SERVICE MANUAL

MITSUBISHI DIESEL ENGINE

S12R

MITSUBISHI
HEAVY INDUSTRIES, LTD.

INTRODUCTION

This service manual is written to familiarize you with the maintenance of your Mitsubishi S12R Diesel Engine. 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. All descriptions, illustrations, specifications, and serial numbers in this manual are effective as of the date printing of this manual.

Mitsubishi reserves the right to change specifications or design without prior notice or obligation.

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6. ENGINE ACCESSORY REMOVAL AND INSTALLATION

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What This Manual Covers

This service manual covers standard specifications for the Mitsubishi S12R Diesel Engine, and describes

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

The fuel injection pump, governor, and turbocharger are described in separate manuals. For non-standard engines, such as marine propulsion engines, etc., supplements have been published to be read with this manual.

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

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

How to Use This Manual

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

   Clogged oil hole

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

   ⑤→②→④→③→①

5. Pay attention to the special notes, cautions, and warnings.

   Notes, Cautions, and Warnings

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

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

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

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

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.

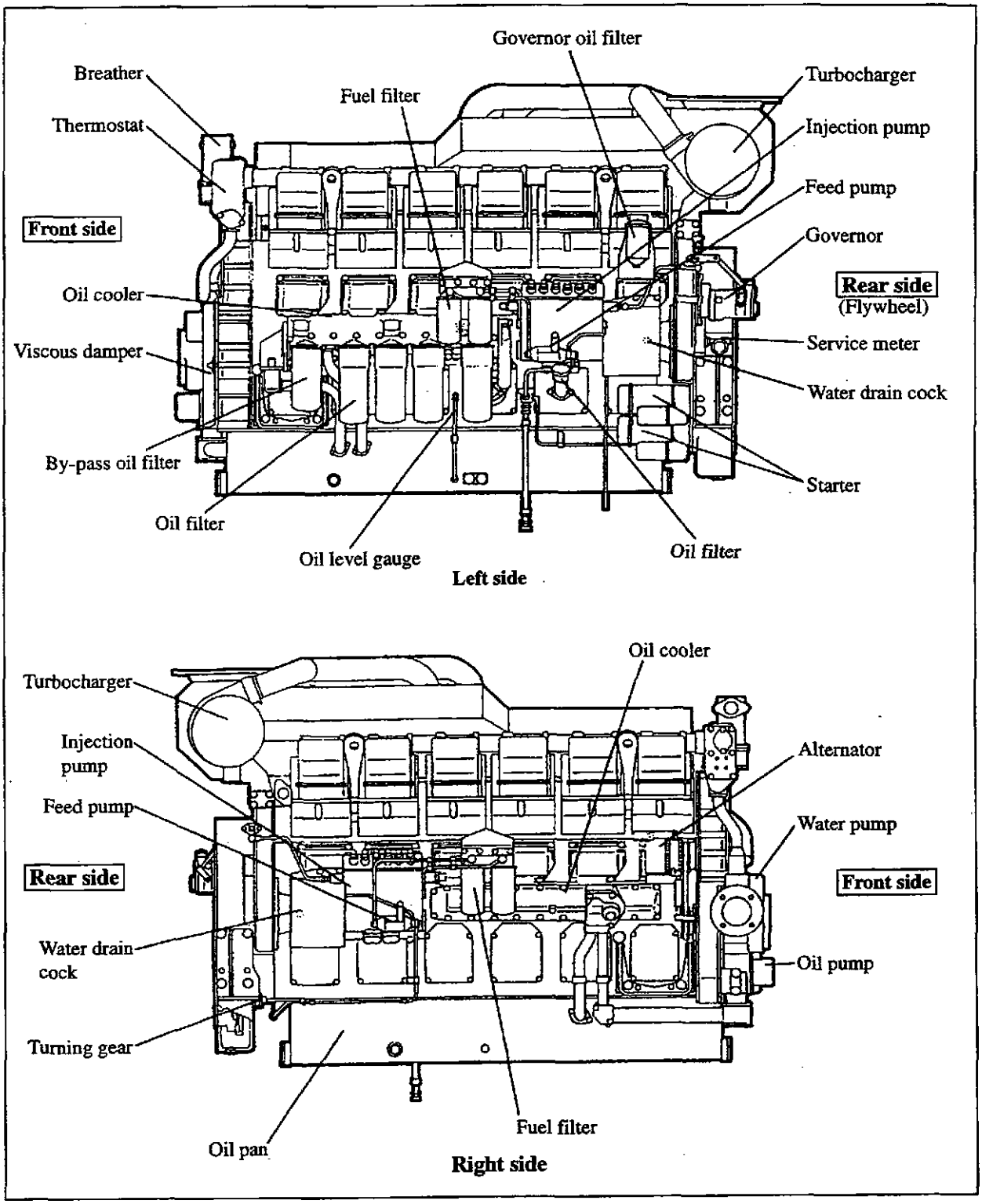
Summary of Manual Contents

Chapter	Contents
1. General	External views, sectional 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 tools	A list of special tools required.
4. Overhaul instructions	Determining when to overhaul the engine, testing compression pressure.
5. Adjustments, Bench Testing, and Performance Tests	Adjustment of valve clearance and fuel system priming, fuel timing adjustment, bench testing, and performance tests.
6. Engine Accessory Removal and installation	Removal and installation of turbochargers, air coolers, fuel injection pumps, alternator, staters, etc.
7. Engine Proper	Disassembly, inspection, and reassembly of the engine proper, to include cylinder heads, valve mechanisms, cylinder liners, pistons, connecting rods, flywheel, timing gears, camshaft, crankcase, crankshaft, main bearings.
8. Inlet and Exhaust Systems	Disassembly, inspection, and reassembly of inlet and exhaust systems, to include air cleaners, inlet manifolds and air coolers, exhaust manifolds, and air heater.
9. Lubrication System	Disassembly, inspection, and reassembly of lubrication system, to include the oil strainer, oil pump, relief valve, oil cooler, and oil filters.
10. Cooling System	Disassembly, inspection, and reassembly of cooling system, to include water pump, thermostats, radiator and fan drive.
11. Fuel System	Disassembly, inspection, and reassembly of the fuel system, to include fuel filters, fuel injection nozzles, Woodward governor drive.
12. Electrical System	Disassembly, inspection, and reassembly of electrical system, to include starters and the alternator.
13. Air Start Systems	Disassembly, inspection, and reassembly of air start systems, to include the air motor, air filter, distributor valve, starter valves, and magnetic valves.
14. Workshop Tips	General precautions for disassembly and reassembly of parts: oil seals, O-rings, bearings, lock plates, and pins.

GENERAL

1. Outline

1.1 External View

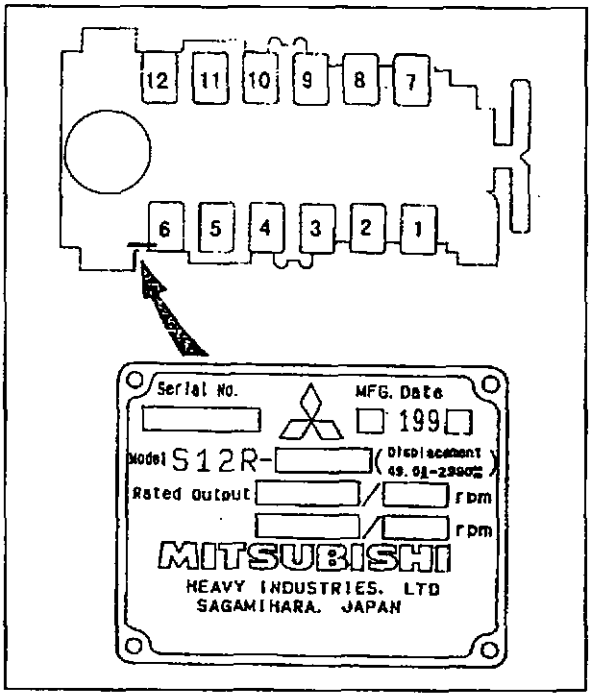


1.2 Engine Serial Number Location

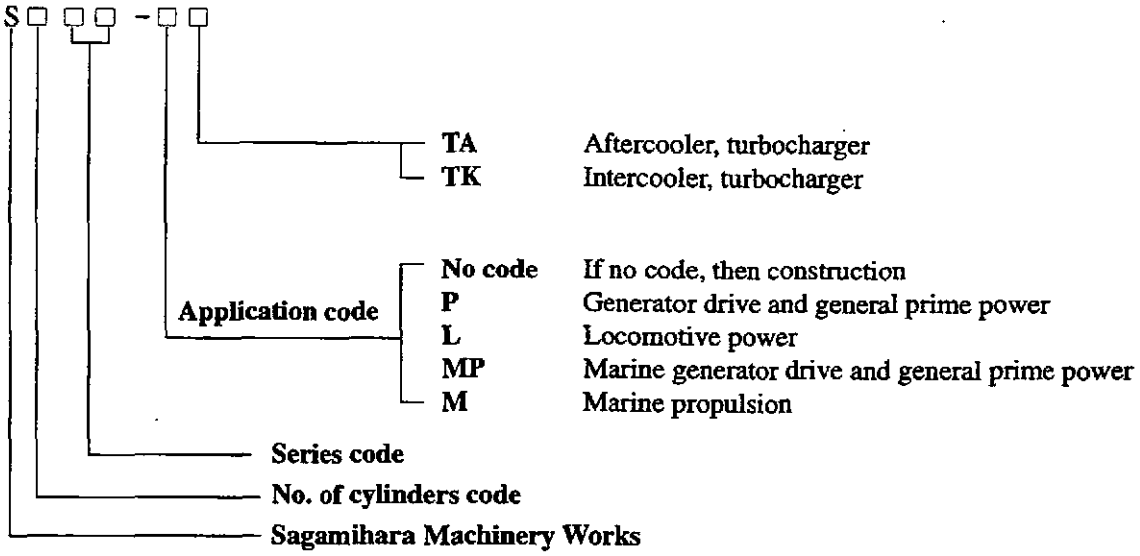
The engine serial number is stamped on the nameplate attached to the left lower side of the engine.

Example: Model Serial No.
S12R 10012

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



2. SPECIFICATIONS

Engine Type				S12R			
				TA	TK	TA–2	TK–2
Main specification / Engine proper	Model			Water-cooled, 4-stroke cycle, tubocharged diesel			
				w/aftercooler	w/intercooler	w/aftercooler	w/intercooler
	No. of cylinder-arrangement			12-V			
	Combustion type			Direct injection			
	Valve mechanism			Overhead			
	Cylinder diameter × stroke		mm (in.)	170 × 180 (6.70 × 7.09)			
	Displacement		ℓ (cu.in.)	49.0 (2990)			
	Compression ratio			14.0:1		13.5:1	
	Fuel			Light oil (JIS K2204 special No. 1-3) or A heavy oil (limited big-name brand)			
	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.)	2320 (91.3)			
		Width	mm (in.)	1360 (53.5)			
		Height	mm (in.)	1565 (61.6)			
	Weight (Dry)		kg (lbf)	4800 (10582)			
	Cylinder liner	Type		Wet type			
	Piston ring	No. of units		Compression rings: 2 Oil ring (w/expander): 1			
	Valve timing (when warm)	Inlet valve	Open	B.T.D.C. 37°			
			Close	A.B.D.C. 44°			
		Exhaust valve	Open	B.B.D.C. 57°			
			Close	A.T.D.C 24°			
	Engine support method			4 point support			
	Starting system			Starter air motor or direct air inlet air inlet starting			
Inlet and exhaust system	Air cleaner	Type		Paper element type or pre-cleaner type			
	Turbocharger	Type		TD15 or TD13			
		No. of units		2			
	Air cooler	Type		Laminated fin-plate type			

Engine Type			S12R			
			TA	TK	TA-2	TK-2
Oil 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)	180 (47.56) approx.			
	Oil pump	Type	Gear pump			
		Delivery capacity ℓ (U.S. gal)/min	240 (63.4) (at 800 rpm engine)			
	Relief valve	Type	Piston valve type			
		Valve opening pressure kgf/cm² (psi) [MPa]	5.2±0.2 (73.97±2.84) [0.51±0.02]			
	Oil cooler	Type	Water-cooled, multi-plate type (housed in the crankcase)			
		Element	10 stages			
	Full-flow oil filter	Type	Paper element type (spin on)			
	Bypass oil filter	Type	Paper element type (spin on)			
	Oil filter alarm	Type	Piston valve type, built-in electric contact points			
		Lamp lighting and valve opening pressure kgf/cm² (psi) [MPa]	$1.5\ ^{+0.3}_{0}$ ($21.34\ ^{+4.27}_{0}$) [$0.15\ ^{+0.3}_{0}$]			
	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			
	Capacity (Engine)		125 approx.			
	Water pump	Type	Centrifugal			
		Delivery capacity ℓ (U.S. gal)/min.	1600 (422.7)			
	Thermostats	Type	Wax type			
		Valve opening temperature °C (°F)	71±2 (159.8±35.6)			
	Radiator	Type	Plate fin or corrugated fin			
	Cooling fan	Type	Aluninum plated, circular arc type			
		No. of blades	8			
		Outside diameter mm (in.)	1524 (60.0)			
Fuel system	Injection pump	Model	PS6 type			
		Manufacturer	Mitsubishi Heavy Industry			
		Plunger outside diameter mm (in.)	17 (0.67)			
		Plunger lead mm (in.)	Counterclockwise, left-hand 35 lead			
		Cam lift mm (in.)	15 (0.59)			
	Feed pump	Model	Bosch KD22Z type			
		Manufacturer	Zexel			
		Cam lift mm (in.)	12 (0.47)			
	Governor	Control system	(Hydraulic) Woodward PSG	(Electrical) Woodward EG-3P or EG-B2P Barber-Coleman DYNA 1		
	Injection nozzles	Model	Hole type			
		Manufacturer	Zexel			
		No. of spray holes	10			
		Spray hole diameter mm (in.) Spray angle (deg.)	ø0.35 (0.013) - 160°			
		Injection pressure kgf/cm$_2$ (psi) [MPa]	350 to 355 (4979 to 5050) [34.32 to 34.81]			
	Fuel filter	Type	Paper element type (spin on)			

Engine Type			S12R			
			TA	TK	TA–2	TK–2
Electrical system	Voltage polarity		24V- – ground			
	Starter	Model	8-23000-1840			
		Manufacturer	Nikko Electric Industry			
		Pinion mesh type	*Pinion shift (Reduction type)*			
		Out put 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 rpm	5000 (at 27V, 30A)			
		Regulated Voltage V	28.5±0.5			
	Safety relay (for starter chattering)	Model	0–25000–7440			
		Manufacturer	Nikko Electric Industry			
		Mominal voltage V	24			
		Rating Seconds	30			
		Operating voltage V	8 to 24			
		Operation interval for starter chattering (at 24V) sec.	2.5 to 3.0 (SS–SW ON-OFF 1 cycle)			
		Allowable temperature °C (F°)	-20 to +50 (-68 to +122)			
		Ground	2-wire system			
	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.

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 postions or directions. Put on your own marks, if necessary, to aid reassembly.

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

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

3.2 Reassembly

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

(2) Use only the correct tools and instruments.

(3) Use only good quality lubricating oils and greases. Be sure to apply a coat of oil, grease, or sealant to parts as specified. (Refer to section 3 of Chapter 2, 'Maintenance Standards.")

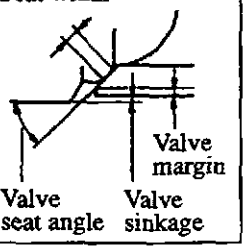
(4) Use a torque wrench to tighten parts when specified tightening torques are required. (Refer to section 2 of Chapter 2, "Maintenance Standards.")

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

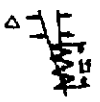
MAINTENANCE STANDARDS

1. Maintenance Standards Table

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
General	Maximum rpm		5 to 10% higher than rated rpm		Faulty if lower or 15% higher then rated rpm		The rated rpm is stamped on the nameplate. Check govemor setting.
	Minimum rpm		600 to 650rpm				
	Compression pressure kgf/cm$_2$ (psi) [MPa]		18.5 (263) [1.81] minimum (at 120 rpm)		Faulty if 13 (185) [1.27] or less		Oil and water temp. 20 to 30°C (68 to 86°F)
	Lube oil pressure kgf/cm$_2$ (psi) [MPa]		5 to 6.5 (71 to 92.5) [0.5 to 0.64] at rated rpm		Faulty if 5 (71) [0.5] or less		Oil temp. 60 to 70° (140 to 158°F)
			2 (28.4) [0.20] minimum at idling		Faulty if 1 (14.2) [0.1] 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	B.T.D.C. 2.5° A.B.D.C. 13° B.B.D.C. 26° A.T.D.C. 10.5° ±2° (crank angle)			Valves are only for checking valve timing and are different from the actual ones.
	Valve clearance (cold)	Inlet valves		0.6 (0.0236)			
		Exhaust valves		0.8 (0.0315)			
	Injection timing		B.T.D.C.	±1° (crank angle)			Varies according to specifications. Refer to caution plate on No.1 rocker cover.
Engine proper	Rockers	Rocker bushing inside diameter	ø36 (1.42)	36.000 to 36.040 (1.41732 to 1.41890)		36.090 (1.42087)	
		Rocker diameter	ø36 (1.42)	35.966 to 35.991 (1.41598 to 1.41697)		35.940 (1.41496)	
	Valves	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 seats and valves	Valve seat angle	30°				Seat width 
		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 (0.085 to 0.096)	2.8 (0.110)		

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Valve seats and valves	Valve margin	3.0 (0.118)	2.8 to 3.2 (0.110 to 0.126)	Refacing permissible up to 2.5 (0.098)		
		Cylinder head bore inside diameter and valve seat diameter	ø60 (2.36)	(–0.070 to –0.130) ((–0.00276 to –0.00512))			– (minus) indicates the valve is closed.
	Valve springs	Free length		73 (2.87)		71 (2.80)	
		Squareness		θ=1.5 (0.059) or less		Δ=2.2 (0.087) over the length	
		Length under test force mm (in.)/kgf (lbf) [N]		66.0 (2.6)/ 29.45 to 32.55 (64.9 to 71.8) [289 to 319]			
	Valve push rods	Runout		0.5 (0.020) maximun		0.5 (0.020)	
	Cylinder heads	Warpage of gasketed surface		0.03 (0.0012) or less	0.07 (0.0028)	0.50 (0.0197)	Regrind slightly.
	Cylinder liners	Inside diameter	ø170 (6.69)	170.000 to 170.040 (6.69291 to 6.69449)	170.200 (6.70079)	170.500 (6.71260)	
		Out-of-roundness		0.02 (0.0008) or less			
		Taper		0.02 (0.0008) or less			
		Squareness with respect to lower face of flange		0.03 (0.0012) or less			
		Protrusion of cylinder liner flange above gasketed surface		0.11 to 0.20 (0.0043 to 0.0079)			
	Pistons	Outside diameter	ø170 (6.69)	169.76 to 169.80 (6.6835 to 6.6850)		169.66 (6.6795)	Measure diameter in the direction teans-verse to pin at piston skirt.
		Variance in weigh among pistons per engine		40g (1.41 oz) or less			

Group	Inspection point			Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Pistons	Pin bore diameter		ø70 (2.76)	70.002 to 70.015 (2.75598 to 2.75650)		70.040 (2.75748)	
		Protrusion			0.06 to 0.65 (0.0024 to 0.0256)			
	Cylinder head gasket	As-installed thickness		1.8 (0.071)	1.77 to 1.83 (0.0697 to 0.0720)			
	Pistons cylinder head	Clearance between piston top and cylinder head			(1.22 to 1.95) ((0.0480 to 0.0768))			
	Piston rings	Gaps	Top		(0.6 to 0.8) ((0.024 to 0.031))		(2.0) (0.079)	If gauge is not available, the general value can be obtained at the cylinder bore.
			Second		(0.6 to 0.8) ((0.024 to 0.031))		(2.0) (0.079)	
			Oil		(0.3 to 0.45) ((0.012 to 0.018))		(2.0) (0.079)	
	Piston pins	Diameter		ø70 (2.76)	69.987 to 70.000 (2.75539 to 2.75591)		69.970 (2.75472)	
	Connecting rods	Bushing inside diameter		ø70 (2.76)	70.020 to 70.040 (2.75669 to 2.75748)		70.070 (2.75866)	
		Bend and twist			0.05/100 (0.0020/3.9) or less			
		End play (rod and crankpin widths)		60 × 2 (2.36 × 0.08)	(0.4 to 0.9) ((0.016 to 0.0354))	(1.4) ((0.055))		
		Variance in weight among connecting rods per engine			40g (1.41oz) or less			
		Big end bore diameter		ø131 (5.16)	131.000 to 131.025 (5.15748 to 5.15846)		131.050 (5.15945)	To be used on combination with bearing caps. Out-of-roundness (largest value - smallest value) < 0.1 mm

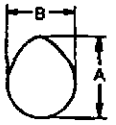
Unit: mm (in.)

Group	Inspection point			Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Connecting rod metals	Thickness of center	STD	3.000 (0.11811)	2.972 to 2.985 (0.11701 to 0.11752)		2.930 (0.11535)	Replace metals if worn down to service limit. Regrind crankpins and use under- beyond service limit.
			– 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) to less			
		Radial runout			0.13 (0.0051) or less			
	Injection pump accessory drive	Drive case bearing journal inside diameter		ø90 (3.54)	89.987 to 90.022 (3.54280 to 3.54417)			
				ø100 (3.94)	99.987 to 100.022 (3.93650 to 3.93787)			
		Bearing Outside diameter		ø90 (3.54)	89.985 to 90.000 (3.54272 to 3.54331)			
				ø100 (3.94)	99.985 to 100.000 (3.93042 to 3.93701)			
		Inside diameter		ø45 (1.77)	44.988 to 45.000 (1.77118 to 1.77165)			
				ø50 (1.97)	49.985 to 50.000 (1.96791 to 1.96850)			
	Injection pump accessory	Drive shaft bearing journal outside		ø45 (1.77)	45.002 to 45.013 (1.77173 to 1.77217)			
				ø50 (1.97)	50.002 to 50.013 (1.96858 to 1.96902)			

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Oil pump drive	Cover bearing journal inside diameter	ø110 (4.33)	110.000 to 110.035 (4.33071 to 4.33209)			
		Plate bearing journal inside diameter	ø110 (4.33)	109.987 to 110.022 (4.33020 to 4.33157)			
		Bearings Outside diameter	ø110 (4.33)	109.985 to 110.000 (4.33012 to 4.33071)			
		Inside diameter	ø50 (1.97)	49.985 to 50.000 (1.96791 to 1.96850)			
		Gear shaft bearing journal diameter	ø50 (1.97)	49.993 to 50.013 (1.96823 to 1.96902)			
	Vibration damper	Radial runout (at periphery)		0.5 (0.020) or less		1.5 (0.059)	Replace every 8000 hours
		Face runout		0.5 (0.020) or less		1.5 (0.059)	
	Timing and front gears	Backlash		(0.12 to 0.18) ((0.0047 to 0.0071))	(0.30) ((0.0118))	(0.50) ((0.0197))	Replace gears
		Idle gear bushing inside diameter	ø50 (1.97)	50.000 to 50.025 (1.96850 to 1.96949)		50.060 (1.97087)	Same as the front oil drive idler, front fan drive idler
		Idle gear diameter	ø50 (1.97)	49.950 to 49.975 (1.96654 to 1.96752)		49.900 (1.96457)	
		Idle gear end play		(0.3 to 0.6) ((0.012 to 0.024))		(1.0) ((0.039))	
		Front idle gear end play		(0.2 to 0.4) ((0.008 to 0.016))		(0.6) ((0.024))	
		Fan drive idle gear end play		(0.25 to 0.75) ((0.0098 to 0.0295))		(1.2) ((0.047))	
		Rear idler bushing inside diameter	ø65 (2.56)	65.000 to 65.030 (2.55906 to 2.56024)		65.060 (2.56142)	

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Timing and front gears	Rear idler shaft diameter	ø65 (2.56)	64.951 to 64.970 (2.55713 to 2.55787)		64.900 (2.55512)	
		Rear idler shaft inside diameter	ø65 (2.56)	65.000 to 65.030 (2.55906 to 2.56024)		65.060 (2.56142)	
		Rear idler bushing diameter	ø65 (2.56)	64.951 to 64.970 (2.55713 to 2.55787)		64.900 (2.55512)	
	Camshaft	Cam lift (A-B)	9.247 (0.36406)	9.197 to 9.297 (0.36209 to 0.36602)		8.45 (0.33268)	
		Runout		0.05 (0.0020) or less	0.08 (0.0031)		Runout at center bushing measured with both ends supported. Repair or replace.
		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 crank case)	ø84 (3.31)	84.000 to 84.035 (3.30709 to 3.30846)		84.10 (3.3110)	Replace bushings and ream them, if necessary, if worn beyond service limit.
		End play	8 (0.31)	(0.10 to 0.25) ((0.0039 to 0.0098))		(0.40) ((0.0157))	Replace thrust plate.
	Crankshaft	Crankpin diameter	ø125 (4.92)	–0.050 to –0.070 (–0.00197 to –0.00276)	–0.110 (–0.00433)		
		Crankpin journal diameter	ø170 (6.69)	–0.060 to –0.080 (–0.00236 to –0.00315)	–0.120 (0.00472)		
		Center to center distance between journal and crankpin	90 (3.54)	±0.1 (±0.004)			

Unit: mm (in.)

