17638]	4.425 [0.17421]
	-0.25 [0.0098]	4.625 [0.18209]	4.550 [0.17913]
	-0.50 [0.0197]	4.750 [0.18701]	4.675 [0.18405]
	-0.75 [0.0295]	4.875 [0.19193]	4.800 [0.18898]
	-1.00 [0.0394]	5.000 [0.19685]	4.925 [0.19390]



Measuring main bearing thickness

NOTE

Four undersizes are available for the main bearings; namely, -0.25 mm [-0.0098 in.], -0.50 mm [-0.0197 in.], -0.75 mm [-0.0295 in.] and -1.00 mm [-0.0394 in.].

(9) 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.

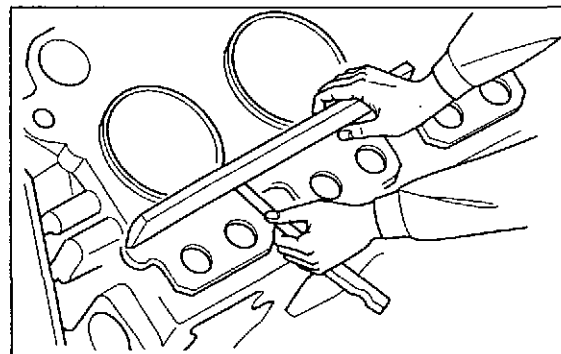
When the crankshaft is refinished to the specified bore dimension, the main bearing does not need to be ground after installation.

(10) Measuring flatness of gasket surface

Measure flatness with a straight edge and feeler gages. If the warpage exceeds the assembly standard, reface the gasket surfaces with a surface grinder.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Flatness of gasket surface	0.1 [0.004] or less	0.2 [0.008]



ENGINE MAIN PARTS

NOTE

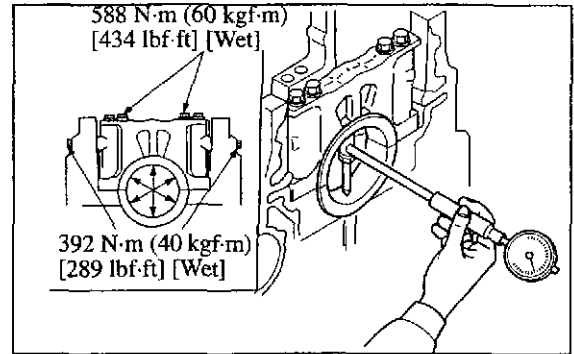
Do not grind the crankcase more than necessary to remove warpage. Excessive grinding can cause the piston protrusion to exceed assembly standard.

(11) Measuring main bearing bore diameter

Secure the end bearing cap to the specified torque, and measure the bore diameter in the three directions.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Main bearing bore diameter	ø179 [7.05]	179.000 to 179.025 [7.04723 to 7.04821]	179.045 [7.04900]



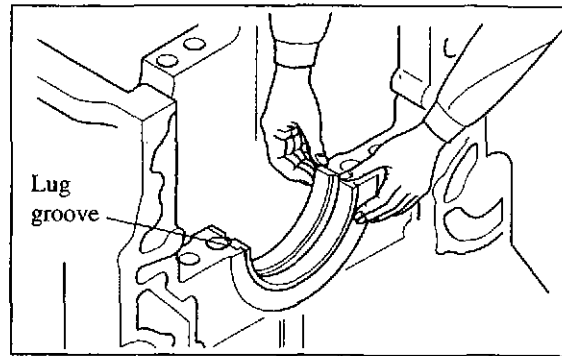
Measuring main bearing bore diameter

5.3 Reassembly

Reassembly is the reverse procedure of disassembly.

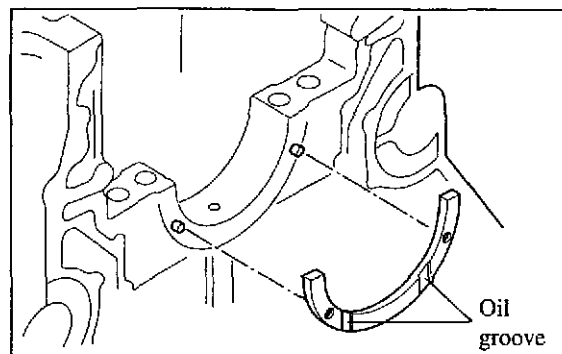
(1) Installing main bearing

- (a) Install each upper shell of the main bearing in the crankcase by fitting its locating lug in the lug groove. The oil holes in the bearings and crankcase will be aligned when the bearings are installed in this way.
- (b) Lightly coat the inside surface of the shells with engine oil.



(2) Installing thrust bearing

- (a) Install the thrust bearings to the No. 9 bearing seat of the crankcase, with the oil groove side of the bearings facing out.
- (b) After installing the crankshaft, install the inner thrust bearing with the oil groove facing inside the crankcase.



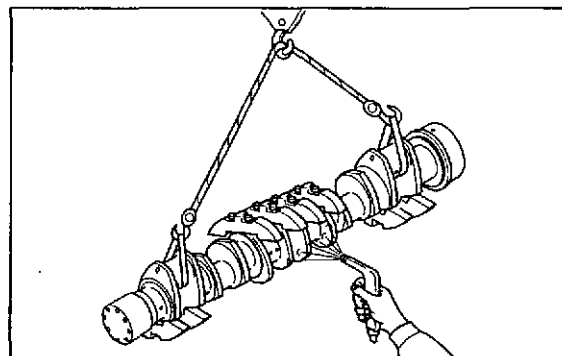
(3) Installing crankshaft

- (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.

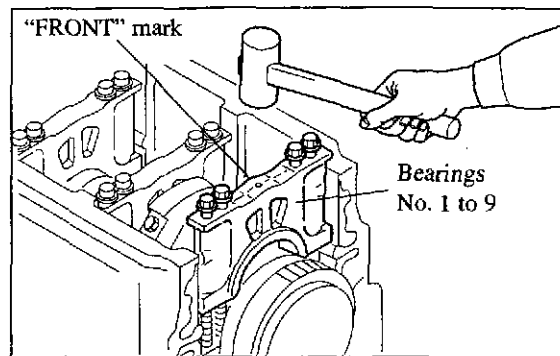
- (b) Hold the crankshaft horizontally with a hoist, then carefully put it on the crankcase.
- (c) Lightly apply engine oil to the journals.



ENGINE MAIN PARTS

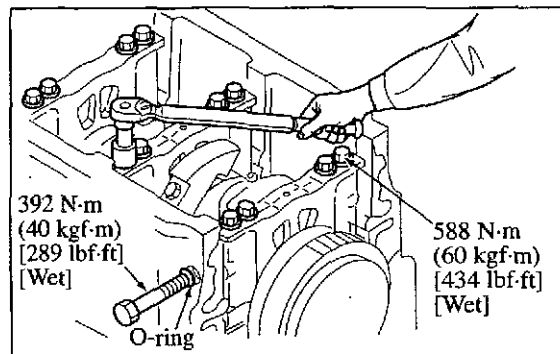
(4) Installing main bearing caps

- (a) Fit the lower shell of the bearing to each bearing cap.
- (b) Install the thrust bearing 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 and "FRONT" mark on the front of the crankcase.
- (d) Coat the threads of the bearing cap bolts with engine oil, then temporarily tighten the bolts.
- (e) Use a soft-head mallet to drive in the bearing caps evenly.



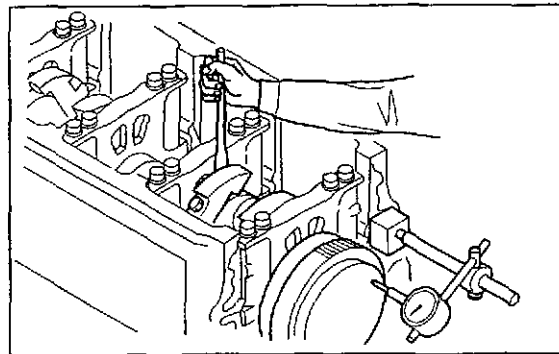
(5) Installing bearing cap bolts

- (a) Temporarily tighten the bearing cap coated with engine oil. Tighten the four bolts progressively and evenly to the specified torque.
- (b) Tighten the left and right side bolts progressively and evenly to the specified torque.
- (c) 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 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) Make sure that all cap bolts and side bolts are tightened.

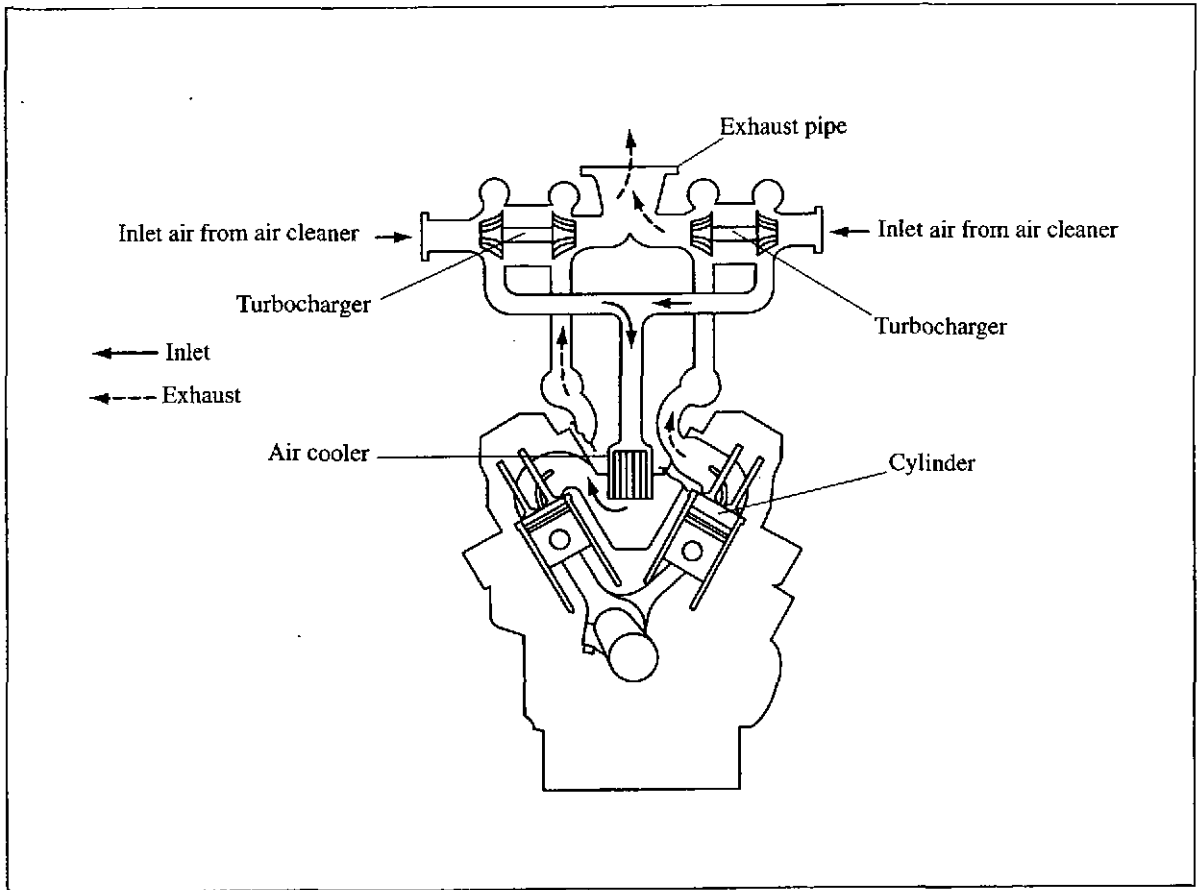


INLET AND EXHAUST SYSTEMS

1. Description	8-2
2. Air Cooler	8-3
2.1 Disassembly	8-3
2.2 Inspection	8-4
3. Exhaust Manifold	8-5
3.1 Disassembly and Inspection	8-5
4. Pre-Cleaner	8-5
4.1 Washing Pre-Cleaner	8-5
5. Turbocharger (TF15)	8-6
5.1 Disassembly	8-6
5.2 Cleaning	8-10
5.3 Inspection	8-12
5.4 Reassembly	8-14

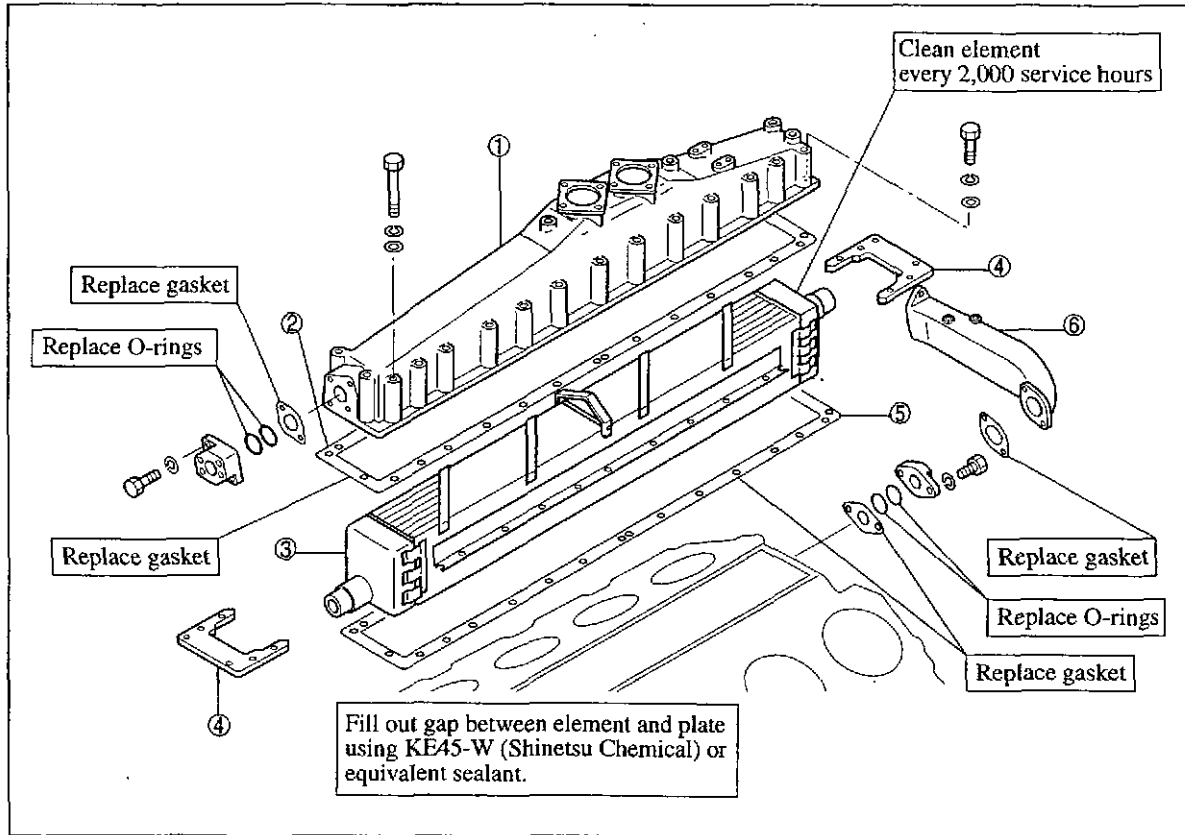
INLET AND EXHAUST SYSTEMS

1. Description



2. Air Cooler

2.1 Disassembly



Disassembly sequence

- | | | |
|-------------------|-----------|-------------------|
| ① Air cooler case | ③ Element | ⑤ Gasket |
| ② Gasket | ④ Plate | ⑥ Water connector |

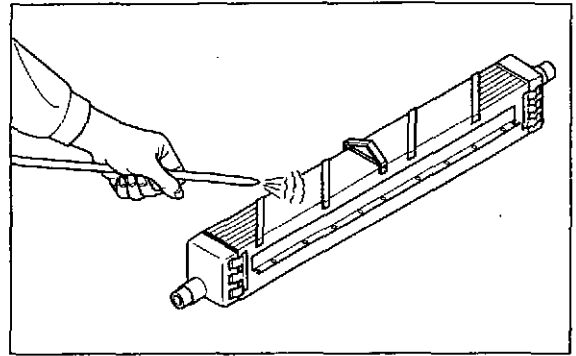
CAUTION

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

2.2 Inspection

(1) Cleaning air cooler

- (a) Remove dirt built up from the air cooler by directing high pressure air of 0.29 to 0.49 MPa (3 to 5kgf/cm²) [43 to 71 psi] (or less) 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 by inserting a $\phi 3$ mm [1/8 in.] bar into each pipe.



NOTE

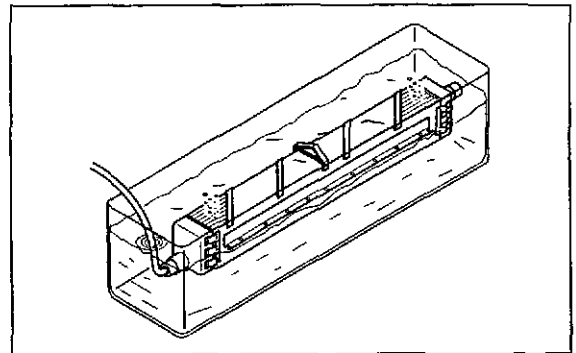
When using caustic soda or soda lime, wear rubber gloves to protect the hands.

(2) Inspecting air cooler for air tightness

Immerse the air cooler in water, then apply high pressure air of 0.39 MPa (4kgf/cm²) [57 psi] to the coolant side to inspect for air leaks.

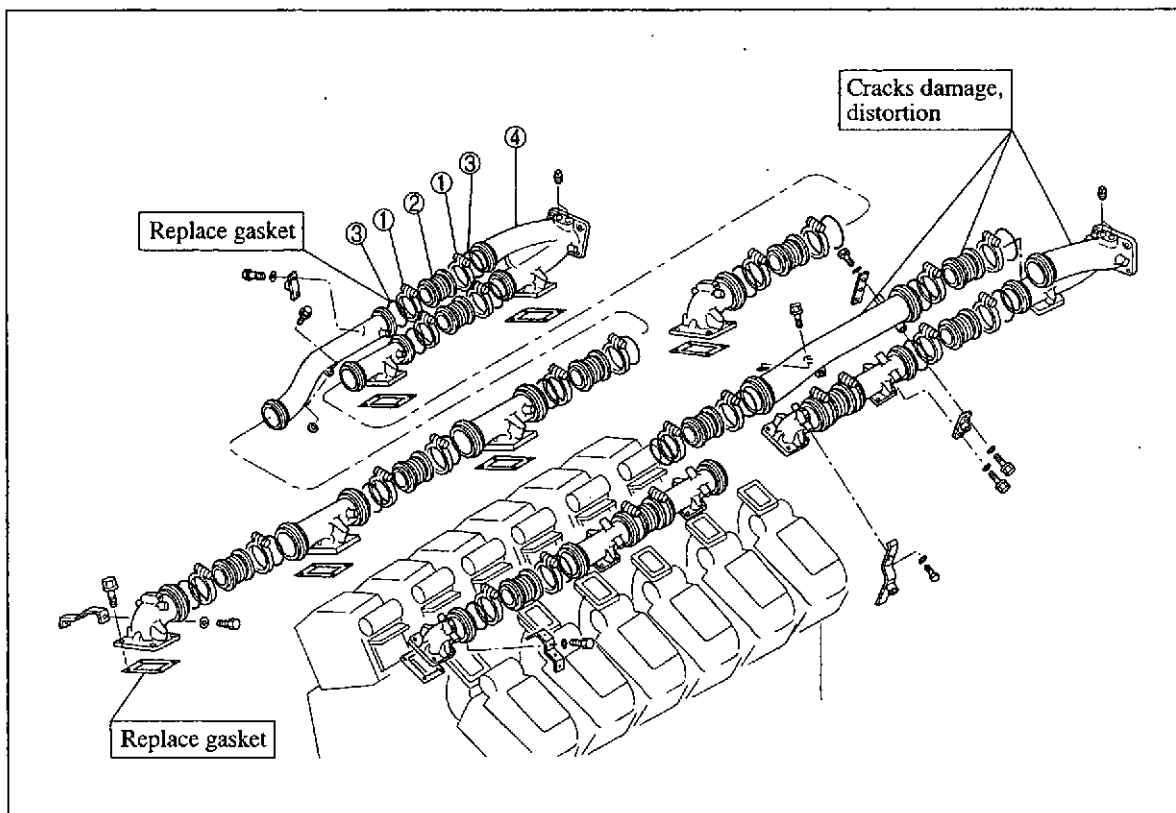
CAUTION

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 Flexible joint ③ Joint gasket ④ Exhaust manifold

NOTE

- (a) Place the gasket ④ with the "MANIFOLD" mark on the exhaust manifold side.
 (b) If the gasket ④ requires replacement, replace all the gaskets together.

CAUTION

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

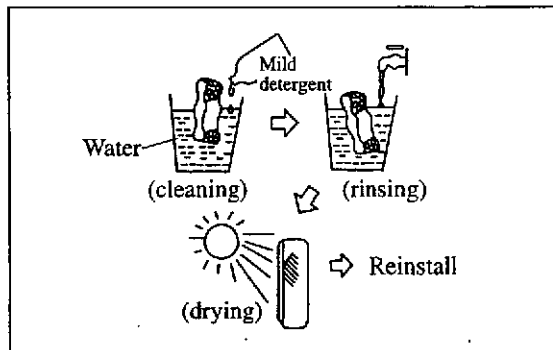
4. Pre-Cleaner

4.1 Washing 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.

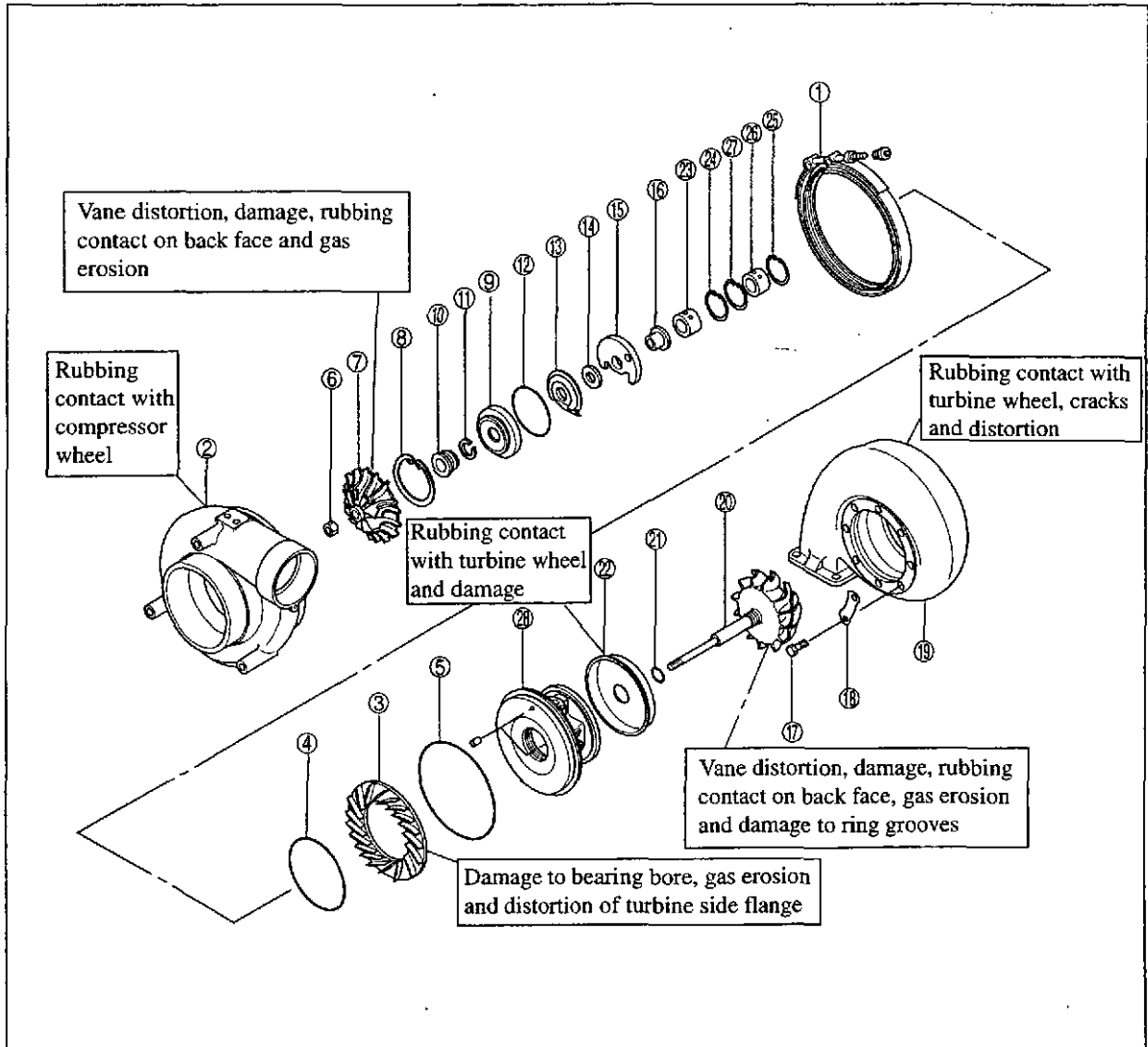
NOTE

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



5. Turbocharger (TF15)

5.1 Disassembly



Disassembly sequence

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

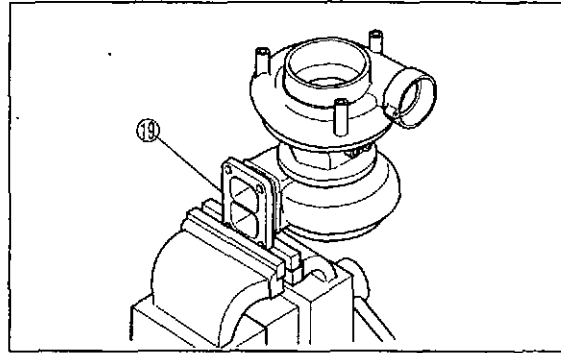
Carefully handle the compressor wheel and turbine wheel during disassembly and assembly, since vanes can easily bend when dropped or hit.

(1) Preparing for disassembly

Mount the turbine housing ⑱ on a vice by clamping at the flange.

CAUTION

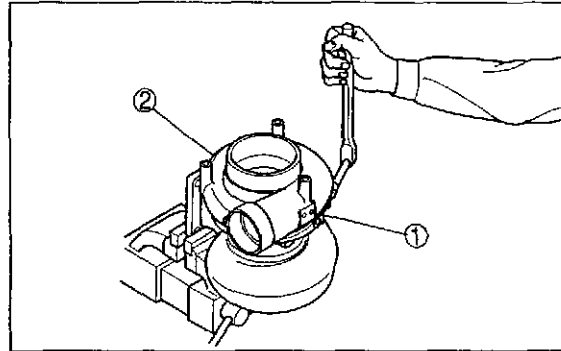
Clamp the flange securely to prevent the turbine housing from loosening or moving during work.



(2) Removing the compressor cover

CAUTION

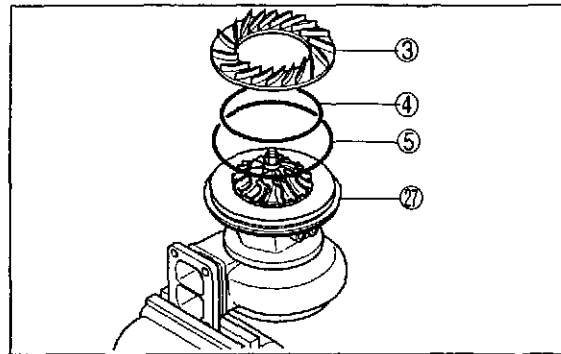
The compressor cover ②, bearing housing ⑳ and turbine housing ⑱ must be re-assembled in correct orientation. Therefore, put alignment marks with a punch or marker.



- (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 ⑳.

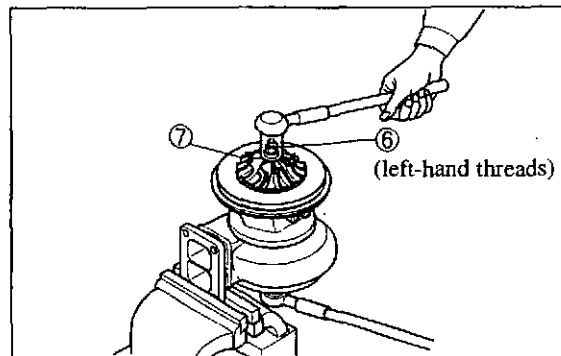


(4) Removing the compressor wheel

CAUTION

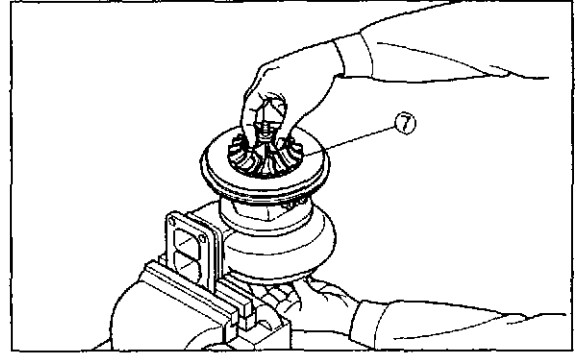
Note that lock nut ⑥ has left-hand threads.

- (a) While holding the boss of the shaft & turbine wheel ㉑, remove the lock nut ⑥ fastening the compressor wheel ⑦.



INLET AND EXHAUST SYSTEMS

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

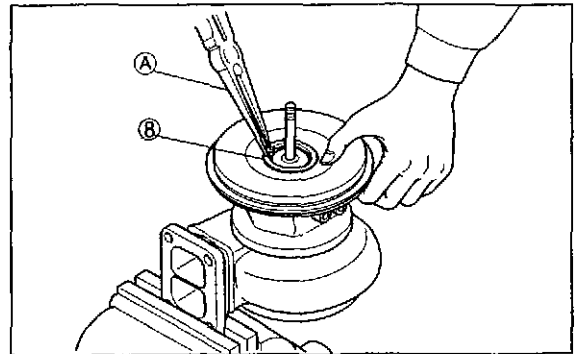


(5) Removing the snap ring

CAUTION

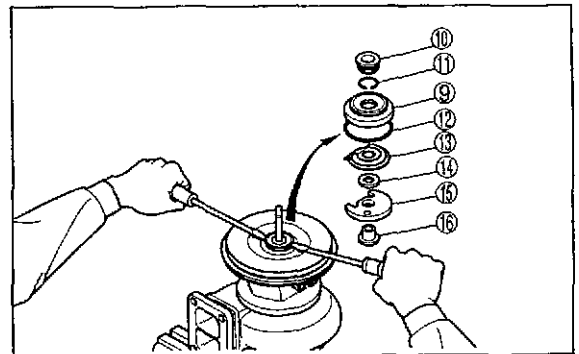
Put a thumb on the snap ring to prevent it from flying out in case the pliers lose grip.

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



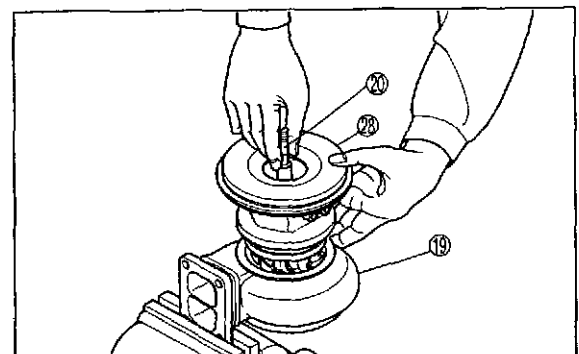
(6) Removing the insert and oil deflector

- (a) Using two screwdrivers, gently pry out the insert ⑨ from the bearing housing ⑳.
- (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 ⑳.
- ⑫ O-ring
 - ⑬ Oil deflector
 - ⑭ Thrust ring (compressor side)
 - ⑮ Thrust bearing
 - ⑯ Thrust ring (turbine side)



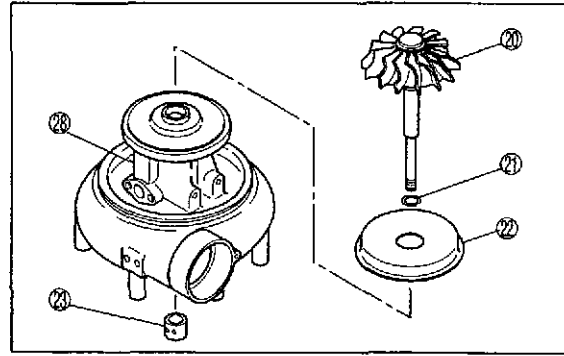
(7) Removing the shaft & turbine wheel

- (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 ㉑ 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.

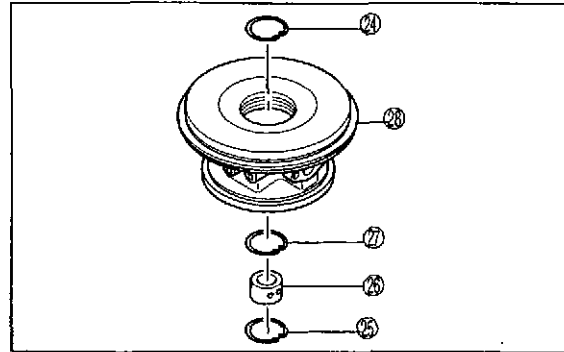
- 20 Shaft & turbine wheel
- 21 Piston ring
- 22 Turbine backplate
- 23 Bearing (compressor side)



(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 } (turbine side)
- 27 Snap ring

5.2 Cleaning

Cleaning

Blasting machines 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.