Group	Inspection point			Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Crankshaft	Parallelism between journals and crankpins			0.01 (0.0004) or less at pin length	0.03 (0.0012)		
		Out of roundness between journals and crankpins			0.01 (0.0004) or less difference between diameters	0.03 (0.0012)		
		Taper of journals and crankpins			0.02 (0.0008) or less difference between diameters	0.03 (0.0012)		
		Fillet radius of crankpins		7 (0.28)	$7.0\,^{0}_{-0.2}$ $(0.276\,^{0}_{-0.008})$			
		Fillet radius of journals		8.5 (0.335)	$8.5\,^{0}_{-0.2}$ $(0.335\,^{0}_{-0.008})$			
		Hardness of journals and crankpins			Hv>590			
		Angular error of crankpins			±0°20'			
		Runout			0.04 (0.0016) or less	0.10 (0.004)		Repair or replace
		End play (shaft thrust width)		67 (2.64)	(0.20 to 0.40) ((0.0079 to 0.016))		(0.50) ((0.0197)) +1.18 (+0.0465) for crank shaft width	Replace thrust plate if worn down to repair limit. Use oversize thrust plate if worn beyond repair limit. +0.25 (+0.0098), +0.50 (0.0197), +0.75 (0.0295)
	Main metals	Thick-ness of center	STD	4.500 (0.17717)	4.467 to 4.480 (0.17587 to 0.17638)		4.425 (0.17421)	Replace metals if worn down to service limit. Regrind crankpins and use undersize metals 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 (0.18406)	
			–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 yo 0.19606)		4.925 (0.19390)	

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Engine proper	Crankcase	Warpage of gasketed surface		0.1 (0.004) or less		0.2 (0.008)	Regrind slightly.
		Main metal bore diameter	ø179 (7.05)	179.000 to 179.025 (7.04724 to 7.04823)		179.045 (7.04902)	
Lubrication system	Oil pump	Drive and driven gear backlash		(0.10 to 0.20) ((0.0039 to 0.0079))		(0.4) ((0.0016))	
		Drive and driven gear clearance in case	ø60 (2.36)	(0.100 to 0.148) ((0.00394 to 0.00583))		Tip clearance (0.35) ((0.0138))	
		Gear end clearance in case	72.5 (2.85)	(0.040 to 0.116) ((0.00157 to 0.00457))		(0.21) ((0.0083))	Remove the coverinstallation packing (width of 0.04 (0.0016)) and measure.
		Shaft diameter	ø30 (1.18)	Drive shaft 29.887 to 29.900 (1.17665 to 1.17717)		Drive shaft 29.840 (1.17480)	
				Driven shaft 29.947 to 29.960 (1.17902 to 1.17953)		Driven shaft 29.900 (1.17717)	
		Bushing inside diameter		30.000 to 30.021 (1.18110 to 1.18193)		30.055 (1.18327)	
	Safety valve	Valve opening pressure, kgf/cm² (psi) [MPa]		13±1.3 (184.9±18.50) [1.27±0.13]			
		Spring installation length/ weight mm (in.) /kgf (lbf) [N]		65.8 (2.59) /36.6 (520.6) [359]		65.8 (2.59) /32 (455.1) [314]	
	Relief valve	Valve opening pressure, kgf/cm² (psi) [MPa]		5.2±0.2 (73.97±2.84) [0.51±0.02]			

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Lubrication system	Oil thermostat	Temperature at which valve starts opening		80 to 84°C (176 to 183.2)			
		Temperature at which valve lift is more than 11 (0.43)		95°C (203°F)			
	Bypass alarm	Lamp lighting and valve opening pressure (*differential* pressure) kgf/cm² (psi) [MPa]		$1.5^{+0.3}_{0}$ (21.3^{+14}_{0}) [$0.15^{+0.03}_{0}$]			Difference in oil pressure is 0.07 (0.1) [0.0069] with a low 1(0.39) shim.
	Piston cooling nozzle	Valve opening pressure, kgf/cm² (psi) [MPa]		2.7 to 3.3 (38 to 47) [0.26 to 0.32]			
Cooling system	Water pump	Bearing bore inside diameter	ø120 (4.72)	119.987 to 120.022 (4.72390 to 4.72528)			
			ø110 (4.33)	110.005 to 110.040 (4.33091 to 4.33228)			Same as the bearing cover.
		Bearing Outside diameter	ø120 (4.72)	119.982 to 120.000 (4.72370 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)	49.985 to 50.000 (1.96791 to 1.96850)			
		Shaft bearing *journal* diameter	ø55 (2.17)	55.011 to 55.024 (2.16759 to 2.16630)			
			ø50 (1.97)	50.011 to 50.024 (1.96894 to 1.96945)			
		Vane front face clearance	1.04 (0.041)	(0.58 to 1.5) ((0.023 to 0.059))			

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Cooling system	Thermo-stat	Temperature at which valve starts opening		71±2°C (159.8± 35.6°F)			
		Temperature at which valve lift is 11 mm (0.43 in.) or more		85°C (185°F)			Check at atmospheric pressure
	Fan drive	Bearing bore inside diameter	ø140 (5.51)	139.986 to 140.026 (5.51126 to 5.51283)			
			ø120 (4.72)	119.987 to 120.022 (4.72390 to 4.72528)			
		Bearing Outside diameter	ø140 (5.51)	139.982 to 140.000 (5.51110 to 5.51181)			
			ø120 (4.72)	119.982 to 120.000 (4.72370 to 4.72441)			
		Inside diameter	ø55 (2.17)	54.985 to 55.000 (2.16476 to 2.16535)			
		Shaft bearing journal diameter	ø55 (2.17)	55.002 to 55.015 (2.16543 to 2.16594)			
Fuel system	Fuel injection nozzle	Valve opening pressure, kgfcm² (psi) [MPa]	350 (4979) [34.32]	350 to 355 (4979 to 5050) [34.32 to 34.81]			
		Spray angle	160°				Check spray performance with a hand tester [at fuel oil temperature 20°C (68°F)]. Replace the nozzle tip if the spray pattern is still bad after washing in clean fuel oil.

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Fuel system	Governor drive	Case drive shaft side bearing bore inside diameter	ø52 (2.05)	51.988 to 52.018 (2.04677 to 2.04795)			
		Drive shaft side bearings Outside diameter	ø52 (2.05)	51.987 to 52.000 (2.04673 to 2.04724)			
		Inside diameter	ø25 (0.98)	24.990 to 25.000 (0.98386 to 0.98425)			
		Drive shaft bearing bore diameter	ø25 (0.98)	25.002 to 25.011 (0.98433 to 0.98469)			
		Case idler shaft side bearing journal inside diameter	ø47 (1.85)	46.989 to 47.014 (1.84996 to 1.85094)			
		Idler shaft side bearing Outside diameter	ø47 (1.85)	46.989 to 47.000 (1.84996 to 1.85039)			
		Inside diameter	ø20 (0.79)	19.990 to 20.000 (0.78701 to 0.78740)			
		Idler shaft bearing journal diameter	ø20 (0.79)	20.002 to 20.011 (0.78748 to 0.78783)			
		Drive shaft gear journal diameter	ø26 (1.02)	26.035 to 26.048 (1.02500 to 1.02551)			
		Drive gear inside diameter	ø26 (1.02)	26.000 to 26.013 (1.02362 to 1.02413)			
		EG-B2P drive shaft and gear journal diameter	ø29 (1.14)	28.959 to 28.980 (1.14012 to 1.14094)			
		EG-B2P drive gear inside diameter	ø29 (1.14)	29.00 to 29.04 (1.1417 to 1.1433)			

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Fuel system	Governor drive	Idler shaft and gear journal outside diameter	ø24 (0.94)	24.035 to 24.048 (0.94626 to 0.94677)			
		Idler gear inside diameter	ø24 (0.94)	24.000 to 24.013 (0.94488 to 0.94539)			
Electrical system	Starter	Commutator outside diameter	ø43 (1.69)			ø42 (1.65)	
		Runout commutator		0.06 (0.0024) or less		0.106 (0.00417)	
		Mica depth in commutator		0.7 to 0.9 (0.0276 to 0.0354)		0.2 (0.008)	
		Brush height		21 to 22 (0.83 to 0.87)		13 (0.51)	
		Brush spring tension (with brush installed), kgf (lbf)	4.5 (64.01) [44.13]	4.0 to 5.0 (8.8 to 11.0) [39.2 to 49.0]		4.0 (8.8) [39.2] maximum	
		Diameter of armature shaft rear side	ø14 (0.55)	13.941 to 13.968 (0.54886 to 0.54992)			
		Diameter of armature shaft front side	ø25 (0.98)	25.002 to 25.011 (0.98433 to 0.98469)			
		Diameter of pinion shaft rear side	ø30 (1.18)	30.002 to 30.011 (1.18118 to 1.18154)			
		Diameter of pinion shaft front side and inside diameter of metal	ø19 (0.75)	(19.000 to 19.033) ((0.74803 to 0.74933))		(0.25) ((0.0098))	
		Front metal	ø19 (0.75)	19.000 to 19.033 (0.7480 to 0.7493)		0.25 (0.0098)	Clearance between shaft and metal
		Pinion	ø19 (0.75)	19.000 to 19.033 (0.7480 to 0.7493)		0.25 (0.0098)	Clearance between shaft and metal

Unit: mm (in.)

Group	Inspection point		Nominal Value	Assembly Standards (Standard clearance)	Repair Limit (Clearance)	Service limit (clearance)	Remarks
Electrical system	Starter	Rear metal	ø14 (0.75)	14.000 to 14.027 (0.5512 to 0.5522)		0.25 (0.0098)	Clearance between shaft and metal
		Armature end play		0.3 to 0.7 (0.0118 to 0.0276)			
		Pinion shaft end play		0.2 to 0.8 (0.0079 to 0.0315)			
	Alternator	Slip ring outside diameter	41 (1.61)	40.8 to 41.02 (1.6063 to 1.6150)		40.6 (1.5984)	
		Brush height	18.5 (0.728)			11.5 (0.453)	Up to wear limit
	Alternator	Brush spring tension kgf (lbf) [N]	380 (0.83) [3.7]	320 to 440 (0.70 to 0.97) [3.1 to 4.3]		200 (0.45) [2.0]	
		Endplay of armature		0.2 to 0.6 (0.0079 to 0.0236)			
		Endplay of pinion shaft		0.2 to 0.6 (0.0079 to 0.0236)			
	Alternator drive belt tension			10 to 15 (0.39 to 0.59)			Push belt at midway between pulleys (force: approx. 10 to 15 kgf (22 to 33 lbf) [98 to 147 N] 
Air start systems	Distributor valve	Valve height		21.5±0.1 (0.84±0.004)	20 (0.79)		
		Shaft clearance in bushing		(0.050 to 0.091) ((0.00197 to 0.00358))	(0.300) ((0.01181))		
	Starter valve	Valve clearance in valve guide	ø15 (0.59)	(0.016 to 0.052) ((0.00063 to 0.00205))		(0.100) ((0.00394))	
		Valve spring free length		36 (1.42)		34 (1.34)	

2. Tightening Torque Table

2.1 Important Bolts and Nuts

Description	Thread Dia × Pitch (M-thread)	Torque			Remarks
		kgf·m	lbf·ft	N·m	
Cylinder head	22 × 2.5	55	398	539	[Wet] 2-step tightening method
Cylinder head nozzle glands (studs)	14 × 2.0	7 to 8	51 to 58	69 to 78	
Rocker case	12 × 1.25	11	80	108	Note (a)
Rocker shaft	14 × 2.0	15	108	147	
Rocker arm lock nuts	12 × 1.25	6.5	47	64	
Bridge lock nuts	10 × 1.25	5.6	40	55	
Camshaft gear	12 × 1.25	11	80	108	
Camshaft thrust plate	12 × 1.25	6	43	59	
Main metal caps	24 × 3.0	60	434	588	[Wet] Note (b)
Main metal cap side bolts	20 × 2.5	40	289	392	[Wet] Note (b)
Hanger	20 × 1.5	40	289	392	
	16 × 1.5	22	159	216	
Piston cooling nozzle	12 × 1.75	3.5	25	34	Note (c)
Timing gear case	16 × 1.5	26	188	255	
Rear plate	12 × 1.25	11	80	108	
	16 × 1.5	22	159	216	
Oil pan	12 × 1.25	6	43	59	
Front mounting bracket	20 × 1.5	40	289	392	
Rear mounting bracket	20 × 1.5	40	289	392	
Connecting rod metal caps	22 × 1.5	55	398	539	[Wet]
Balance weight	22 × 1.5	50	362	490	[Wet]
Flywheel	22 × 1.5	60	434	588	[Wet]
Ring gears	10 × 1.25	6	43	59	
Vibration damper	22 × 1.5	50	362	490	
Rear timing idler gear	12 × 1.25	11	80	108	
Rear idler shaft	20 × 1.5	40	289	392	
Rear idler shaft (nut)	18 × 1.5	20	145	196	
Front gear case	12 × 1.25	6	43	59	
	16 × 1.5	22	159	216	
Front plate	12 × 1.25	6	43	59	
Front idler shaft	12 × 1.25	11	80	108	
Front idler gear thrust plate	10 × 1.25	3	22	29	
Exhaust manifold V-clamp nuts	6 × 1.0	0.9	7	9	
Exhaust manifold mounting bolts	10 × 1.5	10	72	98	
Oil pump and water pump mounting plates	12 × 1.25	6	43	59	
Bearing cover	12 × 1.25	11	80	108	
Injection pump drive case	12 × 1.25	11	80	108	
Injection pump gears (nuts)	30 × 1.5	40	289	392	
Injection pump coupling shaft	14 × 1.5	17 to 18	123 to 130	167 to 177	Tighten the slit part.
Oil pump	12 × 1.25	11	80	108	
Oil pump cover	10 × 1.25	3.4	25	33	

Note: (a) To tighten cylinder head bolts according to the angle method, tighten to 294 N·m {30 kgf·m}, then turn 60° more.

(b) Be 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.

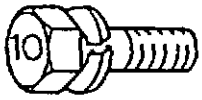
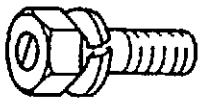
(c) To tighten check valves, be sure to use a torque wrench. Tightening without the use of a torque wrench can result in excessive tightening force, and this can cause valve malfunctions and lead to seizing of pistons due to insufficient lubricating oil during engine operation.

(d) To tighten connecting rod caps according to the angle method, tighten to 245 N·m {25 kgf·m}, then turn 60° more.

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

Description	Thread Dia × Pitch (M-thread)	Torque			Remarks
		kgf·m	lbf·ft	N·m	
Water pump	12 × 1.25	11	80	108	
Water pump shaft pulley (nuts)	30 × 1.5	40	289	392	For alternator drive
Fan drive coupling (nuts)	30 × 1.5	40	289	392	
Fan drive case	12 × 1.25	11	80	108	[Wet]
Fan drive gear (nuts)	30 × 1.5	40	289	392	
Fan drive idler hub	12 × 1.25	11	80	108	
Fan drive idler shaft	12 × 1.25	6	43	59	
Injection pump brackets	12 × 1.25	11	80	108	
Injection pump	12 × 1.25	11	80	108	
Injection pump laminate plate	12 × 1.25	10.5 to 11.5	76 to 83	103 to 113	
Injection pump flywheel (nuts)	24 × 1.5	40	289	392	
Injection pump coupling shaft	14 × 1.5	10		98	
Plunger assembly	12 × 1.25	8 to 8.5	58 to 61	78 to 83	
Delivery valve holder	30 × 1.5	24 to 26	174 to 188	235 to 255	
Injection nozzle gland (nuts)	14 × 1.5	10	72	98	
Injection nozzle chip (nuts)	28 × 1.5	18 to 20	130 to 145	177 to 196	
Nozzle holder cap nuts	14 × 1.5	8 to 8		69 to 78	
Injection nozzle adjusting screw nut	14 × 1.5	3.5 to 4.5	25 to 32	34 to 44	
Injection nozzle inlet connector	16 × 1.65	6.5 to 7.5	47 to 54	64 to 74	
Injection pipes	18 × 1.5	5 to 7		49 to 69	
Fuel rack control lever	8 × 1.5	2.5		25	2-step tightening method
Governor drive case	12 × 1.25	11	80	108	
Starter	12 × 1.25	6	43	59	

2.2 Standard bolts and nuts

	Thread Dia x Pitch, mm (in.)	Width across flats, mm (in.)	Strength classification					
			7T			10.9		
			kgf·m	lbf·ft	N·m	kgf·m	lbf·ft	N·m
Metric automobile screw thread								
	8 × 1.25 (0.31 × 0.049)	12 (0.47)	1.7	12	17	3.1	22	30
	10 × 1.25 (0.39 × 0.049)	14 (0.55)	3.4	25	33	6.1	44	60
	12 × 1.25 (0.47 × 0.049)	17 (0.67)	6.1	44	60	11.0	80	108
	14 × 1.5 (0.55 × 0.059)	22 (0.87)	9.9	72	97	17.9	129	176
	16 × 1.5 (0.63 × 0.059)	24 (0.94)	14.8	107	145	26.7	193	262
	18 × 1.5 (0.71 × 0.059)	27 (1.06)	21.4	155	210	38.5	278	378
	20 × 1.5 (0.79 × 0.059)	30 (1.18)	29.7	215	291	53.4	386	524
	22 × 1.5 (0.87 × 0.059)	32 (1.26)	39.3	284	385	70.8	512	694
	24 × 1.5 (0.94 × 0.059)	36 (1.42)	49.7	359	487	89.5	647	878
	27 × 3 (1.06 × 0.12)		75.3	544	73.8	135.5	980	1328
Metric course screw threads								
	10 × 1.5 (0.39 × 0.059)	14 (0.55)	3.3	24	32	5.9	43	58
	12 × 1.75 (0.47 × 0.069)	17 (0.67)	5.8	42	57	10.4	75	102
	14 × 2 (0.55 × 0.079)	22 (0.87)	9.5	69	93	17.0	123	167
	16 × 2 (0.63 × 0.079)	24 (0.94)	14.2	103	139	25.6	185	251
	18 × 2.5 (0.71 × 0.098)	27 (1.06)	19.8	143	194	35.7	258	350
	20 × 2.5 (0.79 × 0.098)	30 (1.18)	27.7	200	272	49.9	361	489
	22 × 2.5 (0.87 × 0.098)	32 (1.26)	37.0	268	363	66.6	482	653
	24 × 3 (0.94 × 0.12)	36 (1.42)	47.7	345	468	86.0	622	843
	27 × 3 (1.06 × 0.12)	41 (1.61)	70.0	506	686	126.0	911	1236

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 state).

2.3 Standard Eyebolts

Threads Diameter × Pitch (mm)	Width across flats (mm)	Strength classification 4T		
		N·m	lbf·ft	kgf·m
M8 × 1.25	12	8±1	58±0.72	0.8±0.1
M10 × 1.25	14	15±2	10.8±1.45	1.5±0.2
M12 × 1.25	17	25±3	18.1±2.17	2.5±0.3
M14 × 1.5	22	34±4	25.3±2.89	3.5±0.4
M16 × 1.5	24	44±5	32.5±3.62	4.5±0.5
M18 × 1.5	27	74±5	54.2±3.62	7.5±0.5
M20 × 1.5	30	98±10	72.3±7.23	10.0±1.0
M24 × 1.5	36	147±16	108.5±10.8	15.0±1.5
M27 × 1.5	41	226±20	166.3±14.5	23.0±2.0

(Dry)

2.4 Standard Union Nuts

Nominal Diameter	Cap nut size	Width across flats	N·m	lbf·ft	kgf·m
63	M14 × 1.5	19	39	29	4
80	M16 × 1.5	22	49	36	5
100	M20 × 1.5	27	78	58	8
120	M22 × 1.5	30	98	72	10
150	M27 × 1.5	32	157	116	16
180	M30 × 1.5	36	196	145	20
200	M30 × 1.5	36	196	145	20
220	M33 × 1.5	41	245	181	25
254	M36 × 1.5	41	294	217	30

(Dry)

2.5 High-pressure Fuel Injection Pipes

Cap nut size	N·m	lbf·ft	kgf·m
M12 × 1.5	39±5	29±3.6	4±0.5
M14 × 1.5	49±5	36±3.6	5±0.5
M18 × 1.5	59±1	43±7.2	6±1.0

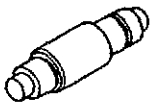
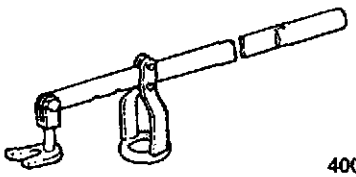
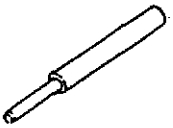
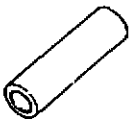
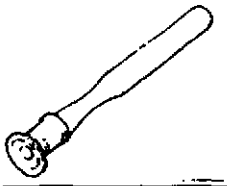
(Dry)

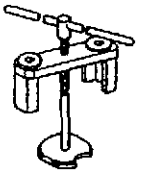
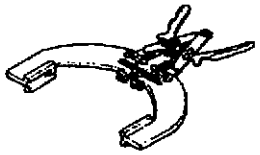
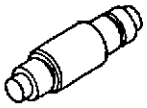
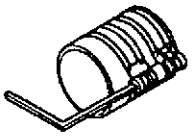
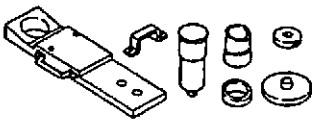
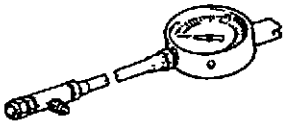
3. Sealants and Lubricants Table

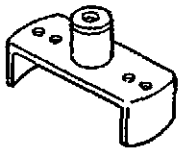
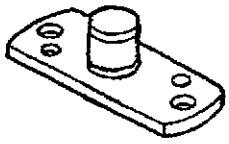
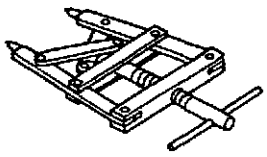
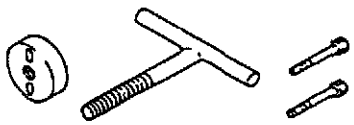
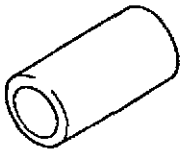
Group	Application point		Sealant or lubricant	How to use
Engine Proper	Cylinder head sealing caps		Hermeseal S-2	Coat holes in crankcase
	Water outlet connectors (Rocker case)		Grease	Grease O-ring joint
	Cylinder liners		Engine oil	Grease O-ring joint
	Front plate, gear case, oil pan, and crankcase		Herdite	Coat three-joint surfaces only
	Rear plate, gear case, oil pan, and crankcase		Herdite	Coat three-joint surfaces only
	Crankcase taper plugs		Sealock, Loctite (made by Three Bond)	Apply to threads
	Oil pan and crankcase		Herdite	Coat joint surfaces only of both sides of packing
	Oil seals		Engine oil	Coat lip of each oil seal
	Front plate, front gear case, and timing gear case		Three Bond 1212	Coat both sides of packing
	Drive case		Three Bond 1212	Apply to flange surface
	Cylinder head gasket		Three Bond 1212	Apply to areas around tappet chambers
Lubrication system	Oil pump	Cover and case	Three Bond 1215	Coat both sides of packing
Cooling system	Water pump	Oil seal	Engine oil	Coat lip of inner seal
		unit seal	LLC solution (antifreeze)	Coat floating seat
	Fan drive	Oil seal	Engine oil	Coat lip of oil seal
Inlet system	Air cooler	Between the element and the both side of plate	Shin-Etsu Chemical Co., Ltd KE45-W or a similar sealant or lubricant.	Fill the gap between the element and the plate.
Others	Taper plugs and cocks not precoated with Three Bond thread sealants.		Vulcanized tape sealing	Wrap threads with 2 turns of tape.

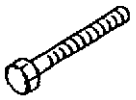
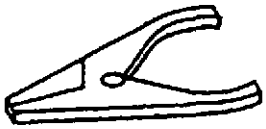
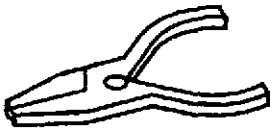
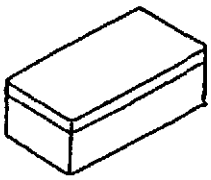
SPECIAL TOOLS

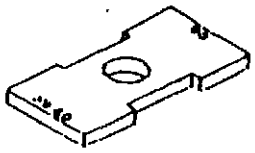
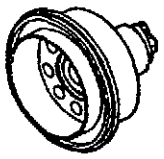
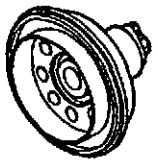
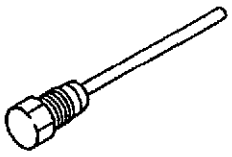
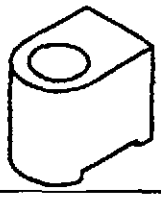
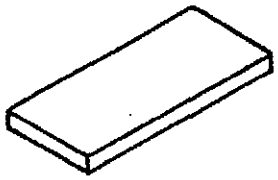
SPECIAL TOOL LIST

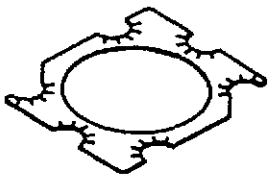
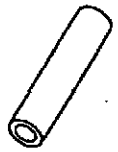
Tool name	Part No.	Shape	Use
Rocker bushing tool	37591 - 02600	 403390	Rocker bushing installation/ removal
Eye nut	37591 - 02400	 401178	Cylinder head suspension
Valve spring pusher	33591 - 04500	 400009	Valve spring removal/ installation
Valve guide remover	33591 - 04300	 400011	Valve guide removal
Valve guide and seal installer	37191 - 01500	 400012	Valve guide and valve stem seal installation
Valve lapper	30091 - 08800	 400013	Valve lapping
Ring pliers	45191 - 08400	 400014	Snap ring removal/ installation

Tool name	Part No.	Shape	Use
Cylinder liner remover	37591 - 04100		Cylinder liner removal
Piston ring tool	37191 - 03200		Piston ring removal/installation
Idler bushing puller	32591 - 02500	 403390	Front idle bushing removal/ installation
Piston installer	37191 - 07100	 400019	Piston installation
Connecting rod bushing installer	37591 - 01010	 404197	Connecting rod bushing removal/installation
Compression gauge adaptor	37591 - 02200	 400023	Compression pressure measurement
Compression gauge	33391 - 02100	 400902	Compression pressure measurement
Socket	58309 - 73100	 400903	For removal/installation of fandrive shaft gear, coupling, injection pump gear, and water pump shaft pulley nut.

Tool name	Part No.	Shape	Use
Torque wrench	32191 - 03100	 400904	
Piston remover	*MM321420*	 403210	*Piston removal*
Slinger installer	37491 - 02100		Oil seal slinger installation (Crankshaft rear side)
Installer guide	37491 - 02200		To be used in combination with slinger installer for oil seal slinger installation (Rear side)
Unit seal installer	37191 - 06300	 400025	Water pump unit seal installation
Water pump pliers	37591 - 03100	 404198	For water pump cover snap ring
Impeller remover	37591 - 03200	 404199	Water pump impeller removal
Ring installer	37791 - 03300	 404200	Pressurized ring insertion for water pump unit seal

Tool name	Part No.	Shape	Use
Ring remover	37791 - 03400	 404608	Water pump unit seal ring removal
Adjustable wrench	F9611 - 15000	 400905	
Jacking bolt	64362 - 68500	 M12 × 1.25 (0.47 × 0.049) - 95 mm (3.74 in.) 404203	
Nozzle tester	41091 - 01500	Nozzle connection pipe M18 × 1.5 (0.71 × 0.059) (Tester side)  400907 M18 × 1.5 (0.71 × 0.059) (Nozzle fitting side)	Nozzle opening pressure measurement
Pliers	49160-91010		
Pliers	49160-90201		
Pliers	49160-90301		
Tool box	49160-90501		

Tool name	Part No.	Shape	Use
Injection coupling gauge	37591-06100		Flywheel and coupling clearance adjustment
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 - 06010		
Projection plate	37598 - 09201		Crankcase ridge depth measurement

Tool name	Part No.	Shape	Use
Head bolt plate	37598-08900		For use in angle-method tightening of head bolts
Head bolt spacer	37598 - 09100		

OVERHAUL INSTRUCTIONS

1. Determination of Overhaul Timing

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

(a) Reduced power

(b) Increased fuel consumption

(c) *Increased engine oil consumption*

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

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

(f) Starting problems

(g) Increased noise from engine parts

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

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

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

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

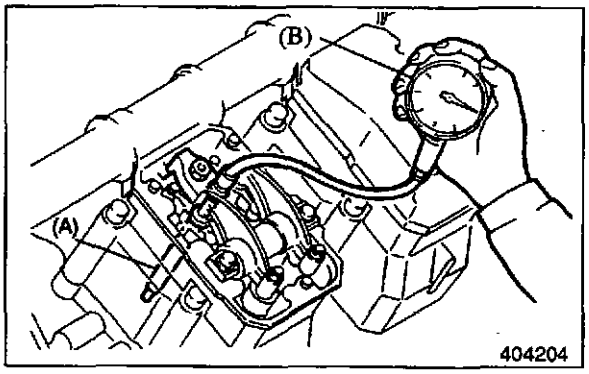
2. Testing the Compression Pressure

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

(2) Attach the adapter (A) (37591-02200) to the adapter and connect pressure gauge (B) (33391 -02100) .

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

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



⚠CAUTION

(a) Measure the compression pressure on all cylinders. It is not a good practice to measure the compression pressure on only two or three cylinders, then make a judgment about the compression on the remaining cylinders.

(b) Compression pressure varies with changes in engine rpm's.
Check engine rpm when measuring compression pressure.

Unit: kgf/cm² (psi) [MPa]

Item	Assembly standard	Repair limit
Compression pressure	18.5 min. (263.2) [1.8]	13 max. (184.9) [1.3]

NOTE

Measure the compression pressure with the engine running at 120 rpm.

⚠CAUTION

(a) Measure the compression pressure at regular intervals to obtain correct data.
(b) The compression pressure will be slightly higher in a new or overhauled engine due to the breaking in the piston rings, valve seats, etc. Pressure will drop slightly after the engine parts are broken in.

ADJUSTMENTS, BENCH TESTING, PERFORMANCE TESTS

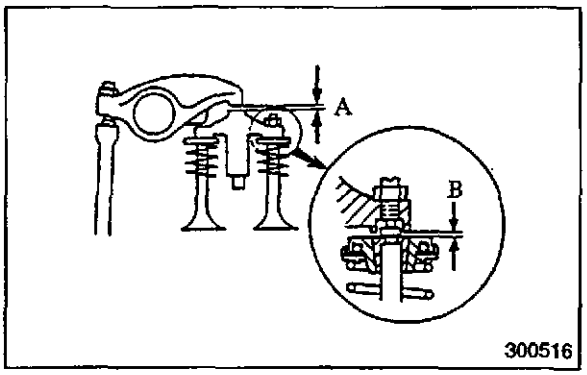
1. Adjustments

1.1 Valve Clearance

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

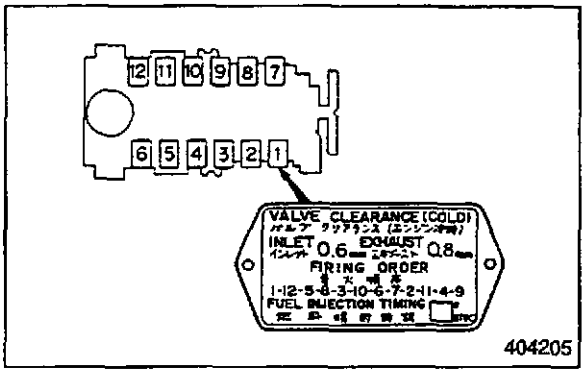
Unit: mm (in.)

Item		Assembly standard
Valve clearance (A)	Inlet valves	0.6 (0.024)
	Exhaust valves	0.8 (0.031)



NOTE

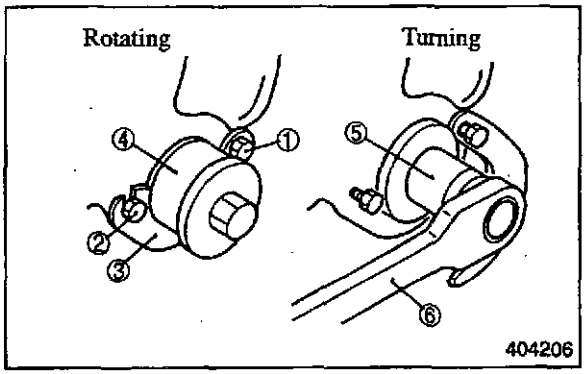
(a) The bridge-to-valve rotator clearance (B) should be more than 1.5 mm (0.059 in.) after the front and rear valve heights have been adjusted. If the clearance is too small, grind the bridge to obtain the specified clearance.
(b) Looking toward the cylinder head, the inlet valves are on the left, the exhaust valves on the right.
(c) The specified clearances for the valves are indicated on the caution plate fitted to the No.1 cylinder rocker cover.



(1) Inspecting valve clearance

(a) 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



NOTE

Note these points when using the turning gear
(a) Loosen bolts ① and ②. Remove the plate ③ from the slot of the shaft ④.
Push the shaft ④ until it reaches its limit.

(b) Make the shaft ④ turn by rotating it with the socket ⑤ and the ratchet handle ⑥. Push down the ratchet handle ⑥ in the normal direction.

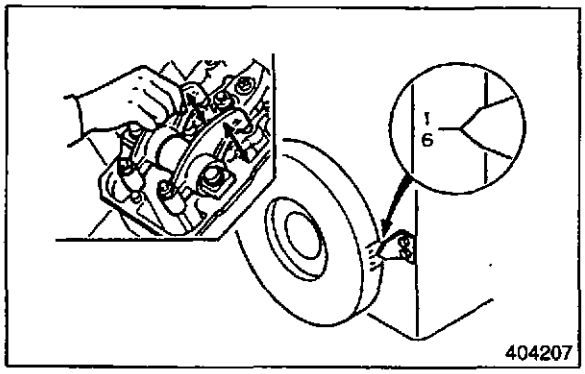
(c) After completing the turn, pull out the shaft ④. Insert the plate ③ into the slot of the shaft ④. Tighten the bolts ① and ②. Check and be sure the plate ③ is inserted into the slot of the shaft ④.

⚠CAUTION

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

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

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

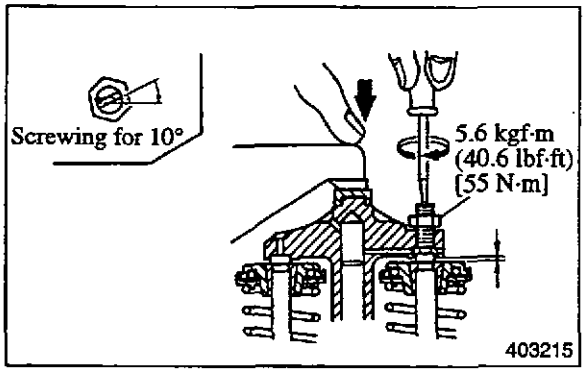


(2) Adjusting front and rear valve heights by the valve bridge

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

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

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



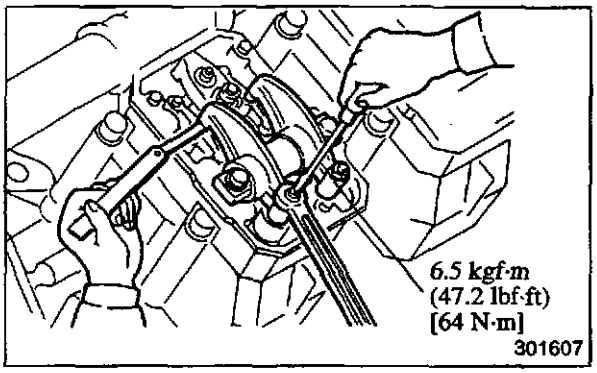
NOTE

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

(3) Adjusting valve clearance

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

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



1.2 Fuel System Priming

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

(1) Fuel filter

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

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

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

(d) Follow the same procedure for both right and left fuel filters.

(2) Fuel injection pumps

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

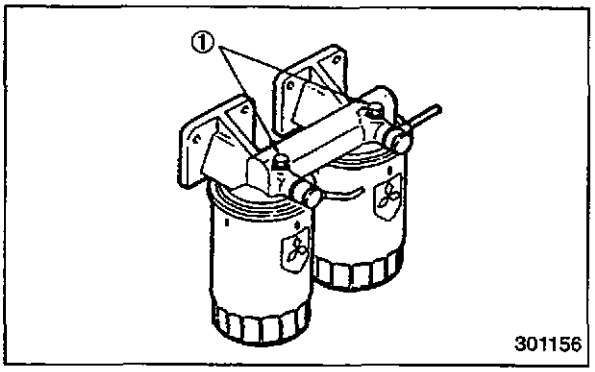
(b) Operate the priming pump handle (2) .

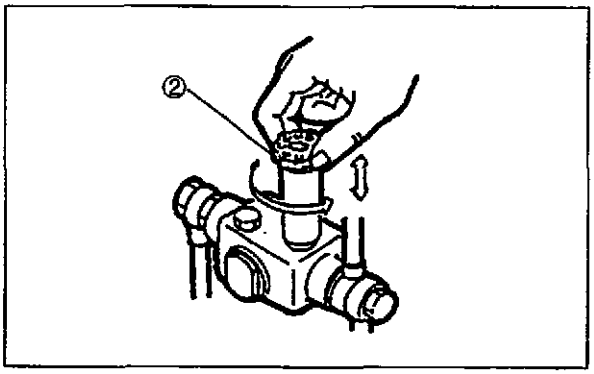
(c) Tighten the air vent plug when fuel flows from the vent hole without bubbles. Lock the priming pump by turning its handle clockwise while pushing it down before tightening the last vent plug.

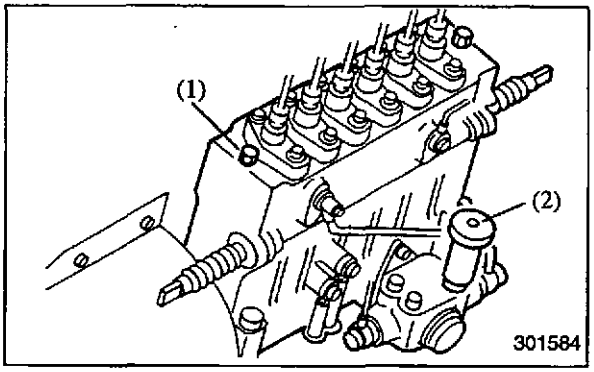
(d) Follow the same procedure for both the right and left injection pumps.

NOTE

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







(3) Tightening priming pump cap

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

NOTE

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

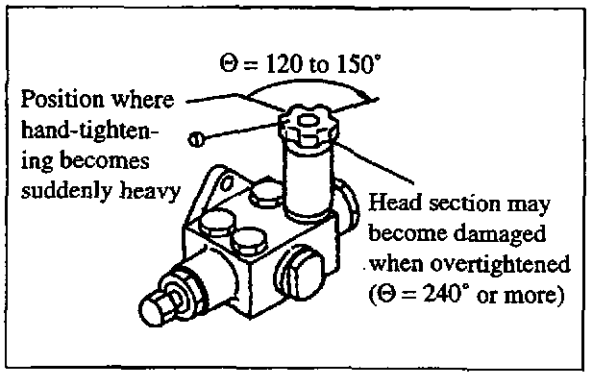
(b) After step (a), further turn the priming pump cap by 120 to 150° using a wrench.

NOTE

After step (a), the priming pump cap should be loose enough to rotate 70 to 90° more when turned forcibly by hand.

CAUTION

Be sure to tighten the priming pump cap according to the specified angle (Θ= 120 to 150°). If the priming pump cap is not tightened firmly, engine operations can result in the wear of internal threads. This can cause the priming pump cap to eject and fuel to flow out.
If the priming pump cap is tightened with excessive force (Θ= 240° or more), the head section of the priming pump can become damaged.

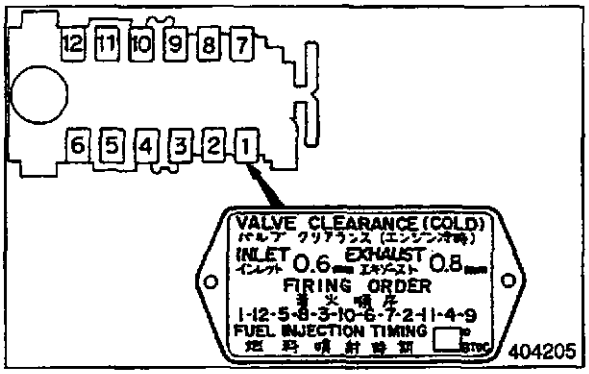


1.3 Fuel Injection Timing Adjustment

Right Hand Injection Pump

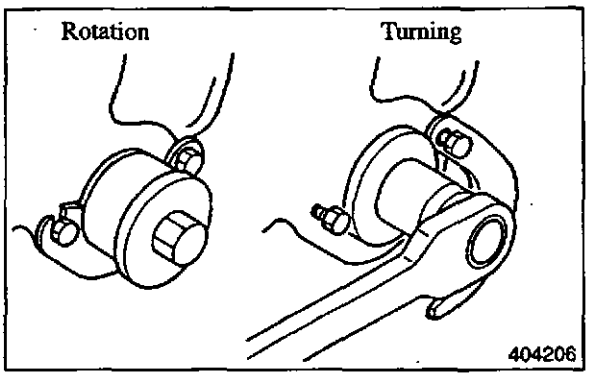
(1) Fuel injection timing and indication

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

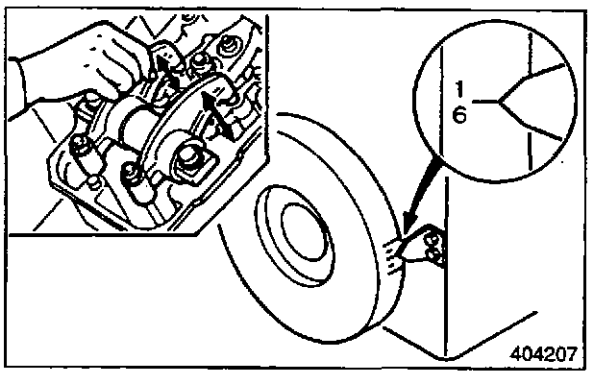


(2) Confirming the position of the No. 1 piston's top dead center on the compression stroke

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



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



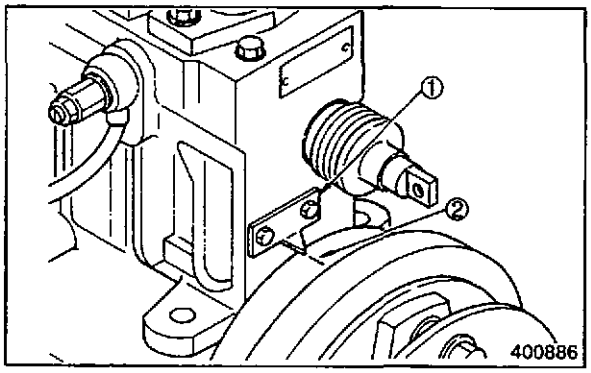
(c) Move the No. 1 cylinder inlet and exhaust valve rocker arms up and down to make sure that they are not being pushed up by their push rods.

⚠CAUTION

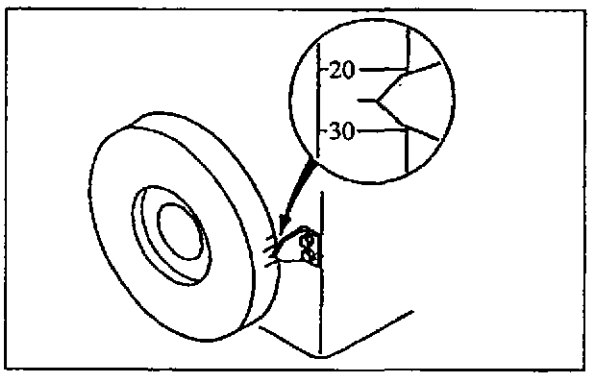
Do not confuse the top dead center on the compression stroke for No. 1 cylinder with that for the No. 6 cylinder.

(3) Inspecting fuel injection timing

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



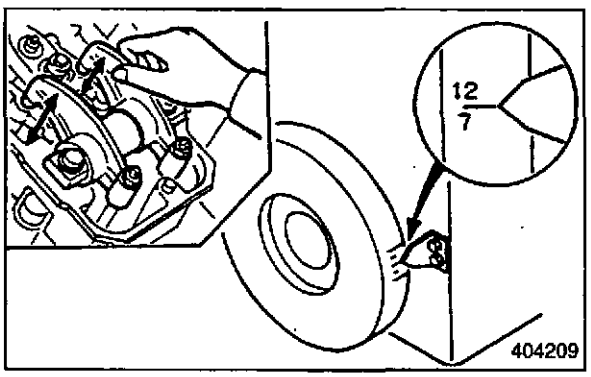
(b) Read the degree angle (injection timing) on the scale of the damper, indicated by the pointer minus (-) mark on the scale.
BTDC on the caution plate means "Before Top Dead Center."



(4) Adjusting fuel injection timing

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

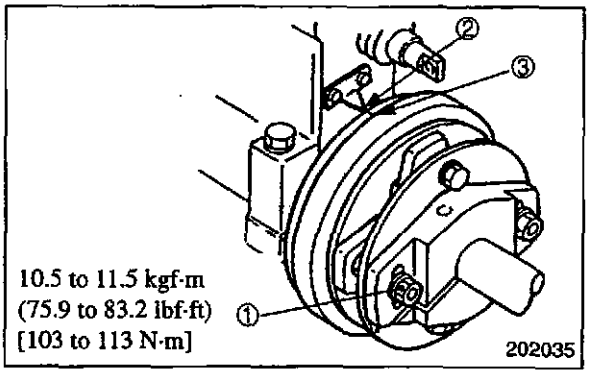
(b) Loosen the coupling bolts ①, then displace the injection pump to align the pointer ② on the pump case with the timing mark ③ on the coupling. Tighten one bolt to the specified torque. After turning the crankshaft, tighten the other bolt.



(c) Inspect the timing again by cranking the engine.

Left-hand Fuel Injection Pump

On this pump, the position where the pointer is aligned with the index numbers "7•12" on the damper is top dead center on the compression stroke of the No. 7 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) The idling speed (no-load) and maximum speed are set for each engine at factory bench testing, then the set bolts are sealed. These settings are to be inspected and adjusted at Mitsubishi service shops only.

(b) After adjusting the governor be sure to seal the stopper.

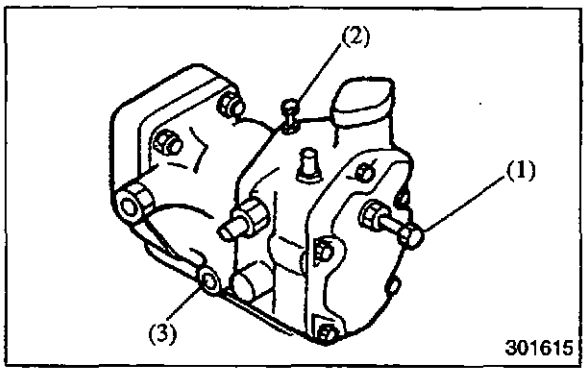
(c) The stoppers are specified to be sealed. Whether the seals are intact or not has important bearing on the validity of claims under the warranty.

(d) When inspecting and adjusting these settings, be ready to operate the engine stop lever manually if the engine overruns.

NOTE

Prior to inspection and adjustment, warm up the engine thoroughly until coolant and oil temperature rise to 70°C (158°F).

PSG Governor



(1) Inspecting and adjusting idling speed setting

(a) Be sure that the speed control lever is in the idling position, then measure the engine speed (rpm).

(b) If idling speed is out of the specified range, reset it with the adjust screw (1) .

(2) Inspecting and adjusting no-load maximum speed setting

(a) Move the speed control lever to maximum speed, then measure the engine speed (rpm).

(b) If the maximum speed is out of the specified range, reset it with the governor set bolt (2) .

(c) Manually change the engine speed to test the governor for response, verifying the ability of the governor to sense changes in speed and to regulate it promptly to the steady-rate speed.

(3) Correcting hunting

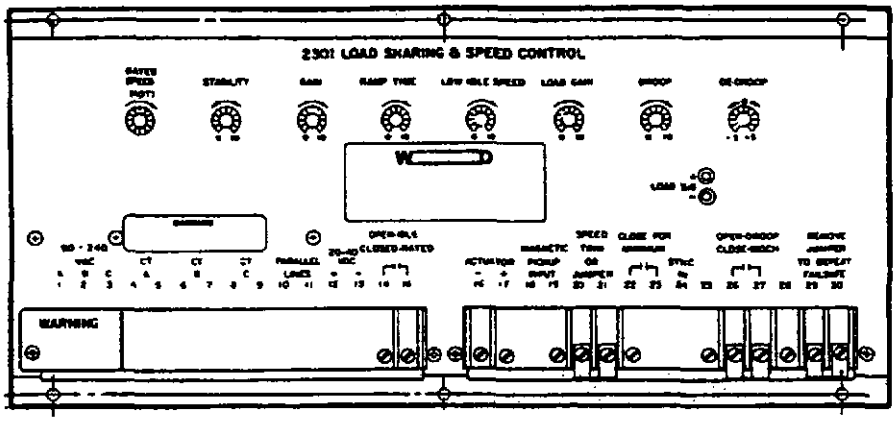
(a) If the engine hunts, adjust it with the needle valve (3). Open the needle valve by turning it counterclockwise (2 to 3 rotations) until the engine hunts. Keep the engine hunting for about 30 seconds, until air is vented from the governor.

(b) Slowly close the needle valve by turning it clockwise until the engine stops hunting.

(c) If the needle is closed too far, this will delay speed regulation with respect to changes in load. Keep the valve backed off at least 1/4 rotation from the fully closed position.

(d) Seal each set bolt.

Woodward 2301 and 2301A Load Sharing & Speed Control Devices (for EG-3P Governors)



400912

(1) Adjusting idling speed setting

(a) Open the external lamp switch (terminals 14-15). The engine speed will drop to the speed which is set by the "LOW IDLE SPEED" potentiometer.

(b) Set the "LOW IDLE SPEED" potentiometer to obtain the specified idling speed.

(c) Make sure that the engine speed is above the "minimum injection" quantity position of the control rack, and is governed as set by the "LOW IDLE SPEED" potentiometer.

(d) If the engine speed fluctuates, reset the "GAIN" and "STABILITY" potentiometers.

(2) Adjusting speed setting (no-load rated speed)

(a) *Close the external lamp switch (terminals* 14-15).

(b) Set "RATED SPEED" with the potentiometer so the engine runs at the rated speed.

(c) If engine speed fluctuates, reset "GAIN" and "STABILITY" potentiometers.

(3) Setting "GAIN" and "STABILITY" potentiometers

(a) Response time of the governor can be increased with larger gain. To increase the gain for this purpose, turn the "GAIN" potentiometer clockwise while you observe the voltmeter until the engine just lacks stability.

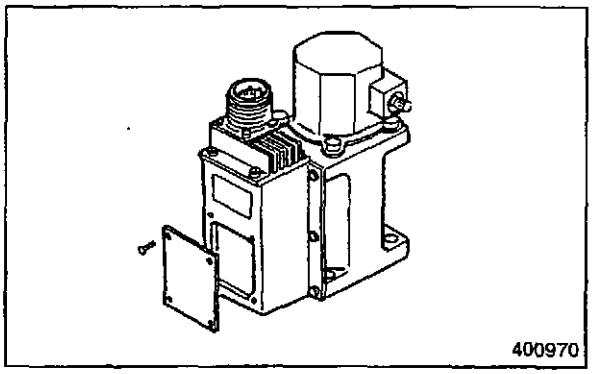
(b) Turn the "STABILITY" potentiometer clockwise or counterclockwise until the engine gains stability.

(c) To verify engine (governor) stability, change the load on the engine in steps, or quickly move the fuel control linkage. If the stability cannot be gained by turning the "STABILITY" potentiometer, turn "GAIN" counterclockwise. If low pitch hunting occurs, turn the "GAIN" potentiometer clockwise.

⚠CAUTION

To obtain the optimum performance, turn the "GAIN" potentiometer clockwise as far as possible. Stop turning just before the engine lacks stability.

Barber-Colman DYNA 1 Governor



(1) Adjusting speed setting

(a) Turn the power source switch OFF, then stop the engine.

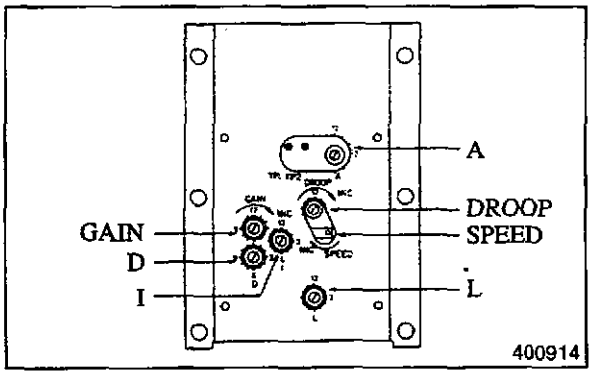
(b) Remove the top cover from the controller, then make sure that the potentiometers are set as shown below.

Potentiometer	Position
A	3 o'clock
GAIN	9 o'clock
D	10 o'clock
I	8 o'clock
L	10 o'clock (adjusted at factory)

(c) Turn the power source and starter switches ON, then start the engine.

(d) Turn the "SPEED" potentiometer to within 20 rotations until the desired engine speed is obtained. This potentiometer can be turned clockwise to increase the speed, or counterclockwise to decrease it. It has no stopper for limiting rotation in either direction.

(e) Set the indicated horsepower with the rack set bolt.



Potentiometer

(2) Correcting hunting

(a) The "A" potentiometer is to be set when the engine is in the no-load condition.
Slowly turn this potentiometer clockwise until the actuator lever quickly vibrates (hunting occurs). Slowly turn it counterclockwise until hunting stops.

⚠CAUTION

If you fail to stop hunting, this can damage the actuator.

(b) If the actuator fails to gain stability (hunting does not stop), slowly turn the "GAIN" potentiometer counterclockwise. If the actuator is stabilized, slowly turn the "GAIN" potentiometer clockwise until hunting starts, then turn it slowly clockwise until hunting stops.

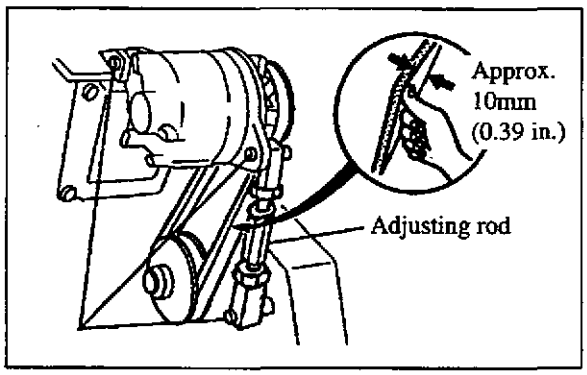
(c) After setting "GAIN", "A", and "D" potentiometers, turn the power source switch OFF. When engine speed is reduced to about 1/2, again turn the power source switch ON. If the engine speed overshoots aumps) the setting, turn the "I" potentiometer counter-clockwise. If the time required to restore the set speed is too long, turn "I" clockwise. Repeat this procedure with the engine running under no load.

(d) After "A", "D", "DROOP", and "GAIN" the set speed will vary slightly. Use the "SPEED" potentiometer to set speed correctly. If "DROOP" has been turned in the speed direction (clockwise), turn "A" slightly counterclockwise and "GAIN" clockwise.

(e) Install the top cover to the controller, then seal the cover bolts.

1.5 Inspecting and adjusting alternator drive belt

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



NOTE

Be sure the drive belt tension is not excessively tight.

Unit: mm (in.)

Item	Assembly Standard
Belt tension	10-15 (0.39-0.59)

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. For this cranking, do not supply fuel to 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 "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 5 to 6.5 kgf/cm^2 (71.1 to 92.5 psi, 0.49 to 0.64 MPa) at rated speed or over 2 to 3 kgf/cm^2 (28.4 to 42.7 psi, 0.20 to 0.29 MPa) at idling speed.

(2) **Coolant temperature** should be 70-90°C (158-194 °F).

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

(4) **Leakage** of oil, coolant, fuel, especially oil leakage from turbocharger lubricating oil pipe connections.

(5) **Knocking** should die away as coolant temperature rises. No other defects should be found.

(6) **Exhaust color, abnormal odors**

2.3 Bench Testing (Dynamometer) Conditions

Here is a summary table of bench testing conditions.

Step	Speed (rpm)	Load (PS)	Time (min.)
1	Idling	No load	5
2	1000	No load	5
3	1200	No load	10
4	Rated (Varies depending on specifications)	25%	10
5	"	50%	10
6	"	75%	30
7	"	100%	20

Rated: Varies according to specifications.

2.4 Inspection and Adjustments After Bench Testing

(a) Adjusting valve clearance

(b) Adjusting injection timing

(c) Tightening external bolts and nuts

3. Performance Tests

There are various performance test procedures, and here the procedures for construction machinery [JIS DI005 (1986)] are described. Other test items may be required on application. Engine performance is judged with integrated test results.