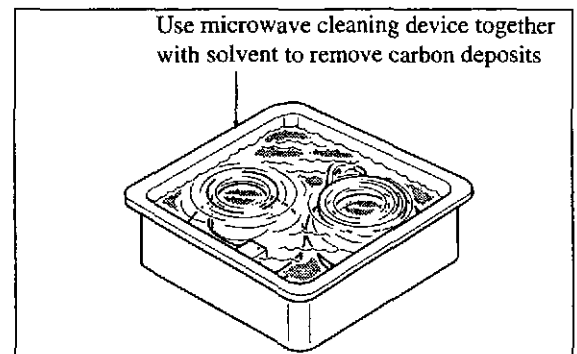
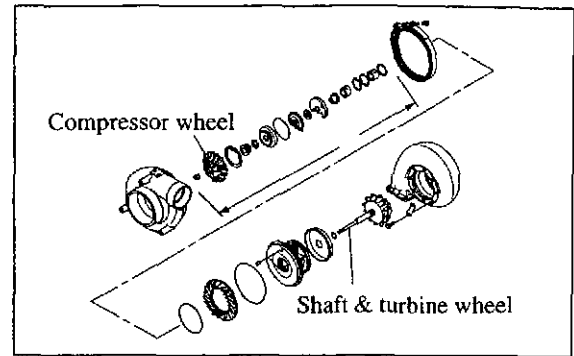
NOTE

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.

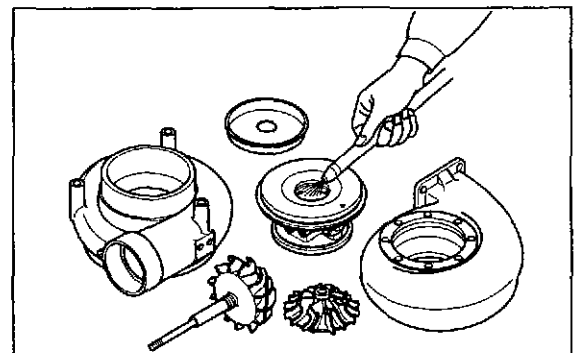
CAUTION

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.



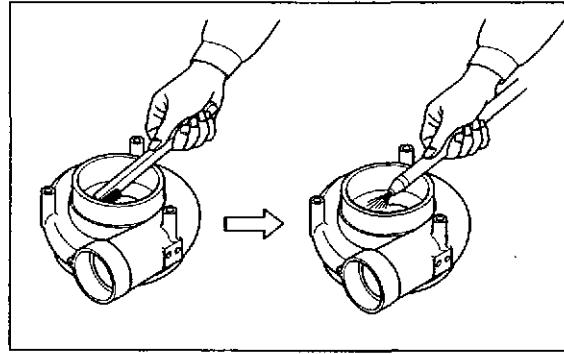
Use microwave cleaning device together with solvent to remove carbon deposits



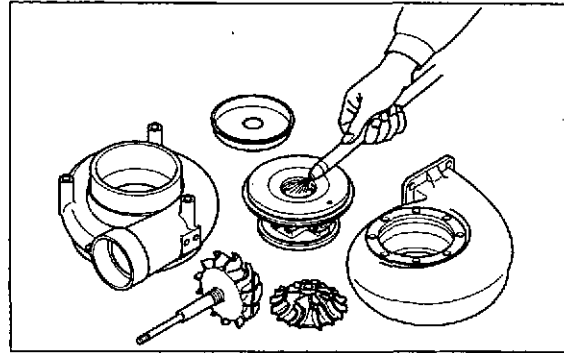
- (4) Using a plastic scrubber or hard brush, remove the carbon deposits thoroughly.

CAUTION

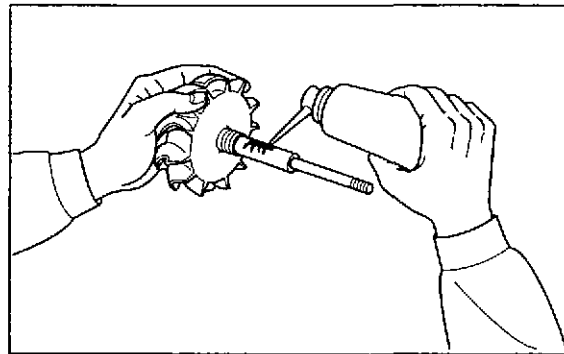
Be careful not to damage the parts. When using a shot blasting machine, be sure to cover the surfaces of the compressor wheel or the ring groove to avoid damaging the surface parts.



- (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

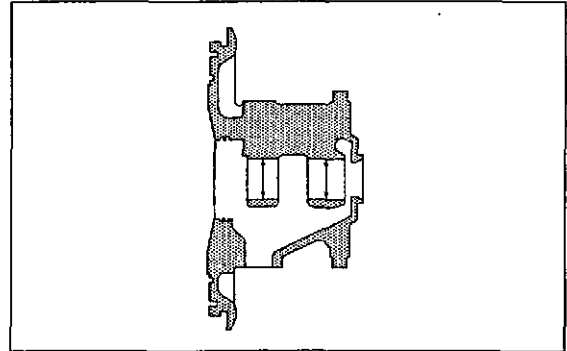
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(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]

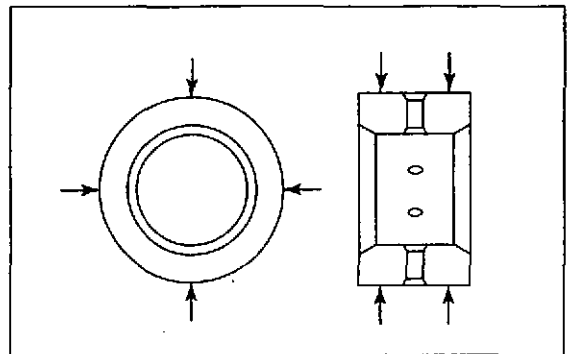


(2) Measuring bearing outside diameter

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]

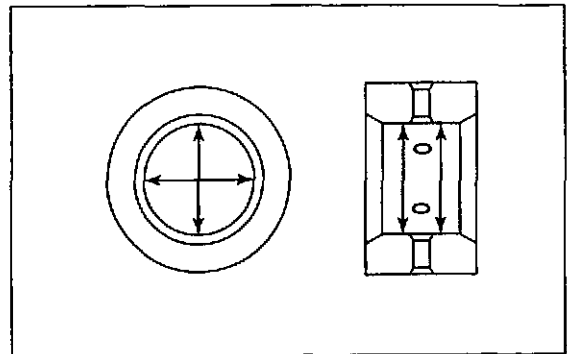


(3) Measuring bearing inside diameter

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

Unit: mm [in.]

Item	Service Limit
Bearing inside diameter	24.0335 [0.9462]

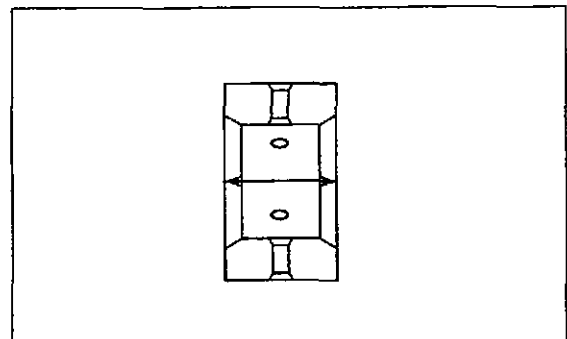


(4) Measuring bearing length

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

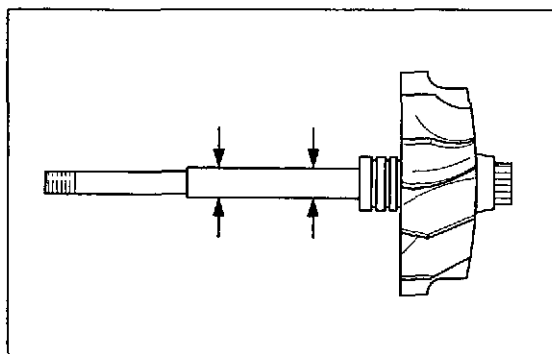
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.

(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

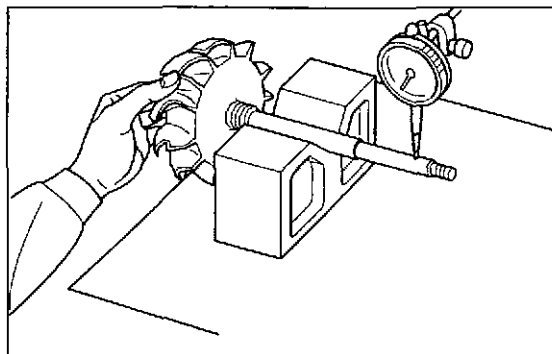
If the shaft is bent, replace. Do not attempt to correct the bend.

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]

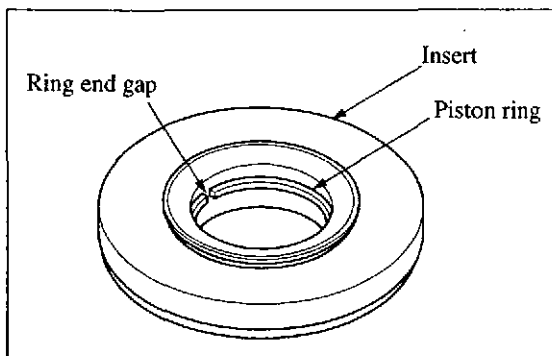


(7) Measuring piston ring end gap

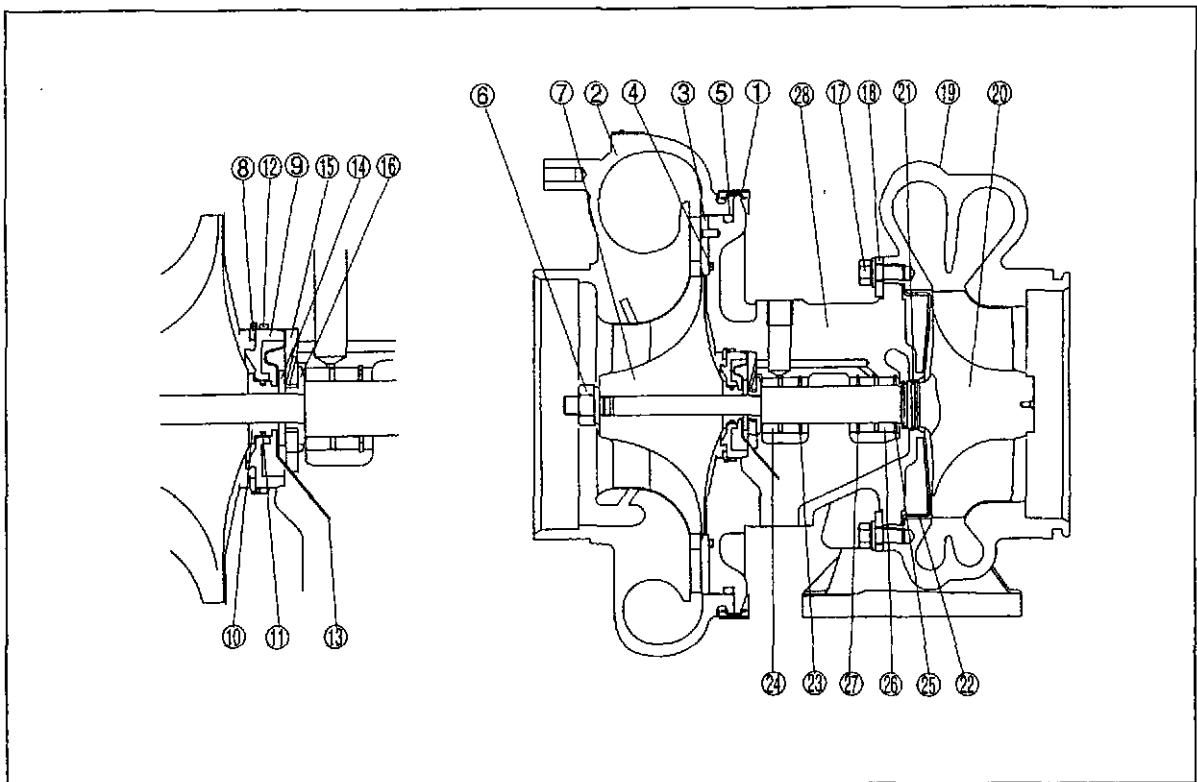
Install a new piston ring squarely in the insert, then measure the piston ring end gap. If the end gap deviates from the assembly standard, replace the insert.

Unit: mm [in.]

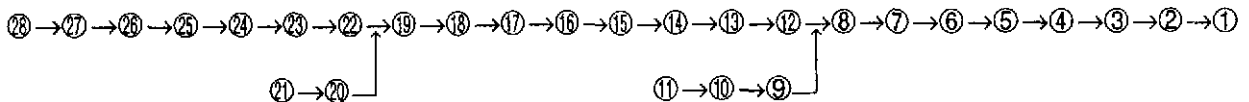
Item	Assembly Standard
Ring end gap	0.05 to 0.20 [0.0020 to 0.0079]



5.4 Reassembly



Reassembly sequence



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
- ⑫ 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.

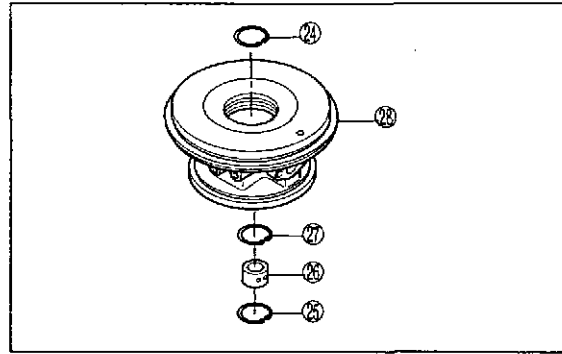
If only one vane is slightly bent or scratched, the part can be reused. However, do not attempt to correct the bend.

(1) Installing the shaft & turbine wheel and bearing

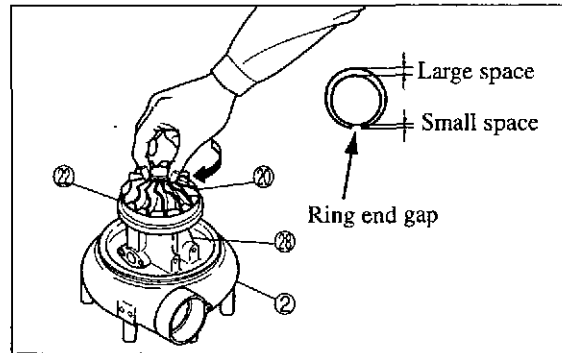
- (a) Install the following parts.
- ⑳ Bearing housing
 - ㉗ Snap ring
 - ㉖ Bearing } (turbine side)
 - ㉕ Snap ring }
 - ㉔ Snap ring (compressor side)

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.



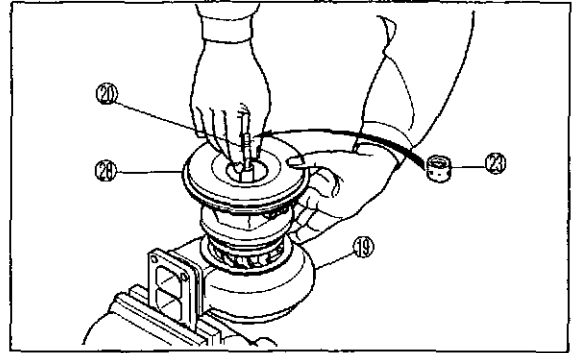
- (b) Place the bearing housing ⑳ on the compressor cover ②, and install the turbine backplate ㉒.
- (c) Insert the piston ring ㉑ into the groove on the shaft & turbine wheel ㉑.
- (d) When installing the shaft & turbine wheel ㉑ mounted with the piston ring in the bearing housing ㉑, position the ring on the shaft as shown in the drawing, and insert the shaft & turbine wheel ㉑ while rotating.



INLET AND EXHAUST SYSTEMS

⚠ 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.

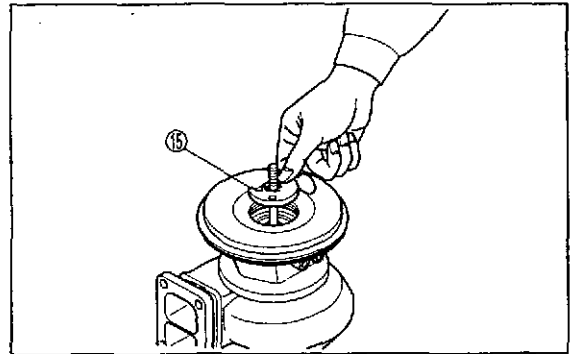


- (e) After installing the shaft & turbine wheel ⑳, hold the shaft end and turn over the assembly so the compressor side faces up:
Then, install the bearing ㉑ on the compressor side.
After the assembly is completed, mount the bearing housing ㉒ on the turbine housing ㉓ and fasten the bolt ㉔ temporarily.

(2) Installing the thrust bearing

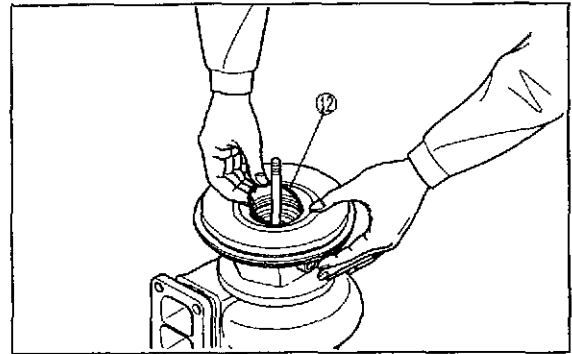
Apply engine oil to both sides of the thrust ring ⑮ and thrust bearing ⑮.

To install the thrust bearing, align the notch to the groove pin.



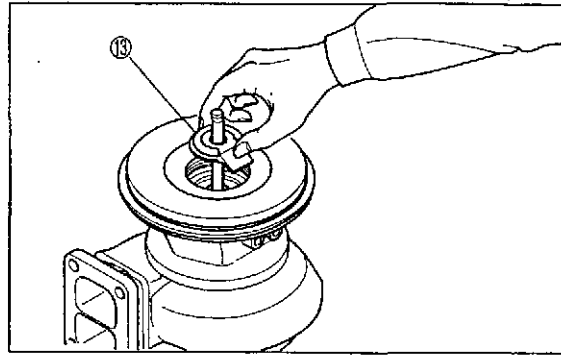
(3) Installing the O-ring

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



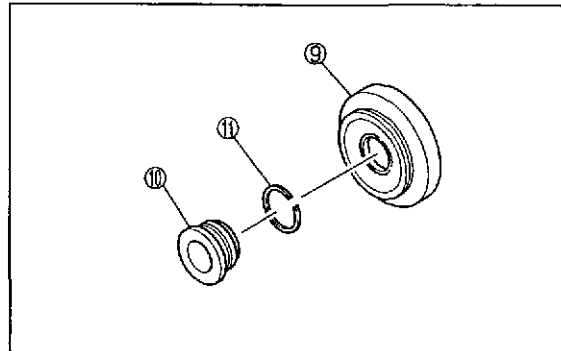
(4) Installing the oil deflector

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 ⑮.

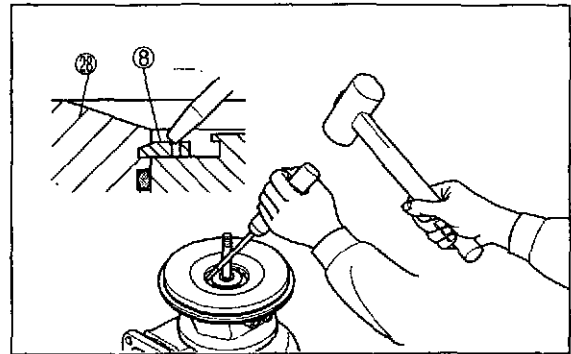
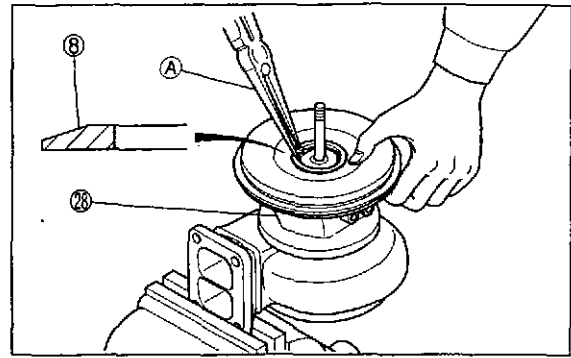
INLET AND EXHAUST SYSTEMS

(6) Installing the snap ring

With the tapered face facing up, install the snap ring ⑧ in the bearing housing ⑳ using the snap ring pliers ㉑ (49160-90101).

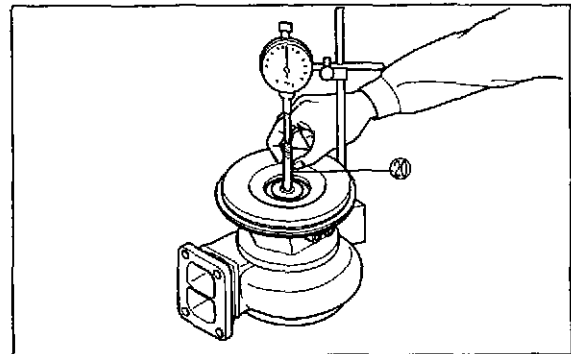
CAUTION

- Be sure to install the snap ring in the correct attitude.
- 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.
- 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 ㉒. 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.



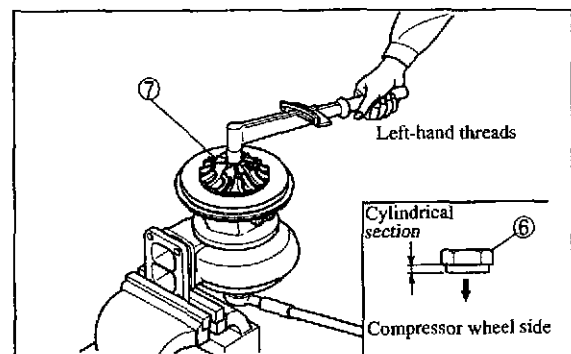
Unit: mm [in.]

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 $90 \pm 3^\circ$.



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

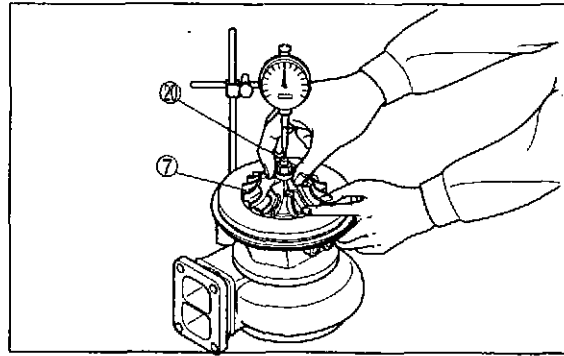
Set a dial gage on the end face of the shaft & turbine wheel ⑩.

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 ⑩. Install the compressor cover ②, and conduct the following measurement.

Using feeler gages, measure clearance between the turbine backplate ② and the back side of the turbine wheel.

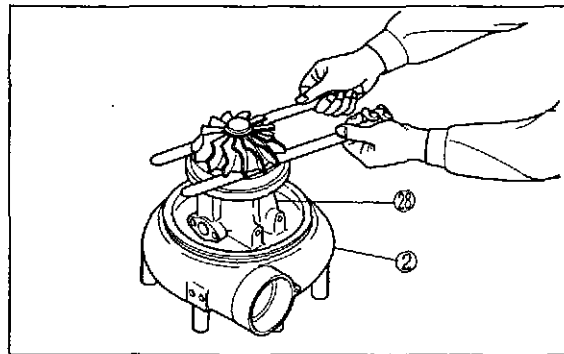
CAUTION

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.

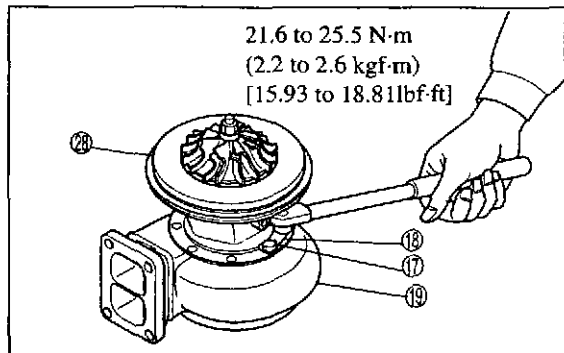
Unit: mm [in.]

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

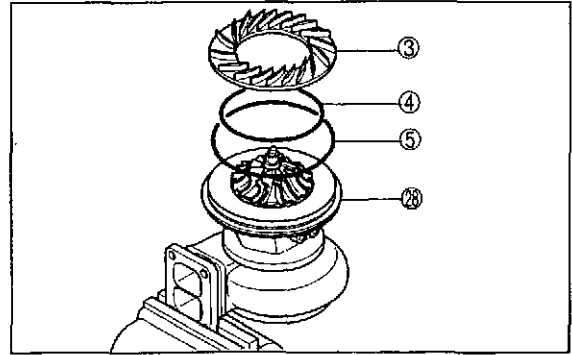
- (a) Check the mounting direction of the turbine housing ⑩, then install on the bearing housing ⑩.
- (b) Apply Moly Disulfide to the threads of the bolt ⑰, install lock plate ⑱ and tighten the bolt.



INLET AND EXHAUST SYSTEMS

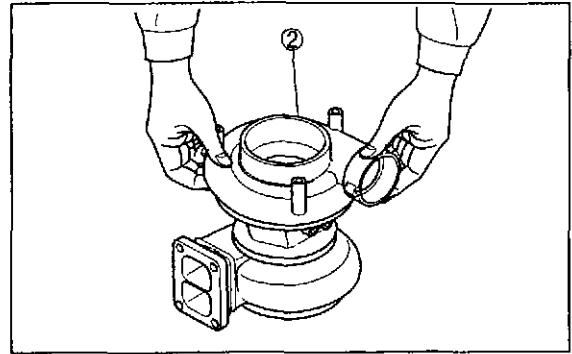
(12) Installing the diffuser

- (a) Apply grease to the O-ring ⑤, ④ and install the bearing housing ⑥.
- (b) Install the diffuser ③.



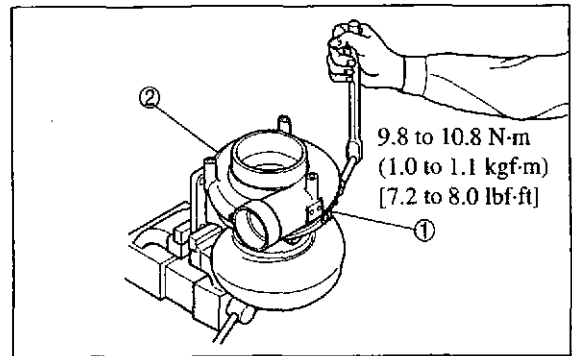
(13) Installing the compressor cover

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



(14) Installing the V-clamp

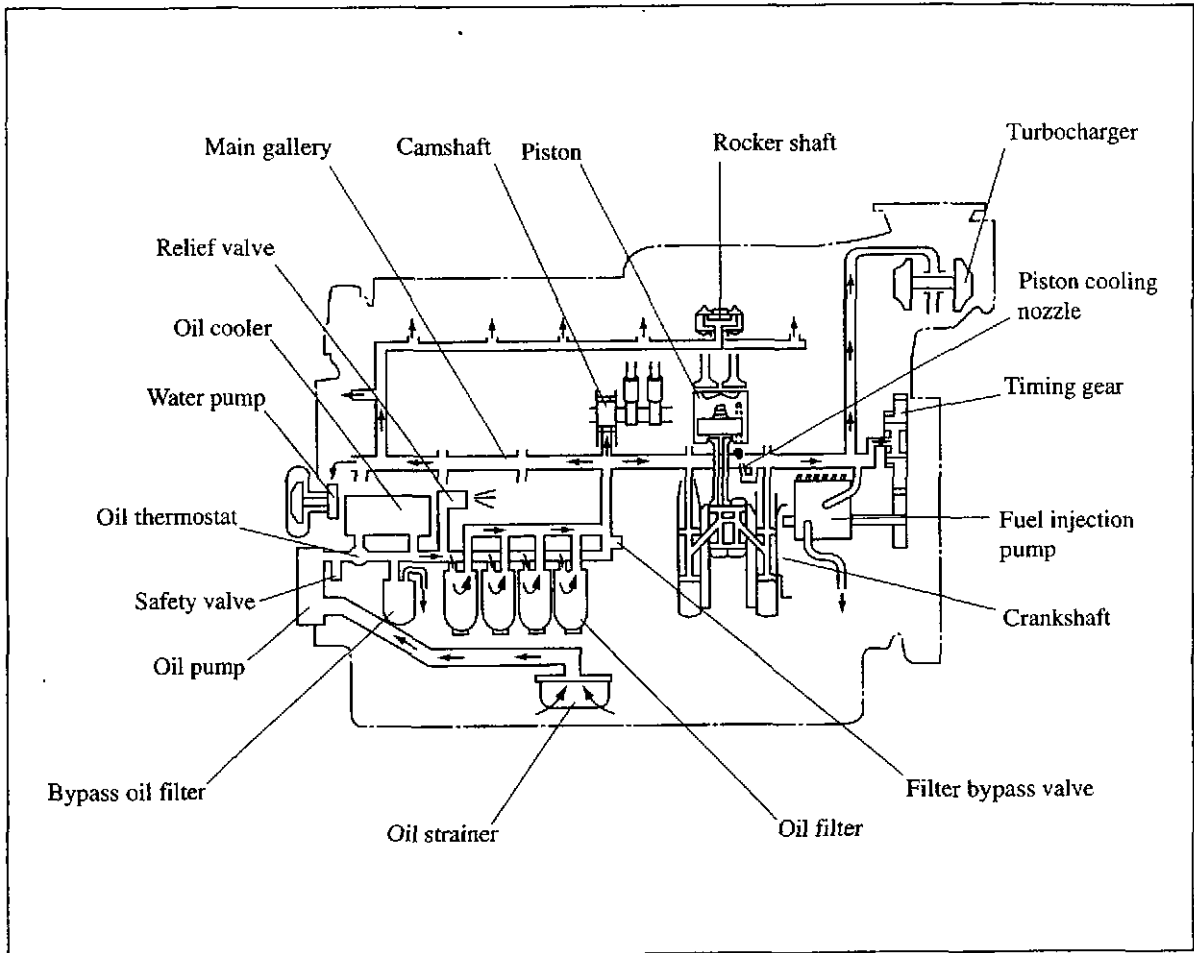
Install the V-clamp ① to the compressor cover ② and tap around it with a soft-faced hammer for more than 3 times and tighten to the specified torque.



LUBRICATION SYSTEM

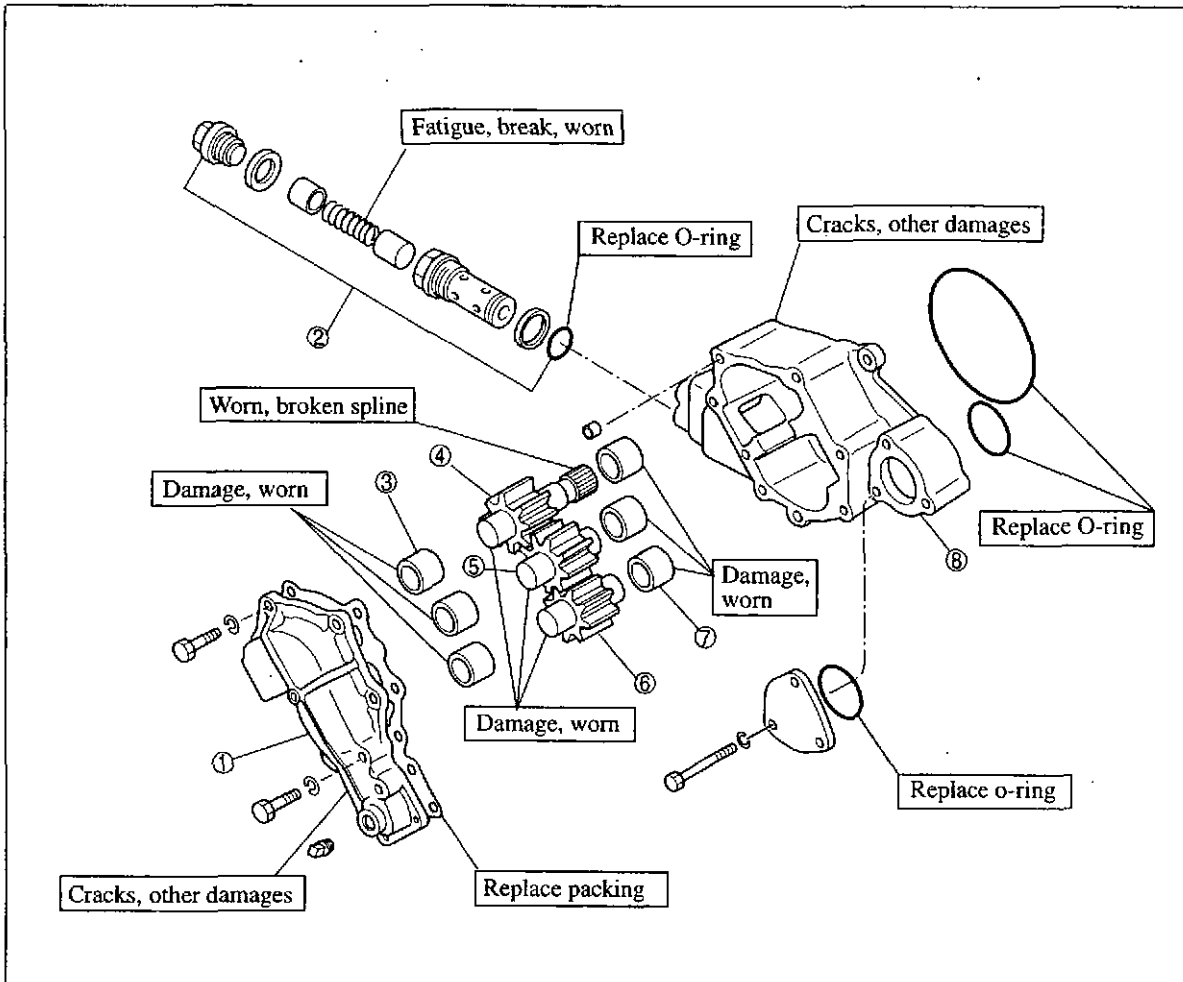
1. Description	9-2
2. Oil Pump and Safety Valve	9-3
2.1 Disassembly	9-3
2.2 Inspection	9-4
2.3 Reassembly	9-7
3. Oil Filters, Oil Filter Alarm, Relief Valve, Left Side Oil Cooler and Oil Thermostat	9-8
3.1 Disassembly	9-8
3.2 Inspection	9-9
3.3 Reassembly	9-12
4. Right Side Oil Cooler and Oil Thermostat	9-13
4.1 Disassembly	9-13
4.2 Inspection	9-13
4.3 Reassembly	9-13

1. Description



2. Oil Pump and Safety Valve

2.1 Disassembly



Disassembly sequence

- ① Oil pump cover
- ② Safety valve assembly
- ③ Bushing

- ④ Drive gear
- ⑤ Driven gear
- ⑥ Driven gear

- ⑦ Bushing
- ⑧ Oil pump case

LUBRICATION SYSTEM

2.2 Inspection

(1) Measuring drive gear and driven gear backlash

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

Unit: mm [in.]

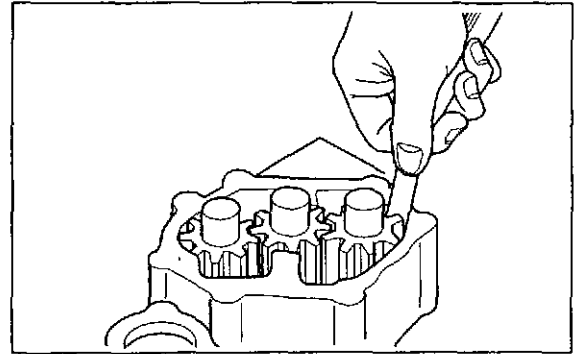
Item	Standard Clearance	Service Limit
Drive and driven gear backlash	0.100 to 0.200 [0.0039 to 0.0079]	0.400 [0.0157]

(2) Measuring clearance between drive gear and driven gear

Use feeler gages to measure the 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
Clearance between drive and driven gears in case	ø60 [2.36]	0.100 to 0.148 [0.00394 to 0.00583]	Tip clearance: 0.350 [0.0138]



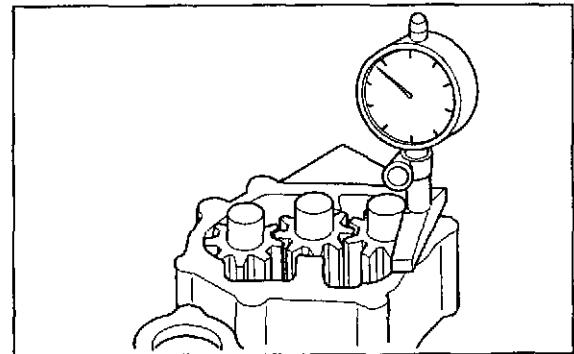
Measuring clearance between drive and driven gear

(3) Measuring pump gear end clearance

Use a dial gage to measure the 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
Clearance between gear width and case	72.5 [2.854]	0.040 to 0.116 [0.00157 to 0.00457]	0.21 [0.0083]



Measuring pump gear end clearance

NOTE

Remove the cover mounting packing (0.04mm [0.0016 in.] thick) when measuring.

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

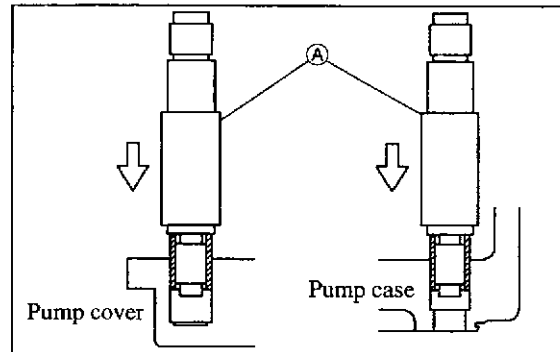
- (a) Check the gear teeth. Replace gears if they are defective.
- (b) Measure the gear shaft and bushing diameters. If the diameter exceeds the service limit, replace its parts.

Unit: mm [in.]

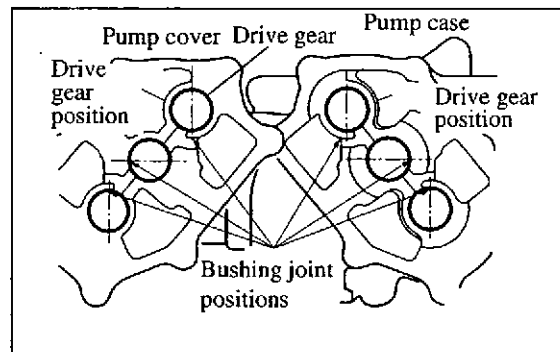
Item	Nominal Value	Assembly Standard	Service Limit
Drive shaft diameter	ø30 [1.18]	29.887 to 29.900 [1.17665 to 1.17717]	29.840 [1.17480]
Driven shaft diameter		29.947 to 29.960 [1.17901 to 1.17953]	29.900 [1.17717]
Bushing inside diameter		30.000 to 30.021 [1.18110 to 1.18103]	30.055 [1.18327]

(5) Replacing oil pump bushings

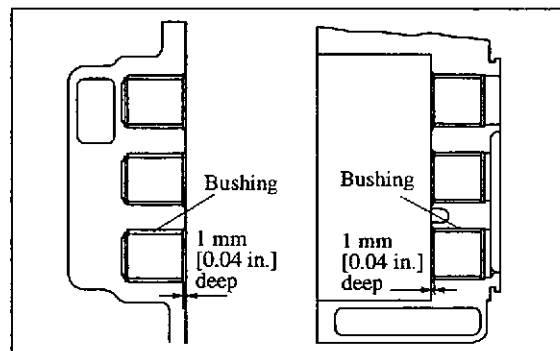
- (a) Remove the oil pump bushing as needed. If the oil pump bushing insertion is too tight to remove it, replace it with the case or cover assembly.
- (b) When you install the pump cover bushing, place the bushing joint positions as shown in the right drawing. (Do not align with the lubrication oil groove.)
- (c) Using the oil pump bushing installer ①, insert the bushing to the position shown in the right drawing.
- (d) After you press a new bushing into position, finish its inside diameter to ø 30H7^{+0.021}₀ mm. [ø1.18H^{+0.0008}₀ in.] 0.8 Ra.



Oil pump bushing match mark positions



Inserting bushing to position

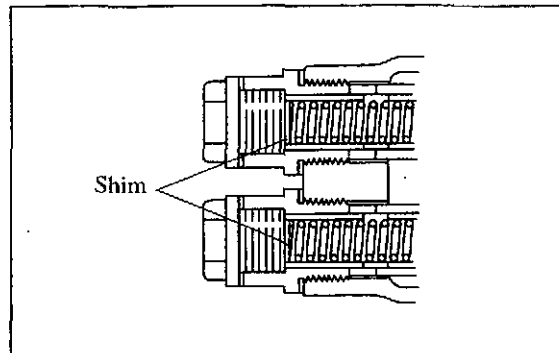


Installing oil pump bushing

LUBRICATION SYSTEM

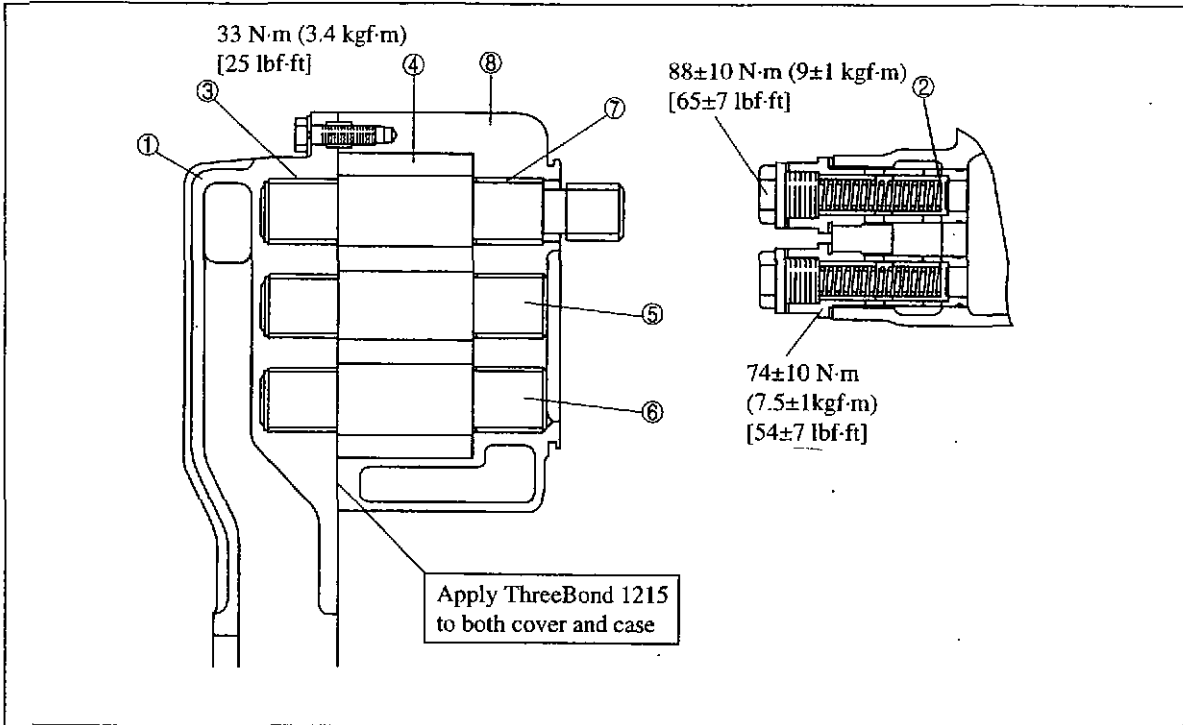
(6) Inspecting safety valve

- (a) Check the valve spring of the oil pump safety valve for fatigue. If excessive fatigue, wear, or break is found, replace the valve spring.
- (b) Measure the valve opening pressure. If the pressure is higher or lower than the assembly standard, increase or decrease the thickness of shim inserted between the spring and spring cap nut. For the thickness of a shim, 1 mm [0.04 in.] corresponds to a change in pressure of 0.10 MPa (1 kgf/cm²) [14.2 psi].



Item	Assembly Standard	Service Limit
Safety valve opening pressure MPa (kgf/cm ²) [psi]	1.27±0.13 (13.0±1.3) [185±18.5]	
Safety valve spring set length /set force mm [in.]/N (kgf) [lbf]	65.8 [2.59]/ 359 (36.6) [80.7]	65.8 [2.59]/ 314 (32) [70.5]

2.3 Reassembly



Reassembly sequence

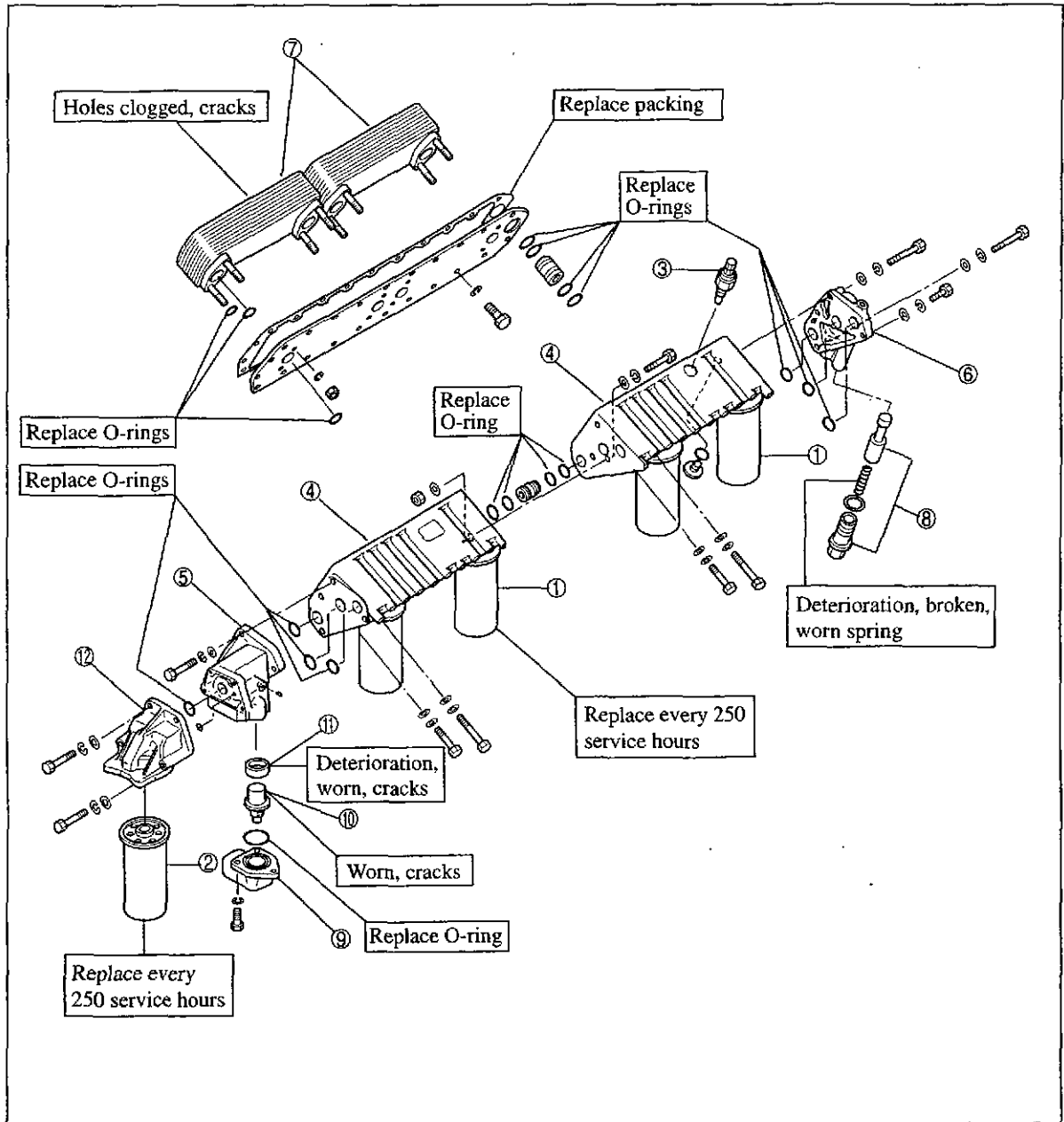
① → ③
⑧ → ⑦ → ④ → ⑤ → ⑥ → ②

NOTE

During reassembly, apply Moly Disulfide to all sliding surfaces. When installing valve assemblies, apply engine oil to O-rings.

3. Oil Filters, Oil Filter Alarm, Relief Valve, Left Side Oil Cooler and Oil Thermostat

3.1 Disassembly



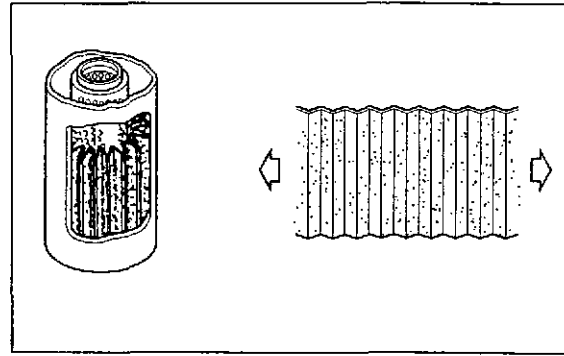
Disassembly sequence

- | | | |
|--------------------------------|-------------------------|-------------------|
| ① Full flow oil filter element | ⑤ Adaptor A assembly | ⑨ Connector |
| ② Bypass oil filter element | ⑥ Adaptor B assembly | ⑩ Oil thermostat |
| ③ Oil filter alarm | ⑦ Oil cooler element | ⑪ Thermostat seal |
| ④ Filter bracket assembly | ⑧ Relief valve assembly | ⑫ Bracket |

3.2 Inspection

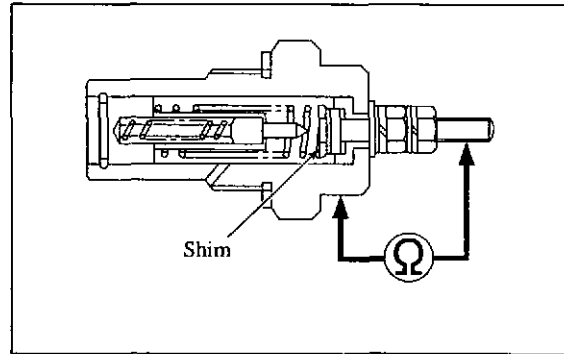
(1) Inspecting oil filter

When you replace the paper element, sample about 500cm³ [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 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 6.86 kPa (0.07 kgf/cm²) [1.00 psi].



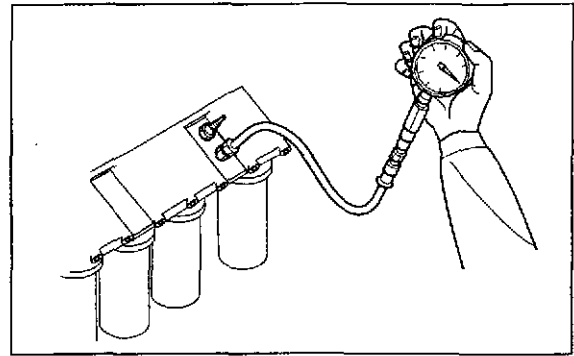
Unit: MPa (kgf/cm²) [psi]

Item	Assembly Standard
Lamp lighting and valve opening pressure (differential pressure)	0.15 to 0.18 (1.5 to 1.8) [21.3 to 25.6]

LUBRICATION SYSTEM

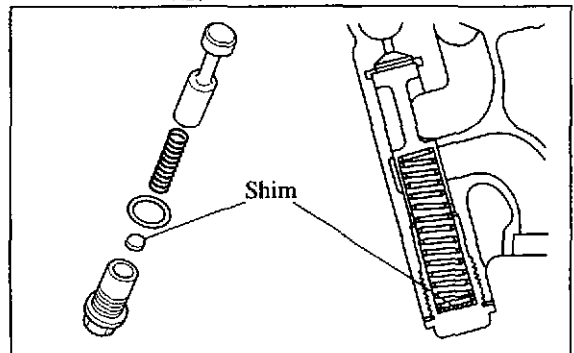
(3) Measuring relief valve pressure

- (a) Remove the taper plug (PT 1/8) on the upper side of the filter bracket, and attach a pressure gage.
- (b) Warm up the engine until the oil temperature rises to 70 to 90°C [158 to 194°F].
- (c) Measure oil pressure at idling speed and maximum speed.
- (d) If the measured oil pressure is lower than the specified value, adjust the valve opening pressure by inserting shims. For shim thickness, 5 mm [0.20 in.] corresponds to a change in pressure of approximately 0.1 MPa (1 kgf/cm²) [14 psi].



Unit: MPa (kgf/cm²) [psi]

Item	Assembly Standard
Set pressure (max. speed)	0.49 to 0.64 (5.0 to 6.5) [71.12 to 92.46]
Relief valve opening pressure	0.51 ± 0.02 (5.2 ± 0.2) [73.97 ± 2.84]



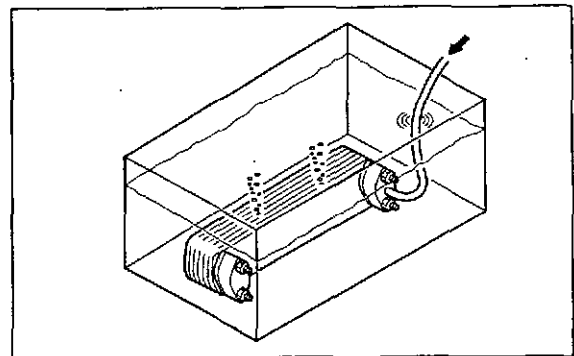
NOTE

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 adjustment with shims is not effective, replace the relief valve and spring.

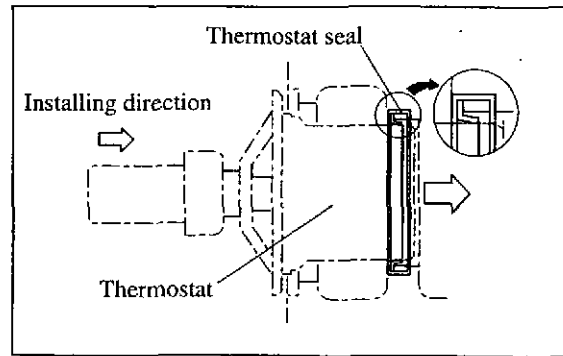
(4) Inspecting left side oil cooler

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.



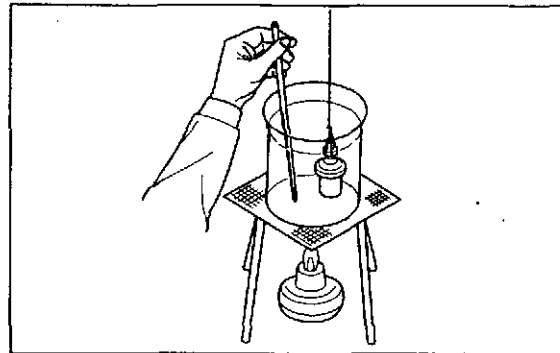
(5) Inspecting left side thermostat

- (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.



Installing seal for thermostat

- (c) Immerse the thermostat in engine oil, then measure the temperature where the valve opens, then measure it again when the valve lift is 11 mm [0.43 in.]. Replace the thermostat if temperatures are not within standard.



Item	Assembly Standard
Valve opening temperature	80 to 84°C [176 to 183.2°F]
Temperature at which valve lift is 11 mm [0.43 in.] or more	95°C [203°F]

NOTE

- (a) Stir the oil to maintain even temperatures during the test.
- (b) At reassembly, confirm the valve opening temperature stamped on its mounting flange.

LUBRICATION SYSTEM

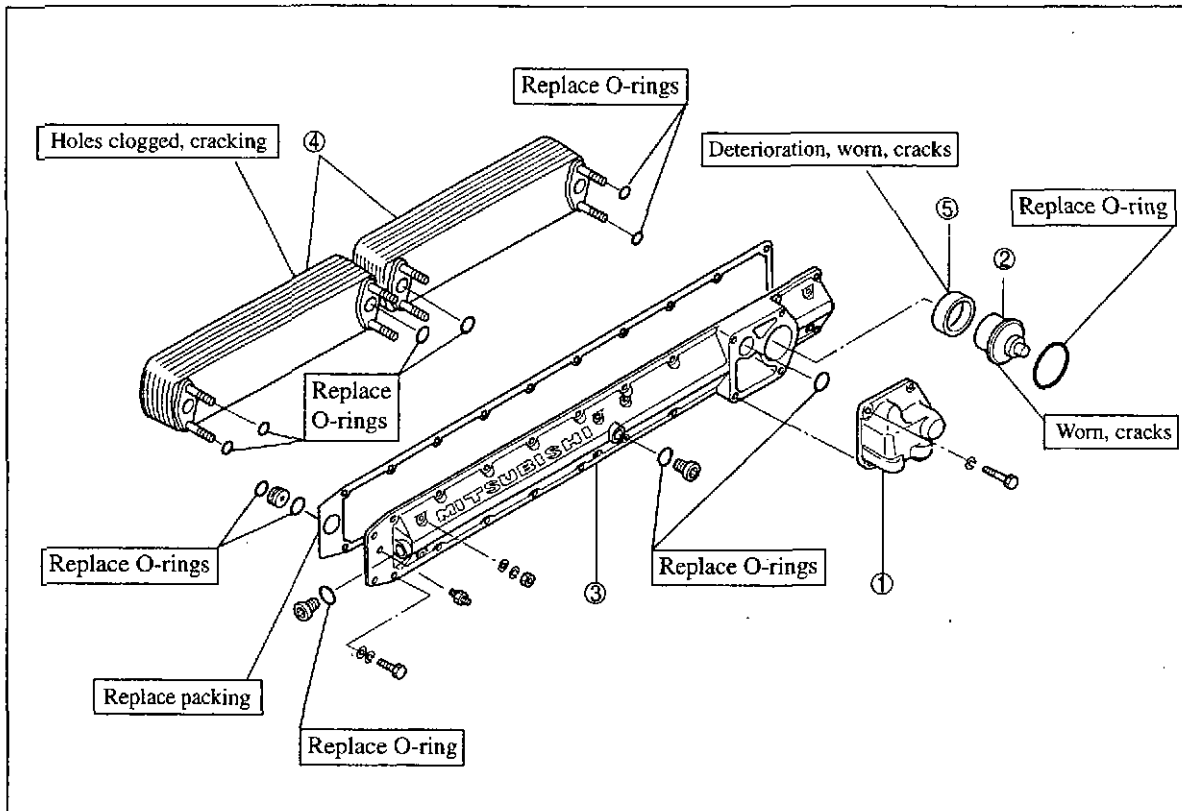
3.3 Reassembly

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) Install the oil filter element with its bracket.

4. Right Side Oil Cooler and Oil Thermostat

4.1 Disassembly



Disassembly sequence

- | | |
|------------------|----------------------|
| ① Connector | ④ Oil cooler element |
| ② Oil thermostat | ⑤ Thermostat seal |
| ③ Oil cooler | |

4.2 Inspection

Follow the same inspection procedure as that for the left side oil cooler and oil thermostat. If any deterioration is found, replace them.

4.3 Reassembly

Reassembly is the reverse procedure of disassembly.

- (1) Install new packing and O-rings for reassembly.
- (2) Before reassembly, clean the oil passage of the oil cooler cover, etc. by flushing them with oil then blowing them with compressed air.

LUBRICATION SYSTEM

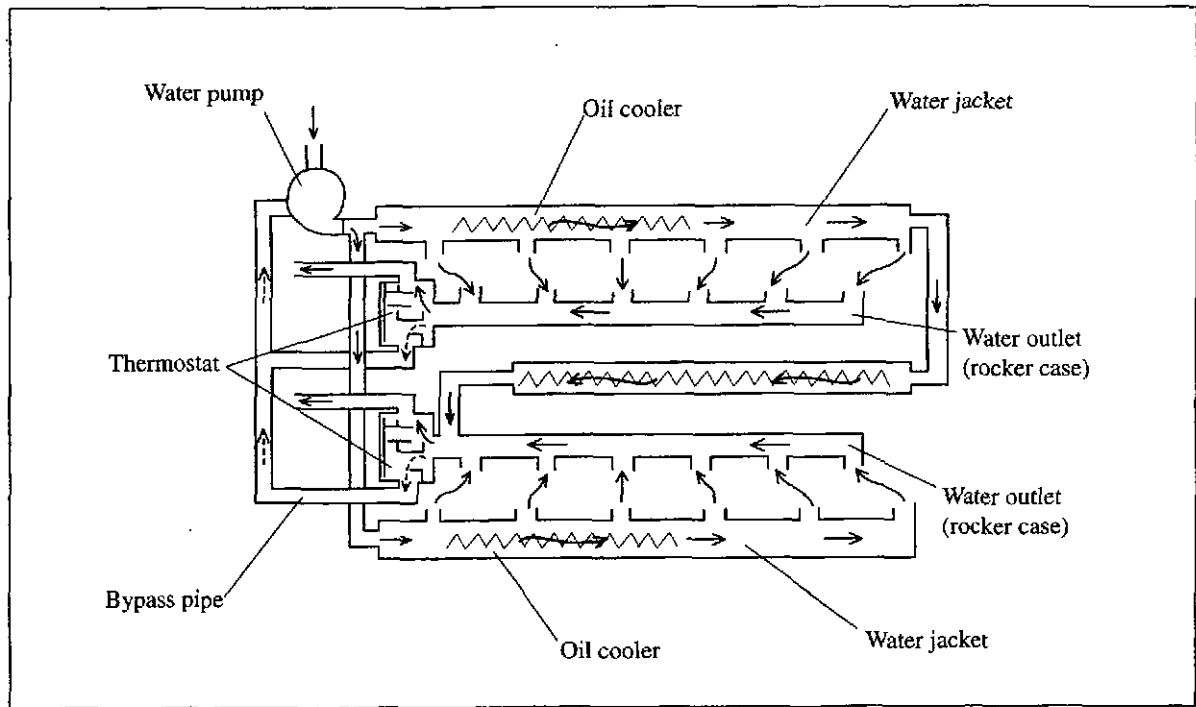
COOLING SYSTEM

1. Description of Cooling System for External Water-cooled Engine	10-2
2. Water Pump	10-3
2.1 Disassembly	10-3
2.2 Inspection	10-6
2.3 Reassembly	10-7
3. Thermostats	10-10
3.1 Disassembly	10-10
3.2 Inspection	10-11
4. Fan Drive	10-12
4.1 Disassembly	10-12
4.2 Inspection	10-13
4.3 Reassembly	10-14

COOLING SYSTEM

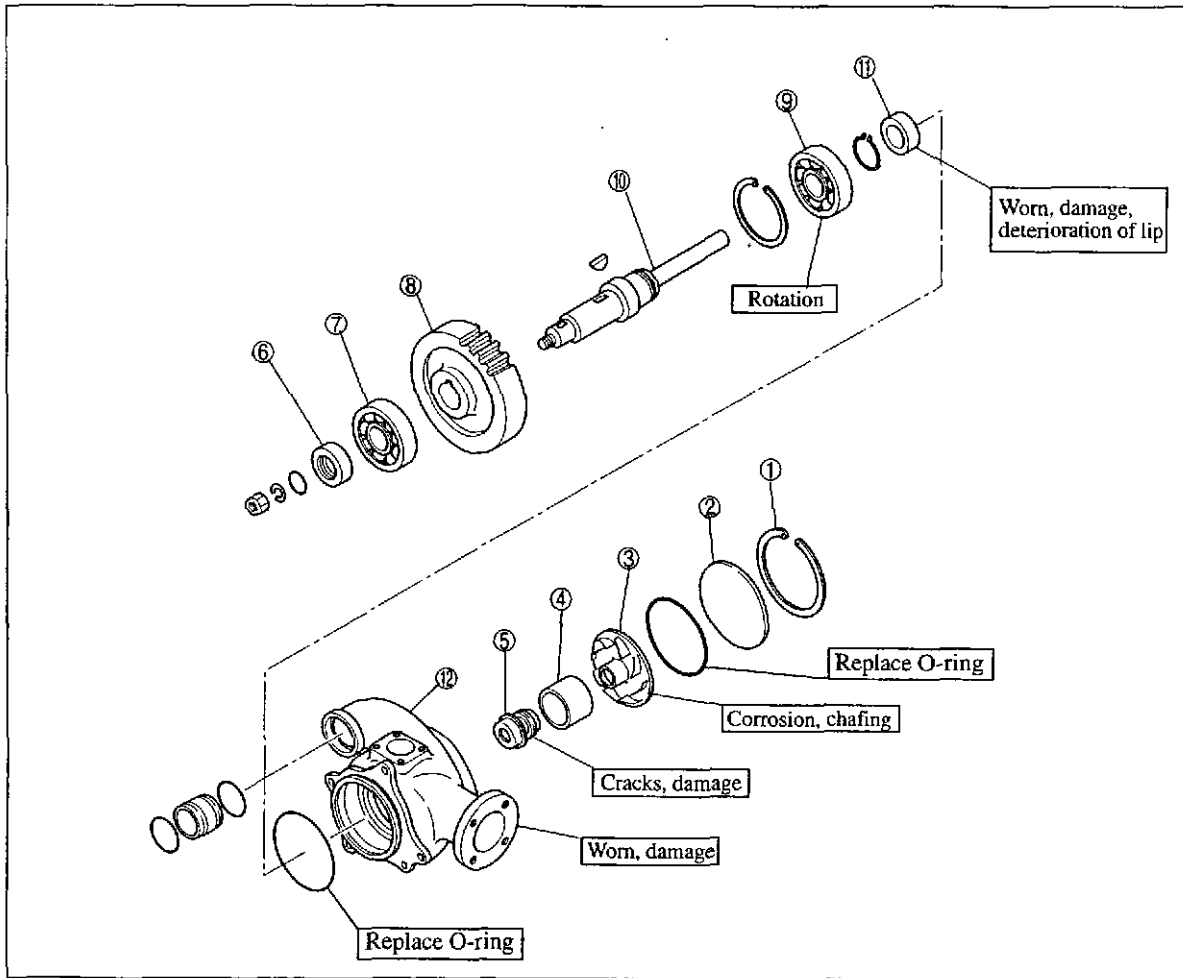
1. Description of Cooling System for External Water-cooled Engine

Dual-circuit cooling (parallel piping)



2. Water Pump

2.1 Disassembly



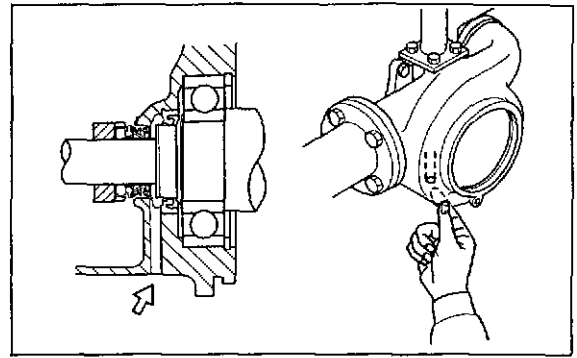
Disassembly sequence

- | | | |
|-----------------------|-------------------|--------------------|
| ① Snap ring | ⑤ Unit seal | ⑨ Bearing |
| ② Cover | ⑥ Oil seal sleeve | ⑩ Water pump shaft |
| ③ Water pump impeller | ⑦ Bearing | ⑪ Oil seal |
| ④ Ring | ⑧ Water pump gear | ⑫ Pump case |

COOLING SYSTEM

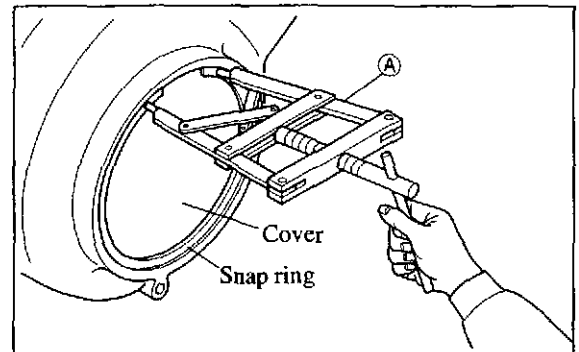
(1) Inspecting wear pump on the engine

Touch the drain port located at the bottom of the pump with your finger. If the port is leaking water, check the condition of the unit seal. If it is leaking oil, the oil seal is defective.