3.1 Standard Equipment

The cooling fan, air cleaner, and alternator are standard engine equipment to be tested.

3.2 Test Items

(1) Fuel consumption test

(2) No-load maximum speed test

(3) No-load minimum speed test

3.3 Test Methods

(1) Fuel consumption test

(a) Engine speed (rpm)

(b) Fuel injection quantity

(c) Engine output

(2) No-load maximum speed test

For this test, the governor should be set for no-load maximum speed.

(3) No-load minimum speed test

(a) The control lever should be set to the stable minimum speed position. "Stable minimum speed" means minimum speed at which the engine rpm's can be quickly dropped from maximum rpm's without stalling.

(b) The no-load minimum speed is the specified rpm.

(4) During performance testing, inspect for leakage of gas, coolant, lubricating oil, or fuel, and for noise or hunting. Make adjustments as needed.

(5) Adjusting engine output

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

Item	Condition
Atmospheric pressure	750 mmHg
Temperature	25°C (77°F)
Atmospheric vapor pressure	11.4 mmHg

Measured axis output and axis torque should be calibrated by the coefficient obtained from the following formula.

$$k = \left\{ \left(\frac{P_0}{p}\right) \cdot \left(\frac{\theta}{\theta_0}\right)^{0.7} \right\}^{fm} \qquad \text{(Non-charged)}$$

$$k = \left\{ \left(\frac{P_0}{p}\right)^{0.7} \cdot \left(\frac{\theta}{\theta_0}\right)^{1.5} \right\}^{fm'} \qquad \text{(Turbocharged)}$$

Po : Measured atmospheric pressure (mmHg)
p : Standard dry atmospheric pressure (743 mmHg, 99 KPa)
θ : Measured temperature (°C + 273)
θ_0 : Standard atmospheric temperature (298 K, 25°C (77°F))
fm, fm' : Main fuel consumption coefficient

$$fm = 0.036 \frac{q}{r} - 1.14 \left(40 \le \frac{q}{r} \le 65\right)$$

$$= 0.3 \left(\frac{q}{r} \le 40\right)$$

$$= 1.2 \left(65 \le \frac{q}{r}\right)$$

q : Fuel supply volume per stroke volume, single stroke (mg/ℓ cycle)

r : Compression ratio of charger (r=1 for non-charged) where k is in the range:
$600 \le p \le 825$ mmHg {$80 \le p \le 110$ KPa}
$10 \le \theta - 273 \le 40$°C (104°F) {$283 \le \theta \le 313$ K}
$0.9 \le k \le 1.1$

If k is out of the above range, and p and θ are within the range, then the calibrated output value is recorded along with relative test conditions.

ENGINE ACCESSORY REMOVAL AND INSTALLATION

This section explains procedures and tips for removal and installation of the accessories, 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 cocks of both sides of the crank case and drain the coolant.

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

Oil capacity: approx. 150 liters (39.6 U.S.gal)

⚠WARNING

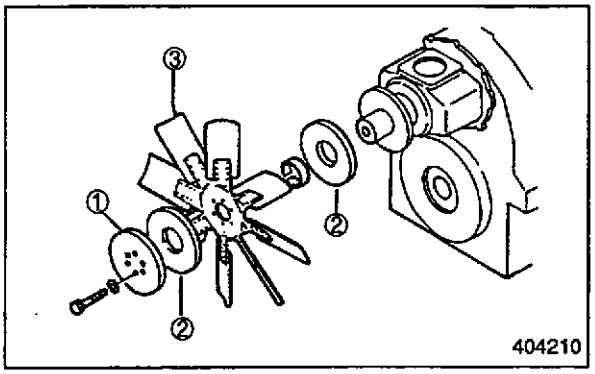
Hot engine oil can cause serious burns. Use caution when you drain the oil.

2. Removing Engine Accessories

(1) Removing the fan

(a) Unscrew the fan mounting bolts and the plate ①, then remove the fan ③ and friction rubbers ②.

Weight: approx. 40 kg (88.2 lb)

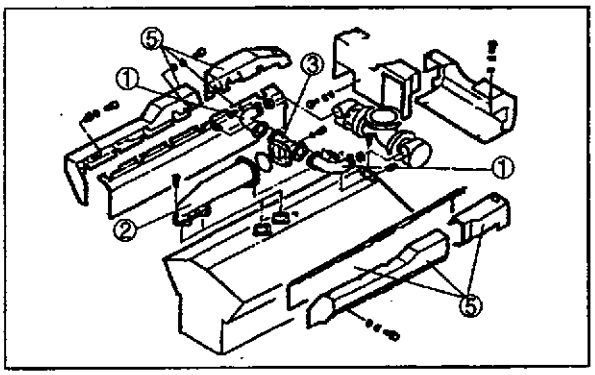


(2) Removing the air duct and insulator

(a) Remove right and left air ducts ①.

(b) Remove duct stays ②, then remove rear air ducts ③ and front ducts ④.

(c) Remove all insulators ⑤.



(3) Removing the turbocharger

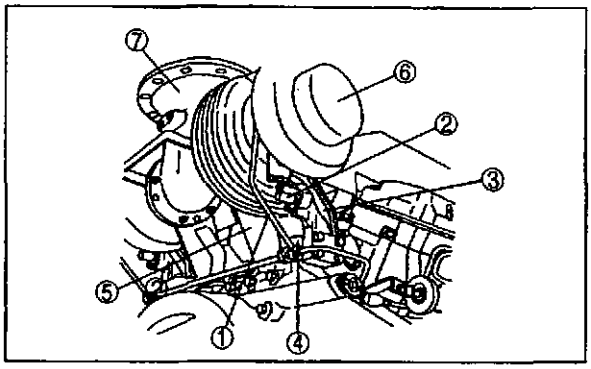
(a) Disconnect the turbocharger lubricating oil pipes ①.

(b) Unscrew the bolts of the turbocharger at the side of the exhaust manifold.

(c) Remove the connector ② and the mounting brackets ③and ④.

(d) Remove the exhaust pipe stay ⑤, the turbocharger ⑥ and the exhaust pipe ⑦.

Weight:	Turbocharger approx. 50 kg (110.2 lb) Exhaust pipe approx. 18 kg (39.7 lb)



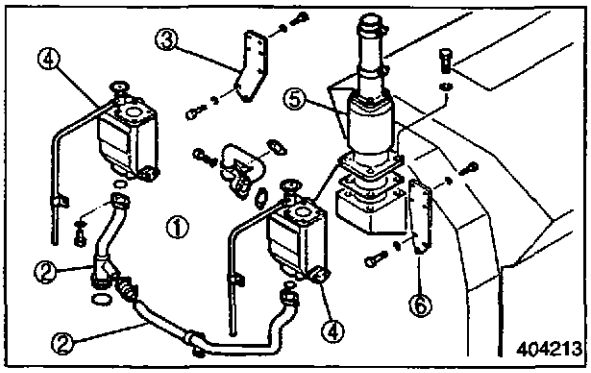
(4) Removing thermostat cases and breather

(a) Remove the water pipe ①.

(b) Remove the water by-pass pipe ②.

(c) Remove the thermostat case mounting bracket ③ and the thermostat case ④.

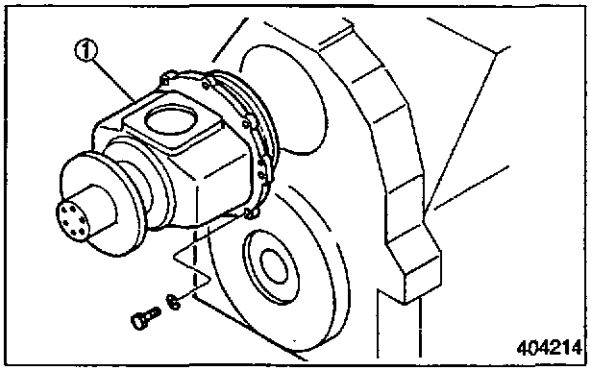
(d) Unscrew the breather mounting bolts and remove the breather ⑤.



(5) Removing the fan drive

Unscrew the fan drive case mounting bolt, then remove the fan drive ①.

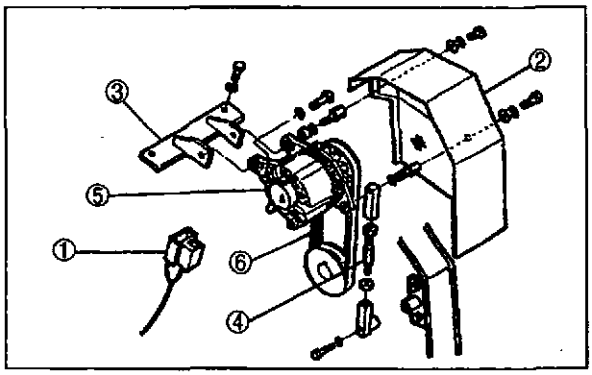
Weight: approx. 45 kg (99.2 lb)



(6) Removing the alternator

(a) Disconnect the harness ①. Remove the belt cover ②, alternator mounting bracket ③, and the belt adjust turn buckle ④. Remove the alternator ⑤.

(b) Remove the V-belt ⑥.

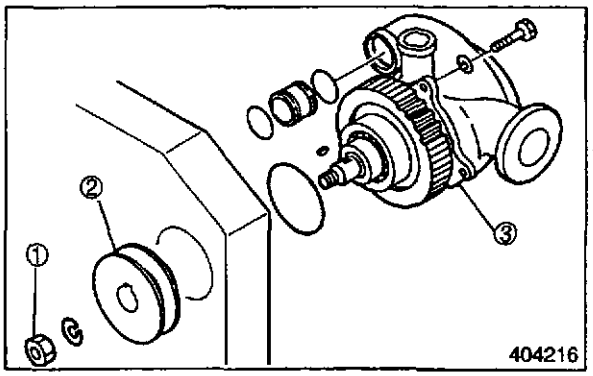


(7) Removing the water pump

(a) Remove the nut ① at the end of the water pump shaft. Remove the alternator driving pulley ②.

(b) Remove the water pump ③ by unscrewing the bolts and nuts.

Weight: approx. 33 kg (72.8 lb)

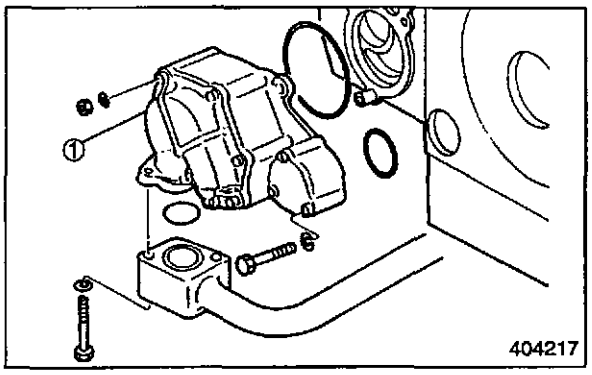


(8) Removing the oil pump

(a) Unscrew the connecting bolt the oil pipe under the oil pump.

(b) Unscrew the oil pump mounting bolt and nut, then remove the oil pump ①.

Weight: approx. 23 kg (50.7 lb)



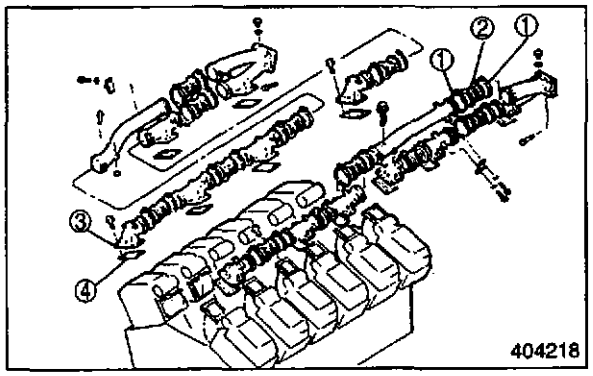
(9) Removing the exhaust manifold

(a) Remove the coupling ① and remove the joint ②.

(b) Unscrew the manifold mounting bolt, then remove the manifold ③ and the gasket ④.

NOTE

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



(10) Removing the air cooler

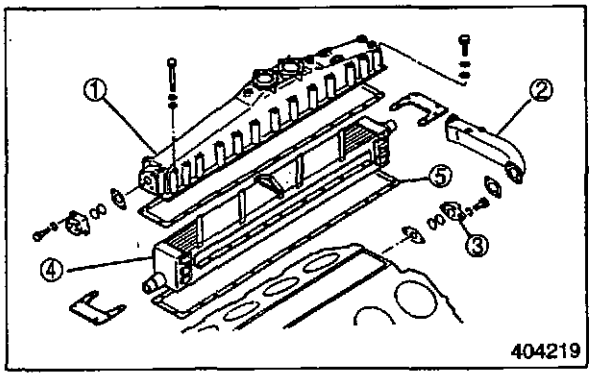
(a) Unscrew the air cooler case mounting bolts and the air cooler case ①.

(b) Disconnect the water pipe ② and connector ③.

(c) Lift the air cooler element ④ and slide it out.

Weight: approx. 69 kg (152.1 lb)

(d) Remove the packing ⑤.

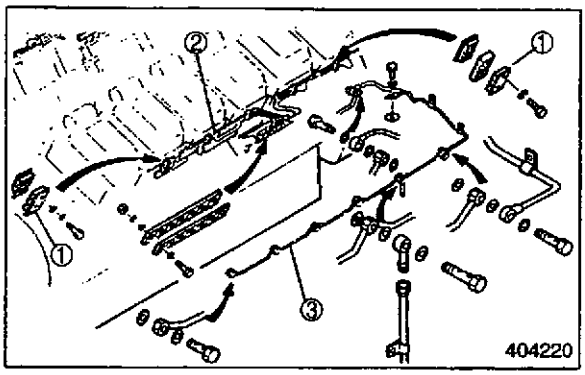


(11) Removing the injection pipe and fuel leak-off pipe

(a) Remove the injection pipe clamp ①.

(b) Remove the injection pipe ②.

(c) Remove the fuel leak-off pipe ③.



NOTE

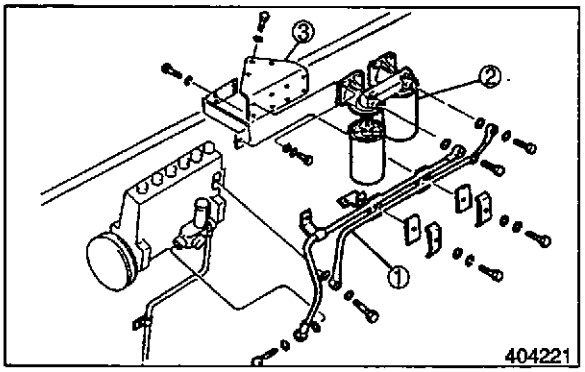
Cover the openings of the injection pump, the nozzle inlet connector, and the injection pipe with rubber caps to prevent dust from entering the fuel line.

(12) Removing the fuel filter

(a) Disconnect the fuel pipe ①.

(b) Unscrew the filter mounting bolts, then remove the fuel filter ②.

(c) Unscrew the filter bracket mounting bolts, then remove the filter bracket ③.



(13) Removing the left and right fuel injection pumps

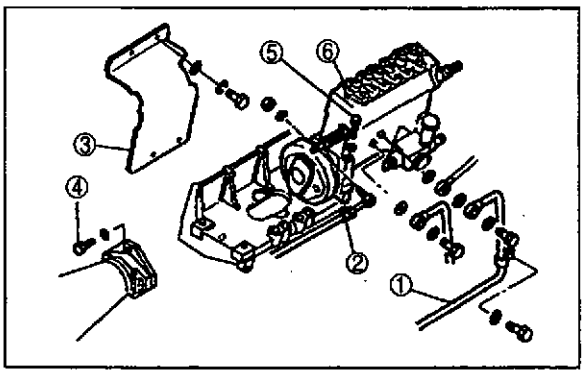
(a) Remove the injection pump drive case lubricant oil pipe ①.

(b) Remove the ball joint mounting nut, then disconnect the link ② from the governor.

(c) Remove the coupling cover ③.

(d) Unscrew the two coupling bolts ④.

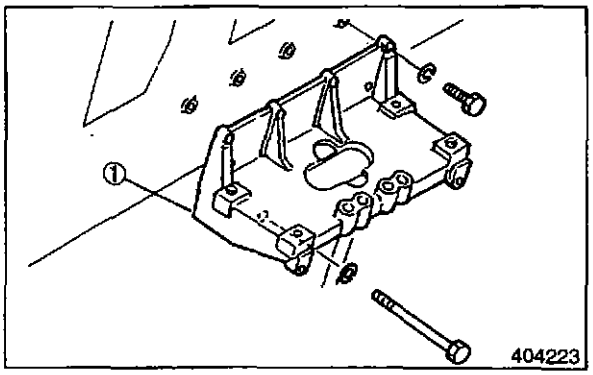
(e) Remove the pump mounting bolt ⑤. Remove the injection pump, complete with the coupling by lifting it up. Leave the laminate plate on the drive shaft.



Weight: approx. 60 kg (132.3 lb)

(14) Removing the injection pump bracket

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



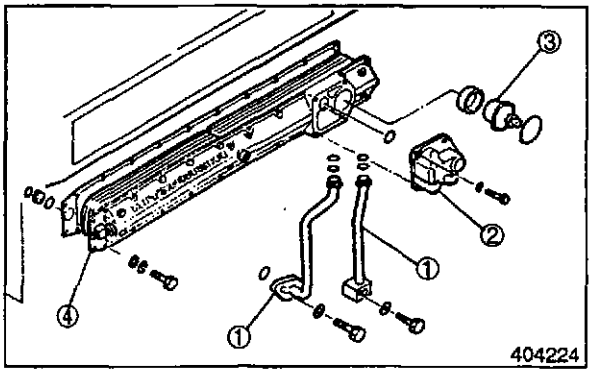
(15) Removing the right oil cooler

(a) Disconnect the oil pipe ① from the oil pan and the oil cooler inlet connector.

(b) After unscrewing the oil cooler inlet connector mounting bolt, disconnect connector ②.

(c) Pull out the oil thermostat ③ from the oil cooler.

(d) Unscrew the oil cooler mounting bolt, then remove the oil cooler ④.



Weight: approx. 20 kg (44.1 lb)

(16) Removing the left oil filter and oil cooler

(a) Disconnect harness from the oil filter alarm.

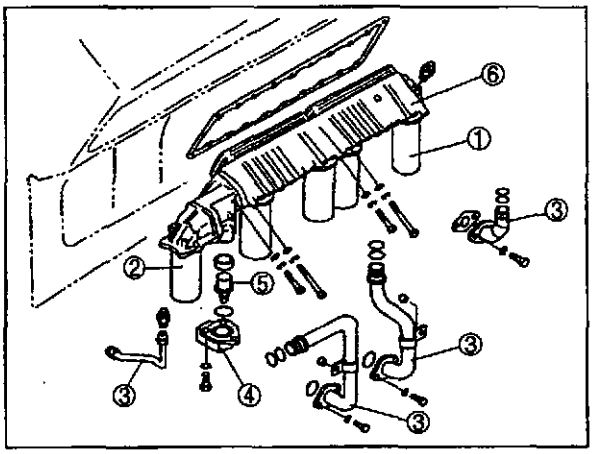
(b) Remove the four oil filter elements ① and the by- pass filter element ②.

(c) Disconnect the oil pipe ③.

(d) Unscrew the oil cooler inlet connector mounting bolt, and disconnect the connector ④.

(e) Remove the oil thermostat ⑤.

(f) After unscrewing the oil filter bracket mounting bolt, remove the filter bracket ⑥ complete with the oil cooler.



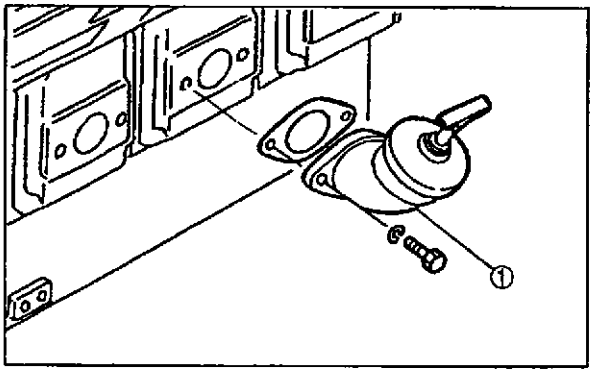
Weight: approx. 45 kg (99.2 lb)

NOTE

Before removing the oil filter element ① and the by-pass filter element ②, make a hole in the bottom of the filter to drain engine oil.

(17) Removing the oil filler

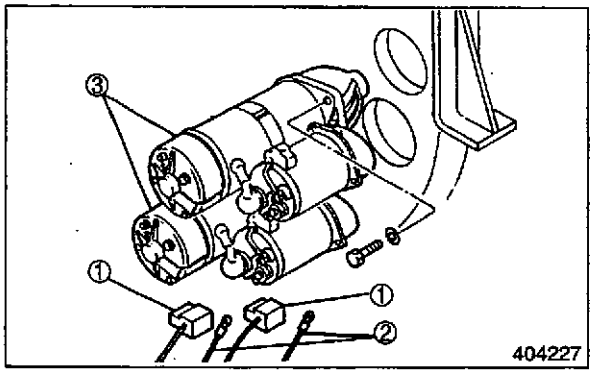
Unscrew the oil filler mounting then remove the oil filler ①.



(18) Removing the starter

Disconnect the harnesses ① and the starter ② by unscrewing the starter ③.

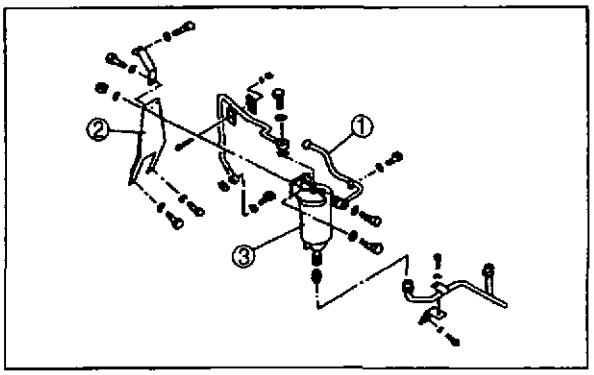
Weight. approx. 19 kg (41.9 lb)



(19) Removing the oil filter for the Woodward governor

(a) Remove the lubricating oil pipe ①.

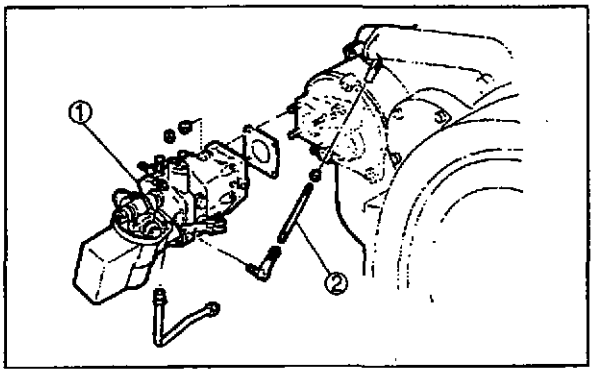
(b) Remove the oil filter mounting bracket ② and the oil filter ③.



(20) Removing the Woodward governor

(a) Unscrew the link ① from the Woodward governor.

(b) Unscrew the governor mounting nuts, then remove the Woodward governor ②.



3. Engine Accessory Installation

To install the engine accessories, follow the removal procedures in reverse order. After installation, service them as follows.

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

(b) Refill the cooling system with coolant.

(c) For easy engine starting, pour engine oil for the governor into the oil filter from its vent plug.

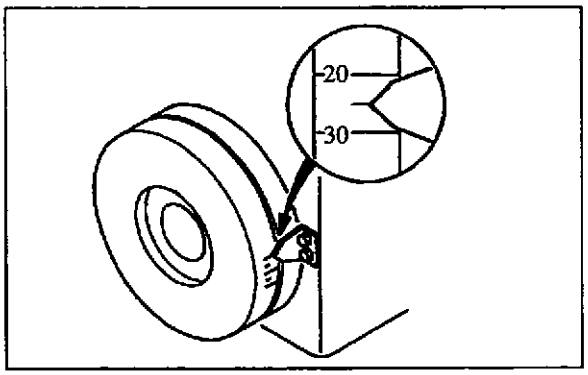
(d) Check each pipe connection for oil or coolant leaks.

(e) Prime the fuel system.

(f) Install the fuel injection pump. After installing the fuel injection pumps, be sure to inspect and adjust the injection timing.

Fuel Injection Pump Installation:
Right Injection Pump

(a) Turn the crankshaft in the normal direction to align the timing marks "1•6" on the viscous damper with the pointer.



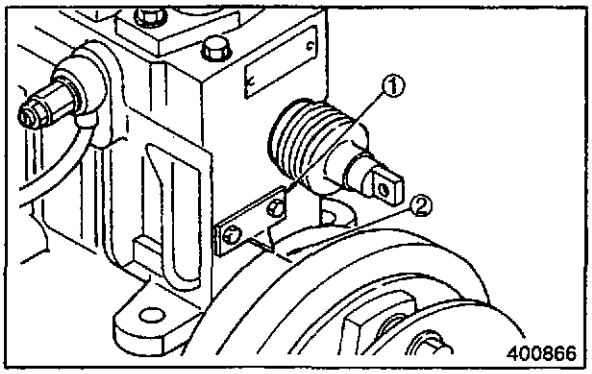
(b) Move the No. 1 cylinder inlet and exhaust valve rocker arms to make sure that they are not being pushed up by their push rods.

(c) Turn the crankshaft once about 60° in reverse. Turn it a little at a time in the normal direction to align the timing mark on the damper with the pointer.

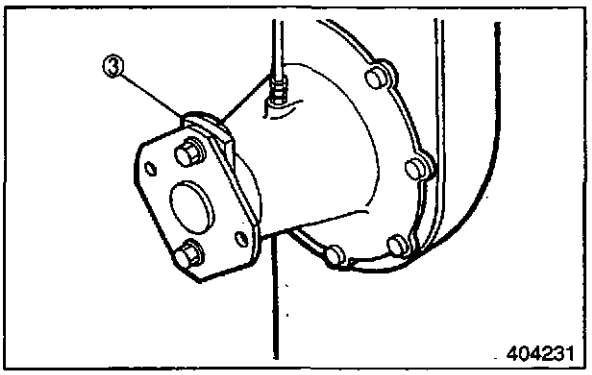
NOTE

Verify the injection timing by referring to the caution plate attached to the No. 1 rocker cover.

(d) Install the coupling to the injection pump, then align the pointer ① on the pump case with mark ② on the coupling.



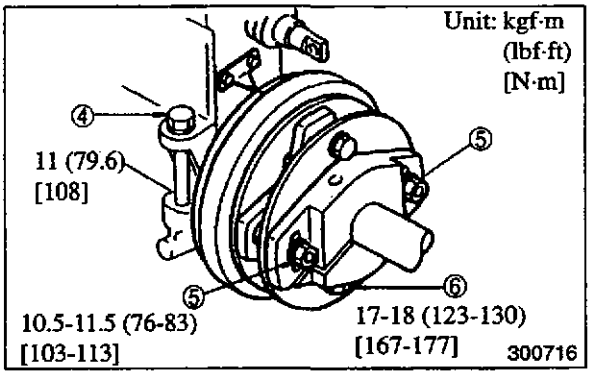
(e) Connect the pump drive coupling ③ to the drive shaft. Loosen the coupling mounting bolts enough.



(f) Put the pump case on the pump bracket, then tighten the mounting bolts ④ temporarily.