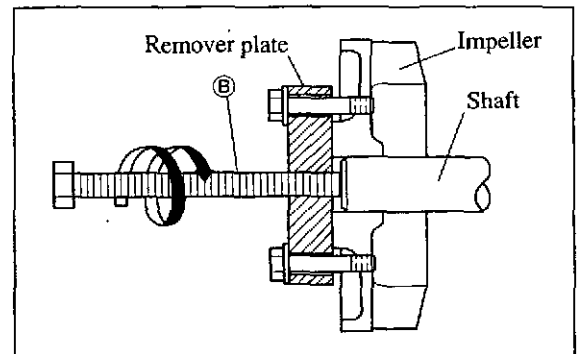
(2) Removing impeller

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



Removing impeller

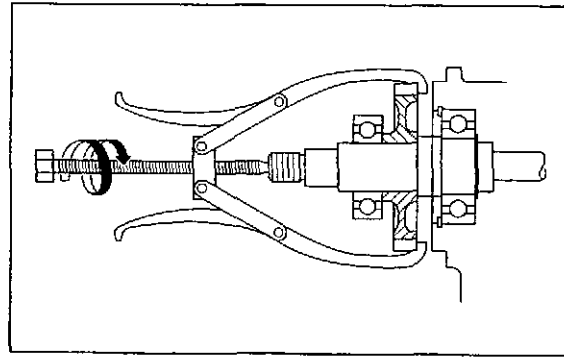
- (b) Remove the impeller with the impeller remover **(B)** (37591-03200).



Removing impeller

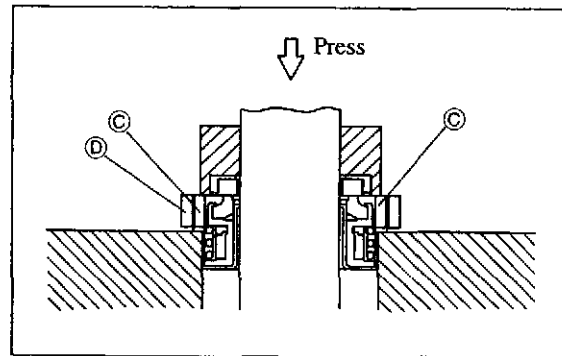
(3) Removing water pump shaft

- (a) Remove the oil seal sleeve.
- (b) Remove the gear and the bearing with the gear puller.
- (c) Remove the snap ring of the impeller side ball bearing.



Removing gear

- (d) Insert the two half rings © of the ring remover (37791-03400) between the unit seal and the pump case as shown in the drawing.
- (e) Fit the outer ring © to the outside of the half rings to prevent them from falling down.
- (f) Support the pump case and push out the end face of the shaft impeller side by pushing with a hand press in the direction of the arrow mark as shown in the drawing.



COOLING SYSTEM

2.2 Inspection

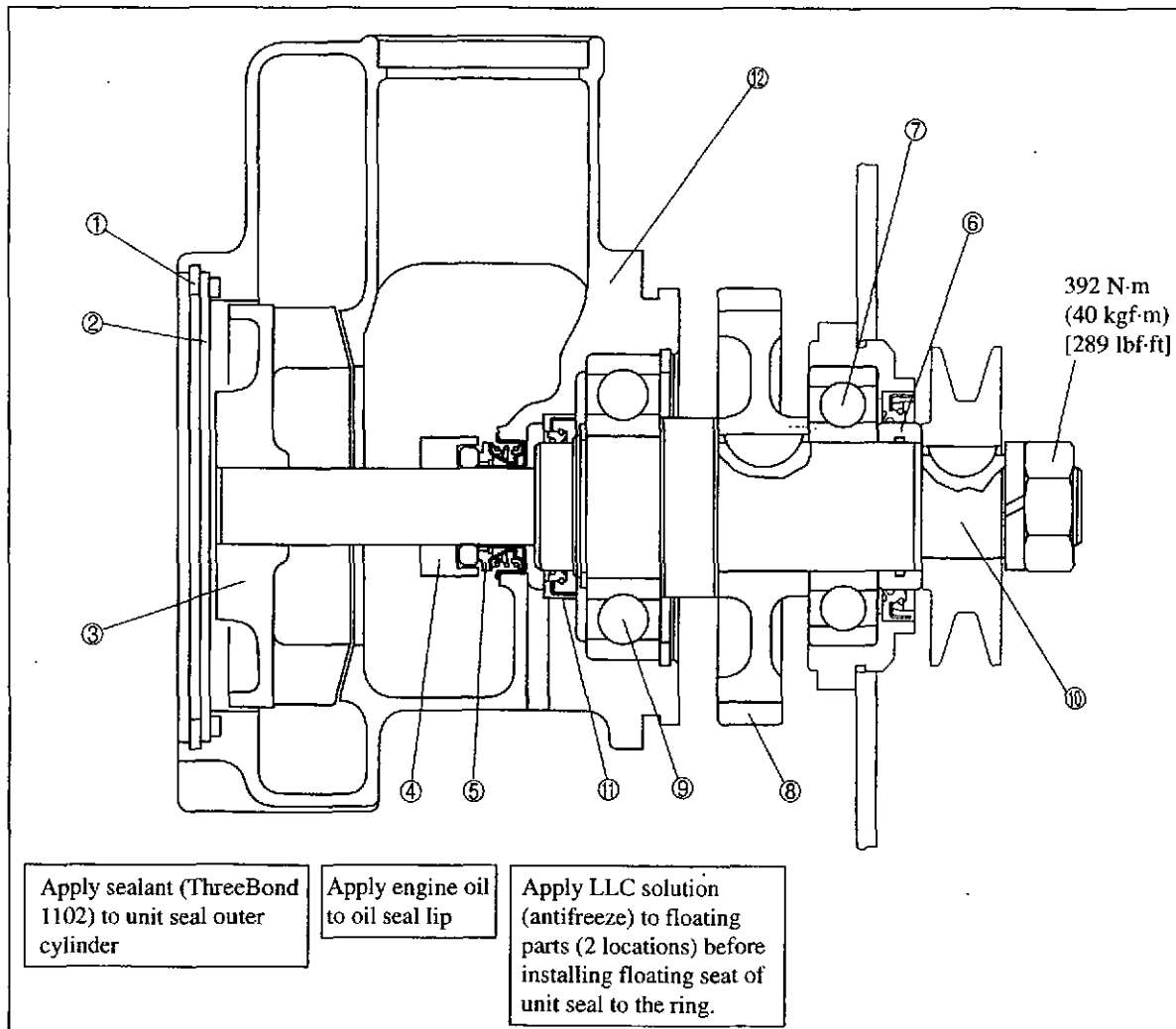
Water pump

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.

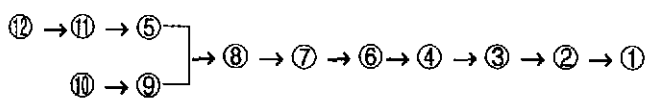
Unit:mm [in.]

Item		Nominal Value	Assembly Standard
Inside diameter of pump case bearing		ø120 [4.72]	119.987 to 120.022 [4.72389 to 4.72527]
		ø110 [4.33]	110.005 to 110.040 [4.33090 to 4.33227]
Bearing	Diameter	ø120 [4.72]	119.985 to 120.000 [4.72381 to 4.72441]
		ø110 [4.33]	109.985 to 110.000 [4.33012 to 4.33071]
	Inside diameter	ø55 [2.17]	54.985 to 55.000 [2.16476 to 2.16535]
		ø50 [1.97]	49.988 to 50.000 [1.96803 to 1.96850]
Diameter of pump shaft on which bearing inner race is fitted		ø55 [2.17]	55.011 to 55.024 [2.16578 to 2.16629]
		ø50 [1.97]	50.011 to 50.024 [1.96893 to 1.96944]
Vane front face clearance		1.04 [0.041]	(0.58 to 1.50) ([0.023 to 0.059])

2.3 Reassembly



Reassembly sequence

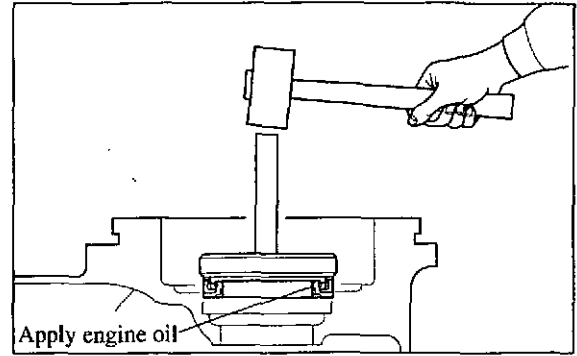


CAUTION

Replace all O-rings, oil seals and unit seals for reassembly.

COOLING SYSTEM

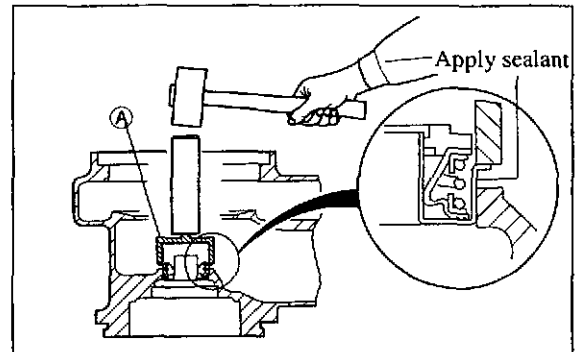
- (1) With the oil seal installer, drive in the oil seal.
Apply engine oil to the oil seal lip.



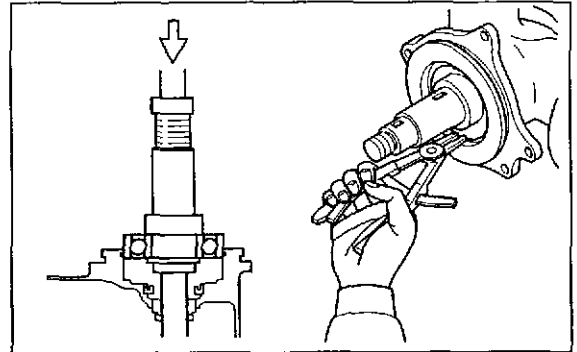
- (2) Use the unit seal installer $\text{\textcircled{A}}$ (37191-06300) to drive in the unit seal.
Replace the unit seal if once disturbed.

NOTE

Install the unit seal after coating with sealant (ThreeBond 1102) to seal the outer ring.



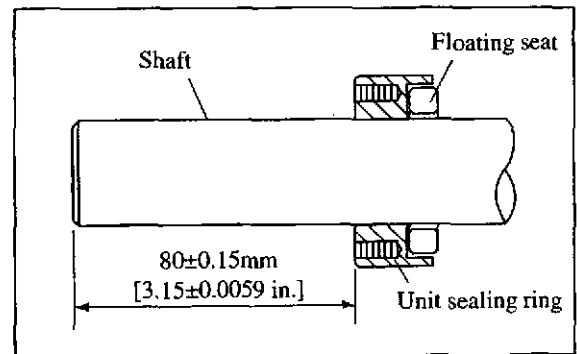
- (3) Use a press to press in the impeller-side pump shaft, complete with ball bearings into the case.
Install the snap ring with its gap down.



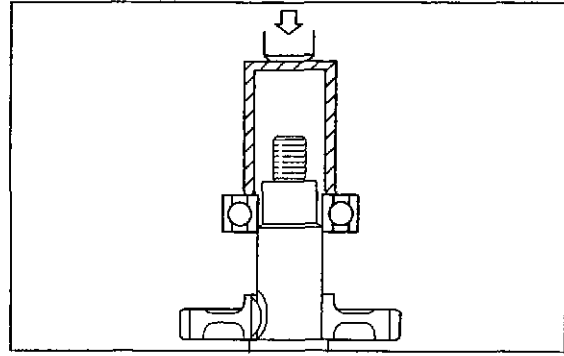
- (4) With a press, press in the unit seal ring with the unit seal floating seat using the ring installer (37791-03300).

NOTE

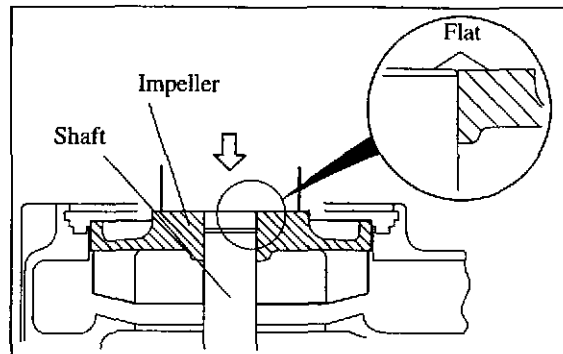
Before installation, coat with LLC solution (anti-freeze) the floating seat at two locations.



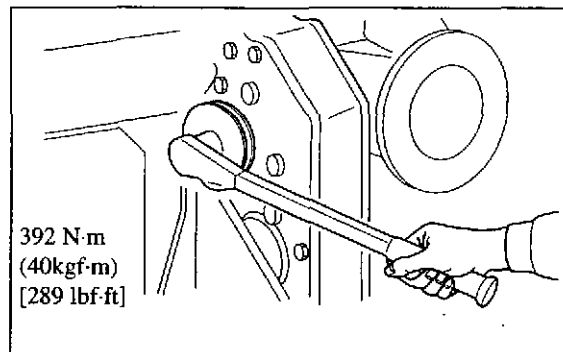
- (5) Insert the gear into the shaft by aligning the key.
Press in the ball bearing on the nut side.



- (6) Press in the impeller to the depth where impeller's boss end face is flush with the shaft end.

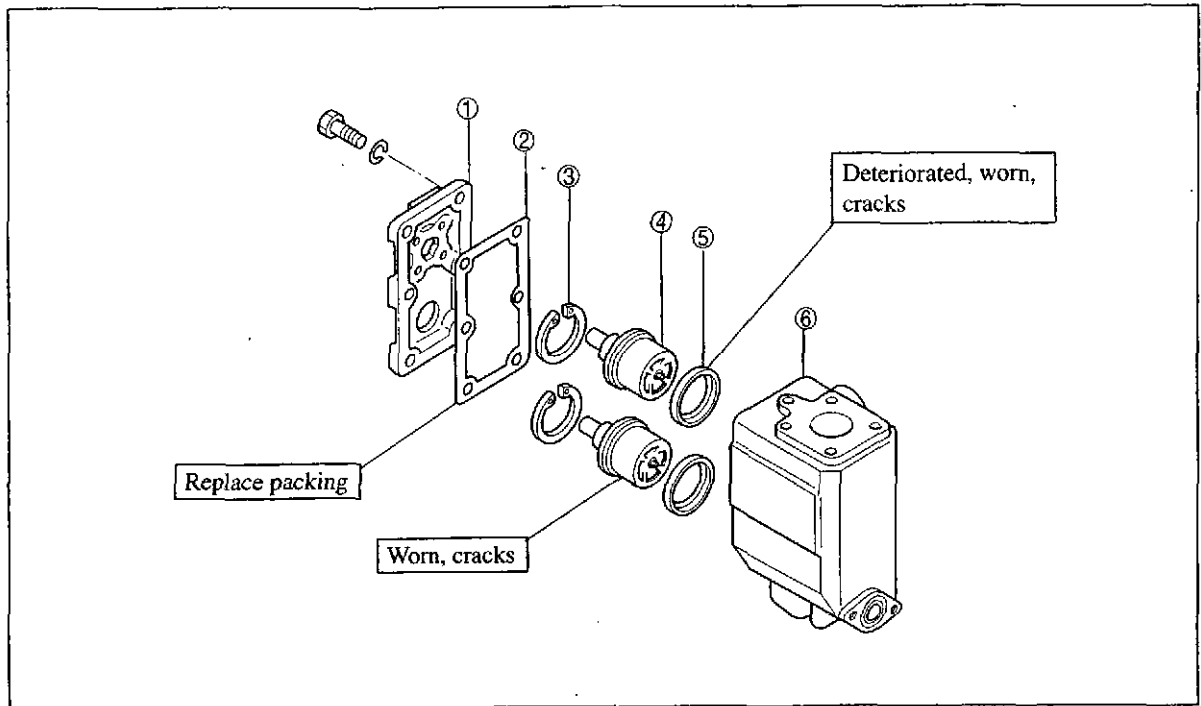


- (7) After installing the water pump assembly, install the alternator pulley and tighten the nut to the specified torque.



3. Thermostats

3.1 Disassembly



Disassembly sequence

- ① Thermostat cover
- ② Packing

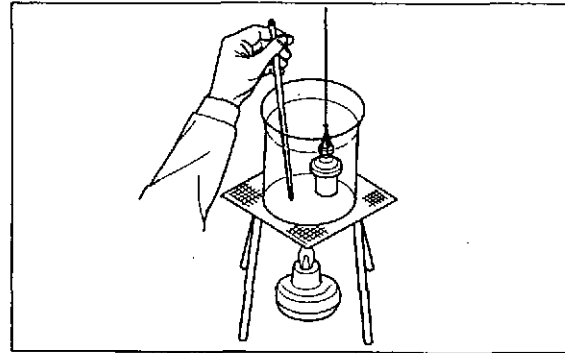
- ③ Snap ring
- ④ Thermostat

- 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 11 mm [0.43 in.]. Replace the thermostat if temperatures are not within standard.

Item	Assembly Standard
Valve opening temperature	69 to 73 [124.2 to 195.4]
Temperature at which valve lift is 11 mm [0.43 in.] or more	85 °C [185 °F]

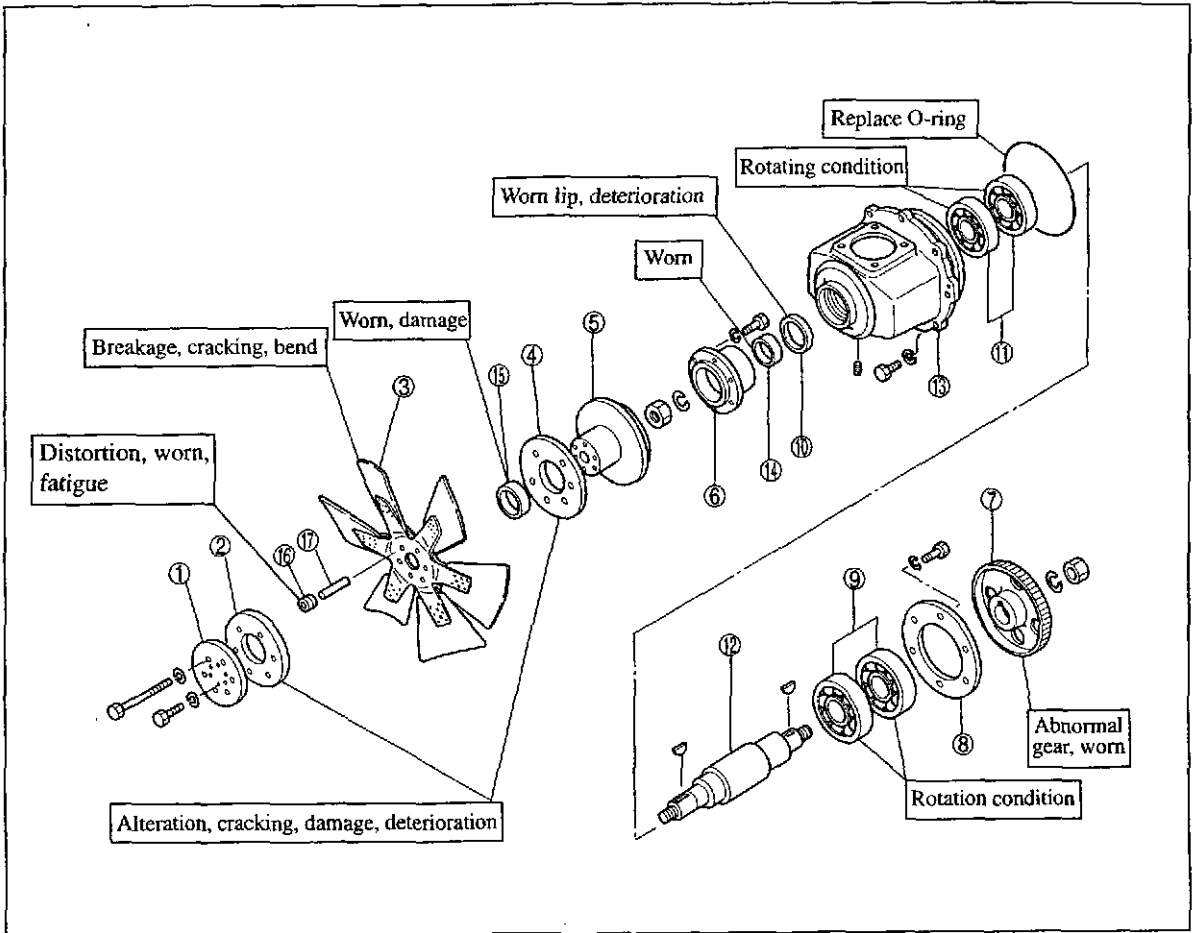


CAUTION

- (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



- | | | |
|-------------------|------------------|-------------------|
| ① Plate | ⑦ Fan drive gear | ⑬ Fan drive case |
| ② Friction rubber | ⑧ Thrust plate | ⑭ Oil seal sleeve |
| ③ Fan | ⑨ Bearing | ⑮ Fan bushing |
| ④ Friction rubber | ⑩ Oil seal | ⑯ Spacer |
| ⑤ Fan hub | ⑪ Bearing | ⑰ Grommet |
| ⑥ Coupling | ⑫ Drive shaft | |

CAUTION

If any one of its blades is broken, the fan vibrates so much as to make the opposite blade liable to break. With this possibility in mind, carefully check each blade for breakage, bend, and similar condition.

4.2 Inspection

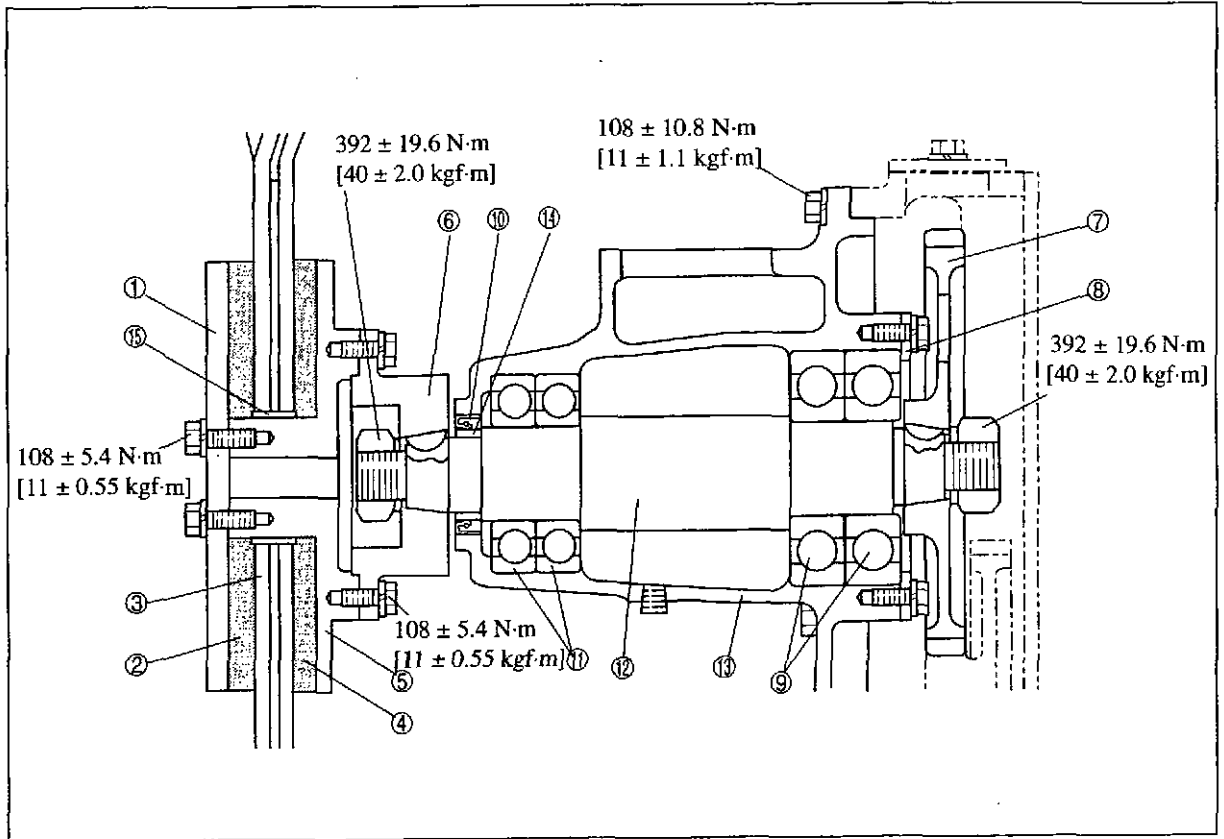
- (1) Measure the bearing-fitted portions of the shaft and case. If excessive wear or damage is found, replace the worn or damaged bearing and shaft or case.

Unit: mm [in.]

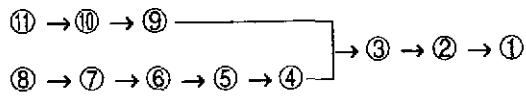
Item		Nominal Value	Assembly Standard
Inside diameter of case in which bearing is installed		ø140 [5.51]	139.986 to 140.026 [5.51544 to 5.51702]
		ø120 [4.72]	119.987 to 120.022 [4.72748 to 4.72886]
Bearing	Outside diameter	ø140 [5.51]	139.982 to 140.000 [5.51530 to 5.51600]
		ø120 [4.72]	119.985 to 120.000 [4.72740 to 4.72800]
	Inside diameter	ø55 [2.17]	54.985 to 55.000 [2.16640 to 2.16700]
Outside diameter of shaft on which bearing is installed		ø55 [2.17]	50.002 to 55.015 [2.16710 to 2.16760]

- (2) Inspect the fan bushing for wear and damage. If it is abnormal, replace it.
- (3) Inspect the friction rubber for deterioration, alteration, cracks, and damage. If it is abnormal, replace it.

4.3 Reassembly



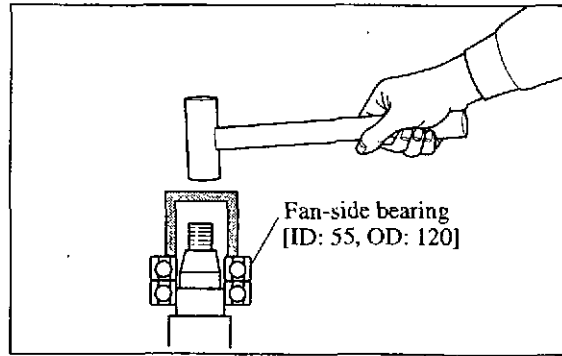
Reassembly sequence



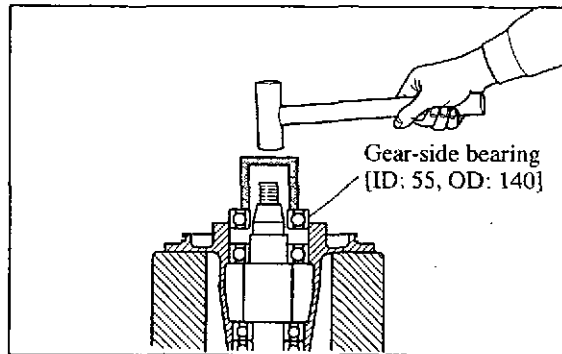
- (1) Install the fan-side bearing onto the shaft using the bearing installer. Install the oil seal into the case.

NOTE

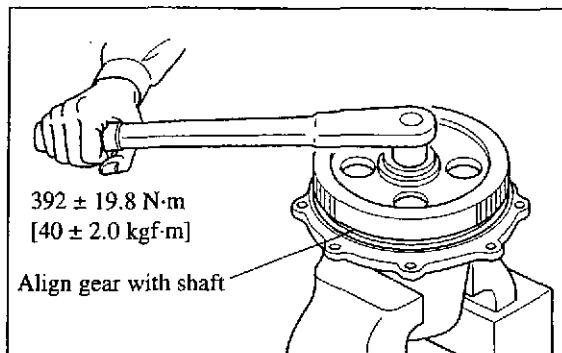
Apply engine oil to the lip of the oil seal before installation.



- (2) Install the shaft into the bracket, install the gear-side bearing onto the shaft and into the case using the bearing installer, and install the thrust plate.

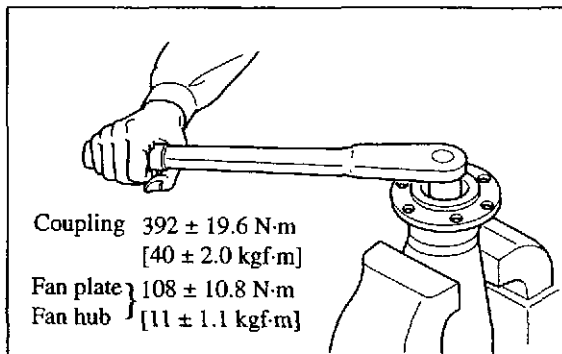


- (3) Install the gear onto the shaft while aligning it with the aligning its keyway with that of the shaft and tighten the nuts to the specified torque.



(4) Installing fan

- (a) Install the coupling onto the shaft while aligning it with the key, aligning its keyway with that of the shaft and tighten the nuts to the specified torque.
- (b) Tighten the bolts securing the coupling and fan hub to the specified torque.
- (c) Install the friction rubber, fan bushing and fan onto the shaft, and tighten the fan plate attaching bolts to the specified torque.



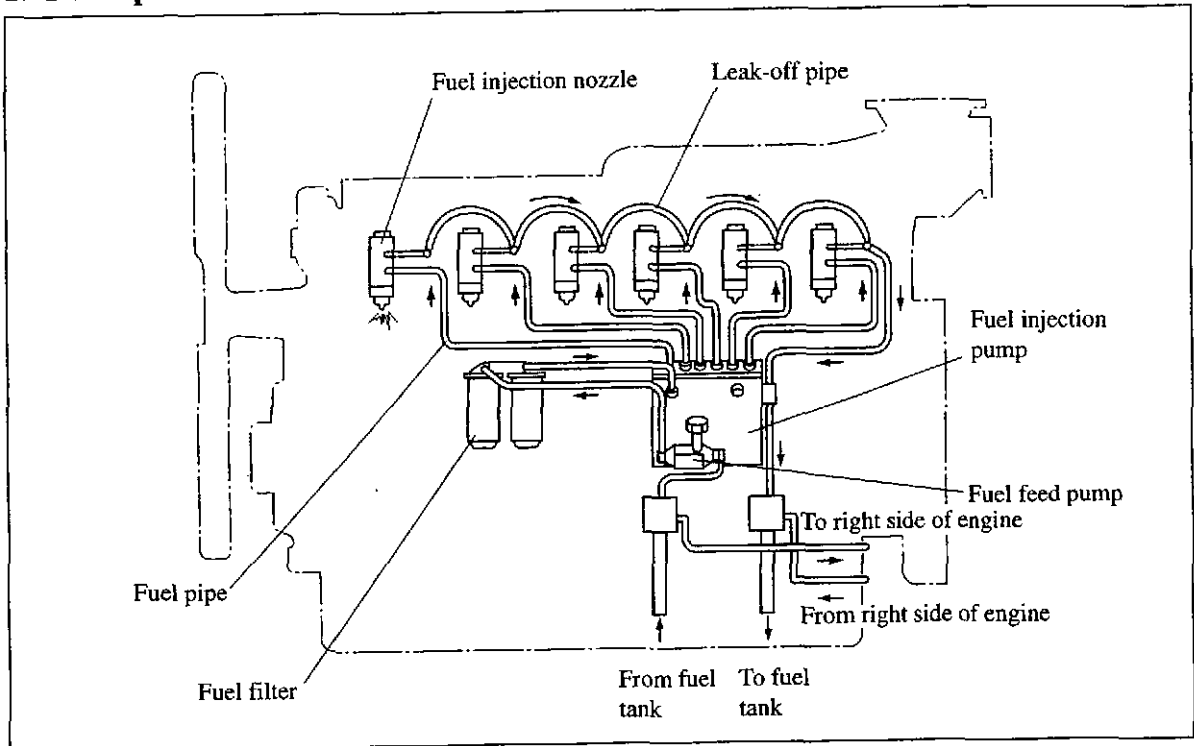
COOLING SYSTEM

FUEL SYSTEM

1. Description	11-2
2. Fuel Filters	11-2
2.1 Disassembly and Inspection	11-2
2.2 Reassembly	11-3
3. Fuel Injection Nozzles	11-4
3.1 Disassembly	11-4
3.2 Inspection and Adjustment	11-5
3.3 Reassembly	11-7
4. Fuel Injection Pump (PS6)	11-8
4.1 Disassembly	11-8
4.2 Inspection	11-15
4.3 Reassembly	11-18
4.4 Adjustment	11-30
5. Fuel Feed Pump	11-33
5.1 Disassembly and Inspection	11-33
5.2 Reassembly	11-34
5.3 Testing	11-35
6. Installing Pick-up	11-36

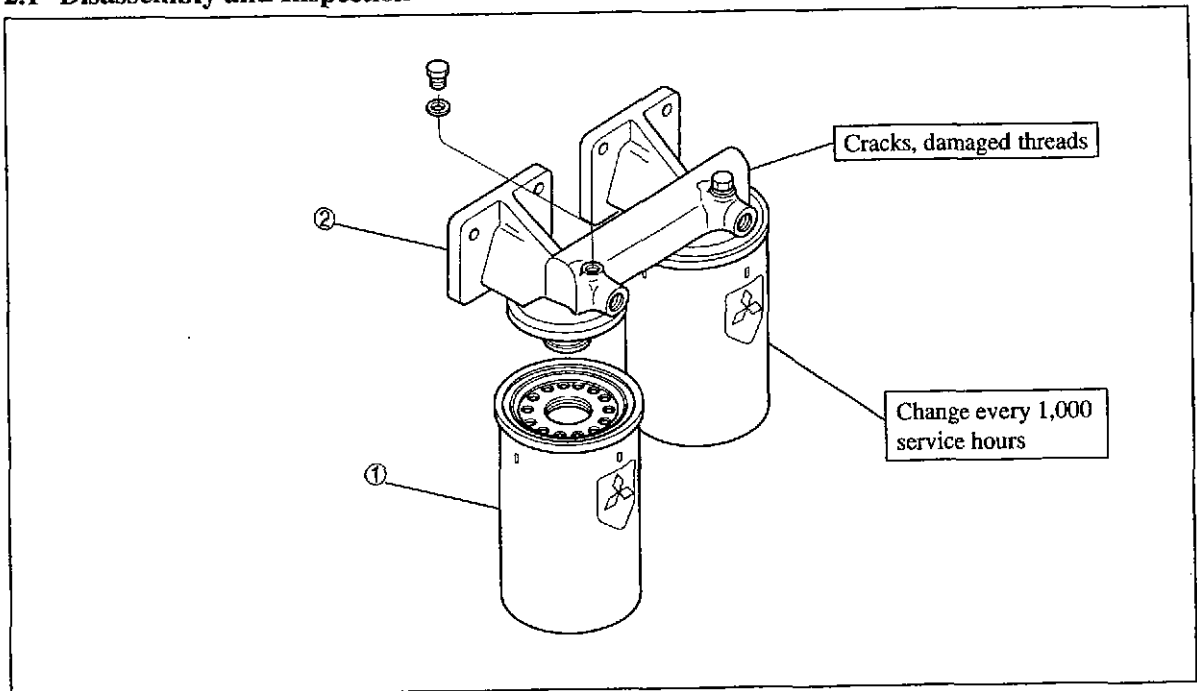
FUEL SYSTEM

1. Description



2. Fuel Filters

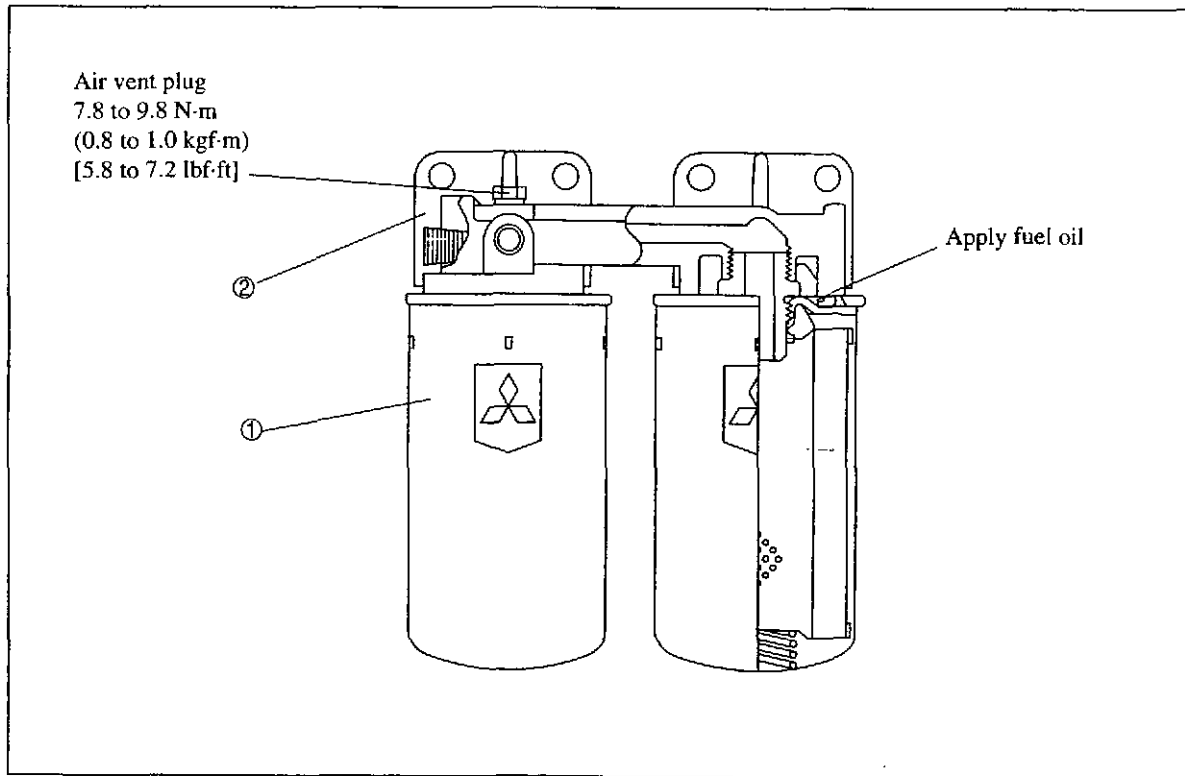
2.1 Disassembly and Inspection



① Element

② Fuel filter bracket

2.2 Reassembly

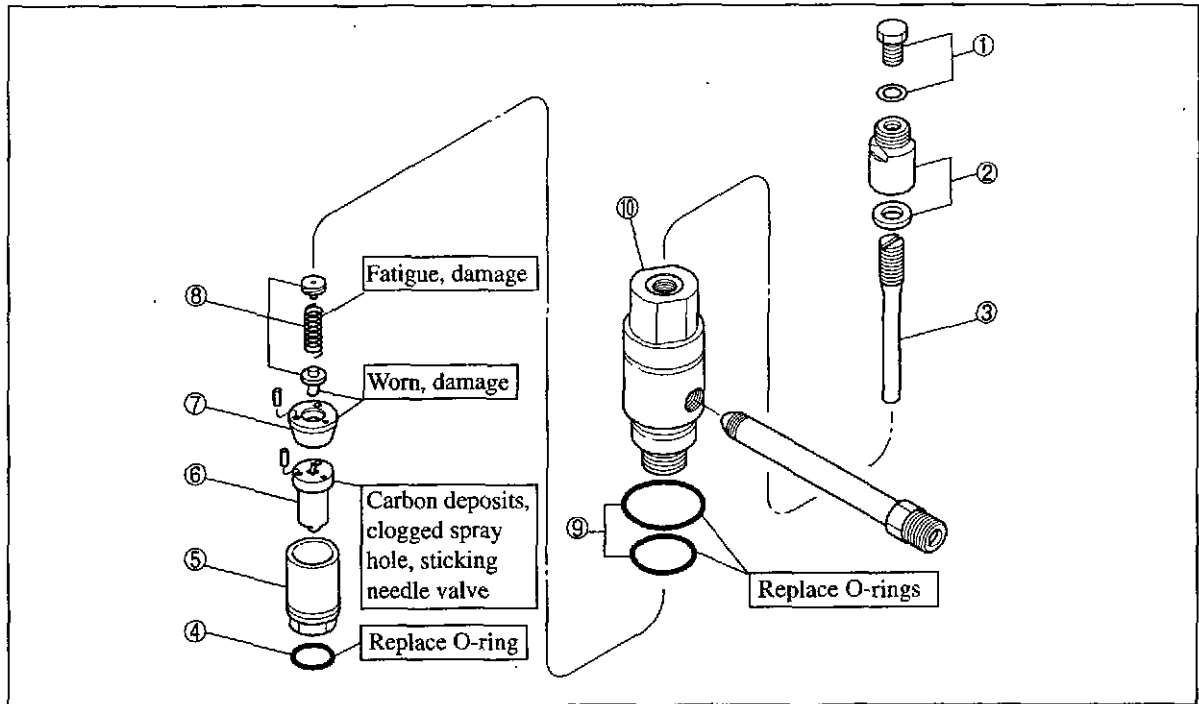


Reassembly sequence

② → ①

3. Fuel Injection Nozzles

3.1 Disassembly



Disassembly sequence

- | | | |
|---------------------|---------------------------------------|-----------------|
| ① Set screw, gasket | ⑤ Retaining nut | ⑨ O-ring |
| ② Cap nut, gasket | ⑥ Nozzle tip | ⑩ Nozzle holder |
| ③ Adjusting screw | ⑦ Spacer | |
| ④ O-ring | ⑧ Pushrod, nozzle spring, spring seat | |

CAUTION

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

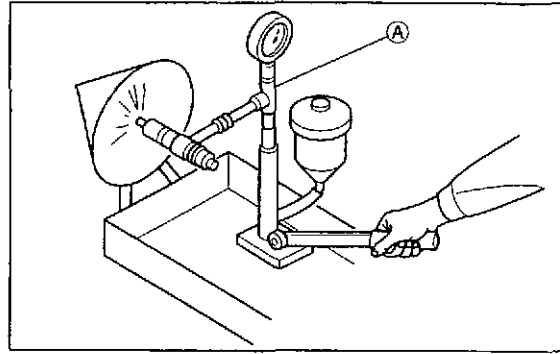
3.2 Inspection and Adjustment

(1) Injection pressure (valve opening pressure)

- (a) Install the nozzle on the tester **A** (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]

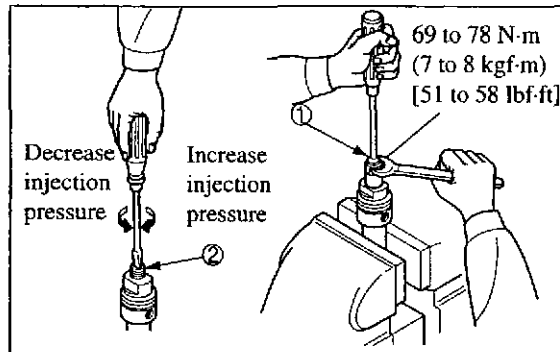
Item	Nominal Value	Assembly Standard
Injection pressure (Valve opening pressure)	34.32 (350) [4979]	34.32 to 34.81 (350 to 355) [4979 to 5050]



CAUTION

During injection testing, never attempt to touch the spray hole of the injection nozzle.

- (b) To adjust the injection pressure, remove the cap nut **1** from the nozzle holder, loosen the jam nut, then turn the adjusting screw **2** in either direction with a screwdriver.
- (c) After completing the adjustment, tighten the cap nut and the jam nut to the specified torque.
- (d) Re-check the injection pressure to make sure that it is correct.

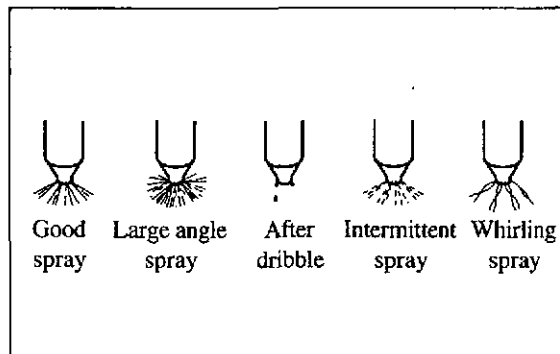


(2) Spray pattern

- (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

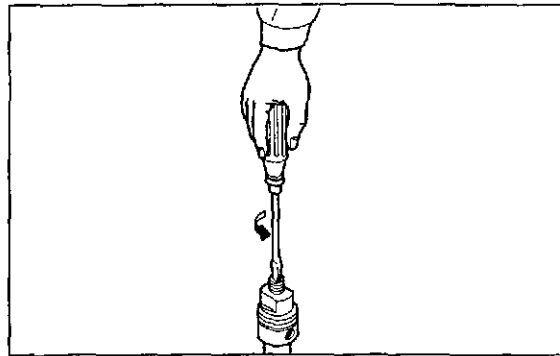
When changing parts, be sure to use our designated parts. Unless our designated parts are used, the exhaust emission regulations cannot be met.



Spray patterns

FUEL SYSTEM

- (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.

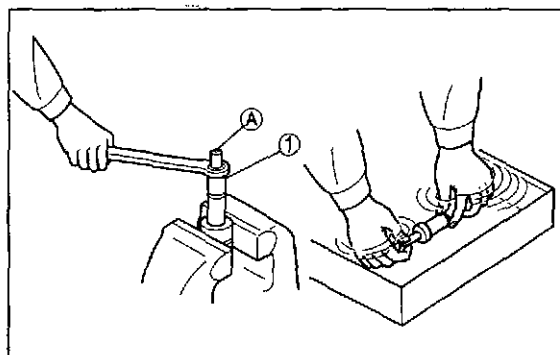


(3) Washing or replacing nozzle tip

- (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

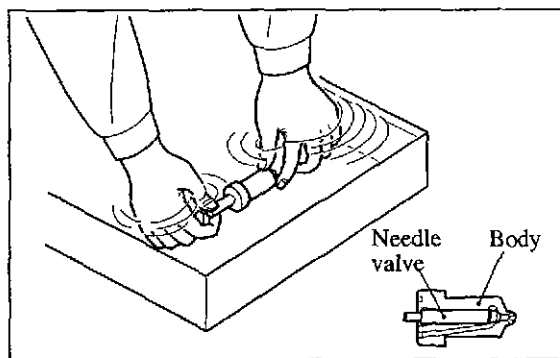
When pulling out the nozzle tip, do not damage the tip ②.



- (c) Wash the nozzle tip in cleaning diesel fuel oil. After washing, assemble the needle valve and body in clean diesel fuel.

NOTE

The needle valve and body are finely finished. Do not swap the combination of the valve and body.

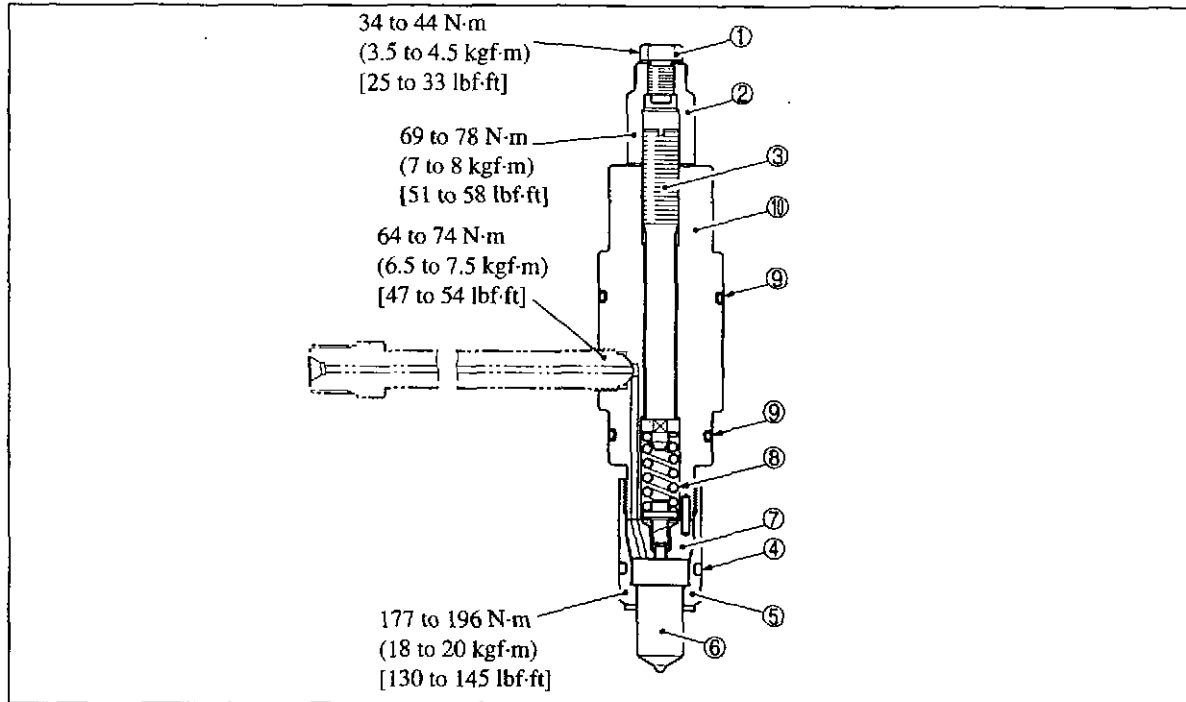


- (d) Tighten the retaining nut to the specified torque.
- (e) If the spray pattern is still bad after the nozzle has been adjusted and cleaned, replace the nozzle tip.

NOTE

New nozzle tips are coated with vaseline to preserve them. Wash them in diesel fuel before installation.

3.3 Reassembly



Reassembly sequence

⑩ → ④ → ⑨ → ⑧ → ⑦ → ⑥ → ⑤ → ③ → ② → ①

CAUTION

Tighten the retaining nut ⑤ 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.

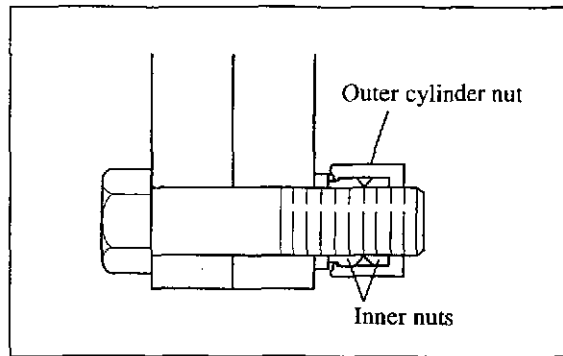
(1) Preparing for disassembly

- (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.

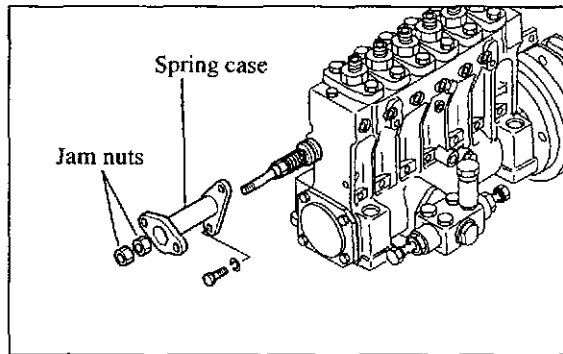
CAUTION

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.



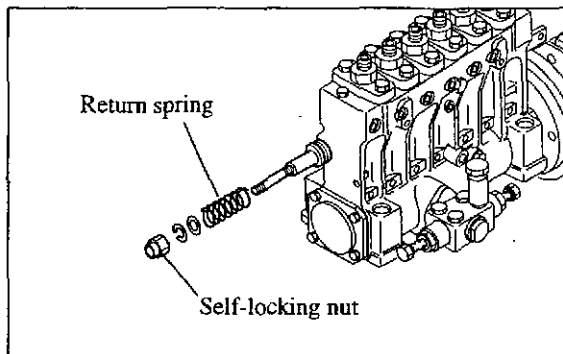
- (b) Remove the rack set cap.
- (c) Remove the two jam nuts, and then remove the spring case.



- (d) Remove the self-locking nut, and then remove the return spring.

CAUTION

Do not reuse the removed self-locking nut.



FUEL SYSTEM

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.

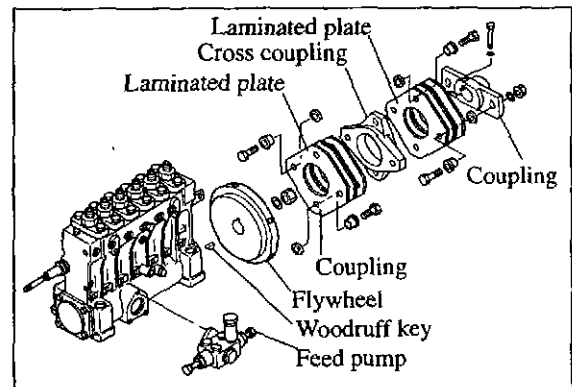
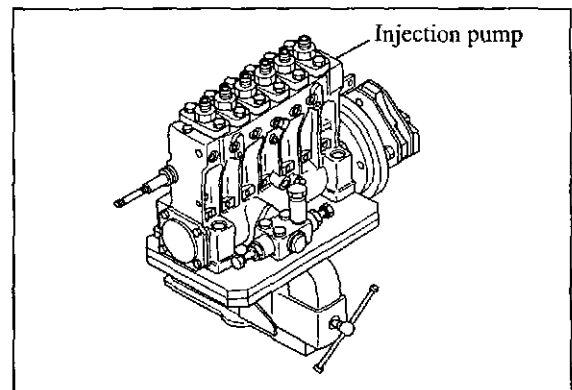
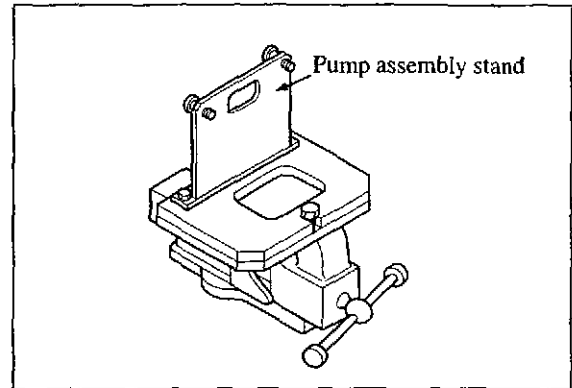
(g) Clean the outer surface of the injection pump, and mount the pump on the pump assembly stand (special tool).

Injection pump mass	60 kg [132 lb]
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(h) Remove the couplings, laminated plates, cross coupling, flywheel and feed pump.

NOTE

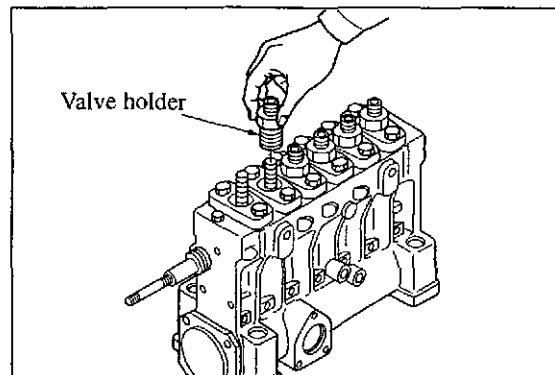
When removing the flywheel mounting nut, insert turning bar into the turning bar hole located at the flywheel periphery, in order for the flywheel to avoid slipping.



(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.

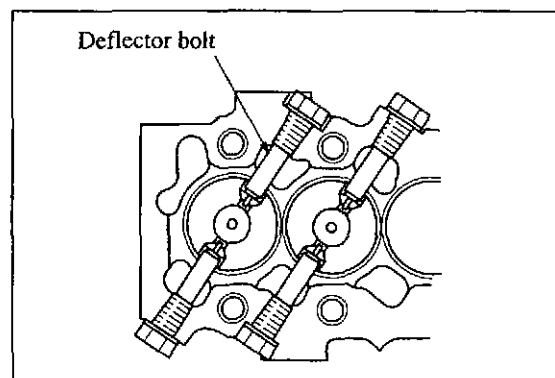


Dismount valve holders, and remove spring seats CPVs and CPV seats.

(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)

- Position the cam at the bottom dead center in the cylinder from which the plunger assembly is removed.
- Remove the deflector bolts from the pump case.
- 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

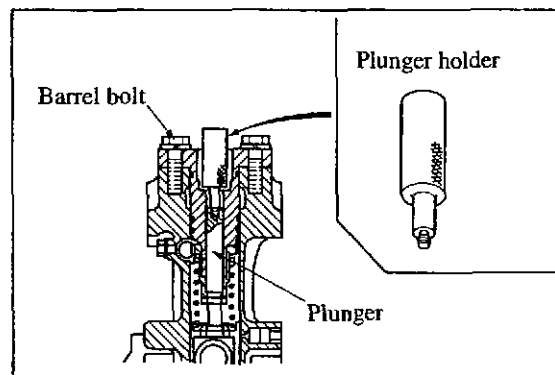
- Loosen the two barrel bolts alternately, and lift the plunger assembly and remove.

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.



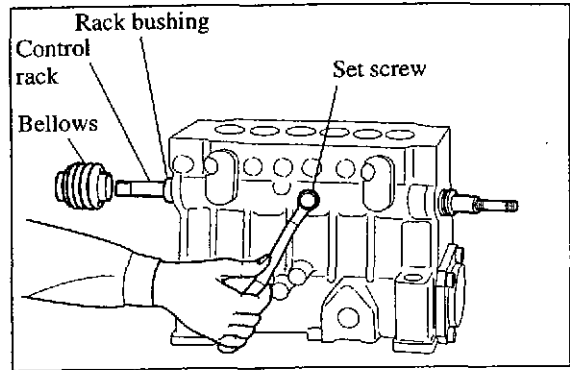
FUEL SYSTEM

(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.

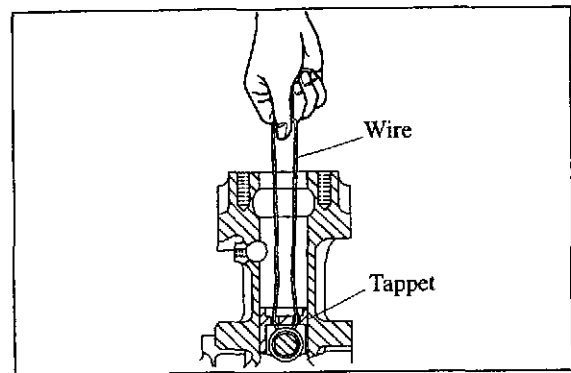
NOTE

- (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.



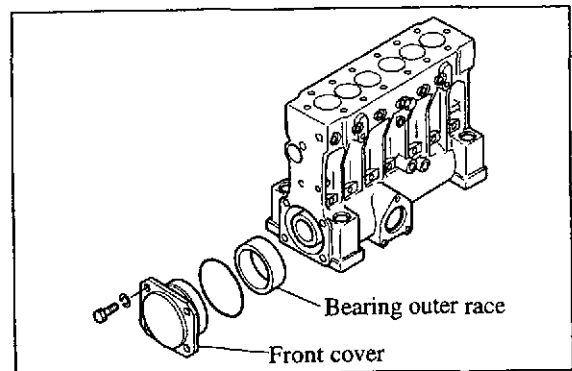
(5) Removing tappets

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.

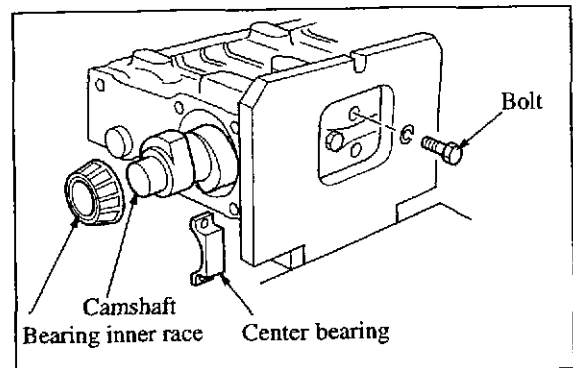


(6) Removing the camshaft

- (a) Unscrew four front cover mounting bolts, and remove the front cover and bearing outer race.

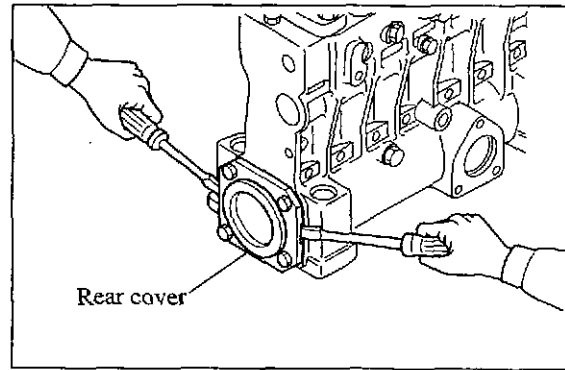


- (b) Lay the pump case on its side, and remove two center bearing mounting bolts.
- (c) Strike the camshaft on the drive-side end with a soft hammer to remove the camshaft and center bearing.
- (d) Remove the bearing inner races from both ends of the camshaft.



(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.



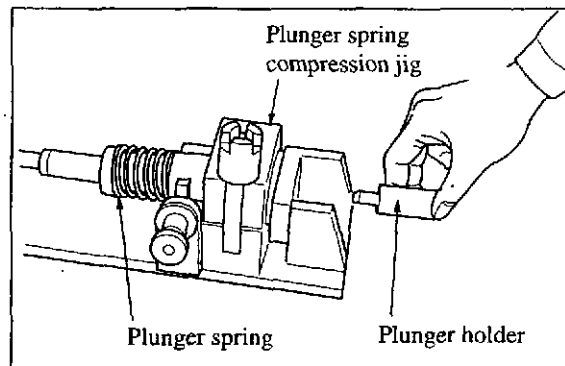
(8) Disassembling plunger assemblies

CAUTION

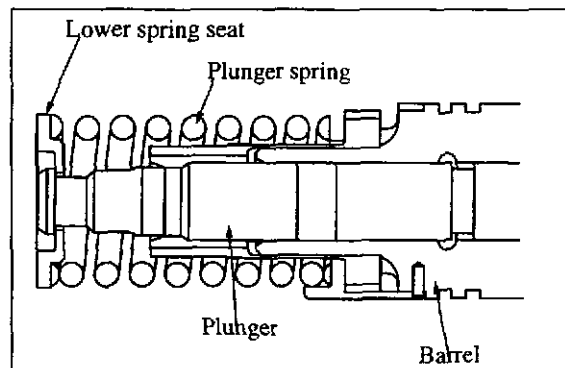
- Keep flames away when using diesel fuel.
- Handle plungers carefully to prevent damage and scratches.
- Place the removed plungers in a tray filled with clean diesel fuel, arranging parts neatly to ensure correct installation in original cylinders.
- Do not change the original combinations of plungers 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.

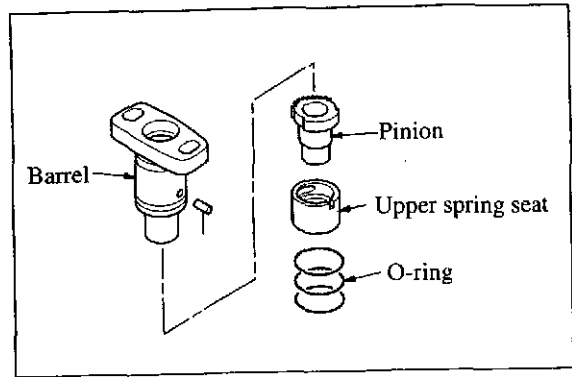


FUEL SYSTEM

- (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

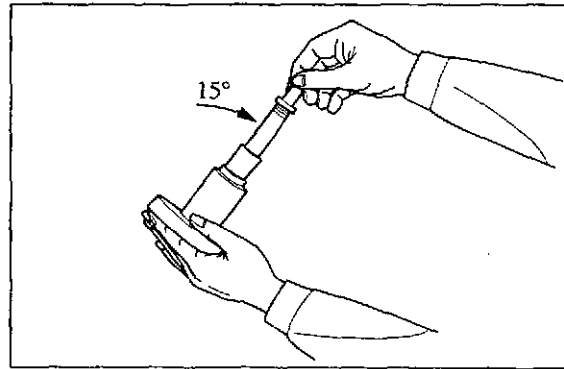
CAUTION

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

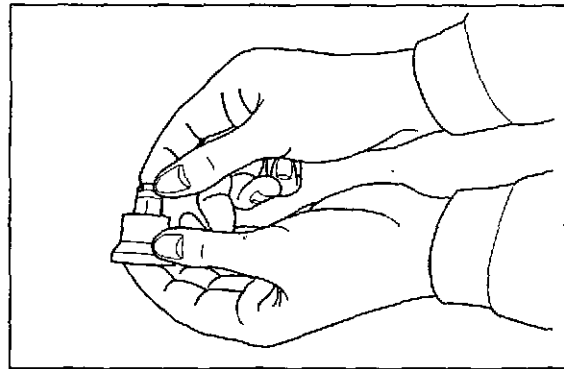
- (a) Inspect the lead section and tip of each plunger for wear, scratches, discoloration and erosion.
- (b) After washing with clean diesel fuel, check each plunger by tilting it approximately 15° and lifting it approximately 30 to 35 mm [1.18 to 1.38 in.], as shown in the right diagram. Change the 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.



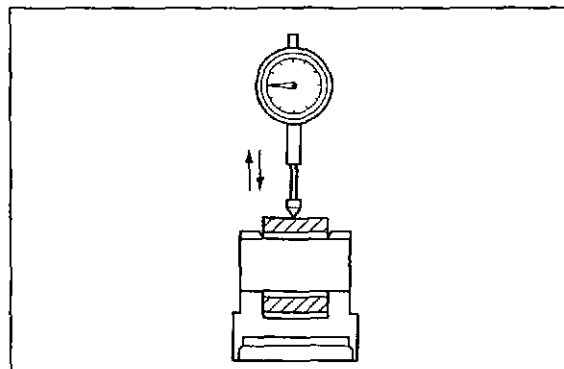
Inspecting CPV for smooth movement

(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]



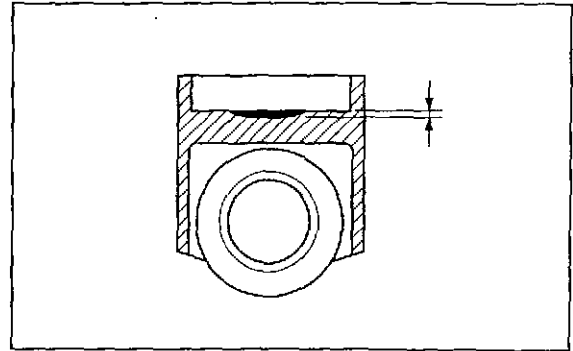
Measuring overall clearance of tappet roller

FUEL SYSTEM

- (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.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Camshaft deflection	0.05 [0.0020]	0.15 [0.0059]

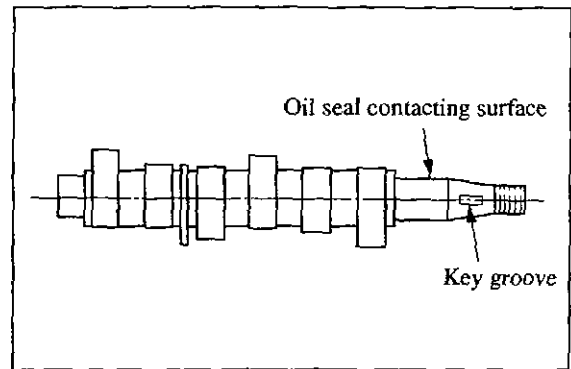
- (c) Check the oil seal contacting surface for wear. If the amount of wear exceeds the service limit, insert an oversized sleeve.