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

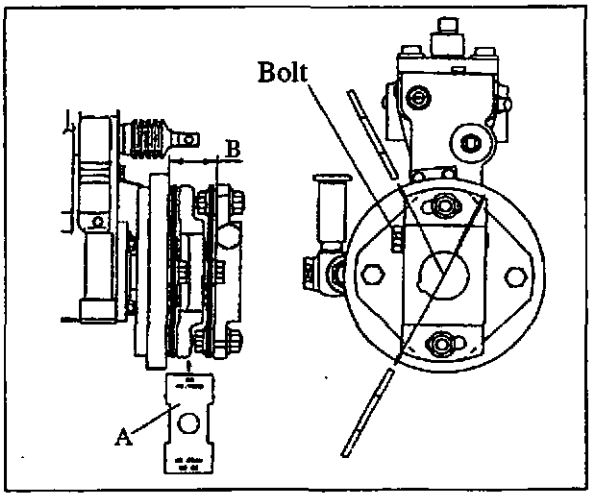
(h) Tighten the two coupling bolts ⑤ temporarily. Using injection coupling gauge (A) (87591-06100), adjust the clearance between the flywheel and coupling.



1) Insert the side of the gauge marked with "GO" to determine clearance (B) between the flywheel and coupling, then tighten the bolt.

2) Make sure the side of the gauge marked with "NO GO" does not enter the gap. Only the side marked with "GO" should fit into the gap. (Clearance between flywheel and coupling: 49±0.25 mm)

3) If the inspection in step 2) shows that the clearance is not 49±0.25 mm, loosen the bolt and readjust the clearance.



(i) Tighten the pump mounting bolt ④ firmly. Be sure that the coupling mark ② aligns with the pump case pointer ①. Tighten the two connecting nuts ⑤ as specified.

(j) Tighten the shaft tightening bolt ⑥ of the coupling as specified.

NOTE

Apply equal and specified torques on each coupling bolt. Coupling damage or wrong injection timing can be caused by improper tightening of bolts.

Fuel Injection Pump Installation:
Left Injection Pump

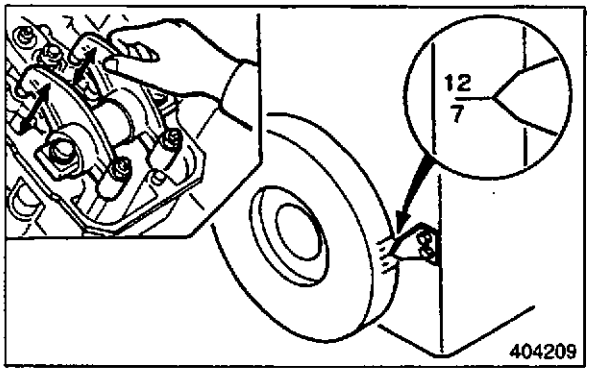
(a) To install this pump, align the timing marks "7•12" on the viscous damper with the pointer. At this position make sure that both inlet and exhaust valves of the No. 7 cylinder piston is at top dead center of the compression stroke.

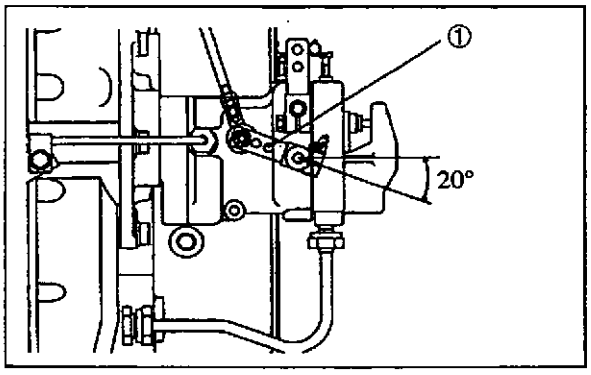
(b) For subsequent steps, follow the procedures described for the right injection pump above.

Adjusting Injection Quantities of Left and Right Pumps

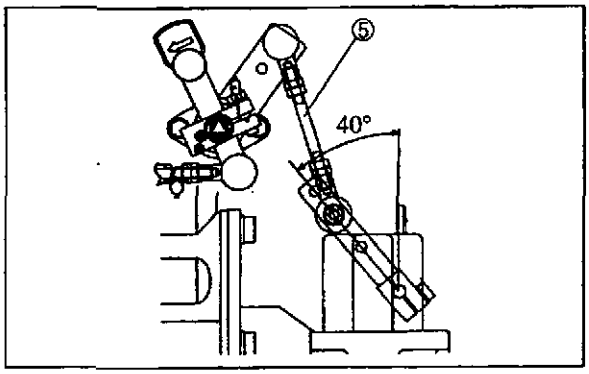
(a) To adjust, push in the racks of the pumps all the way to the non-injection position, then turn the adjusting rod of the linkage of the left injection pump.

(b) After adjusting, tighten the lock nut of the adjusting rod and seal it with a wire.

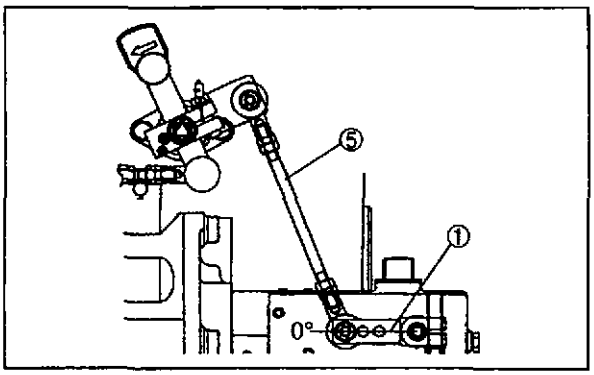




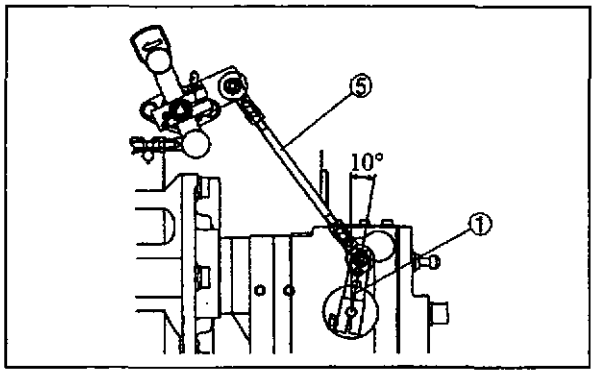
PSG type



Barber Coleman type

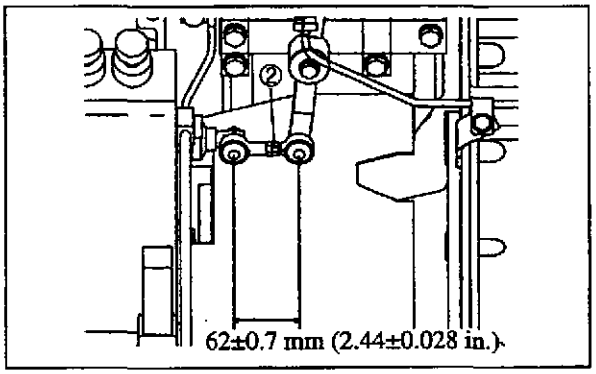


EG-3P type



EG-B2P type

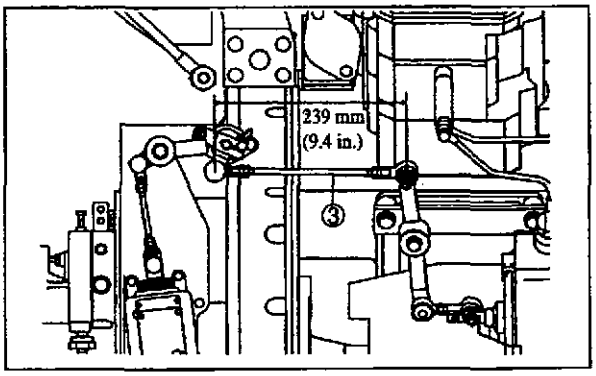
(c) Install links ② on the right- and left-hand banks, making sure that the installation length is 62±0.7 mm (2.44±0.028 in.).



(d) Install link ③ on the right-hand bank.

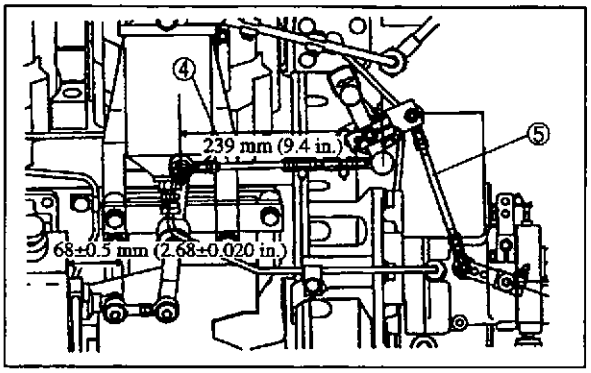
NOTE

Link ③ has a fixed length of 239 mm (9.4 in.).



(e) Install link ④ on the left-hand bank, making sure that the length is 239 mm (9.4 in.) (same as for the right-hand bank).

(f) Install rod ⑤ while adjusting the length of the rod to achieve a distance of 68±0.5 (2.68 ±0.020 in.) mm between the rack end surface and the pump case end surface.



NOTE

Make sure more than 8 mm (0.31 in.) of threads of the rod and ball joint are engaged on both ends.

(g) Check to make sure the rack stroke is approximately 2 mm (0.08 in.) when stopper lever ⑥ is pulled fully to the STOP side.

(4) Adjusting and inspecting stop solenoid and start rack limit solenoid

[RUN-OFF solenoid]

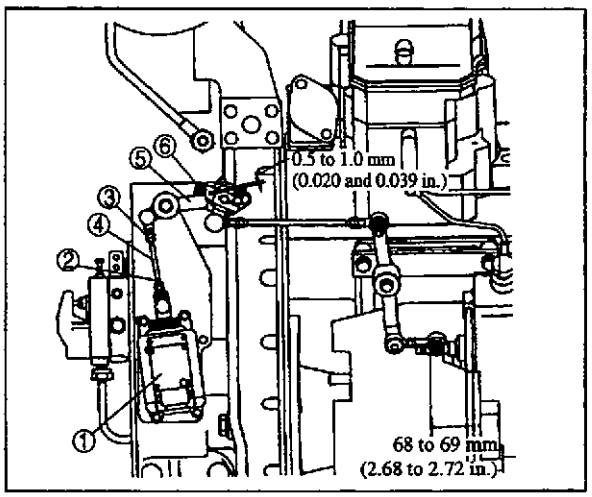
< Adjustment >

(a) Supply electric current to solenoid ① (contracted condition).

(b) Loosen nuts ② and ③.

(c) Rotate rod ④ to adjust the clearance between lever ⑤ and follower ⑥ to between 0.5 and 1.0 mm (0.020 and 0.039 in.).

(d) Tighten nuts ② and ③.



RUN-OFF solenoid

< Inspection >

(e) Cut off electric current to solenoid ① (extended condition).

(f) After adjusting the exhaust temperature for the right- and left-hand banks, operate the engine at high idling speed.

(g) Supply electric current to solenoid ① (contracted condition).

(h) After the engine stops completely, check to make sure the distance between the rack end surface and pump case end surface is 68 to 69 mm (2.68 to 2.72 in.) on both banks.

NOTE

It should be noted that the engine may not stop if the distance between the rack end surface and pump case is more than 70 mm (2.76 in.).

[RUN-ON solenoid]

< Adjustment >

(a) Cut off electric current to solenoid ① (extended condition).

(b) Loosen bolt ②.

(c) Move solenoid ① to adjust the clearance between adapter ② and follower ④ to between 0.5 and 1.0 mm (0.020 and 0.039 in.).

(d) Tighten bolt ②.

< Inspection >

(e) Supply electric current to solenoid ① (contracted condition).

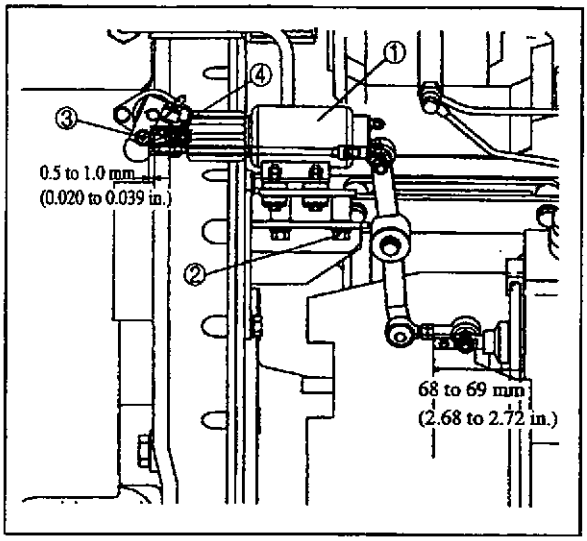
(f) After adjusting the exhaust temperature for the right- and left-hand banks, operate the engine at high idling speed.

(g) Cut off electric current to solenoid ① (extended condition).

(h) After the engine stops completely, check to make sure the distance between the rack end surface and pump case end surface is 68 to 69 mm (2.68 to 2.72 in.) on both banks.

NOTE

It should be noted that the engine may not stop if the distance between the rack end surface and pump case is more than 70 mm (2.76 in.).



RUN-ON solenoid

[RUN-ON start rack limit solenoid]

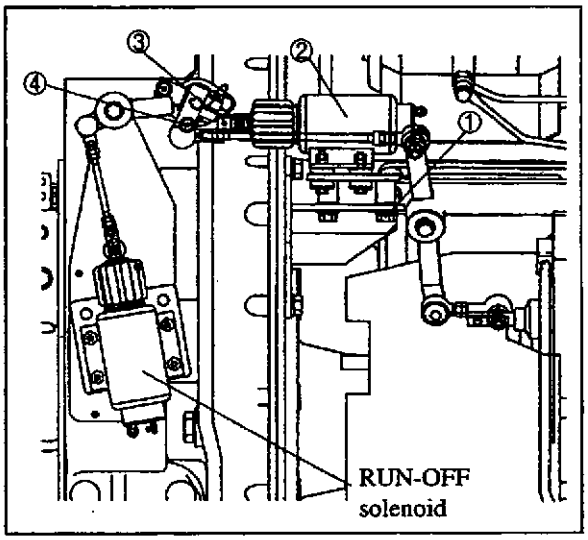
< Adjustment >

(a) Loosen bolt ①.

(b) Cut off electric current to start rack limit solenoid ② (extended condition).

(c) With the distance between the rack end surface and pump case end surface set to 81 mm (3.19 in.), adjust the position of solenoid ② so that adapter ③ and follower ④ contact each other.

(d) Tighten bolt ①.



RUN-ON start rack limit solenoid

< Inspection >

(e) Stop the engine.

(f) Cut off electric current to start rack limit solenoid (2) (extended condition).

(g) Move the fuel pump rack to the FULL direction, making sure that the rack does not move more than 81 mm (3.19 in.).

[RUN-OFF start rack limit solenoid]

< Adjustment >

(a) Loosen nuts (1) and (2).

(b) Supply electric current to start rack limit solenoid (3) (contracted condition).

(c) With the distance between the rack end surface and pump case end surface set to 81 mm (3.19 in.), rotate rod (6) until lever (4) and follower (5) contact each other.

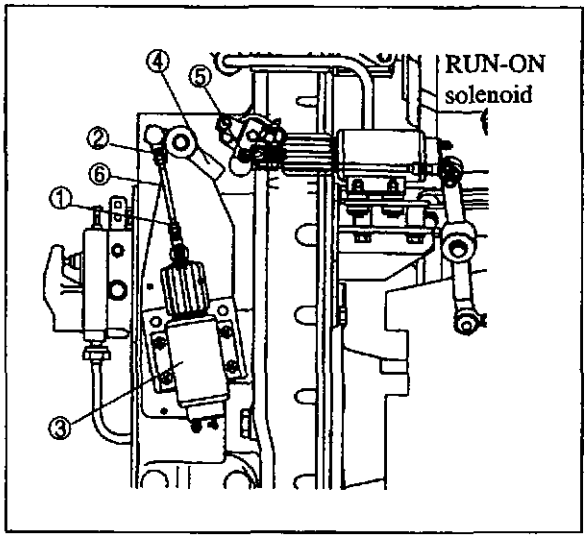
(d) Tighten nuts (1) and (2).

< Inspection >

(e) Stop the engine.

(f) Supply electric current to start rack limit solenoid (3) (contracted condition).

(g) Move the fuel pump rack to the FULL direction, making sure that the rack does not move more than 81 mm (3.19 in.).

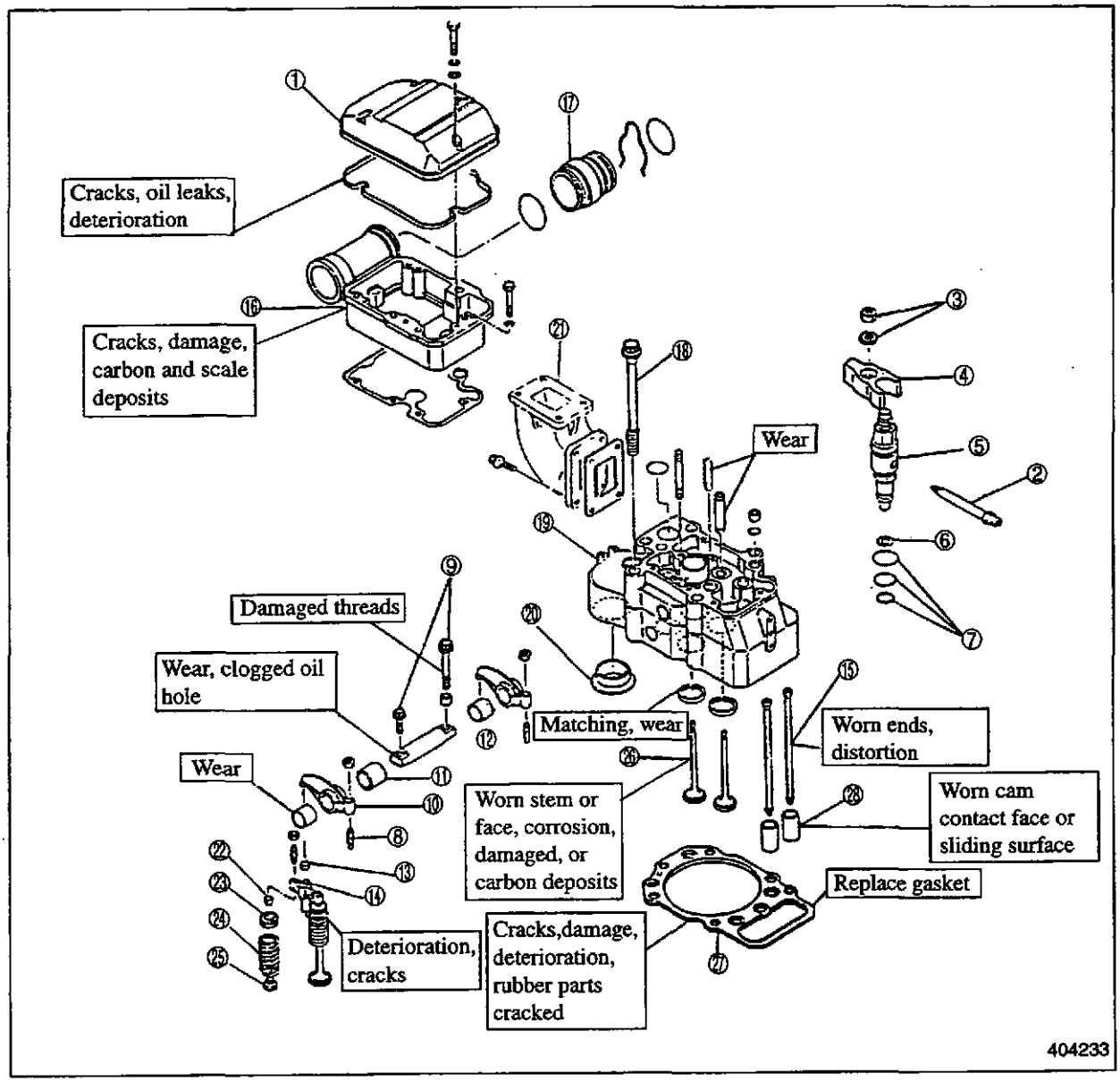


RUN-OFF start rack limit solenoid

THE ENGINE PROPER

1. Cylinder Heads and Valve Mechanism

1.1 Disassembly



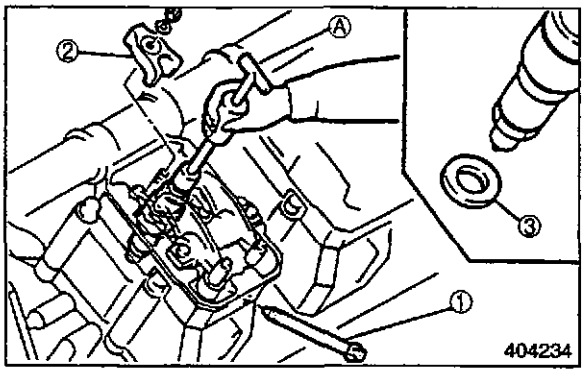
① Rocker cover
② Fuel inlet connector
③ Nut, washer
④ Injection nozzle gland
⑤ Injection nozzle
⑥ Gasket
⑦ O-ring
⑧ Adjusting screw
⑨ Bolt
⑩ Rocker
⑪ Spacer
⑫ Rockershaft
⑬ Bridge cap
⑭ Valve bridge
⑮ Push rod
⑯ Rocker case
⑰ Water outlet connector
⑱ Cylinder head bolt
⑲ Cylinder head
⑳ Inlet port packing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

(1) Removing fuel injection nozzles

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

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

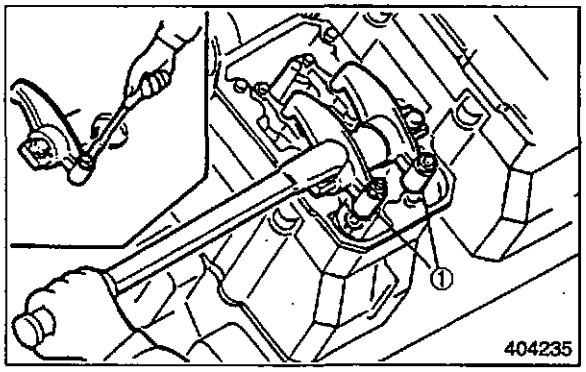
(c) Put away the nozzle and the inlet connector where you can find them later. Do not damage the nozzle tip.



(2) Removing the rockershaft assemblies

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

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

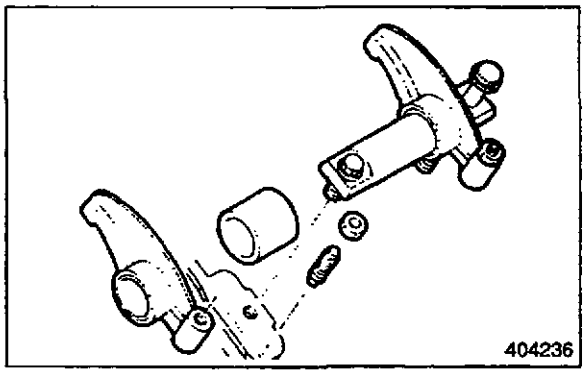


(3) Disassembling rockershaft assemblies

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

(4) Removing the valve bridge

Remove the valve bridge and bridge cap.



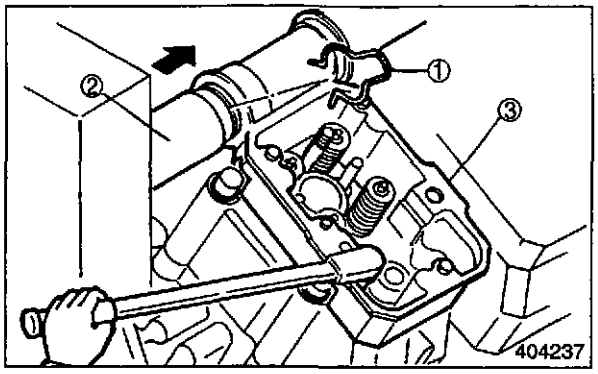
NOTE

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

(5) Removing the rocker case

(a) Remove the snap ring ① of the water outlet connector. Slide the connector ② towards the snap ring.

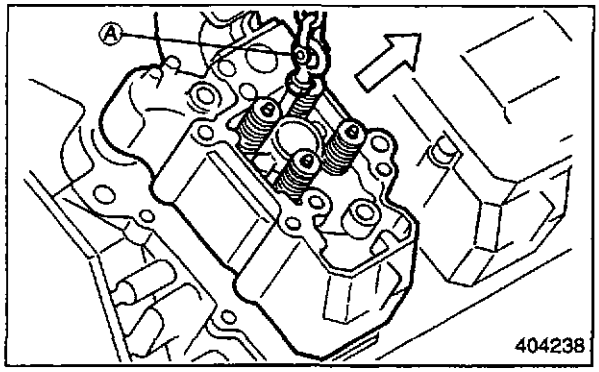
(b) Unscrew the rocker case mounting bolts, then remove the rocker case ③ from the cylinder head.



(6) Removing cylinder head assemblies

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

Cylinder head weight: approx. 35kg. (77.2 lb)



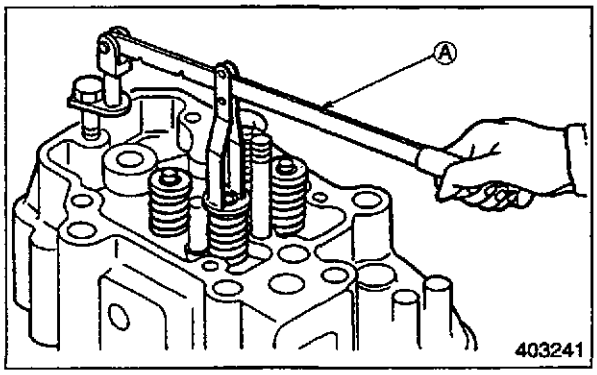
(b) Remove the cylinder head gasket

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

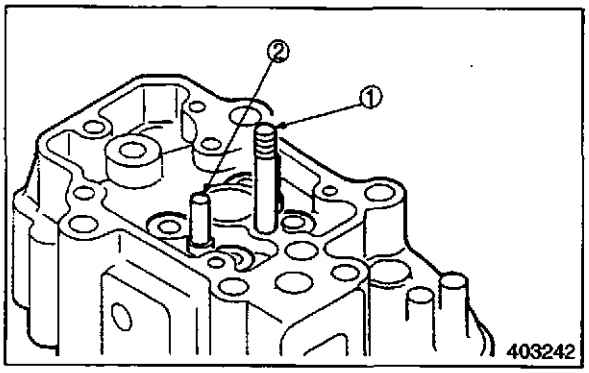


NOTE

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

(8) Removing studs, guides, etc.