CAUTION

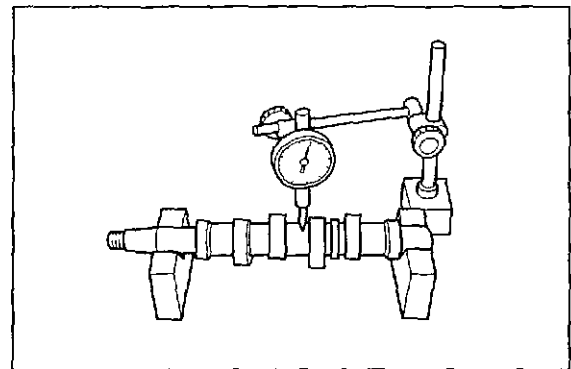
- Insert the oversize sleeve after installing the bearing inner race.
- The bearing inner race cannot be installed after the oversize sleeve is mounted in place.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Outside diameter of camshaft at oil seal contacting section	$\phi 35$ [1.38]	34.938 to 34.963 [1.37551 to 1.37649]	34.800 [1.37008]



Inspecting camshaft outer surfaces



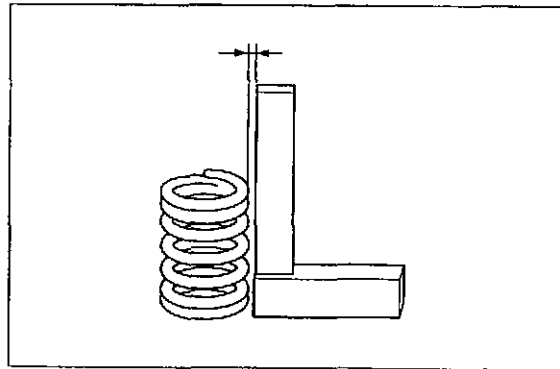
Measuring camshaft deflection

(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

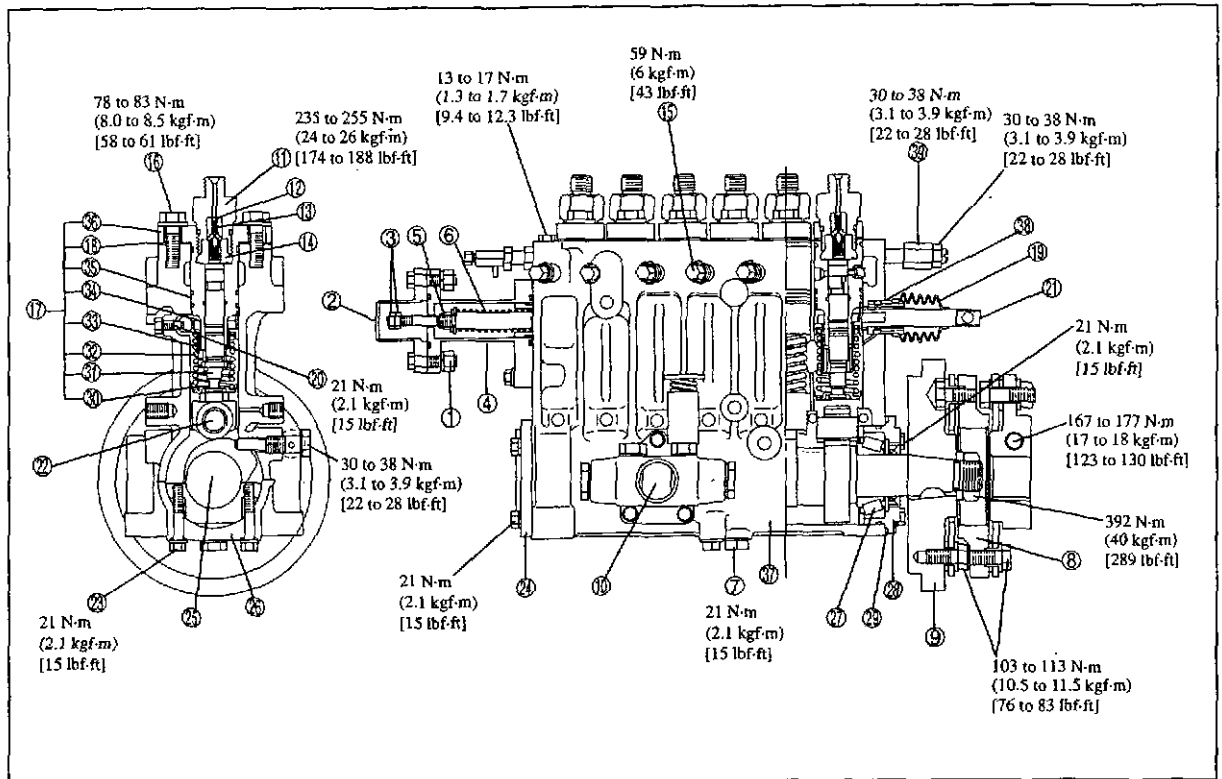
Check the pump case for surface scratches, dents, cracks and damage. If critical flaws are found, replace with a new part.

(9) O-rings, bellows and sealing washers

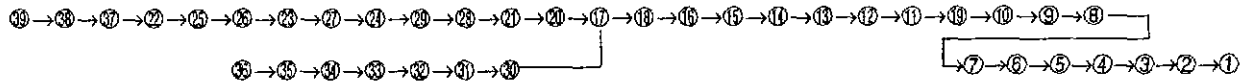
Replace all removed O-rings, bellows and sealing washers with new parts.

FUEL SYSTEM

4.3 Reassembly



Reassembly sequence



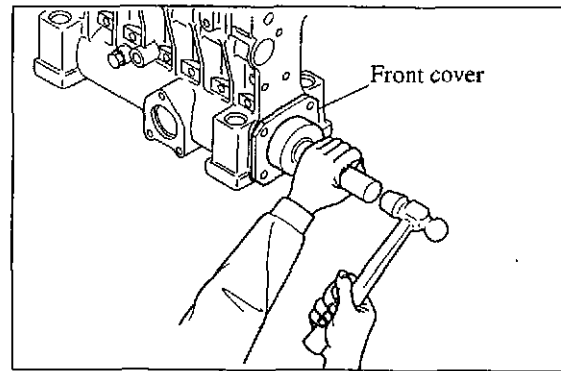
CAUTION

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

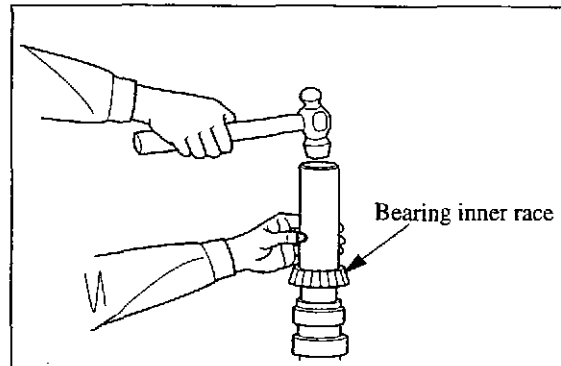
- (a) Install the O-ring and bearing outer race on the front cover. To prevent damage to the O-ring, apply engine oil or grease.
- (b) Install the front cover to the pump case by striking with a hammer.
- (c) Tighten the mounting bolts to 21 N·m (2.1 kgf·m) [15.2 lbf·ft].



Installing the bearing and front cover

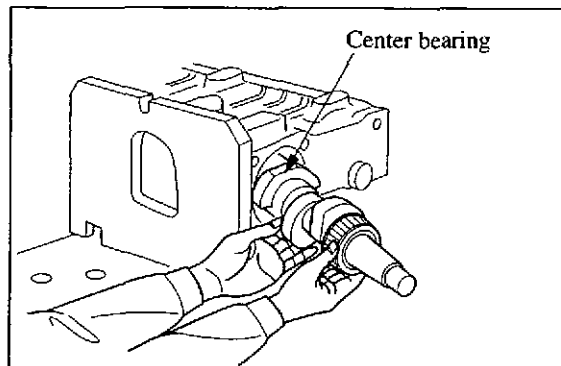
(2) Installing the camshaft and center bearing

- (a) Install the bearing inner races on both sides of the camshaft by striking with a hammer.



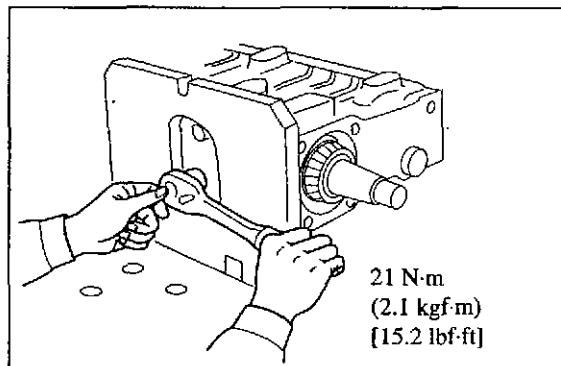
Installing the camshaft and center bearing (1)

- (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)

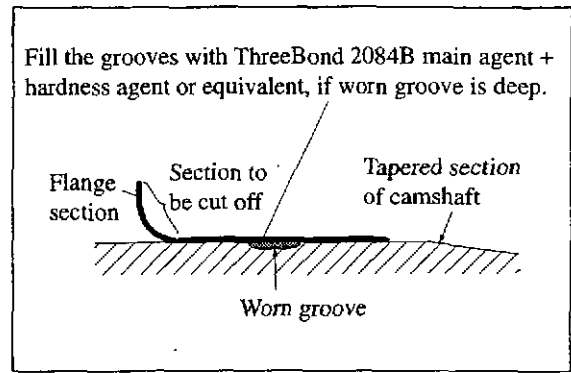
- (d) Slowly turn the camshaft until the bolt holes of the center bearing align with the bolt holes of the pump case. Alternating the tightening operation between the upper and lower mounting bolts before reaching the specified torque to ensure even tightening force.



Installing the camshaft and center bearing (3)

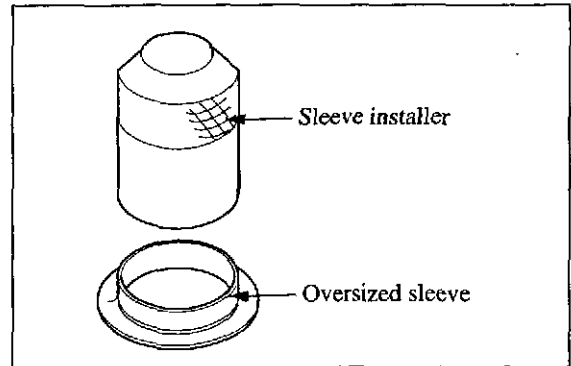
[Installation of oversized sleeve]

- 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.

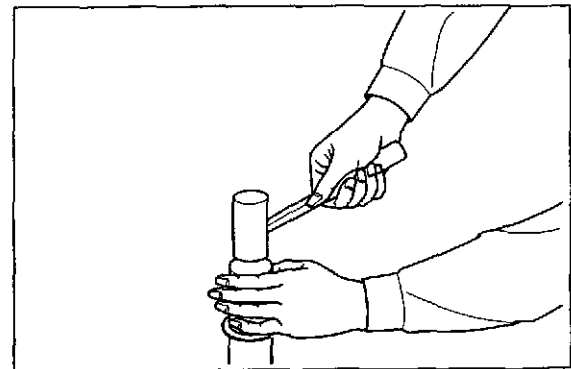


Driving jig and oversized sleeve

Name of special tool	Part No.
Sleeve installer	482Q2-09301

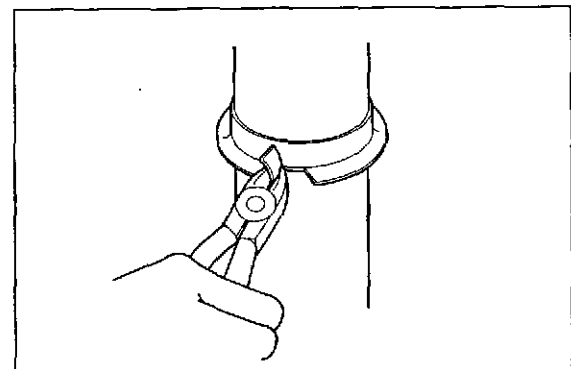
NOTE

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

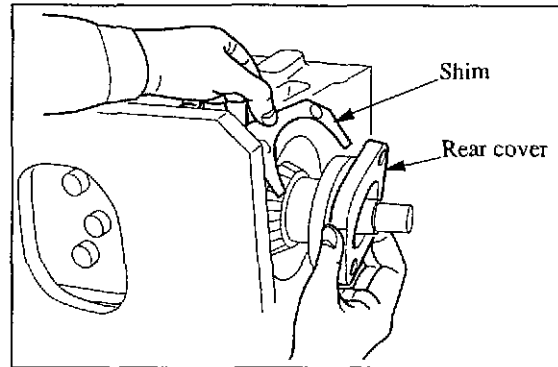
(3) Installation of rear cover

- (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

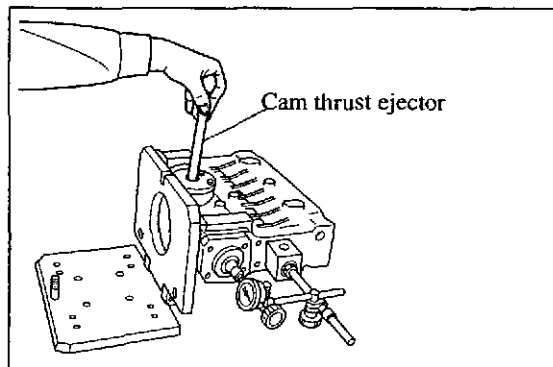
(4) Measuring camshaft thrust clearance

- (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

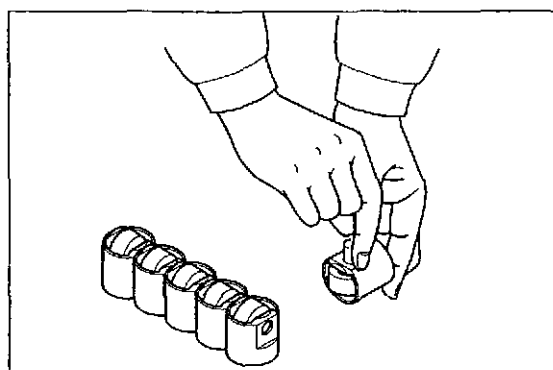
- (b) If the measured clearance deviates from the assembly standard, increase or decrease the shim thickness to make adjustment.
- (c) Turn the camshaft to make sure it rotates smooth.

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

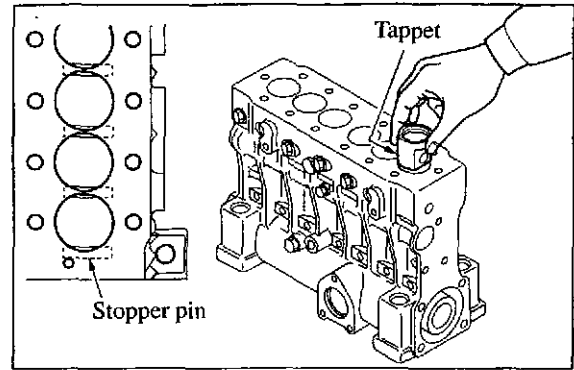
- (a) Install the tappet roller and roller bearing in each tappet, and insert the tappet pin in each assembly.
- (b) Apply lubricating oil to each part.
- (c) After the assembly, make sure the roller rotates smoothly without sticking.



Installing tappet (1)

FUEL SYSTEM

- (d) Install tappets in the pump case by positioning each tappet so the flat section of each tappet engages securely with the stopper pin.

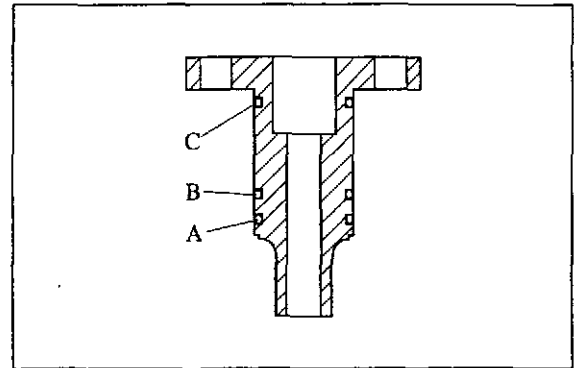


Installing tappet (2)

- (6) Assembling plunger assemblies
(a) Install three O-rings on each barrel.

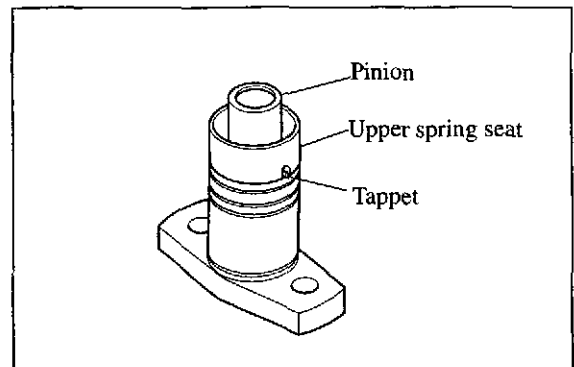
NOTE

- (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.



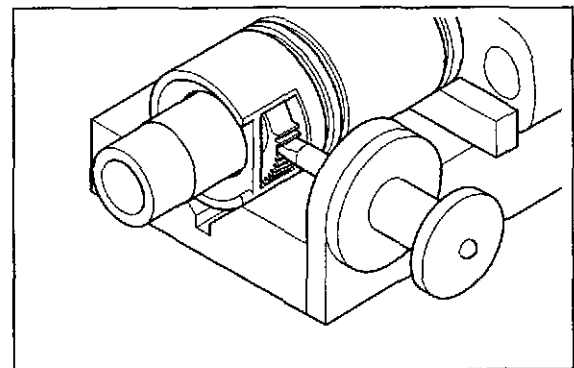
Assembling plunger assembly (1)

- (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.



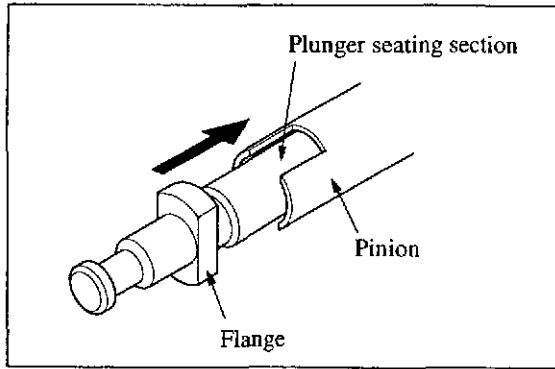
Assembling plunger assembly (2)

- (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.



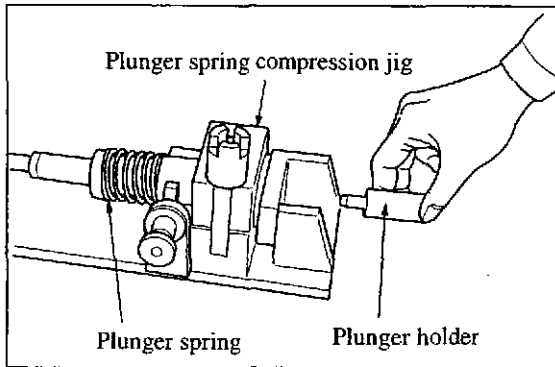
Assembling plunger assembly (3)

- (f) Align the flange section of the plunger with the plunger seating section of the pinion by using a screwdriver.



Assembling plunger assembly (4)

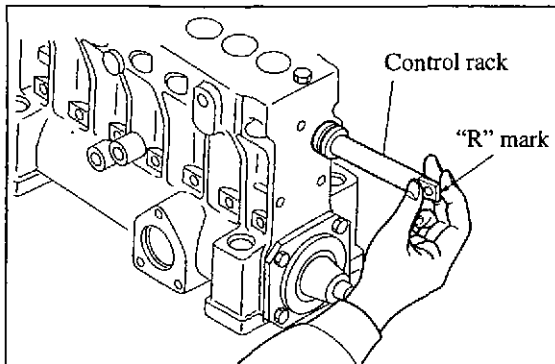
- (g) Install the plunger, plunger spring and lower spring seat. Press down the knob of the jig to insert the plunger into the plunger seating section, then screw the plunger holder (special tool) into the threaded hole in the plunger head.



Assembling plunger assembly (5)

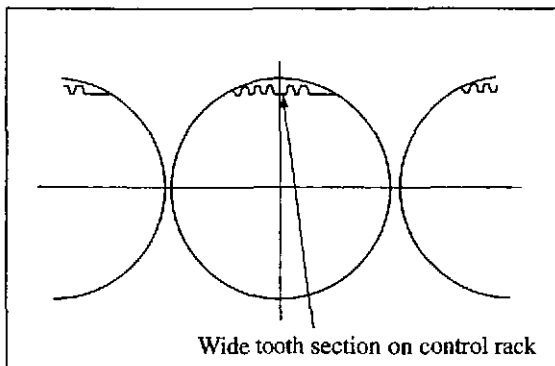
(7) Installing the control rack

- (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)

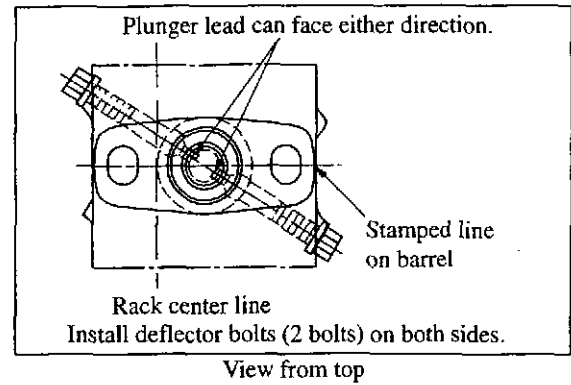
FUEL SYSTEM

(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]

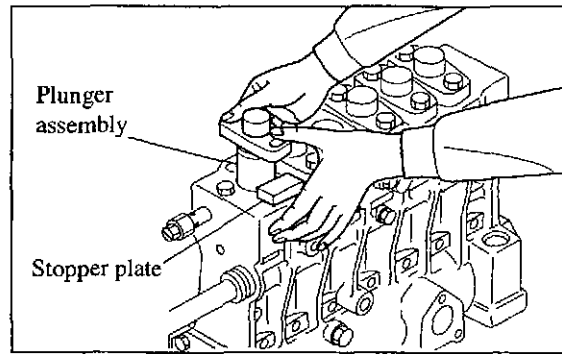


(9) Installing plunger assemblies

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.



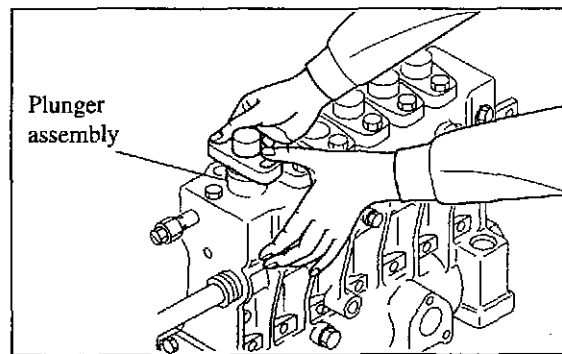
Installing plunger assembly (1)

Name of special tool	Part No.
Stopper plate	48291-00500

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.

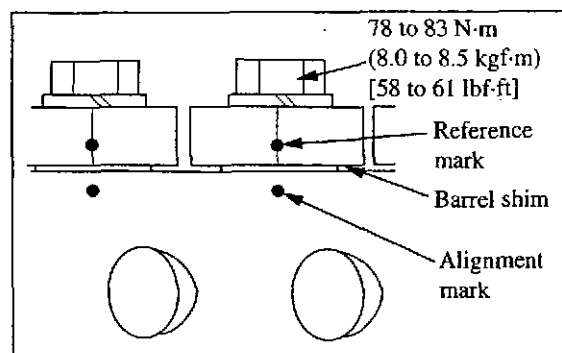


Installing plunger assembly (2)

CAUTION

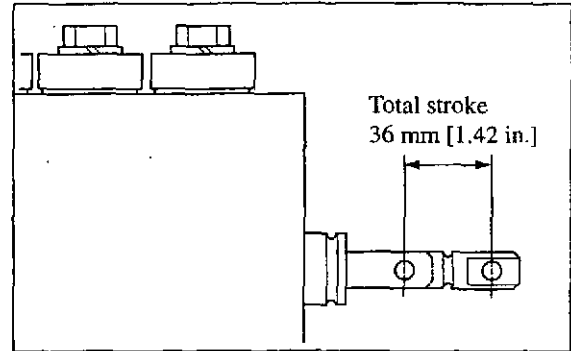
In each cylinder, insert barrel shims of the same thickness, one in front and one in back. (Do not use two or more shims at one location.) If the shim thickness varies in the front and back of a cylinder, the rack may not move smoothly, causing hunting and other problems.

- (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].



FUEL SYSTEM

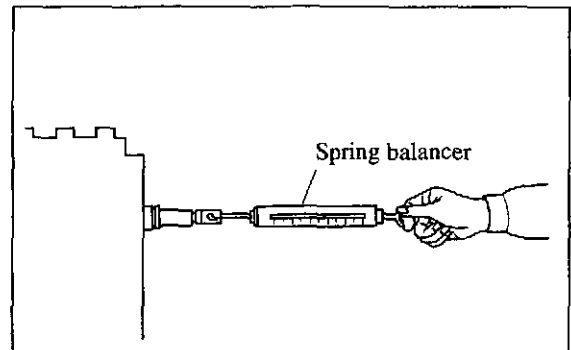
- (g) Remove the plunger holder (special tool), and check to make sure the control rack slides and strokes smoothly.



- (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.

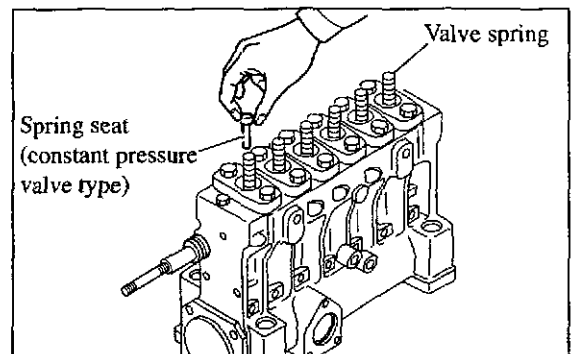
Unit: N (gf) [lbf]

Item	Assembly Standard
Control rack sliding resistance	4.9 (500) [1.10] or less



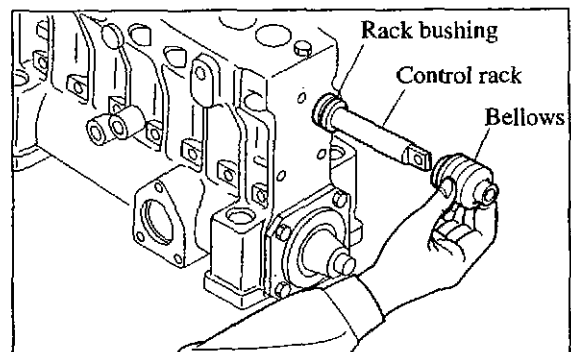
- (b) After making sure the rack sliding resistance is lower than the standard value, install the deflector bolts on the pump case to 41 N·m (4.2 kgf·m) [30 lbf·ft].

- (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.

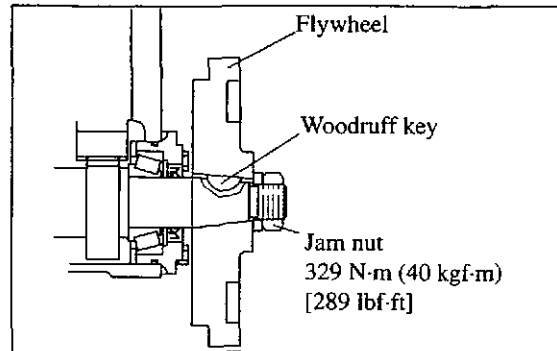


Installing the bellows

- (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).



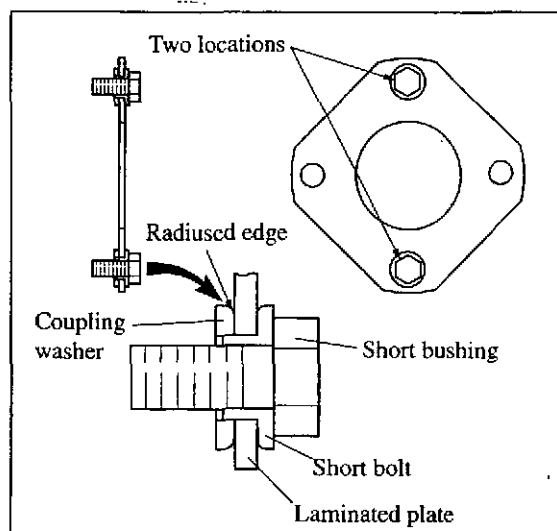
Installing the flywheel

- (b) Install the flywheel by aligning it with the woodruff key on the camshaft, and tighten the jam nut to the specified torque.

- (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.



Installing the coupling assembly (1)

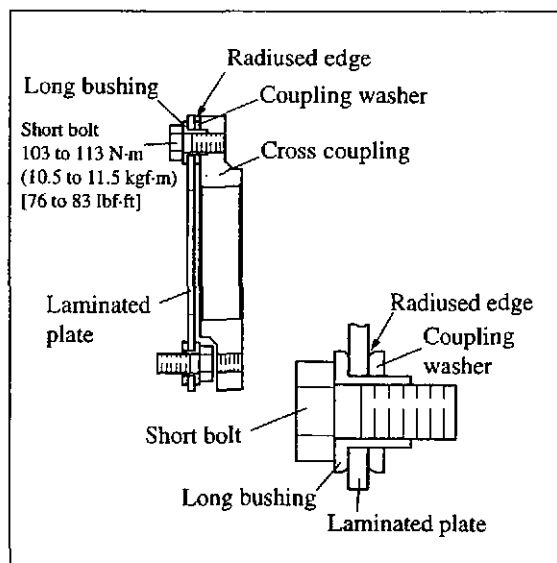
CAUTION

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.

- (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.

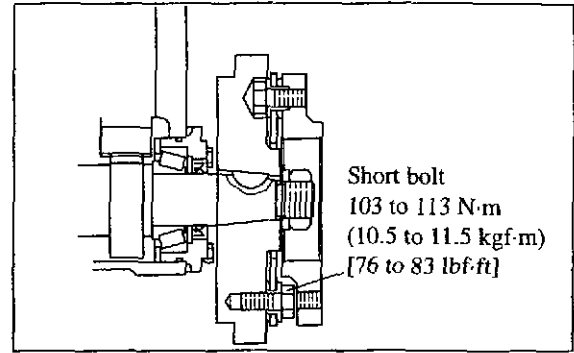
Tighten the short bolts to 103 to 113 N·m (10.5 to 11.5 kgf·m) [76 to 83 lbf·ft].

NOTE

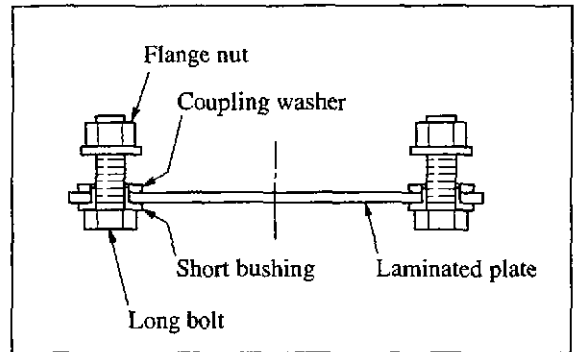
- (a) Set the side of the coupling washer with a radiused outer edge on the laminated plate.

CAUTION

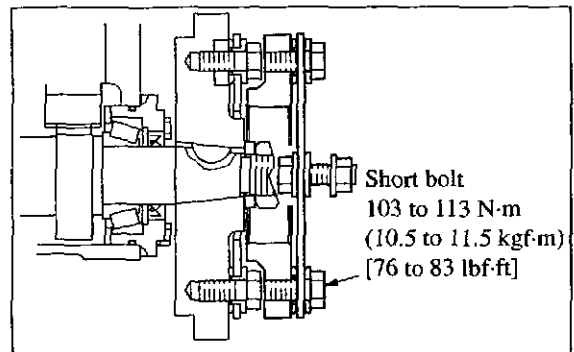
Make sure that the "S" mark on the camshaft end and the key groove on the coupling are positioned as shown in the diagram in installation. Since the coupling can fit into position even if it is turned 180° from the correct installation position, be sure to inspect carefully to prevent injection timing deviation.



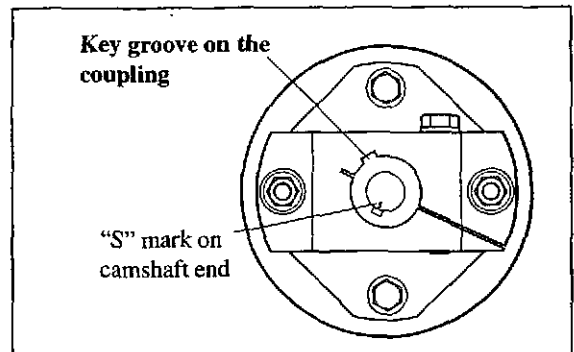
Installing the coupling assembly (3)



Installing the coupling assembly (4)



Installing the coupling assembly (5)



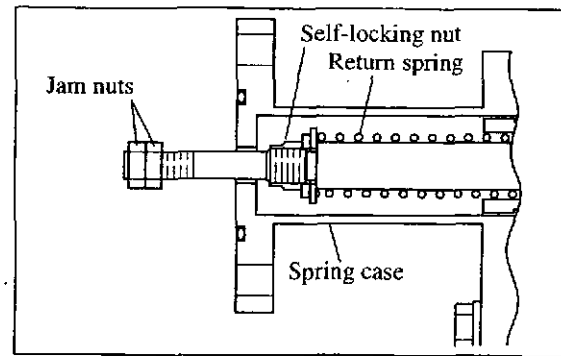
Assembly positions of camshaft and coupling
(View from rear end of drive side)

(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.

FUEL SYSTEM

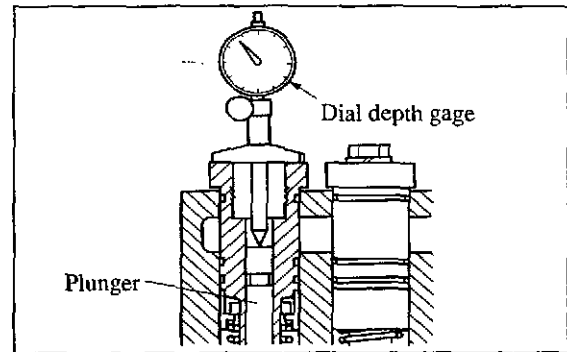
4.4 Adjustment

After the pump reassembly, mount the pump on the injection pump tester and make the following adjustments.

Adjustment of fuel injection timing

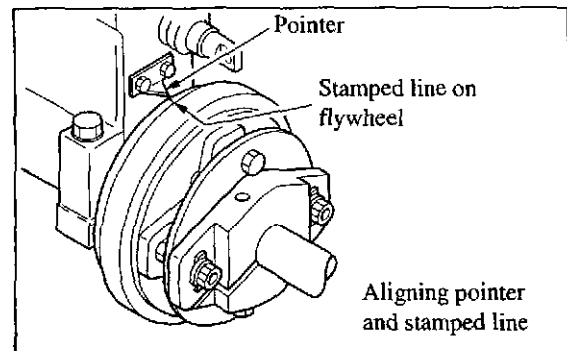
(1) Prestroke adjustment

- (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.



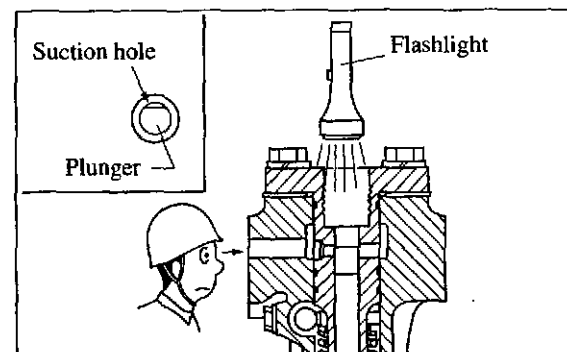
Prestroke adjustment (1)

- (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.

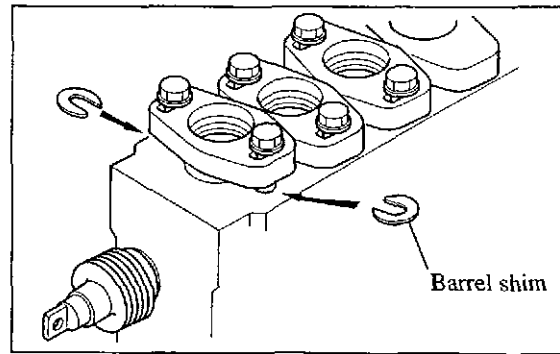


Prestroke adjustment (2)

- (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.

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]

Item	PS6
Injection start interval	60 ± 0.5°

Injection sequence

6 cylinders	1-5-3-6-2-4
-------------	-------------

FUEL SYSTEM

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: $40 \pm 10^\circ\text{C}$ ($104 \pm 18^\circ\text{F}$)

⚠ CAUTION

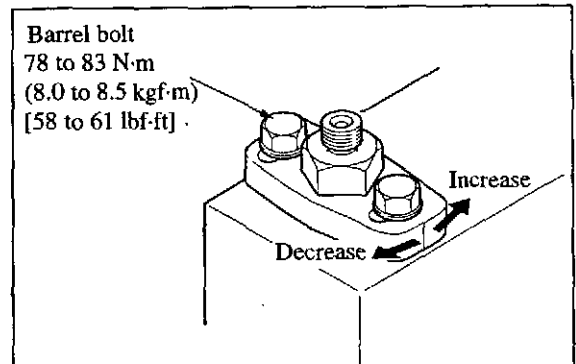
Do not attempt to adjust the injection volume without proper equipment. The injection volume must be adjusted by our company or a Mitsubishi dealer equipped with proper instruments.

Nozzle assembly part No. (No. of nozzles – Nozzle diameter (mm [in.]))	37560-05000 (10 – $\phi 0.29$ [$\phi 0.0114$])
Nozzle valve opening pressure MPa (kgf/cm ²) [psi]	35.0 to 35.5 (350 to 355) [4979 to 5050]
Feed pressure MPa (kgf/cm ²) [psi]	0.3 ± 0.05 (3 ± 0.5) [43 \pm 7]
Injection pipe part No. (Outside diameter (mm [in.]) × Inside diameter (mm [in.]) – Length (mm [in.]))	37561-37700 ($\phi 7 \times \phi 2.8 - 1286$) [$\phi 0.276 \times \phi 0.110 - 50.63$]
Fuel pressure at pump inlet MPa (kgf/cm ²) [psi]	0.3 ± 0.05 (3 ± 0.5) [42.7 \pm 0.7]
Lubrication oil pressure at pump inlet MPa (kgf/cm ²) [psi]	0.5 ± 0.05 (5 ± 0.5) [71.1 \pm 0.7]

• Injection amount adjustment specifications

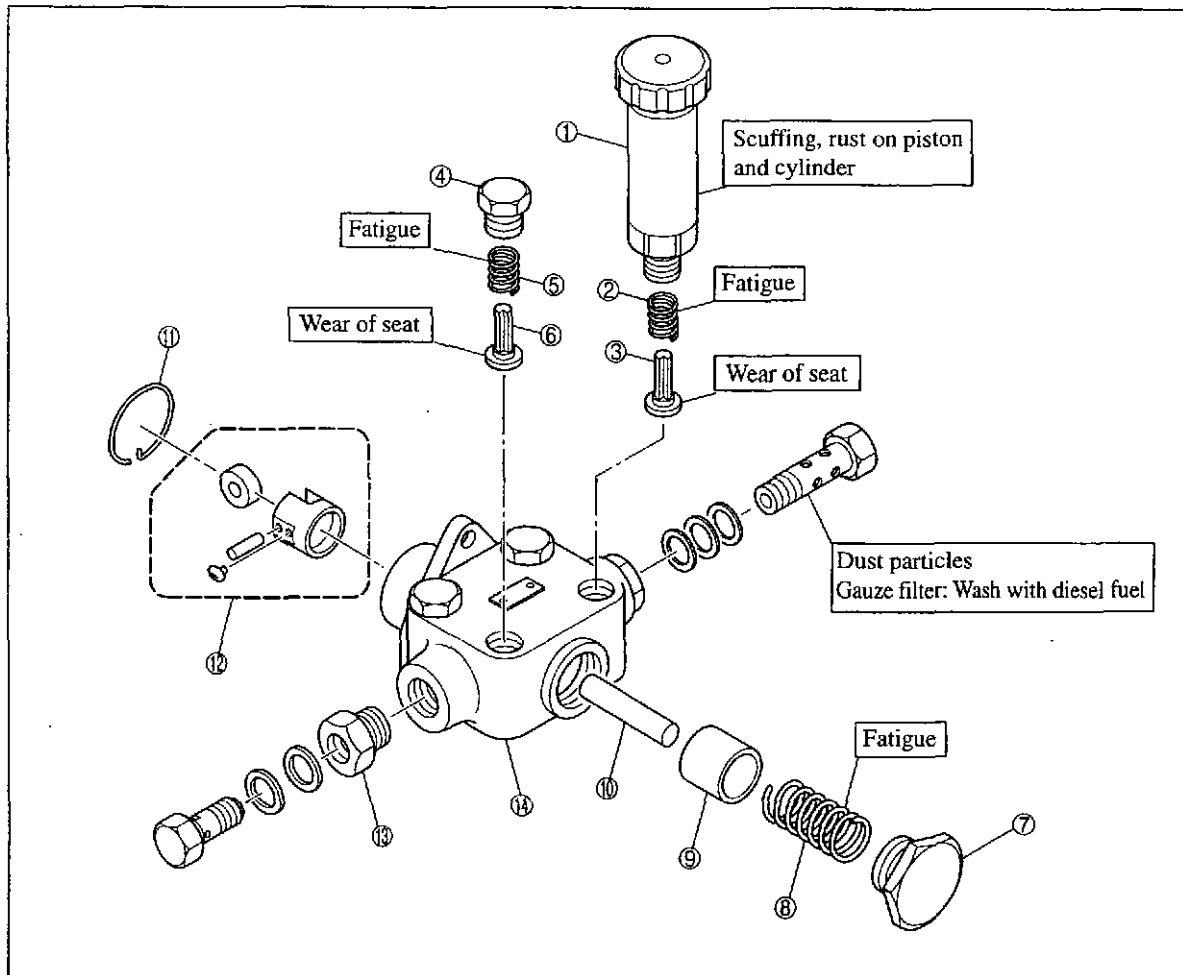
Item	Rack position / pump rotation speed	Average injection amount / number of strokes
Adjustment point 1	17 mm / 900 min^{-1} [0.67 in.]	$72 \pm 3 \text{ g} / 200 \text{ st}$ [2.54 \pm 0.11 oz.]

- (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

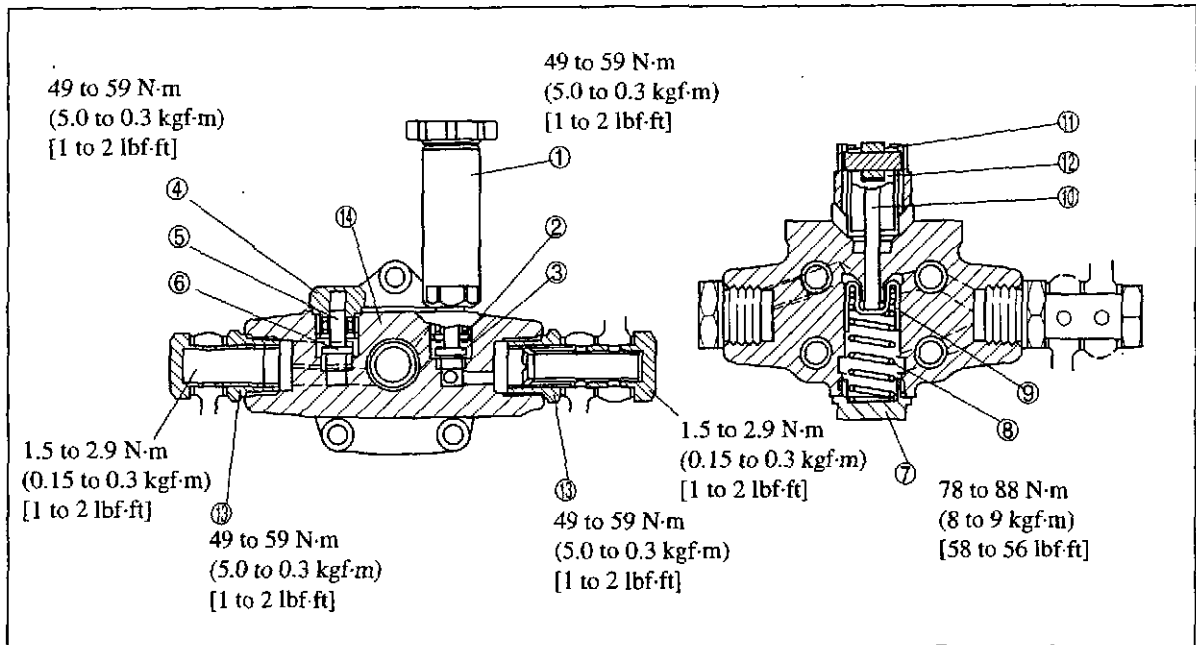


- | | | |
|----------------|------------|----------------|
| ① Priming pump | ⑥ Valve | ⑪ Snap ring |
| ② Spring | ⑦ Plug | ⑫ Tappet |
| ③ Valve | ⑧ Spring | ⑬ Adapter |
| ④ Plug | ⑨ Piston | ⑭ Pump housing |
| ⑤ Spring | ⑩ Push rod | |

CAUTION

- (a) When handling diesel fuel, never use open flame or fire nearby.
- (b) Before removing the gauze filter, remove as many dust particles as possible from its small openings. If it is removed in the clogged condition, it may be twisted and damaged.

5.2 Reassembly



Reassembly Sequence

- ⑭→⑬→⑫→⑪→⑩→⑨→⑧→⑦→⑥→⑤→④→③→②→①

(1) Tightening priming cap

- (a) Finger tighten the priming cap until the required tightening force suddenly increases.

NOTE

Mark the priming cap in this condition to facilitate the subsequent steps.

- (b) From the finger-tightened condition in (a) above, tighten the priming cap to the angle θ of $90^\circ \pm 10^\circ$.

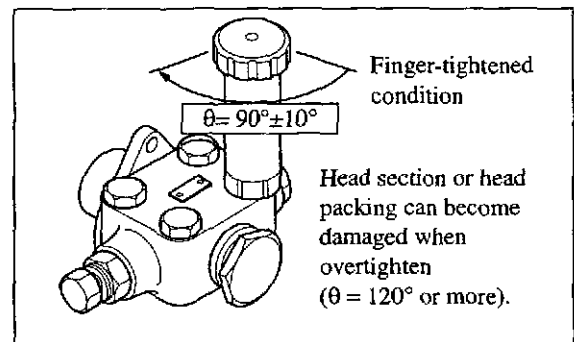
NOTE

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

CAUTION

Be sure to tighten the priming cap to an appropriate angle θ of $90^\circ \pm 10^\circ$

- (a) If undertightened, the priming cap may have the internal threads worn by the vibration of the engine and may eventually come off, gushing forth the fuel.
- (b) If overtightened (or tightened to an angle θ of 120° or more), the priming cap may be damaged in the head.



Tightening priming cap

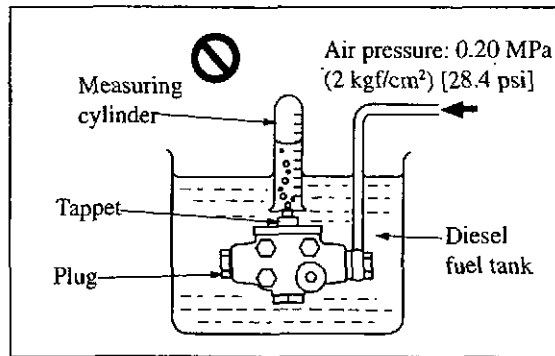
5.3 Testing

CAUTION

When handling diesel fuel, never use open flame or fire nearby.

(1) Airtightness test

- (a) Plug the discharge port of the feed pump, and introduce compressed air (0.20 MPa (2 kgf/cm²) [28.4 psi]) through the suction port.
- (b) Place the feed pump in diesel fuel, and check it for any air leakage.



Testing feed pump for airtightness

(2) Feed pressure test

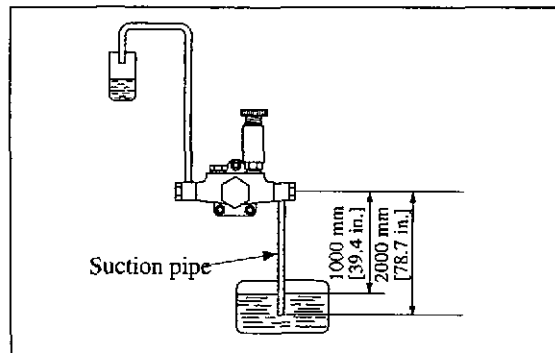
(a) Test conditions

Suction pipe: 15 mm [0.6 in.] OD × 13 mm [0.5 in.] ID × 2000 mm [78.7 in.] long

Suction height: 1000 mm [39.4 in.]

Cam lift: 12 mm [0.5 in.]/revolution

Drive the feed pump under the above test conditions, and measure the time to the start of fuel discharge.



Testing feed pump for feed pressure

Unit: sec

Item	Assembly Standard
Feed pressure (pump at 100 min ⁻¹ [spm])	Discharge start time: 20 sec or less

(3) Suction capacity test of priming pump

- (a) Discharge all fuel from the feed pump under the test conditions of (2) above.
- (b) Operate the priming button at a speed of 60 to 100 strokes/min, and count the strokes until the priming pump sucks up the fuel.

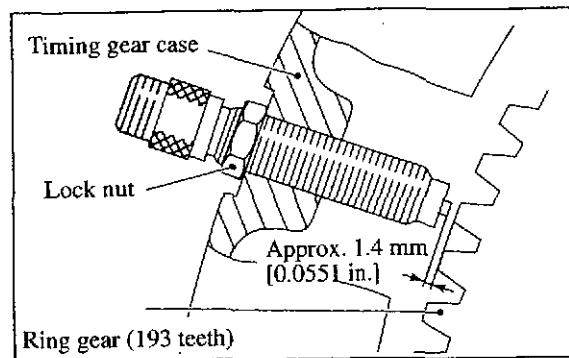
Unit: st/min

Item	Assembly Standard
Priming button discharge start	No. of pumping operations 30 strokes/min or less

FUEL SYSTEM

6. Installing Pick-up

- (a) Rotate the engine with the turning gear and position a tooth of the ring gear at the center of the pick-up.
- (b) Screw in the pick-up gently until the tip of the pick-up touches the tooth of the gear. Draw it back about a quarter of a rotation then fix the lock nut.



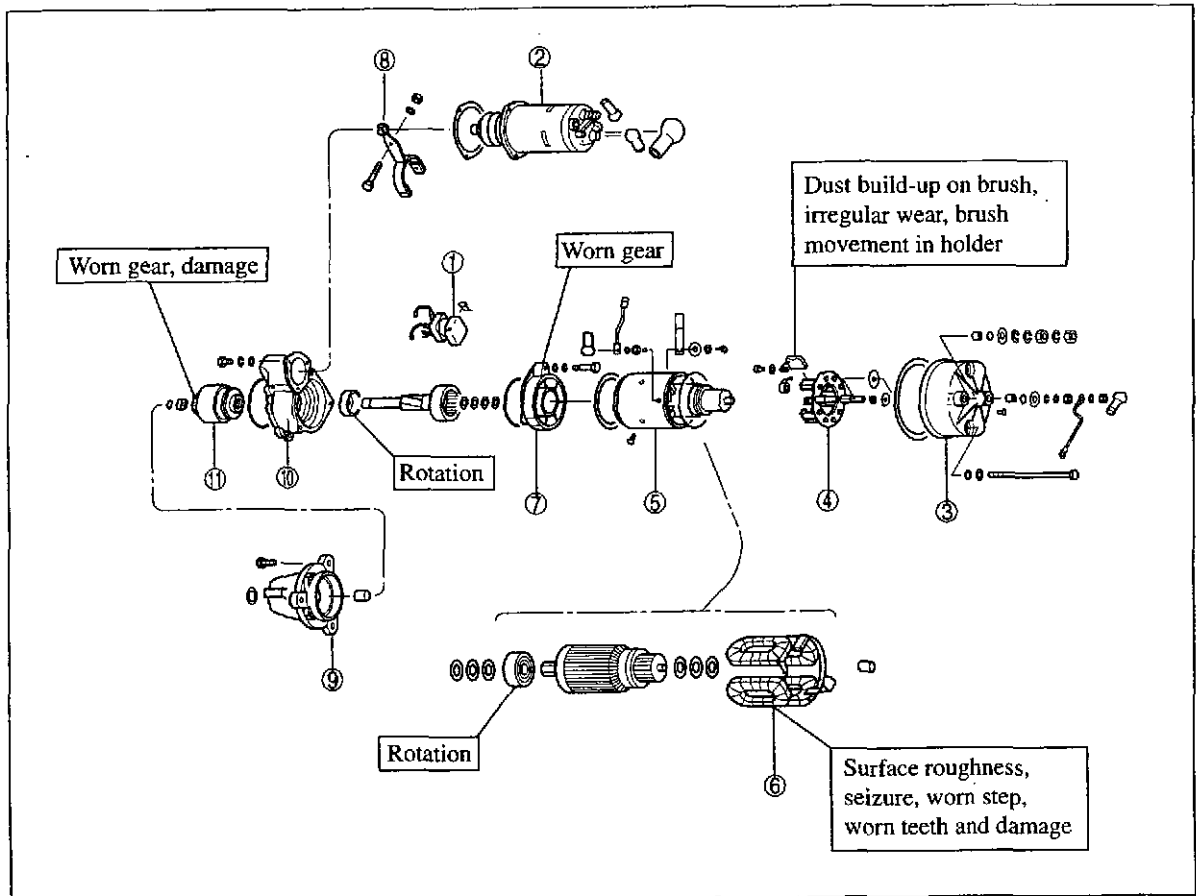
ELECTRICAL SYSTEM

1. Starter	12-2
1.1 Disassembly	12-2
1.2 Inspection and Repair	12-5
1.3 Reassembly	12-9
2. Alternator	12-13
2.1 Disassembly	12-13
2.2 Inspection and Repair	12-14
2.3 Reassembly	12-16

ELECTRICAL SYSTEM

1. Starter

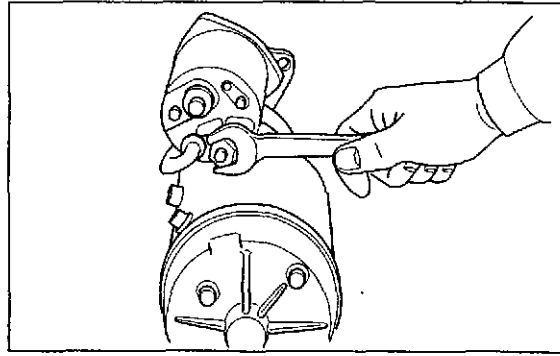
1.1 Disassembly



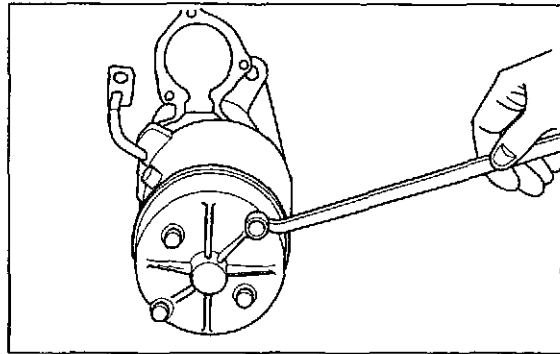
Disassembly sequence

- | | | |
|----------------------------|---------------------|--------------------------|
| ① Safety switch | ⑤ Yoke assembly | ⑨ Front bracket |
| ② Magnetic switch assembly | ⑥ Armature assembly | ⑩ Pinion case |
| ③ Rear bracket | ⑦ Center bracket | ⑪ Pinion clutch assembly |
| ④ Brush holder assembly | ⑧ Lever assembly | |

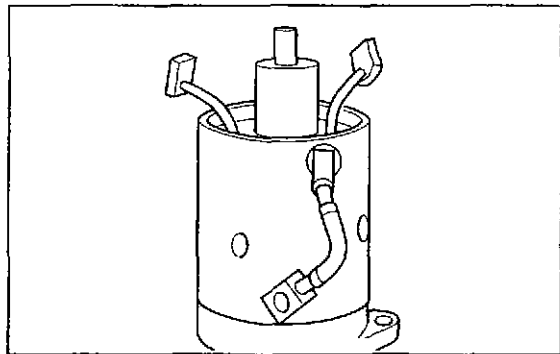
- (1) After removing the safety switch, remove the lead wire, then the magnetic switch assembly.



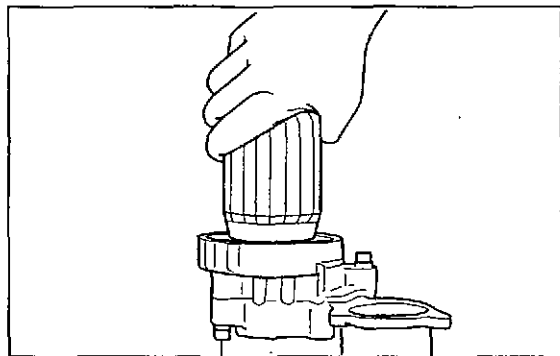
- (2) Unscrew the through bolts and the brush holder mounting screws, then remove the rear bracket.



- (3) Remove the brushes from the brush holder assembly, then remove the yoke.

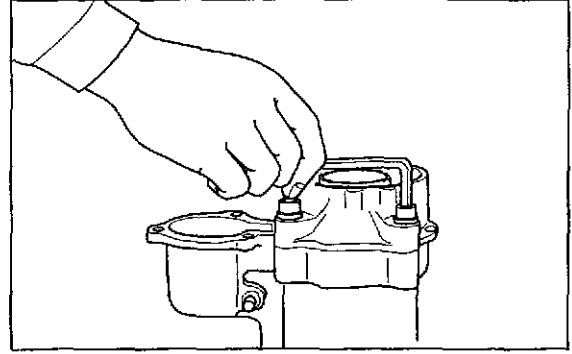


- (4) Pull out the armature assembly.

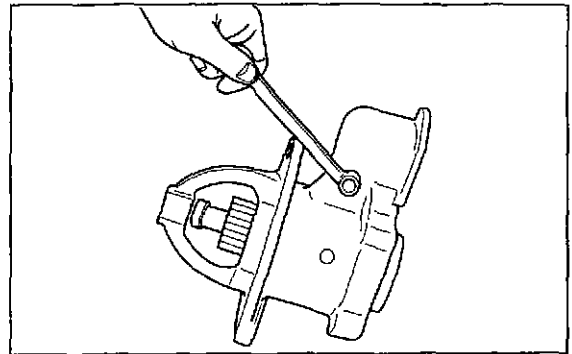


ELECTRICAL SYSTEM

(5) Remove the center bracket.



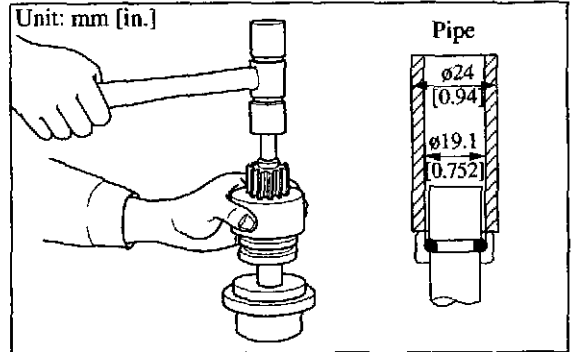
(6) Remove the lever pin, inner housing, and shift lever from the pinion case.



(7) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.

Unit: mm [in.]

Item		Nominal value	Standard	Remarks
Pinion shaft	Shaft diameter on rear side	ø30 [1.18]	30.002 to 30.011 [1.18118 to 1.18153]	Replace pinion shaft
	Shaft diameter on front side	ø19 [0.75]	18.900 to 18.940 [0.74409 to 0.74567]	Replace pinion shaft

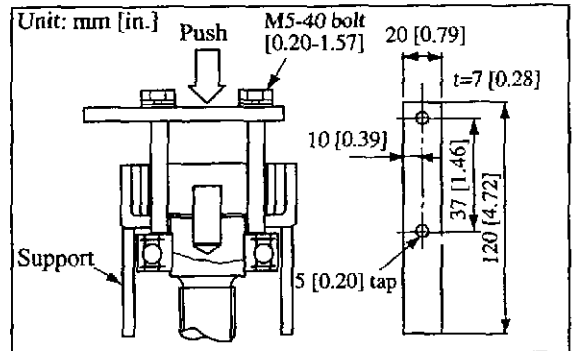


NOTE

To remove the shaft bearing for replacement, use a bearing puller as shown in the drawing.

Unit: mm [in.]

Item		Nominal value	Standard	Limit	Remarks
Bearing	Front bearing	ø19 [0.75]	19.000 to 19.033 [0.7480 to 0.7493]	0.25 [0.0098]	Clearance between bearing and shaft
	Pinion	ø19 [0.75]	19.000 to 19.033 [0.7480 to 0.7493]	0.25 [0.0098]	



Pinion shaft bearing puller

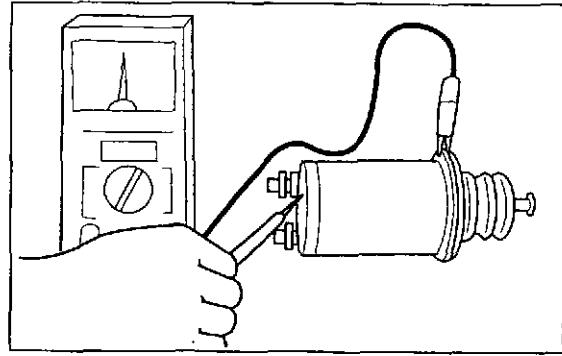
1.2 Inspection and Repair

Magnetic Switch

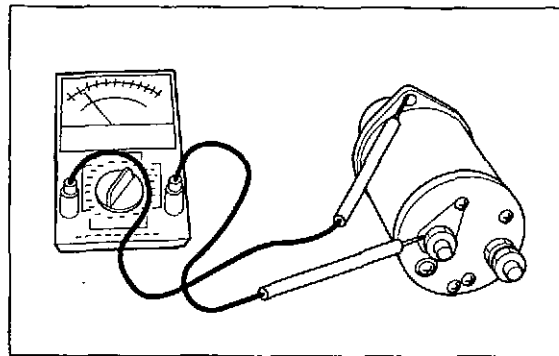
(1) Testing magnetic switch coil

- (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



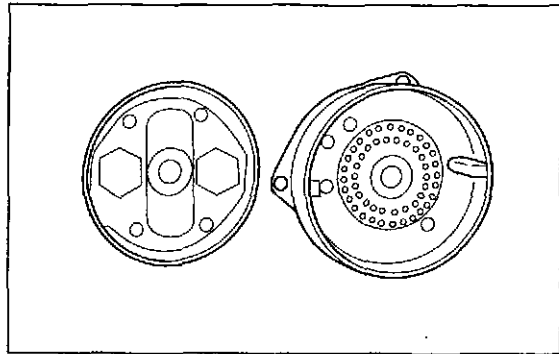
- (b) Apply voltage of 24 volts between the M terminal of the magnetic switch and the case. Under this condition, push in the plunger by hand. When you release your hand, the plunger should not be attracted.



(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

Under no circumstances should only the magnetic switch be tested.

ELECTRICAL SYSTEM

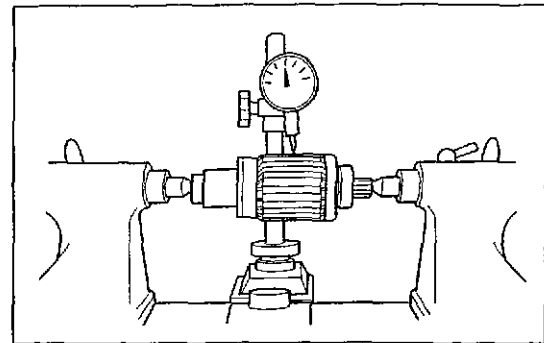
Armature

(1) Measuring armature shaft deflection and bearing journal diameters

- (a) Using a dial gage, measure the shaft deflection. If the deflection exceeds the standard, repair or replace the armature.

Unit: mm [in.]

Item	Standard	Remarks
Armature shaft deflection (1/2 value of measurement at center journal when shaft is supported at both ends)	0.05 [0.00197]	1/2 value of runout



- (b) Measure the bearing journal diameters of the armature shaft. If the measured values are no within the standard ranges, replace the armature.

Unit: mm [in.]

Item	Nominal value	Standard	Remarks
Armature	Diameter of shaft rear side ø14 [0.55]	13.941 to 13.968 [0.54886 to 0.54992]	Replace armature
	Diameter of shaft front side ø25 [0.98]	25.002 to 25.011 [0.98433 to 0.98468]	

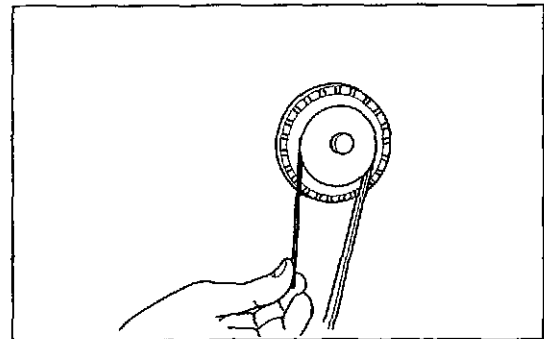
(2) Inspecting commutator

- (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]

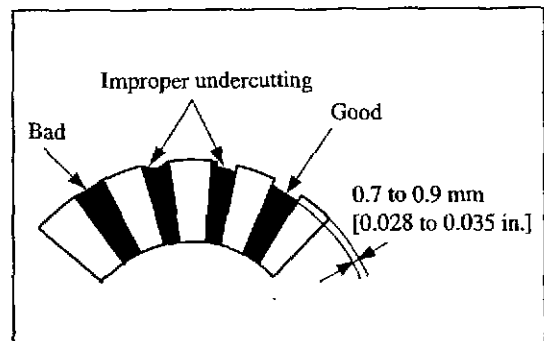


- (b) Measuring mica depth

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.]