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



1.2 Inspection and Repair

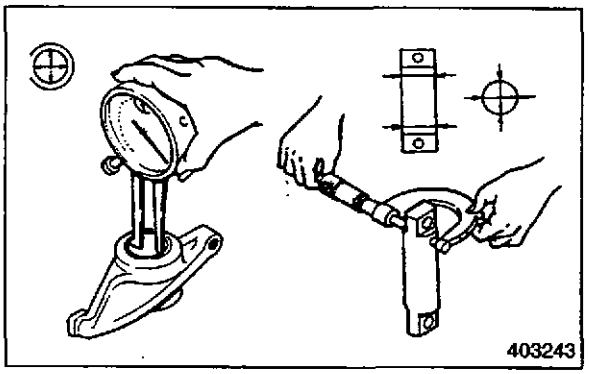
Rockers, Rocker Bushings, Rockershafts

(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)	36.000-36.040 (1.41732-1.41890)	36.090 (1.42087)
Rockershaft diameter	Ø36 (1.42)	35.966-35.991 (1.41598-1.41697)	35.940 (1.41496)



Measuring rocker bushing and rockershaft

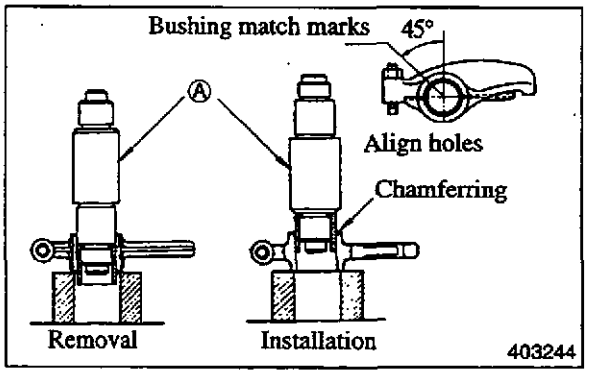
(2) Replacing locker bushings

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

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

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

(c) After installing the bushing, measure its inside diameter to make sure that it is $ø36^{+0.04}_{0}$ ($1.42^{+0.0016}_{0}$). If the diameter is not within this tolerance, refinish to standard tolerance by reaming ($ø36\ ^{+0.04}_{0}\ \frac{3.2S}{\nabla\nabla\nabla}$) ((ø1.42 $\frac{3.2S}{\nabla\nabla\nabla}$)).



Replacing the rocker bushing

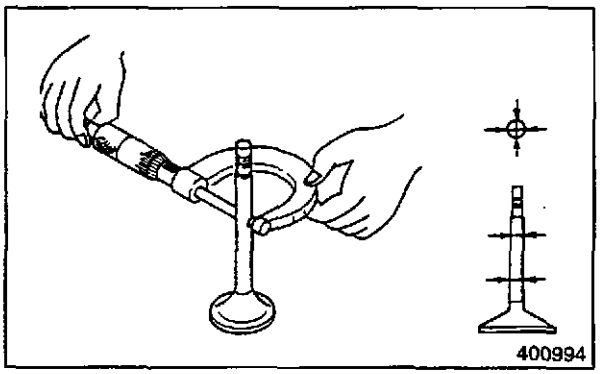
Valve guide and Valve Stems

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

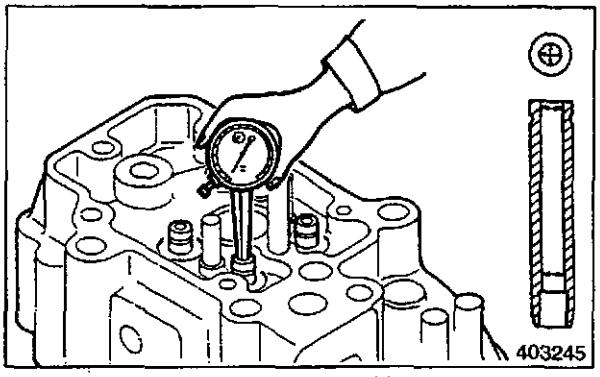
The valve guide wears more rapidly at its tooth end than at any other location. Measure the inside diameter of the guide at its ends and at the middle in two directions. If the service limitis exceeded, replace the guide.

Unit: mm (in.)

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



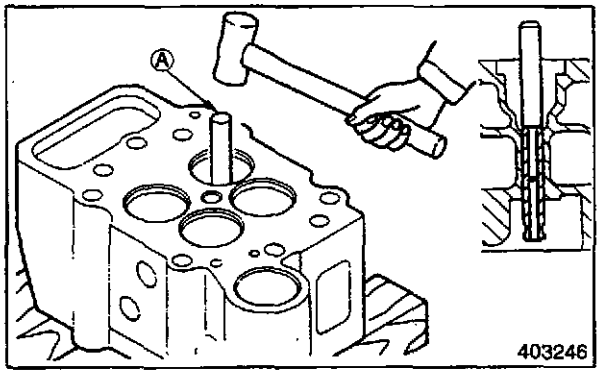
Measuring valve stems



Measuring valve guide inside diameter

(2) Replacing valve guides and stem seals

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

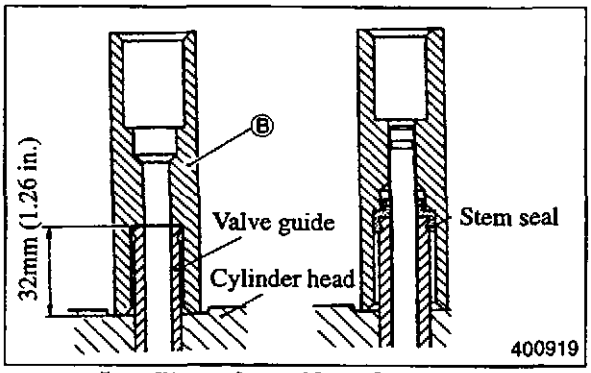


Removing valve guide

(b) Use a 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 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 comes in contact with the valve guide. When installing the stem seal, coat the seal rubbing surface of the stem with engine oil to ensure initial lubrication of the stem seal lip.
(c) Use a new stem seal.



Installing valve guide and stem seal

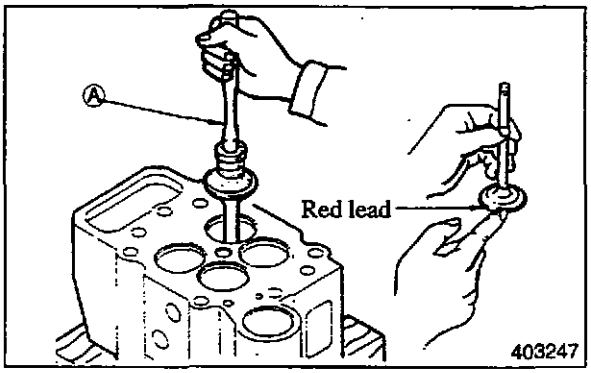
Valves and Valve Seats

(1) Inspecting the valve face

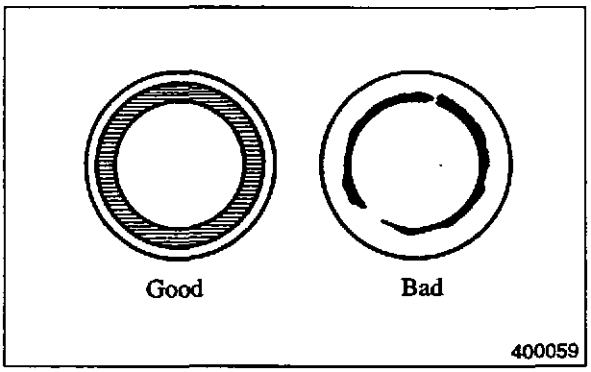
Coat the valve face lightly with red lead. Use valve lapper Ⓐ (30091-08800) to inspect the valve contact with its seat. If the contact is not uniform, or if the valve is defective, or if the repair limit is exceeded, repair or replace the valve and valve seat.

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.



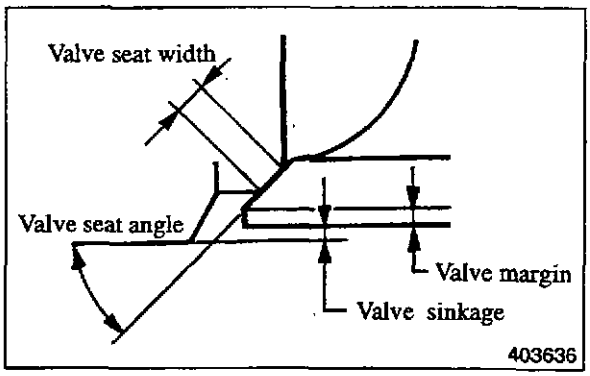
Inspecting a valve face



Valve contact with its seat

Unit: mm (in.)

Item		Assembly Standard	Repair Limit
Valve seat	Angle	30°	
	Valve sinkage	-0.2-0.2 (-0.0079-0.0079)	1.0 (0.0394)
	Width	2.15-2.45 (0.0846-0.0965)	2.8 (0.1102)
Valve margin		2.8-3.2 (0.1102-0.1260)	2.5 (0.0984) by refacing

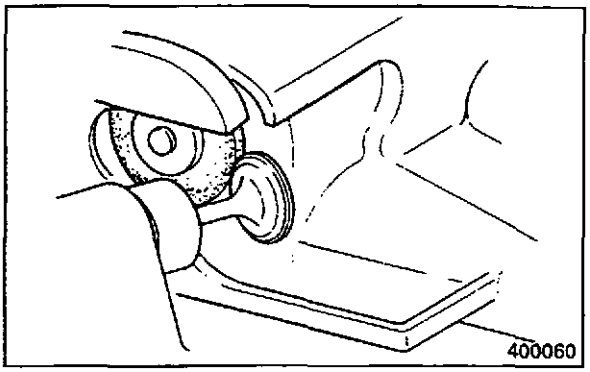


(2) Refacing the valve face

If the valve face is badly worn, reface it with a valve facer.

NOTE

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



Refacing a valve

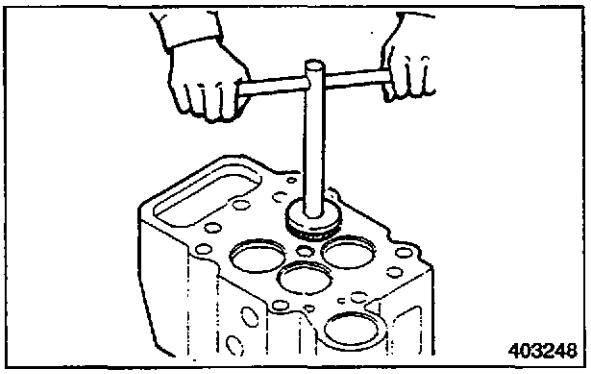
(3) Refacing valve seats

(a) Use a valve seat cutter or valve seat grinder to cut the valve seat. After cutting, grind the seat lightly using #400 grade sandpaper inserted between the cutter and valve seat.

(b) Lap the valve in the valve seat.

NOTE

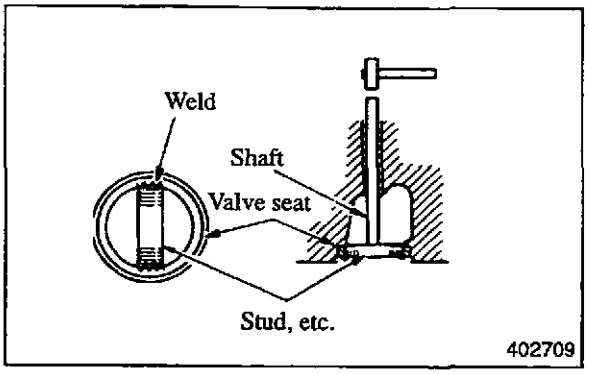
(a) Cut or grind the valve seat only as needed for refacing.
(b) Replace the valve seat if the seat width is more than the repair limit as a result of wear or cutting.
(c) Replace the valve seat if the valve sinkage exceeds the repair limit after refacing.



Refacing a valve seat

(4) Repairing valve seats

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



Removing a valve seat

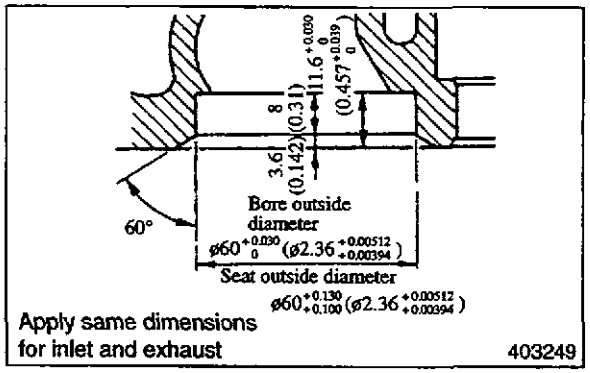
⚠CAUTION

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

(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 clearance standards.

Unit: mm (in.)

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



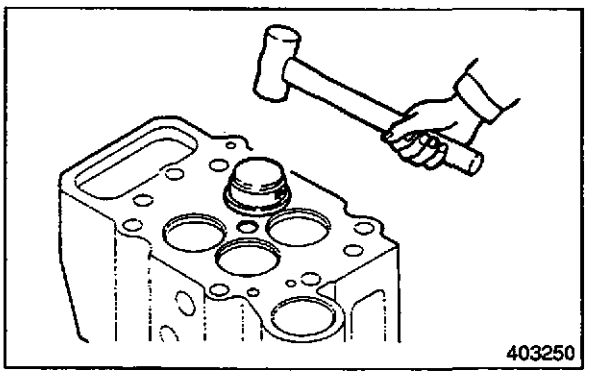
Valve seat dimensions

NOTE

A minus (-) indicates interference.

(c) Chill the valve seat in liquid nitrogen (about -170°C ((-338°F))) for more than 4 minutes with the cylinder head kept at normal temperature, or heat the cylinder head to 80°C or 100°C (176°F or 212°F) with the valve seat chilled in ether or alcohol containing dry ice.

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

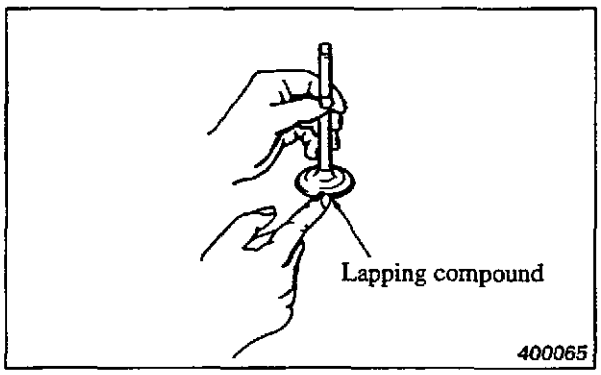


Installing a valve seat

(5) Lapping valves in valve seats

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

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



Coating valve with lapping compound

NOTE

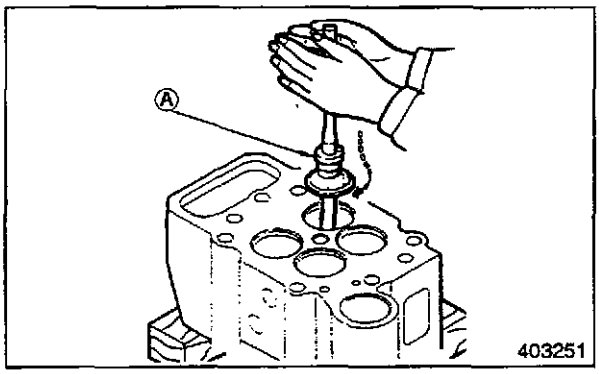
(a) Do not permit the compound to come in contact with the valve stem.
(b) Use a compound of 120 to 150 mesh for initial lapping and a compound finer than 200 mesh for finish lapping.
(c) Mixing the compound with a small amount of engine oil will facilitate coating.

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

(c) Wash off the compound with diesel fuel.

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

(e) Check the valve face for contact.

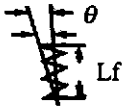


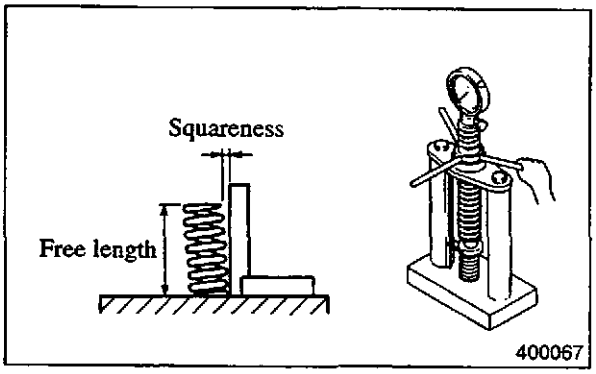
Lapping a valve in its valve seat

Valve Springs: Measuring Squareness And Free Length

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

Unit: mm (in.)

Item	Assembly Standard	Repair Limit
Free length	73 (2.87)	71 (2.80)
Squareness	θ=1.5° max. 	Δ=2.2 (0.087) over the length
Length under test force/test forces mm (in.)/ kgf (lbf) [N]	66.0 (2.6)/ 29.45-32.55 (64.92-71.76) [289-319]	



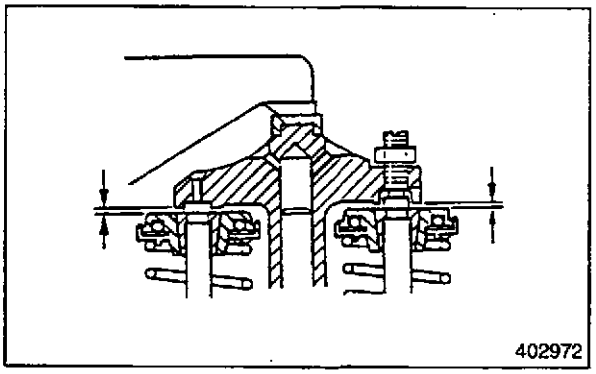
Measuring a valve spring

Valve Bridges and Bridge Caps

Check the clearance between the bridge and the rotator (cotter).

(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.

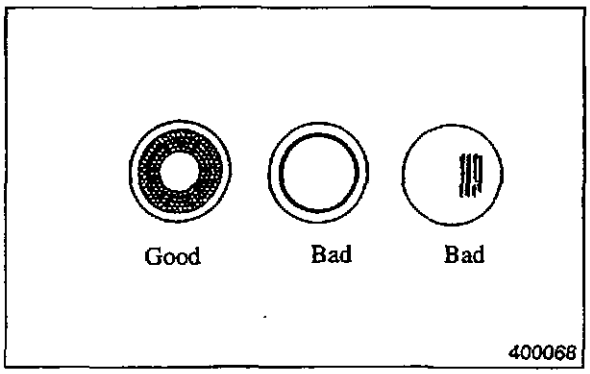
(b) Check the condition of the bridge cap. Replace it if it is badly worn.



Checking bridge-to-rotor clearance

Tappets and Push Rods

(1) Inspect cam contacts if the cam faces are excessively worn.



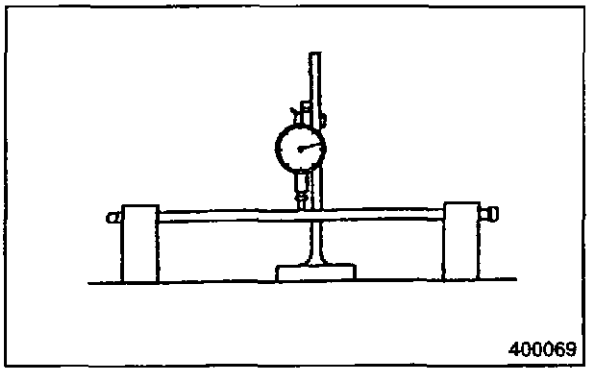
Tappet cam contact face

(2) Inspecting valve push rods for runout

If the runout exceeds the assembly standard, replace the push rods.

Unit: mm (in.)

Item	Assembly Standard
Push rod runout	Less than 0.5 (0.020)



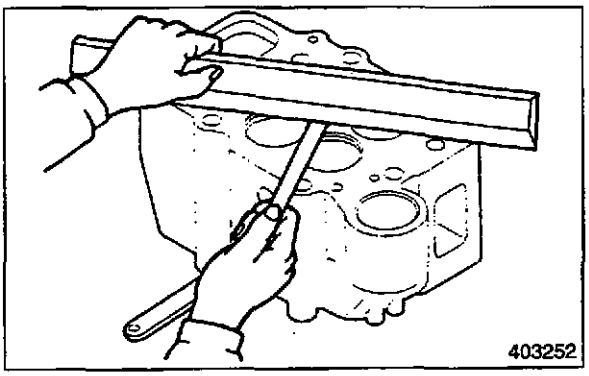
Measuring valve push rod runout

Cylinder Head

Use a straight edge and feeler gauge 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	Assy. Stand.	Repair Limit	Service Limit
Head warp	< 0.03 (0.0012)	0.07 (0.0028)	0.50 (0.0197)

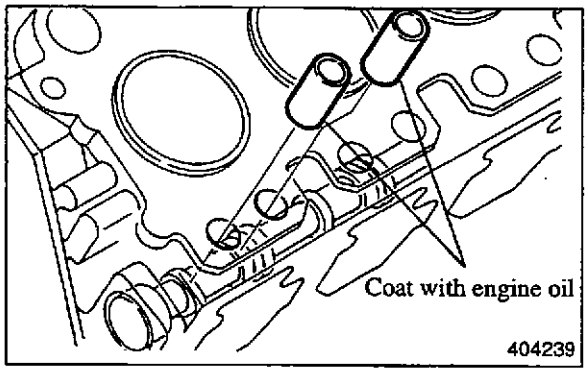


Measuring head gasket warpage

1.3 Reassembly

(1) Installing tappets

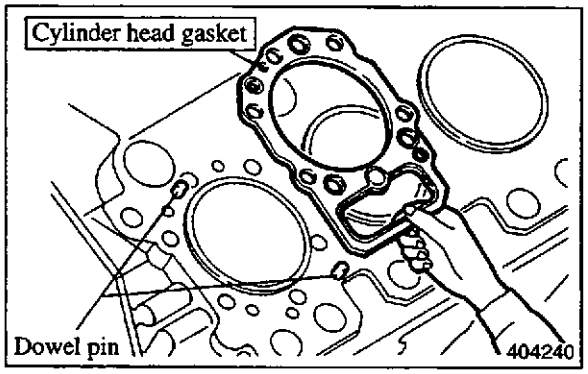
Insert tappets coated with engine oil into the tappet holes and make them seat softly on the camshaft.



(2) Installing cylinder head gaskets

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

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



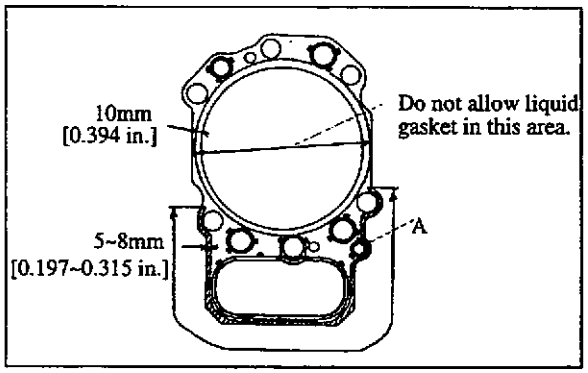
• Application of liquid gasket

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

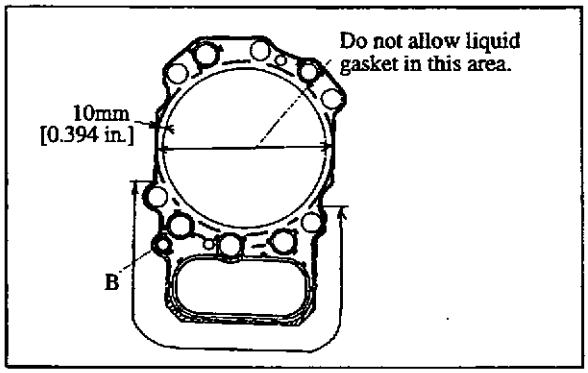
Do not apply an excessive amount of liquid gasket, since it can press the head gasket O-ring and cause deformation. Do not allow liquid gasket to adhere around the bore; otherwise, gas leakage can occur.

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

The diagram on the right shows the areas and amounts of liquid gasket application.



Application of liquid gasket on head-facing side



NOTE: (a) Apply liquid gasket (37594-01300) to areas 5 to 8 mm [0.197~0.315 in.] from the periphery of the head gasket.

(b) Liquid gasket should be applied to areas indicated in the diagram 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. [0.008~0.020 in.]

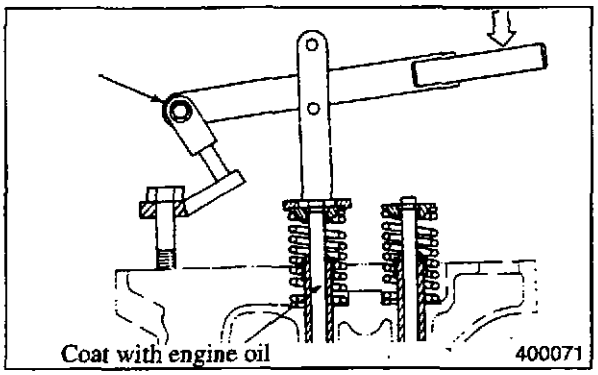
(d) Sections (A) and (B) are very close to O-rings. Make sure that there is no large amount of liquid gasket on the edge at these sections.

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

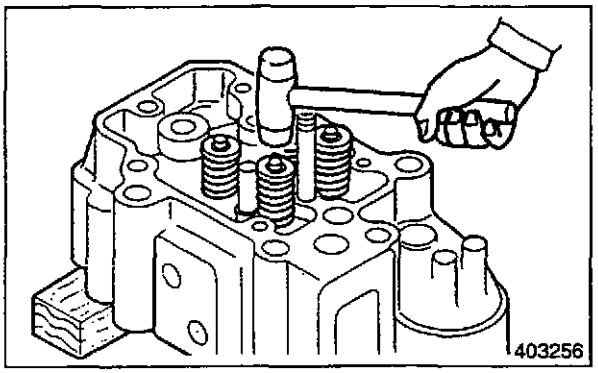
(3) *Reassembling the cylinder heads*

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

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



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

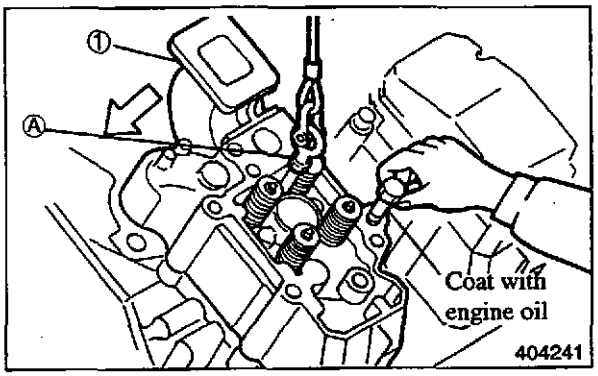


(4) Installing cylinder head assemblies

(a) Install the exhaust connector ① to the cylinder head, while pushing down the exhaust connector so it touches the edge of the bolt hole.

NOTE

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



(b) Install eye nut Ⓐ (37591-02400) on the stud bolt. Attach a shackle and wire rope to the eye nut and lift the cylinder head assembly. Set the head position to coincide with the position of the dowel pin so the head is slightly separated. Screw the head bolts coated with engine oil.

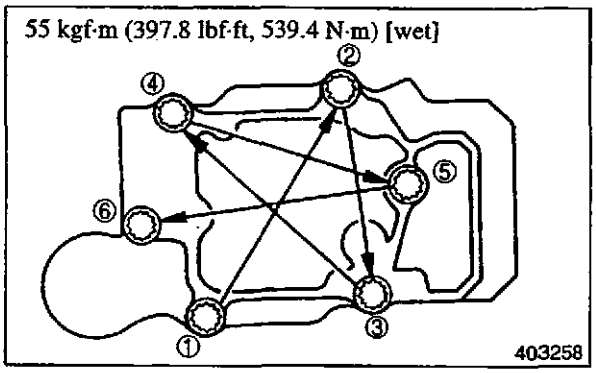
(c) Tighten the cylinder head bolts with the specified torque in the order shown in the drawing.

NOTE

To tighten cylinder head bolts according to the angle method, tighten to 294 N·m {30 kgf·m}, then turn 60° more.

⚠CAUTION

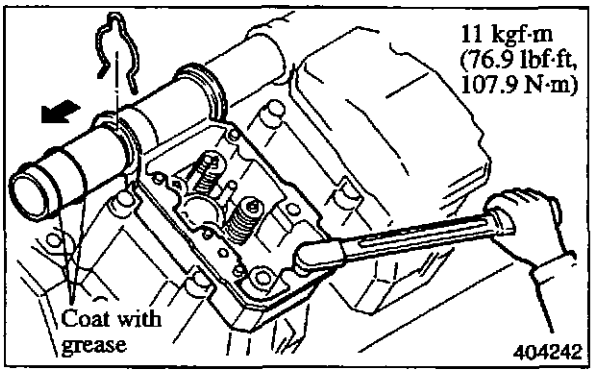
(a) The cylinder head bolts should be screwed down after wiping off the coating of engine oil.
(b) Before you install the cylinder head assembly, measure the protrusion of each piston. Make sure that the protrusion is correct.



Head bolt tightening sequence

(5) Installing the rocker case

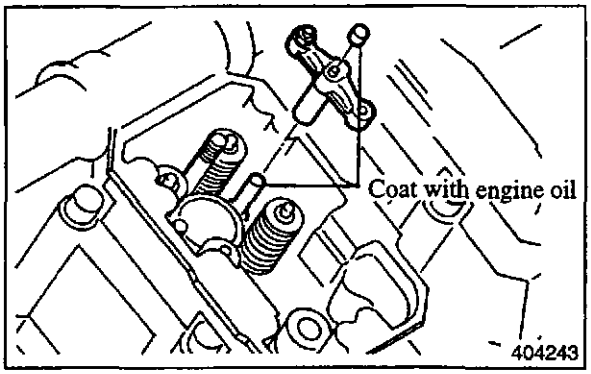
(a) Insert the water outlet connector fully into the rocker case.
(b) Install the rocker case so it meets the dowel pins.
(c) Tighten the rocker case mounting bolts to the specified torque.
(d) Insert the water outlet connector by sliding it from the next rocker case after coating the O-ring with grease.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



(6) Installing valve bridges and caps

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

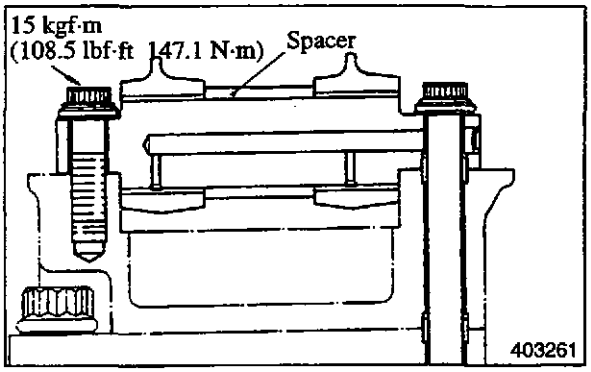
(b) Coat the bridge contact face of the bridge caps with engine oil. Install the caps in position, being careful not to let them fall into the crankcase through the push rod holes.



(7) Installing rockershaft assemblies

(a) Align the notch of the rockershaft with the bolt hole of the rockershaft bracket, then insert the bolt into the bolt hole.

(b) Insert the long bolt for securing the head and rocker bracket with the O-ring through the bolt hole of the rocker bracket into the cylinder head.



⚠CAUTION

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

(8) Installing injection nozzle assemblies

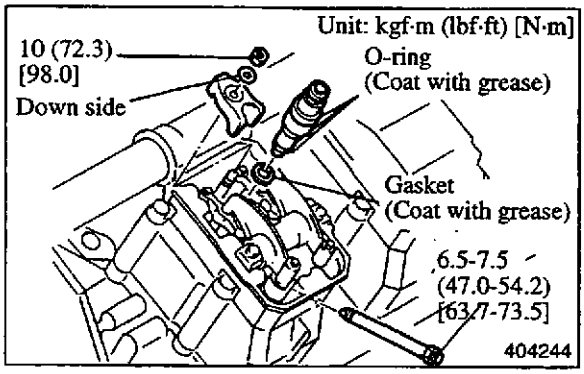
(a) Disconnect the fuel inlet connector from the nozzle assemblies.

(b) Install 3 O-rings to the nozzle and coat with grease.

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

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

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



NOTE

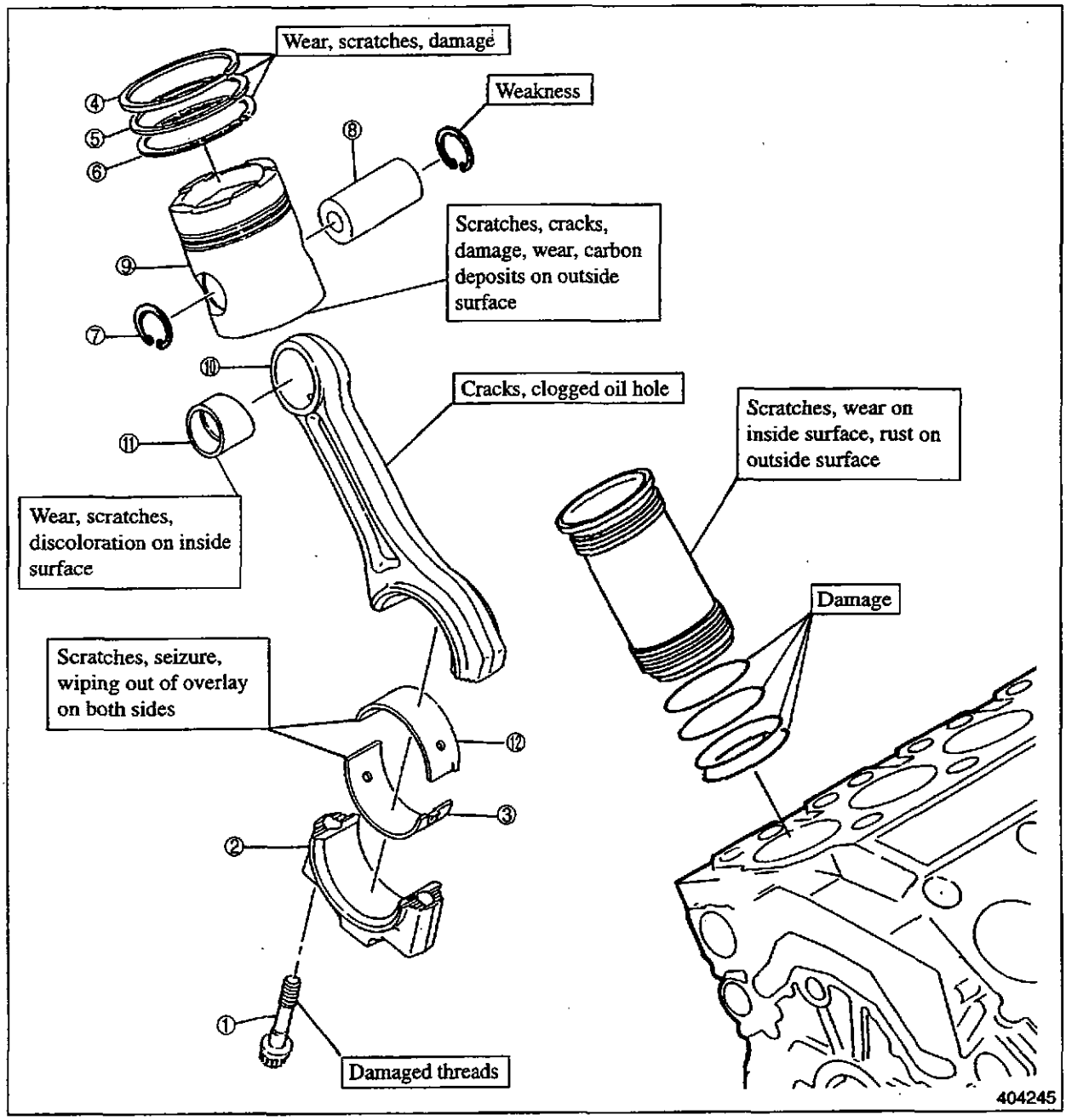
(a) Maintain equal distances between the fuel inlet connector and the cylinder head before tightening to the specified torque.
(b) Be sure to install the gasket when installing the nozzle assemblies.

(9) Adjusting valve clearance

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

2. Cylinder Liners, Pistons, and Connecting Rods

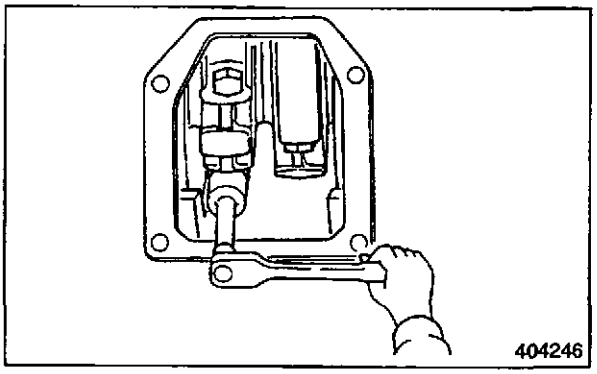
2.1 Disassembly



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

(1) Removing connecting rod caps

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

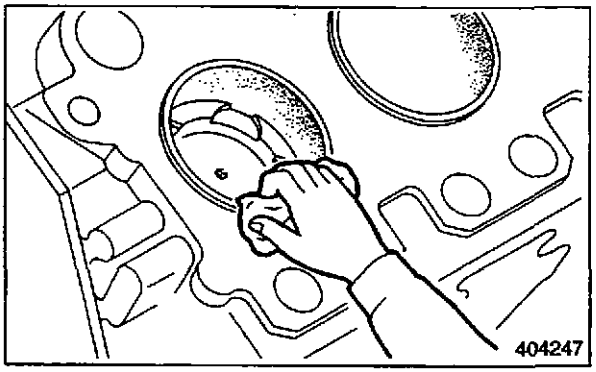


NOTE

(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

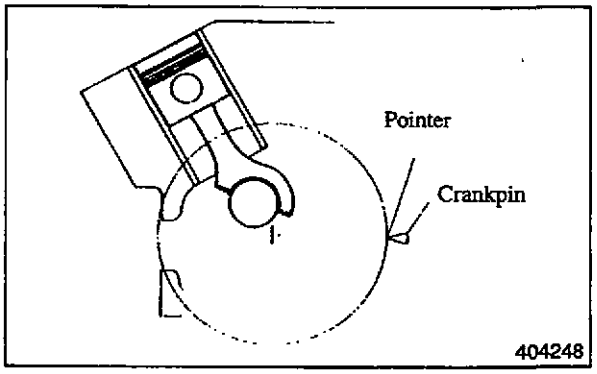
Use a cloth or oil paper to remove all carbon deposits from the upper areas of the cylinder liner. If any carbon deposits are present, this will make it difficult to pull a piston up.



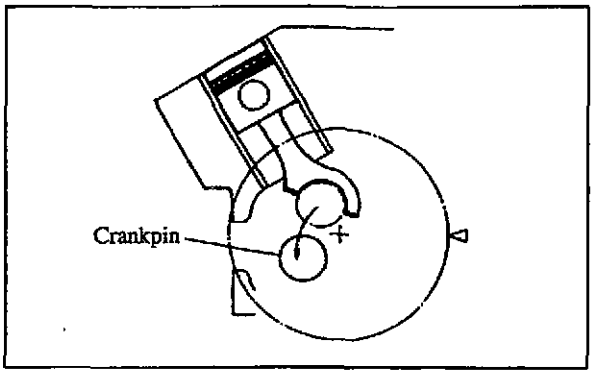
(3) Removing pistons

Pistons for Right Bank Cylinders

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



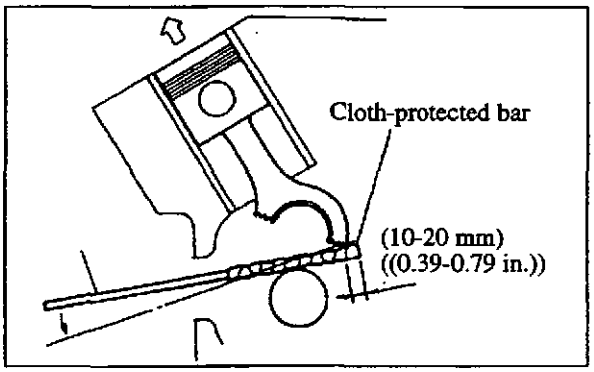
(b) Turn the crankshaft in reverse until the crank pin comes off the connecting rod and the joint of the rod is visible in the inspection hole on the side of the crankcase.



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

⚠CAUTION

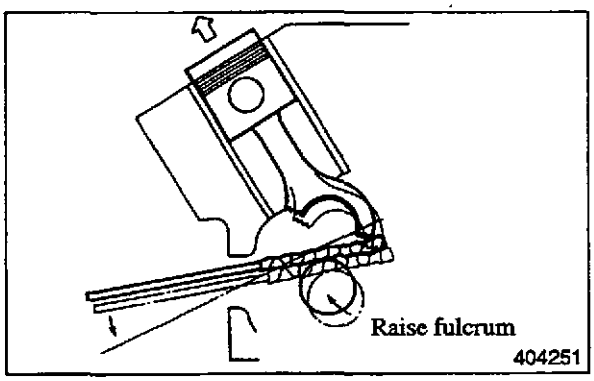
If you force the turning bar, you may not be able to remove the piston assembly. Insert the bar so it protrudes about 10-20 mm (0.39-0.79 in.) from the bottom end of the large end.



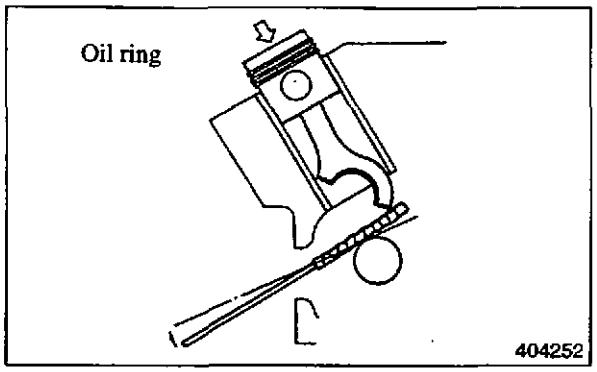
(d) Turn the crankshaft in the normal direction just a little at a time to raise the crank pin (fulcrum) while pushing down on the outer end of the bar to raise the piston assembly.

⚠CAUTION

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



(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.

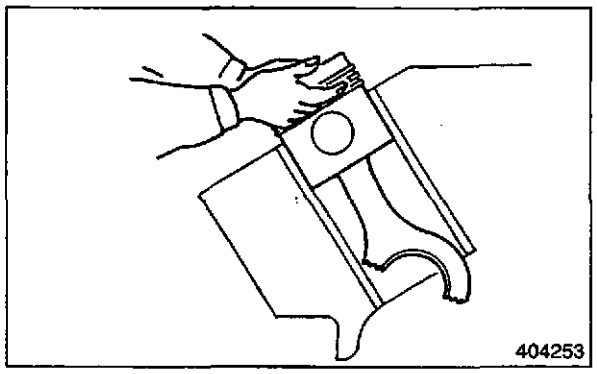


⚠CAUTION

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

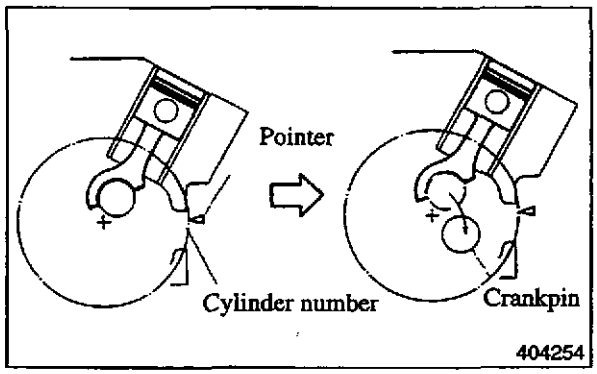
(f) While holding the compression ring portion of the piston with your hands, carefully pull the piston from the cylinder liner, then rest its skirt on the top of the crankcase.

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



Pistons for Left Bank Cylinders

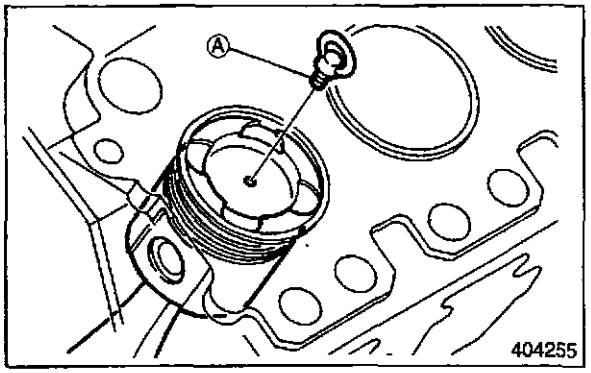
Removal procedure is the same as that for removing pistons for right bank cylinders. The only difference is that the position of the crank pin and the direction of the crankshaft rotation for removal are reversed.



Using the Piston Remover

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

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

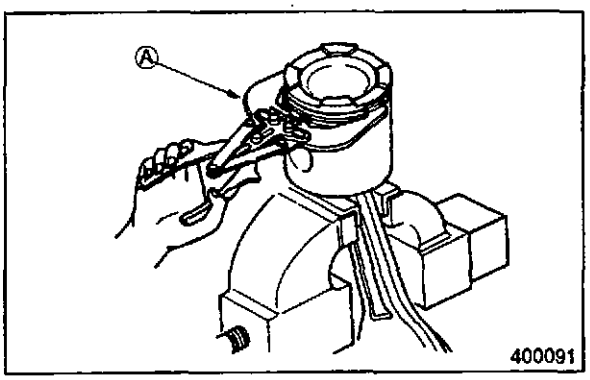


⚠CAUTION

(a) 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.
(b) Do not damage the cylinder liner bore with the connecting rod.

(4) Removing the piston ring

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

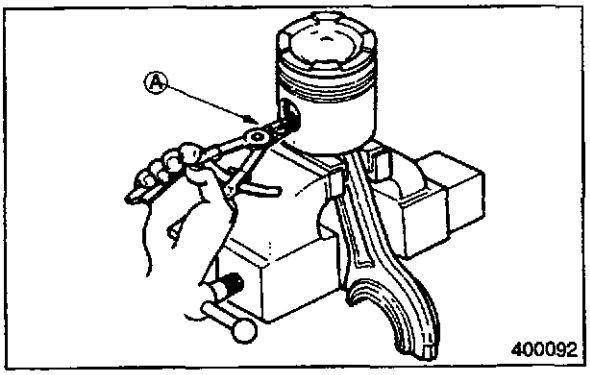


(5) Removing piston pins from a piston

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

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

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



2.2 Inspection and Repair

Cylinder Liners

(1) Measuring cylinder liner inside diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service limit
Cylinder liner inside diameter	ø170 (ø6.69)	170.000-170.040 (6.69291-6.69449)	170.500 (6.71260)

NOTE

The method of measuring the protrusion of an existing liner differs from the method of measuring the protrusion of a cylinder liner that has been newly installed.

(2) Measuring cylinder liner protrusion

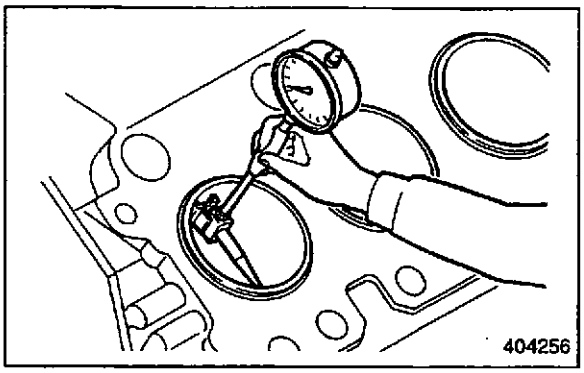
Measure the protrusion of each liner at its flange with dial gauge as shown. If the protrusion is not within the assembly standards, change the position of the liner relative to its bore, or use the liner in another bore.

Unit: mm (in.)

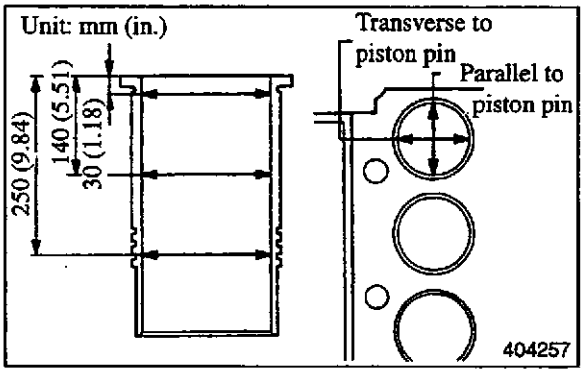
Item	Assembly Standard
Cylinder liner protrusion at flange	0.11-0.20 (0.004-0.008)

⚠CAUTION

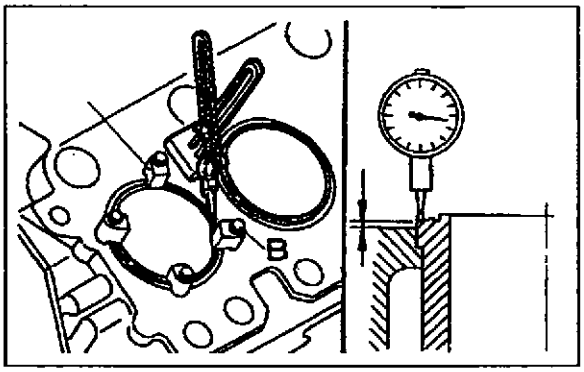
If the protrusion is less then the assembly standard, the gasket will fail to seal the bore resulting in gas leakage.



Measuring cylinder liner



Cylinder liner measuring diagram



Measuring cylinder liner protrusion

• When cylinder head has just been removed

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

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

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

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

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

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

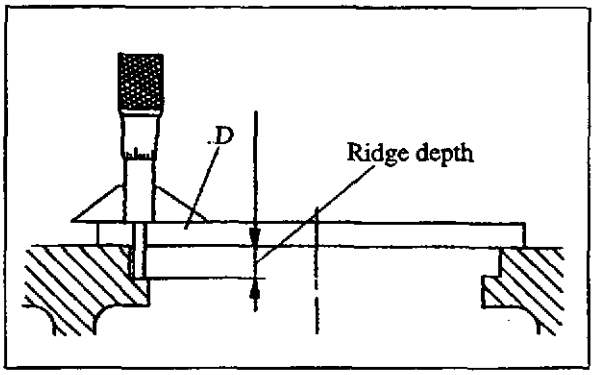
(a) Remove the cylinder liner, and study the cylinder liner contacting surface of the crankcase.

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

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

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

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



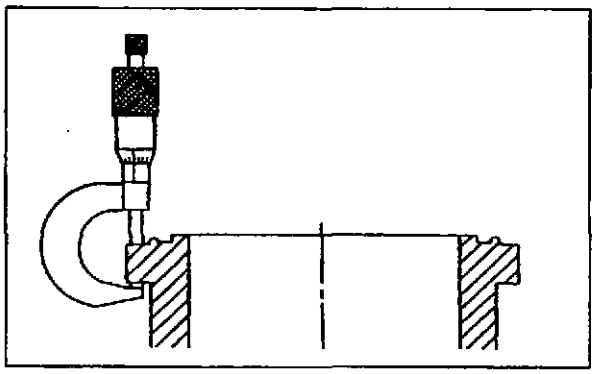
Unit: mm (in.)

	Assembly standard
Crankcase ridge depth	$14^{+0.05}_{0}$ ($0.55^{+0.0020}_{0}$)

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

Unit: mm (in.)

	Assembly standard
Thickness of cylinder liner collar	$14^{+0.20}_{+0.16}$ ($0.55^{+0.0079}_{+0.0063}$)



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

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

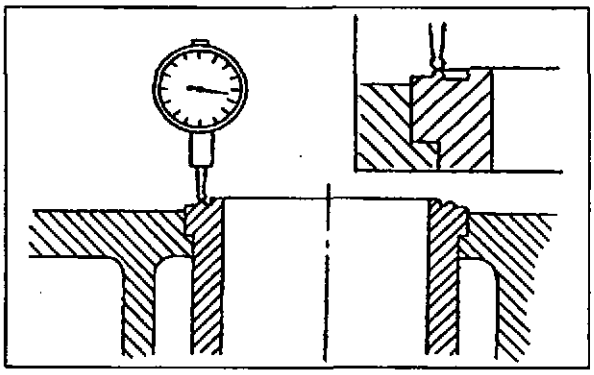
• Measuring cylinder liner projection

(a) Place a dial gauge on the top surface of the cylinder liner, and set the indicator to 0 (zero).

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

Unit: mm (in.)

	Assembly standard
Cylinder liner projection	0.2±0.04 (0.008±0.002)



Measuring cylinder liner projection

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

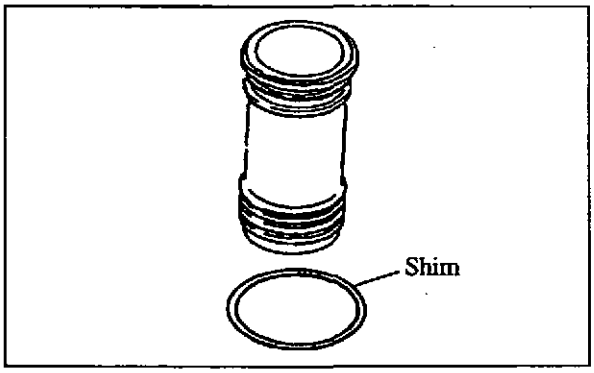
• Inserting cylinder liner shim

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

NOTE

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

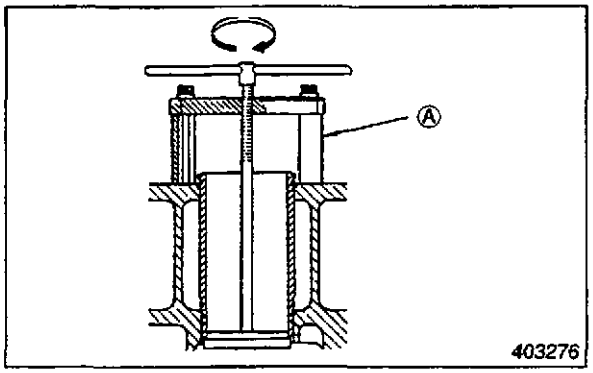
Thickness of shim	Part No.
0.05 mm (0.0020 in.)	37507-02510
0.10 mm (0.0039 in.)	37507-02500
0.15 mm (0.0059 in.)	37507-02520



Inserting cylinder liner shim

(3) Replacing cylinder liners

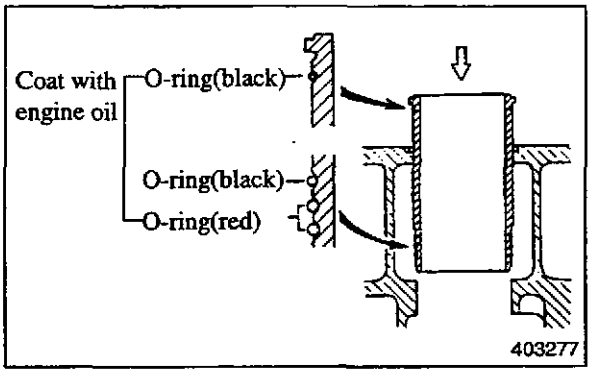
(a) Use the cylinder liner remover Ⓐ (37591-04100) to remove the cylinder liner from the crankcase for replacement.



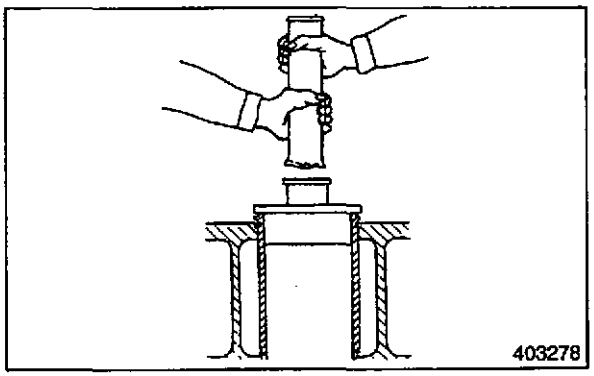
(b) Attach O-rings to the new cylinder liner, then carefully insert the liner into the bore of the crankcase.