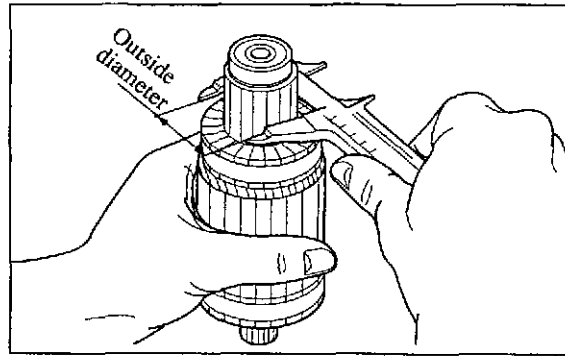
Item	Assembly Standard	Repair Limit
Commutator mica depth	0.7 to 0.9 [0.028 to 0.035]	0.2 [0.008]



- (c) Measure the commutator outside diameter. If the measured value is less than the limit, replace the armature.

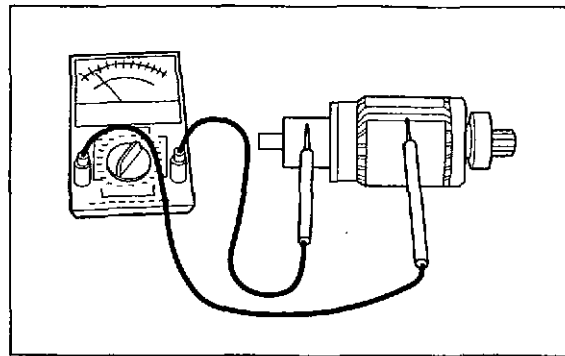
Unit: mm [in.]

Item	Nominal value	Limit
Commutator outside diameter	ø43 [1.69]	ø42 [1.65]



(3) Testing armature coil

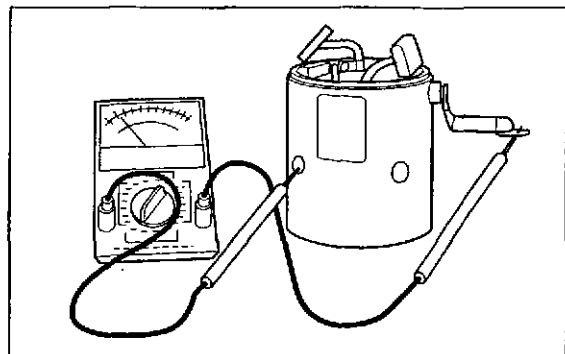
- (a) Use a growler to test the armature for short circuits. If the hacksaw blade vibrates against the core, replace the armature.
- (b) If there is continuity between the commutator and shaft, replace the armature.



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.



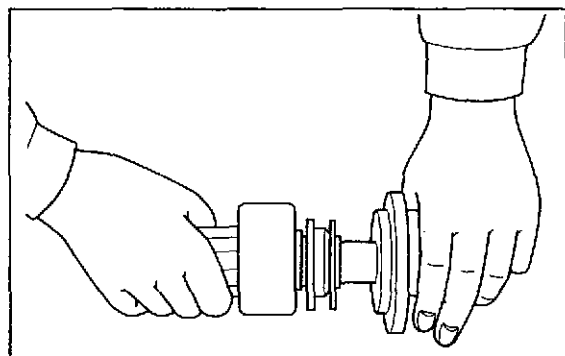
Overrunning Clutch

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.



ELECTRICAL SYSTEM

Brushes

(1) Inspecting for wear

Unit: mm [in.]

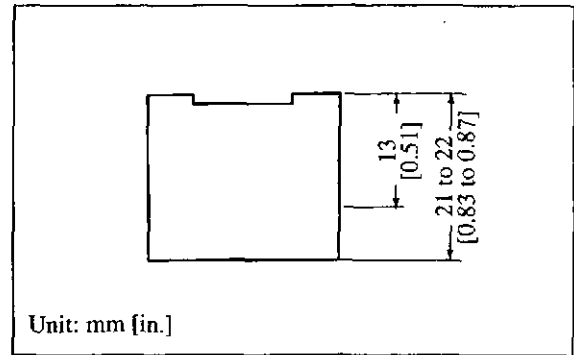
Item	Assembly Standard	Service Limit
Brush height	21 to 22 [0.83 to 0.87]	13 [0.51]

Repair unevenly worn brushes.

(2) Testing brush spring tension

Unit: N (kgf) [lbf]

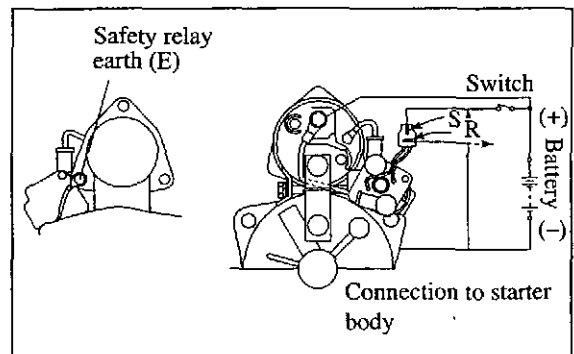
Item	Nominal Value	Assembly Standard	Service Limit
Brush spring tension	44.13 (4.5) [9.92]	39.23 to 49.03 (4.0 to 5.0) [9 to 11]	39.23 (4.0) [9]



Safety Switch

Connect the safety switch as shown, and check the starter and safety switch operations.

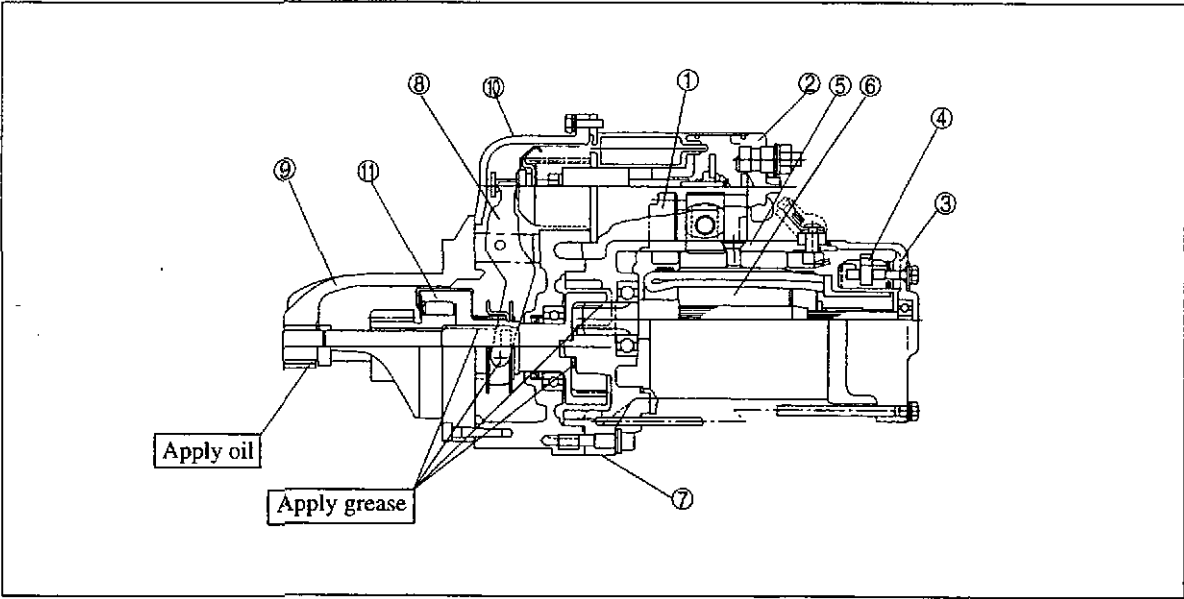
- (1) Connect the R terminal to the battery minus (-) side.
- (2) Turn the switch on, and check that the starter turns.
- (3) After step (2) above is completed, if you remove the R terminal from the battery minus (-) side, or if you connect the terminal to the battery plus (+) side after removal, make sure you stop the starter operation.



CAUTION

When you are making connections, pay special attention to the battery's polarity (+) (-).

1.3 Reassembly

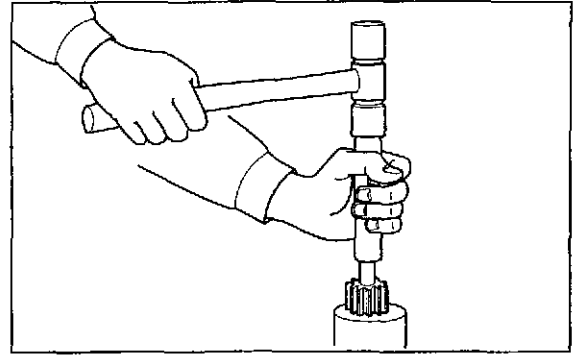


Reassembly sequence

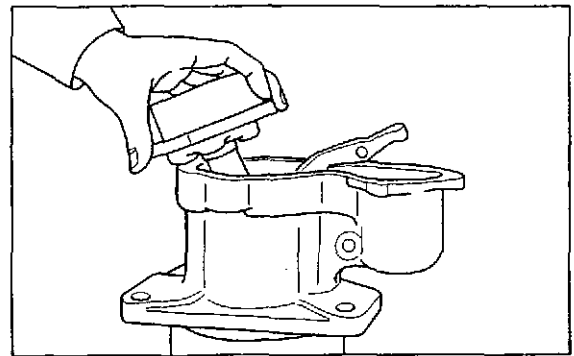
- ⑩ → ⑨ → ⑪ → ⑧ → ⑦ → ⑥ → ⑤ → ④ → ③ → ② → ①

ELECTRICAL SYSTEM

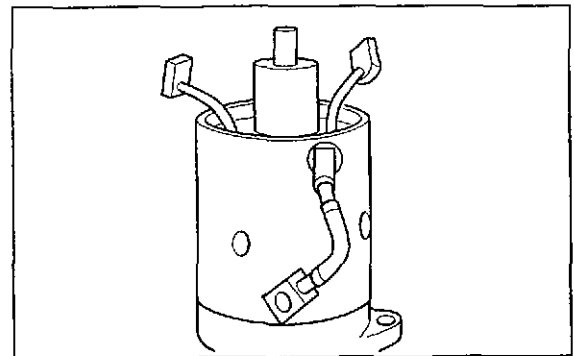
- (1) Install the center bracket, overrunning clutch and pinion stopper to the pinion shaft. Insert the shaft in position by tapping it with a soft-head mallet.



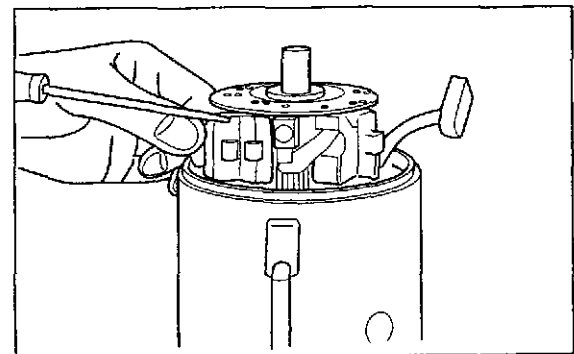
- (2) Install the shift lever and pinion shaft to the front bracket by aligning the matching mark on the shift lever.



- (3) Install the armature and yoke to the center bracket, making sure that the dowel pin enters its hole.

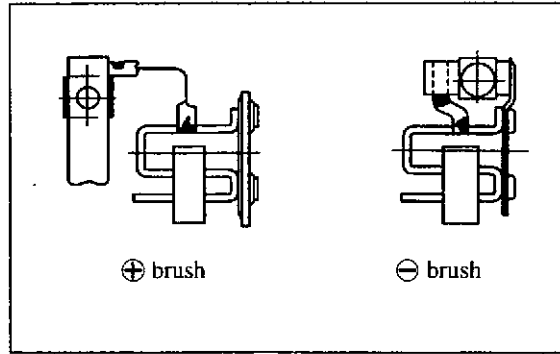


- (4) Install the brushes and brush holders.

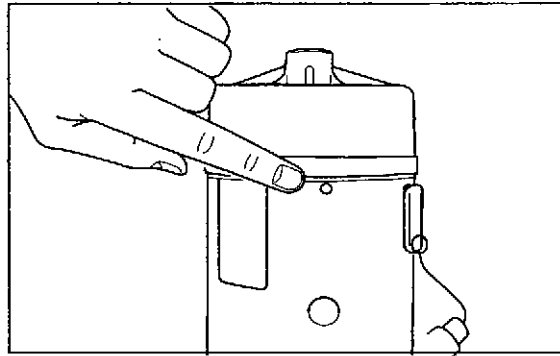


NOTE

Install the positive (+) side brush and negative (-) side brush as shown.



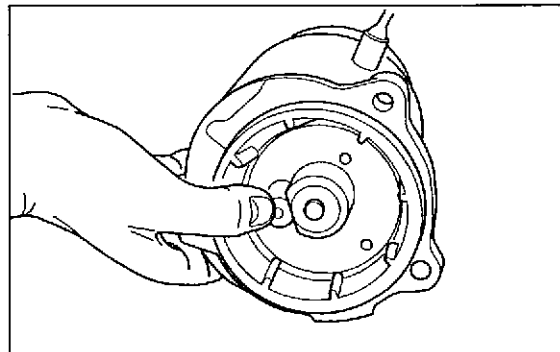
- (5) Install the rear bracket to the yoke by aligning the matching marks. Secure the brush holders with bolts, then tighten the through bolts.



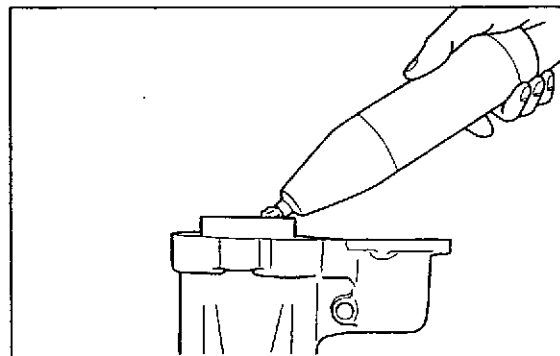
- (6) Measure the end play of the armature. If the end play exceeds the assembly standard, adjust it on the rear side. Test the motor unit, and make sure the measured value is 24V, 90A or lower.

Unit: mm [in.]

Item	Assembly Standard
Armature end play	0.15 to 0.75 [0.0059 to 0.0295]



- (7) Liberally coat the internal gear with Nikko Grease R, then install the pinion shaft to the gear.

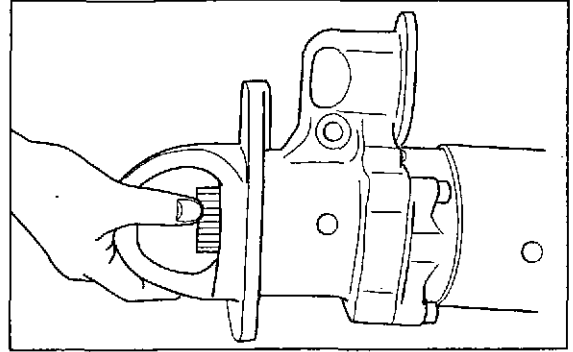


ELECTRICAL SYSTEM

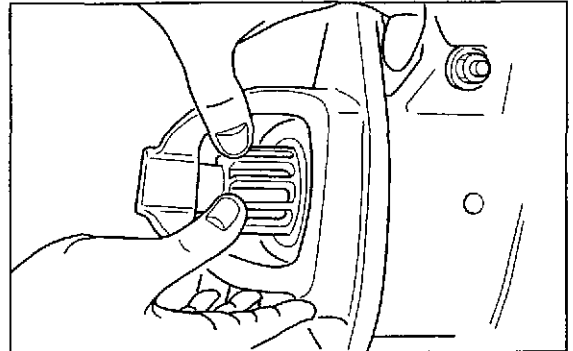
- (8) Measure the end play of the pinion shaft. If the end play exceeds the assembly standard, adjust it on the internal gear side.

Unit: mm [in.]

Item	Assembly Standard
Pinion shaft end play	0.2 to 0.8 [0.008 to 0.031]

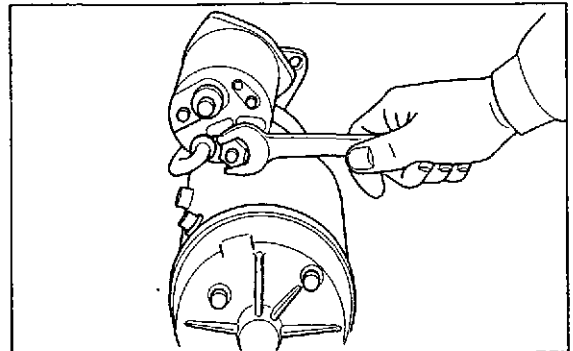


- (9) Install the magnetic switch. Apply a voltage of 24 volts between the C and E terminals. Connect the lead wire and energize the circuit between the M and E terminals (within 1 second). After the pinion has shifted, measure retraction length of the pinion. If the measurement is not within 1.5 to 5 mm [0.06 to 0.20 in.], use the magnetic switch adjusting screw to make adjustments.



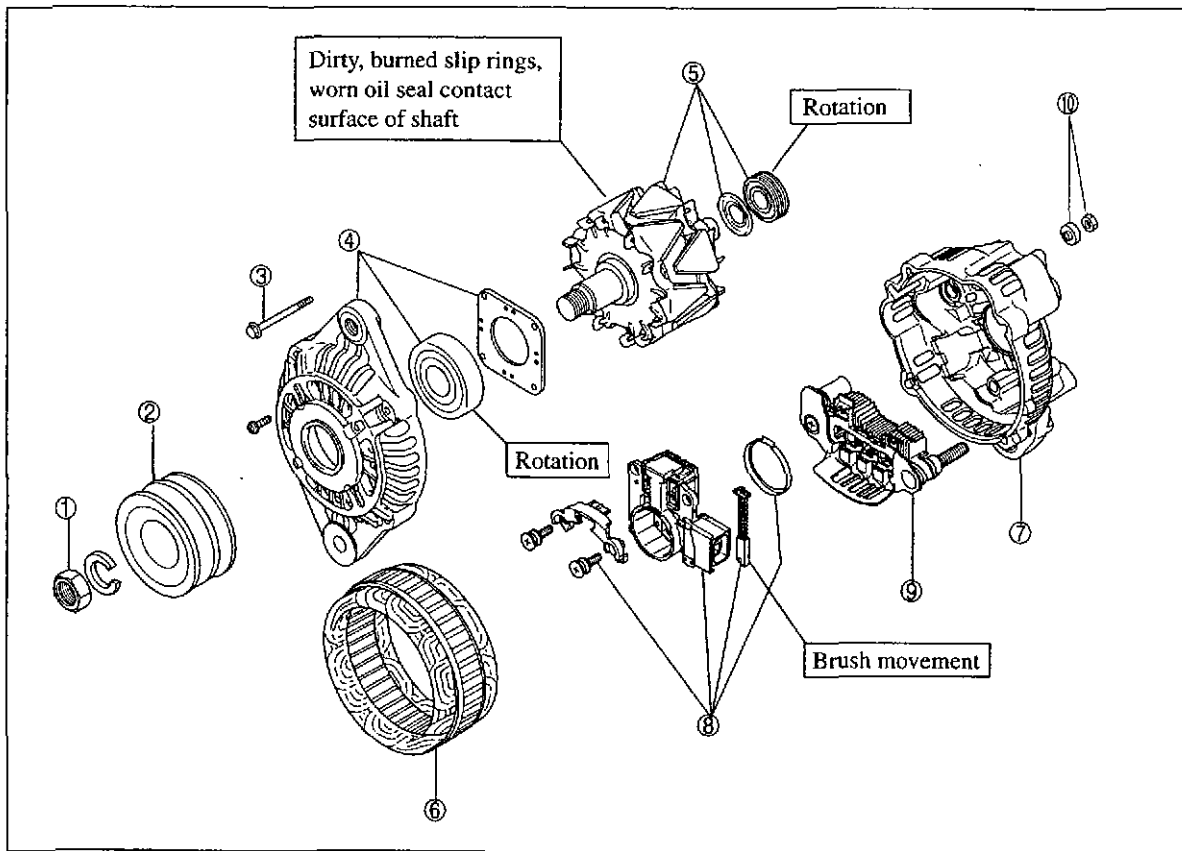
- (10) Secure the lead wire.

- (11) Install the safety switch.



2. Alternator

2.1 Disassembly



Disassembly sequence

- ① Nut, washer
- ② Pulley
- ③ 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

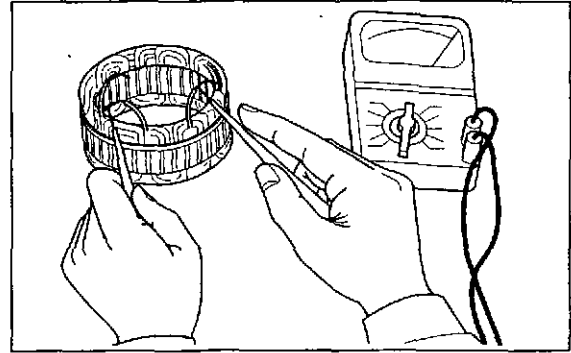
(1) Stator

(a) Testing stator coil for open circuits

If there is no continuity among the four lead wires, replace the stator.

(b) Testing stator coil for grounding

If there is continuity between the coil and core, replace the stator.



Testing stator coil

(2) Rotor

(a) Testing rotor coil for open circuits

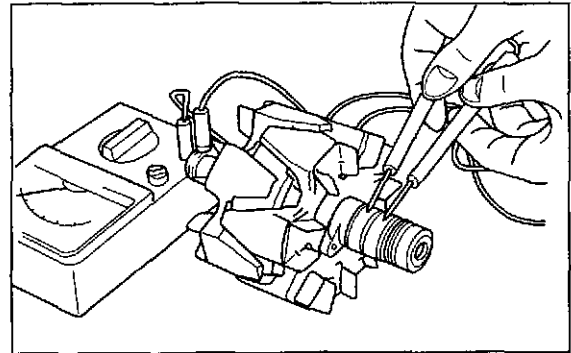
If there is no continuity between the slip rings, replace the rotor.

(b) Testing 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.



Testing rotor coil for open circuits

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

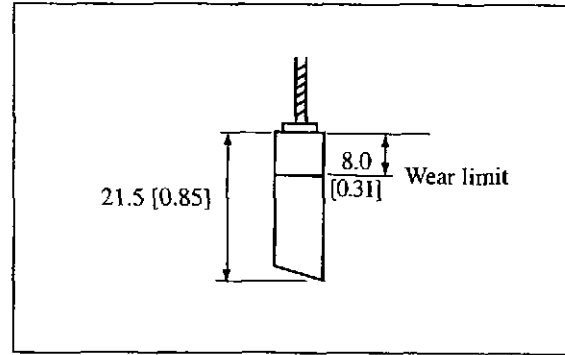
Unit: mm [in.]

Item	Nominal Value	Service Limit
Brush height	21.5 [0.85]	8 [0.31]

(b) Brush spring tension

Unit: N (gf) [lbf]

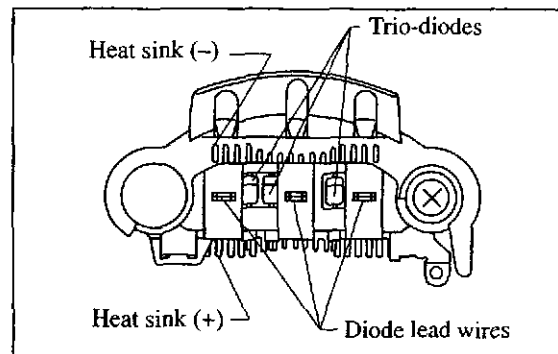
Item	Assembly Standard	Service Limit
Brush spring tension	3.1 to 4.3 (320 to 440) [0.70 to 0.97]	1.8 (180) [0.40]



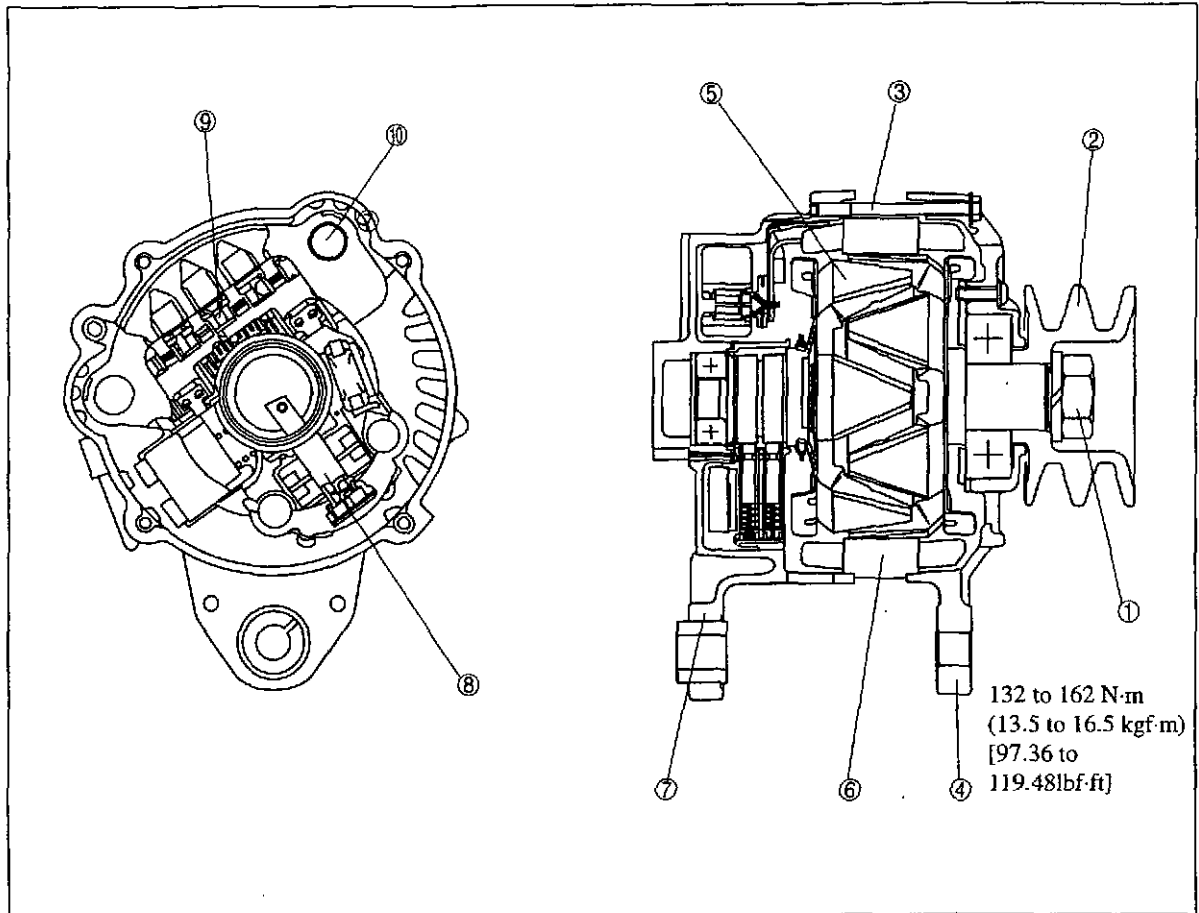
Brush wear

(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

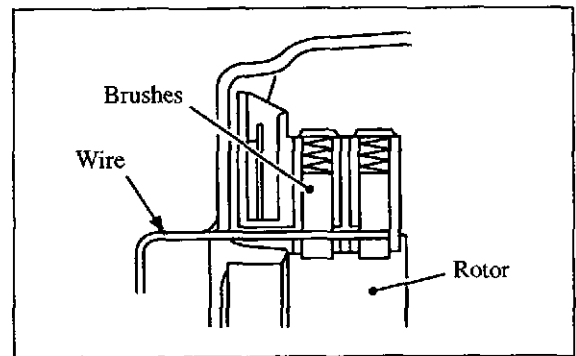


Reassembly sequence

⑦ → ⑩ → ⑨ → ⑧ → ⑥ → ⑤ → ④ → ③ → ② → ①

(1) Installing 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	13-2
1.1 Oil Seal	13-2
1.2 O-Ring	13-3
1.3 Bearing	13-3
1.4 Lock Plate	13-4
1.5 Split Pin and Spring Pin	13-4

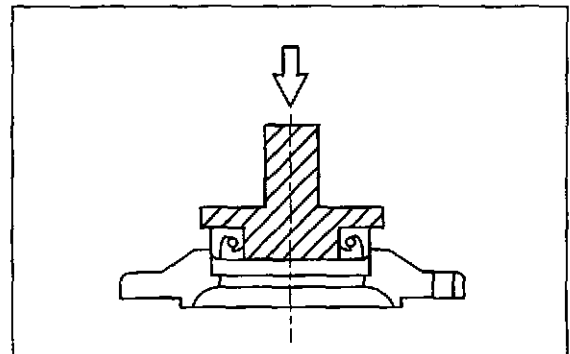
1. Precautions for Disassembly and Reassembly

1.1 Oil Seal

When installing oil seals, carefully observe the following points.

(1) Driving oil seals into housings

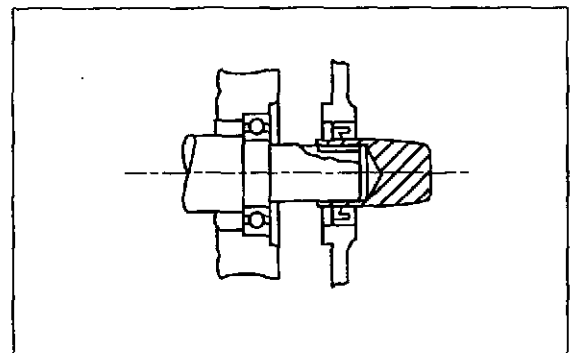
- (a) Check the seal lip for damage, and make sure to position correctly in the housing.
- (b) Apply a smear of grease to the surface of the oil seal to fit into the housing bore.
- (c) Use an oil seal driver to guide the seal lip and drive the outer diameter squarely. To avoid damage to the oil seal and leaking, never hammer on it directly.



Oil seal driver

(2) Driving oil seals onto shafts

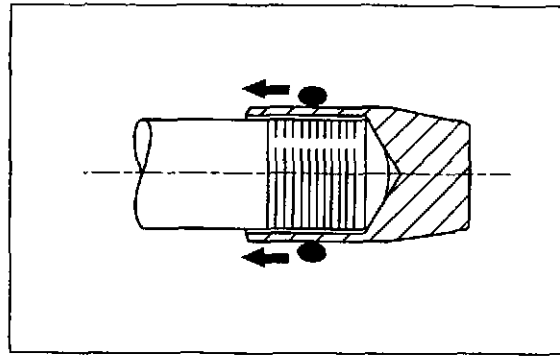
- (a) Apply a smear of grease to the oil seal lip.
- (b) Use an oil seal guide of the type shown when driving the oil seal over the stepped portion, splines, threads, or key way to prevent damage to the oil seal lip.



Oil seal guide

1.2 O-Ring

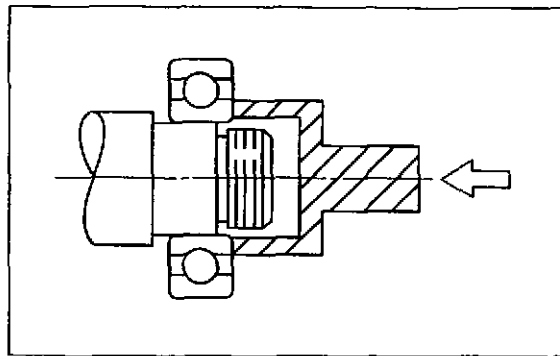
Use an O-ring guide to install an O-ring over stepped parts, splines, threads, or key way to prevent damage to the ring. Apply a smear of grease to the O-ring before installation.



O-ring guide

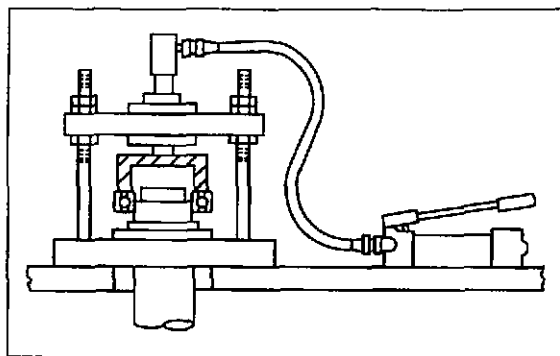
1.3 Bearing

(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.

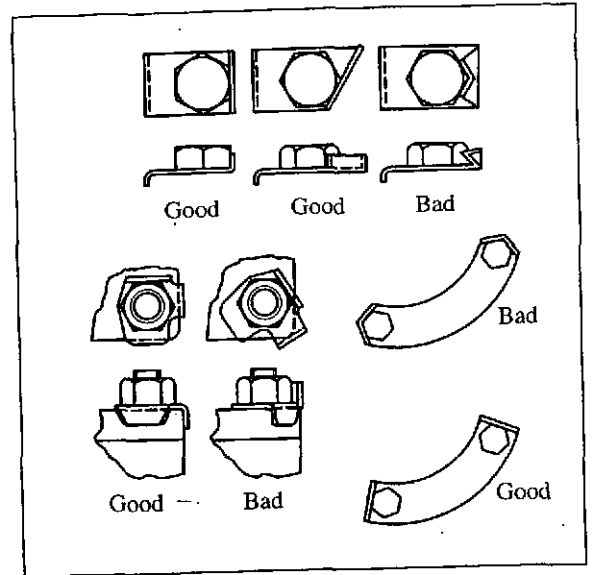


Bearing installation with a press

WORKSHOP TIPS

1.4 Lock Plate

Bend lock plates against the flats of the nuts or bolt heads as shown.



Bending lock plate

1.5 Split Pin and Spring Pin

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.