⚠CAUTION

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



(c) After inserting the liner into the bore, lightly tap it on the top with the installer so it rests on its flange in the counterbore formed by the crankcase. After seating the liner, tap on it several times to be sure that it is properly installed.



NOTE

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

Pistons

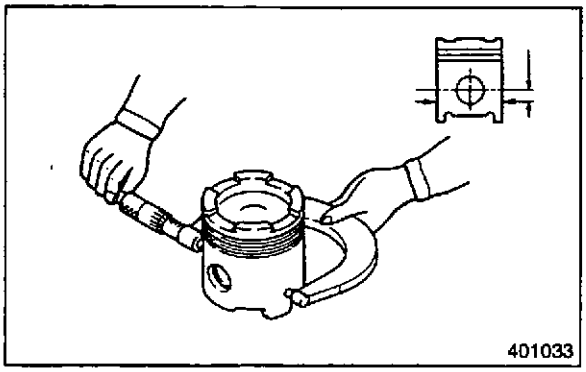
Check the combustion chamber and inside surfaces of the piston bosses. Replace the piston if any defects are found.

(1) Measuring piston diameter

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

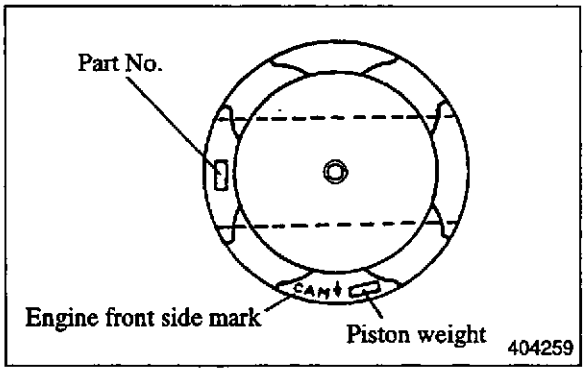
Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service limit
Piston diameter	ø170 (ø6.69)	169.76-169.80 (6.6835-6.6850)	169.66 (6.6795)
Weight Variance among pistons		40 g (0.09 lb) max.	



Measuring piston diameter

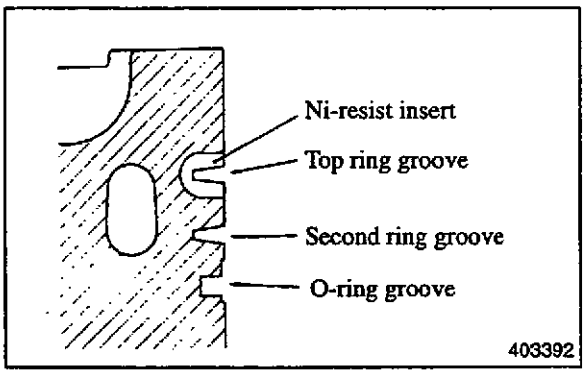
(b) The piston weight is stamped on the top of each piston.



Piston weight stamp location

(2) Inspecting piston ring grooves

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



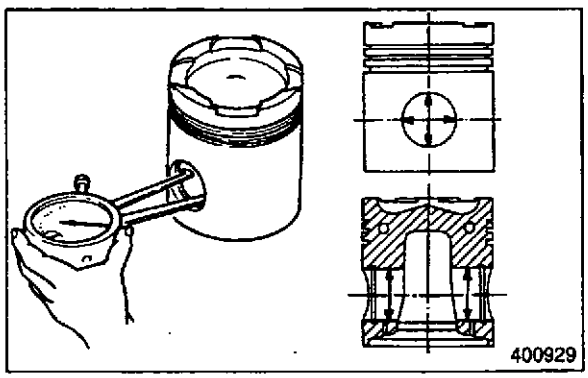
Inspecting piston ring grooves

(3) Measuring piston pin bore diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service limit
Piston pin bore diameter	ø 70 (2.76)	70.002-70.015 (2.75598-2.75650)	70.040 (2.75748)



Measuring piston bore diameter

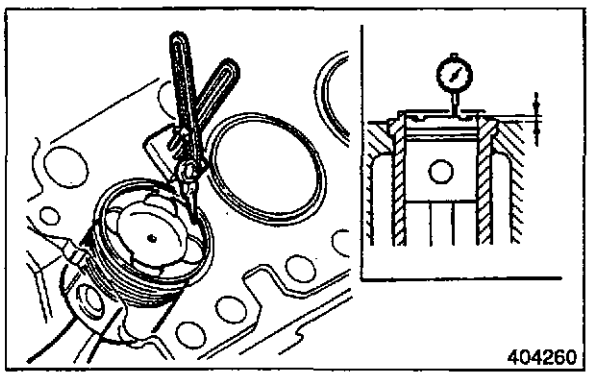
(4) Measuring piston protrusion

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

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

(b) Set up the dial gauge at the top of the crankcase. Set the gauge 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 clearance between the piston top and cylinder head.



Measuring piston protrusion

Unit: mm (in.)

Item	Assembly Standard
Piston protrusion	0.06-0.65 (0.0024-0.0256)
Installed thickness of cylinder head gasket	1.77-1.83 (0.0697-0.0721)
Clearance between piston top and cylinder head	1.22-1.95 (0.0480-0.0768)

⚠CAUTION

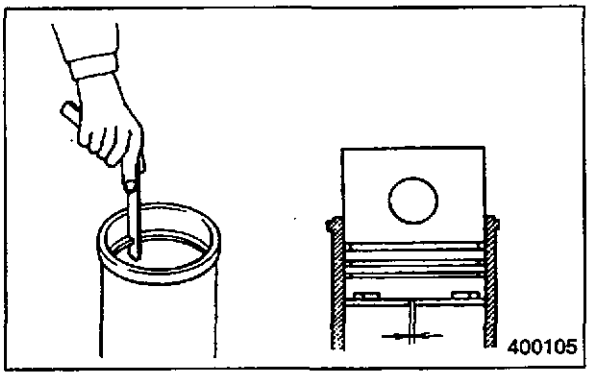
Keep the piston protrusion with assembly standard range to maintain high engine performance and to prevent the valves from interfering with the piston.

Piston Rings

(1) Measuring gaps

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

Master cylinder liner inside diameter: 170 ± 0 mm (6.69 ± 0 in.)



Measuring piston ring gap

NOTE

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

Unit: mm (in.)

Item		Standard Clearance	Service Limit
Piston ring gaps	Top	0.6-0.8 (0.024-0.031)	2.0 (0.079)
	Second	0.6-0.8 (0.024-0.031)	
	Oil	0.3-0.45 (0.012-0.018)	

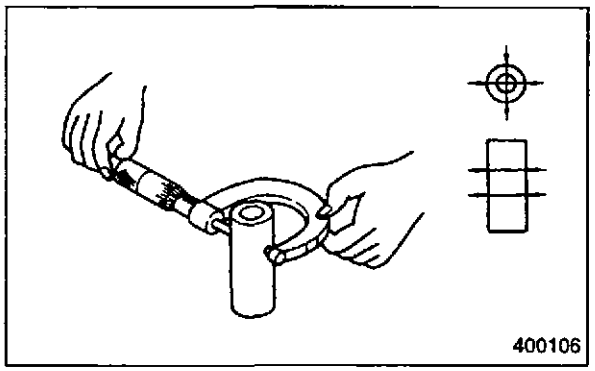
Piston Pins

(1) Measuring piston pin diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service limit
Piston pin outside diameter	ø70 (2.76)	69.987-70.000 (2.75539-2.75591)	69.970 (2.75472)



Measuring piston pin diameter

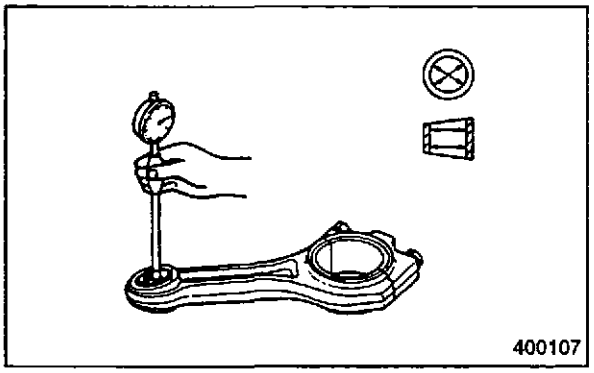
Connecting Rods, Connecting Rod Bearings, and Bushings

(1) Measuring small-end bushing inside diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service limit
Connecting rod bushing inside diameter	ø70 (2.76)	70.020-70.040 (2.75669-2.75748)	70.070 (2.75866)



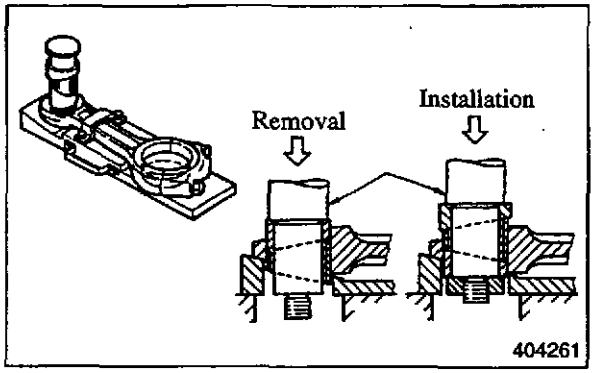
Measuring connecting rod bushing inside diameter

(2) Replacing connecting rod bushings

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

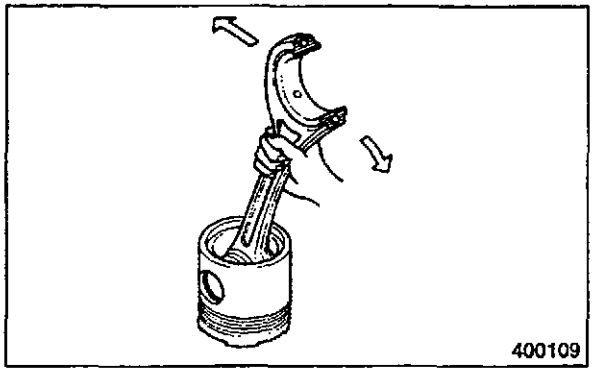
(b) When installing a new bushing, align the oil holes in the bushing and connecting rod.

(c) After installing the bushing, finish its inside diameter to $\phi 70\ ^{+0.040}_{+0.020}$ ($2.76\ ^{+0.00157}_{+0.00079}$ in.) $\frac{1.6S}{}$ and its parallel bushing with respect to the large-end metal to 0.05 mm (0.002 in.) by reaming.



Replacing connecting rod bushing

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

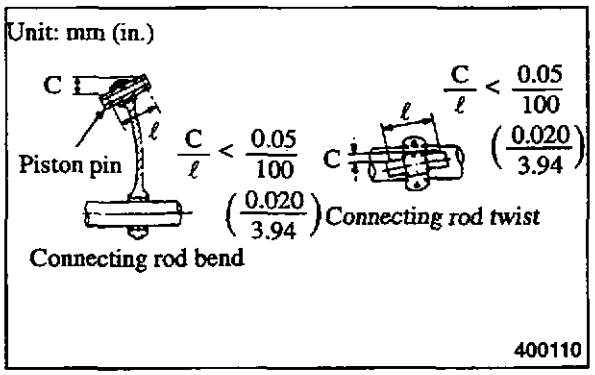


(3) Inspecting connecting rods for bend and twist.

(a) Measure C and ℓ. If the measurement at C is larger than 0.05 mm per 100 mm (0.020 in. per 3.94 in.) of ℓ, straighten the rod with a press.

NOTE

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

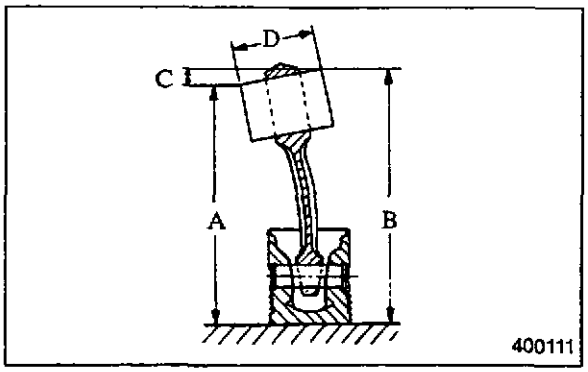


Inspecting connecting rod

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

Unit: mm (in.)

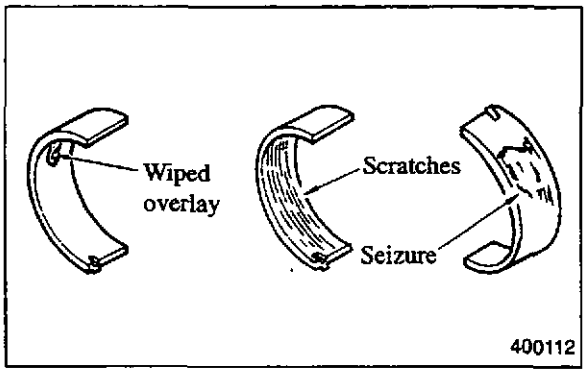
Item	Assembly Standard
Connecting rod bend and twist (C/D)	0.05/100 max. (0.020/3.94)



Inspecting connecting rod installed on piston

(4) Inspecting connecting rod large-end metals

Inspect each metal shell for wiped overlay, scratching, seizure, pitting, and other defects. If any defect is found, replace the shell.



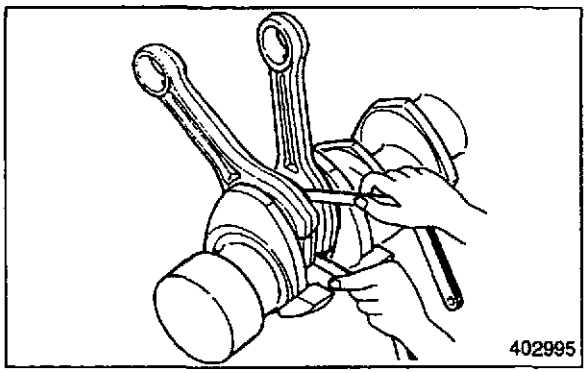
(5) Measuring connecting rod end play

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

Unit: mm (in.)

Item	Nominal Value	Standard Clearance (Nominal)	Service Limit
Connecting rod end play*	60 × 2 (2.36 × 0.08)	0.4-0.9 (0.02 to 0.035)	1.4 (0.055)

*Widths of connecting rod and crank pin



Measuring connecting rod end play

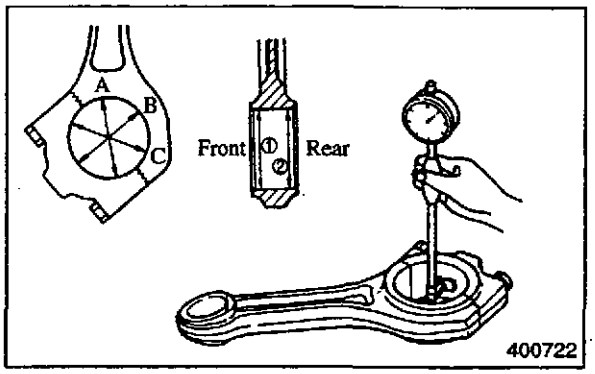
(6) Variance in weight among connecting rods per engine

When replacing connecting rods, make sure that the variance in weight among connecting rods per engine is within the assembly standards below.

Item	Assembly Standard
Variance in weight among connecting rods per engine	40 g (0.09 lb) max.

(7) Measuring connecting rod large-end bore diameter

Measure the connecting rod big-end bore diameter in directions A, B and C and at front and rear positions (1) and (2), as shown in the diagram. To obtain the out-of-roundness value, subtract the smallest measured value from the largest measured value.



Measuring connecting rod large-bore diameter

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit	Out-of-roundness
Connecting rod large-end bore diameter	ø131 (5.16)	131.000-131.025 (5.15748-5.15846)	131.050 (5.15945)	0.100 (0.00394)

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

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

(9) Measuring connecting rod metal thickness

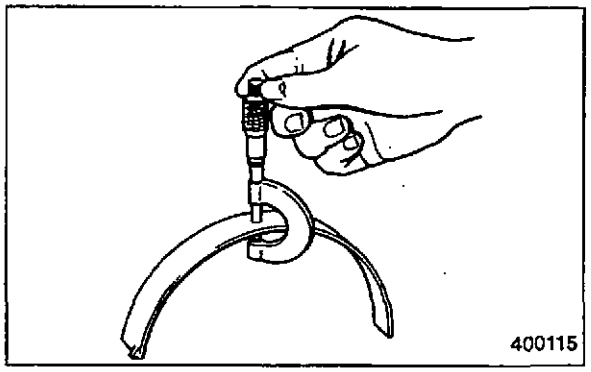
Use a ball-point micrometer to measure the center of each metal shell. If the thickness exceeds the service limit on the upper or lower shell, replace both shells as a set.

Unit: mm (in.)

Item		Nominal Value	Assembly Standard	Service Limit
Connecting rod metal thickness	STD	3.000 (0.11811)	2.972-2.985 (0.11701 to 0.11752)	2.930 (0.11535)
	-0.25 (-0.0098)	3.125 (0.12303)	3.097-3.110 (0.12193 to 0.12244)	3.055 (0.11831)
	-0.50 (-0.0197)	3.250 (0.12795)	3.222-3.235 (0.12685 to 0.12736)	3.180 (0.12520)
	-0.75 (-0.0295)	3.375 (0.13287)	3.347-3.360 (0.13177 to 0.13228)	3.305 (0.13012)
	-1.00 (-0.0394)	3.500 (0.13780)	3.472-3.485 (0.13669 to 0.13709)	3.430 (0.13504)

NOTE

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



Measuring connecting rod metal thickness

2.3 Reassembly

Reassembly is done in the reverse order of disassembly.

(1) Reassembling pistons on connecting rods

(a) Head the piston with a piston heater or with hot water.

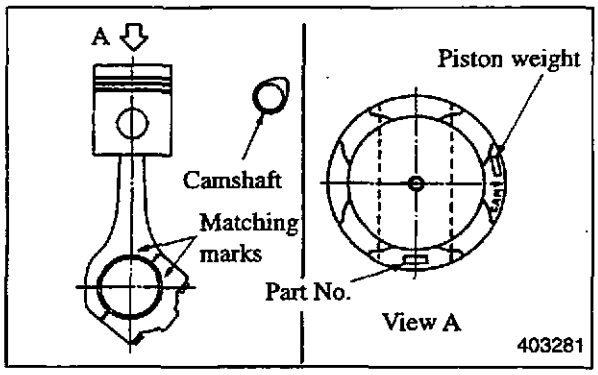
(b) Coat the piston pin with engine oil, then insert it in position through the connecting rod.

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

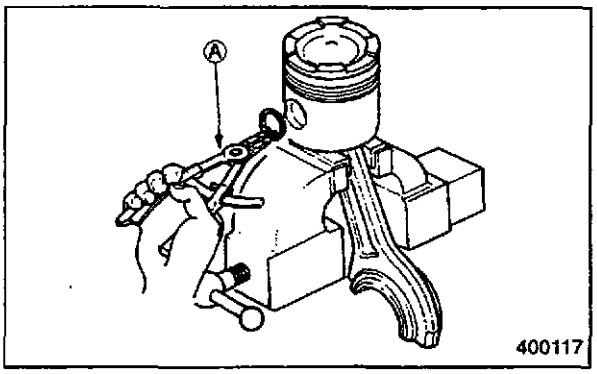
(d) Use ring pliers Ⓐ (45191-08400) to install the snap rings in the grooves of the pistons. Make sure that the rings are not fatigued and that they fit in the grooves properly.

NOTE

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



Matching marks on connecting rod

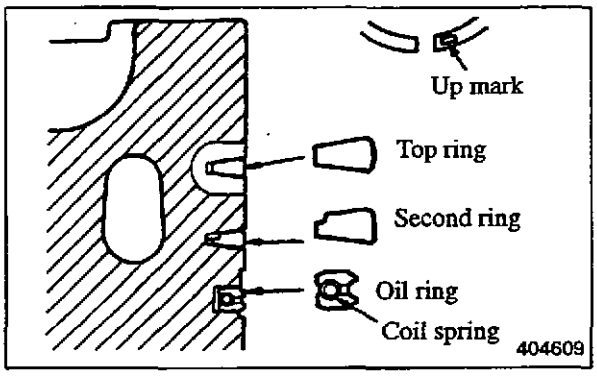


(2) Installing piston rings

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

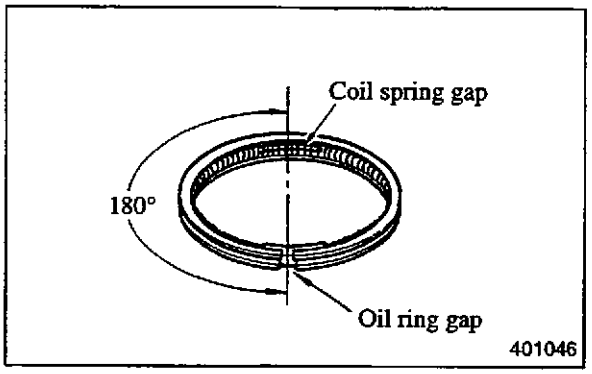
CAUTION

The top piston ring and second piston ring are marked "RH", and the oil ring in marked "R" near the gap on the side each ring. Install the rings with these marks facing up. Install them this way to avoid excessive oil consumption and Overheating



Piston and piston ring arrangement

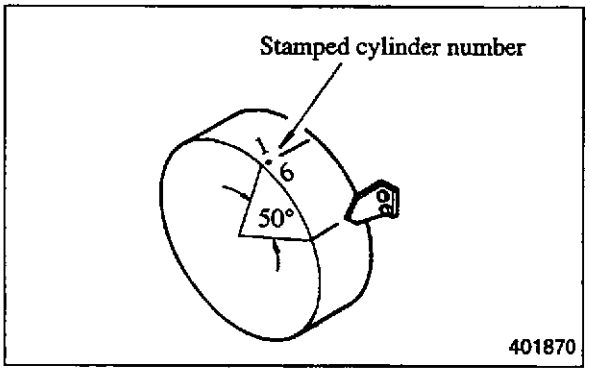
(b) Install the oil ring with its gap positioned at 180° to the coil spring.



(3) Preparation before installing pistons

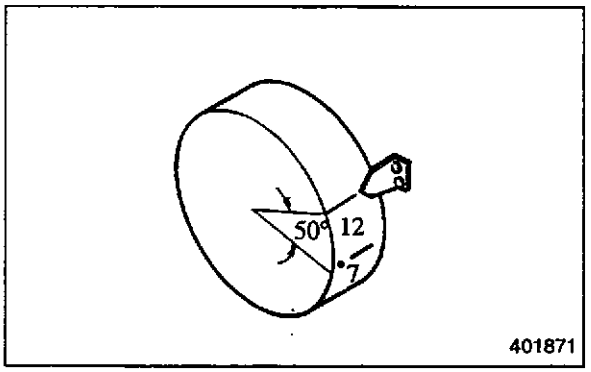
(a) Pistons for right bank cylinders

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.

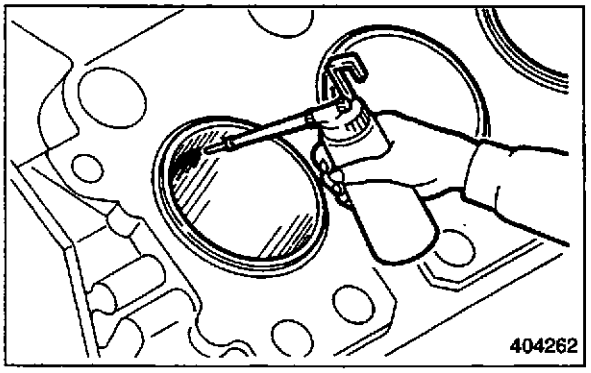


(b) Pistons for left bank cylinders

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.

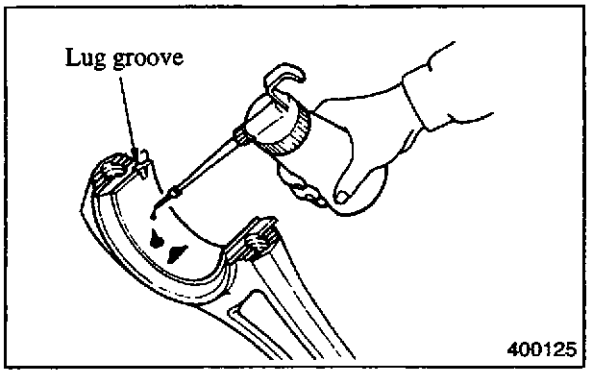


(c) Clean the cylinder liner bore surface and crank pin by wiping with a cloth, then coat it with engine oil.



(4) Installing connecting rod metal upper shells

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

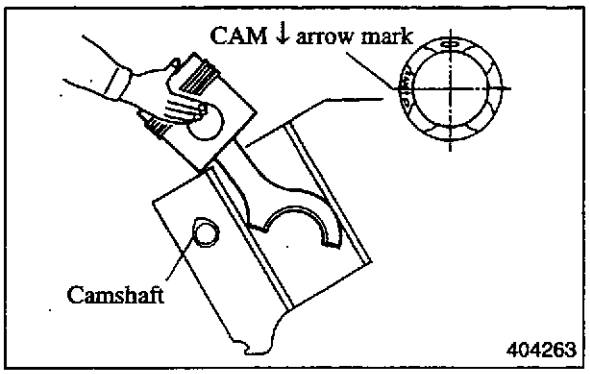


(5) Inserting pistons

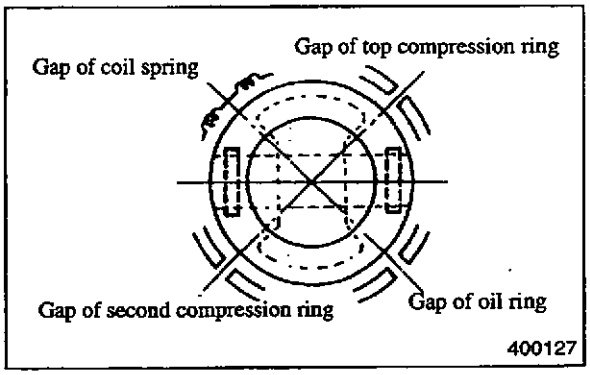
(a) Put the connecting rod in the cylinder liner, and carefully rest the piston on top of the crankcase.

⚠CAUTION

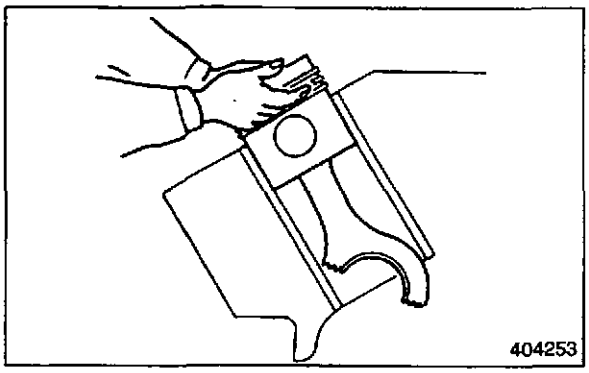
(a) Make sure the arrow mark ↓ above the "CAM" on top of the piston points forward.
(b) When placing the connecting rod in the liner, keep it away from the oil jet nozzle by observing the rod through the inspection hole of the crankcase. Do not rotate the piston.



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



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



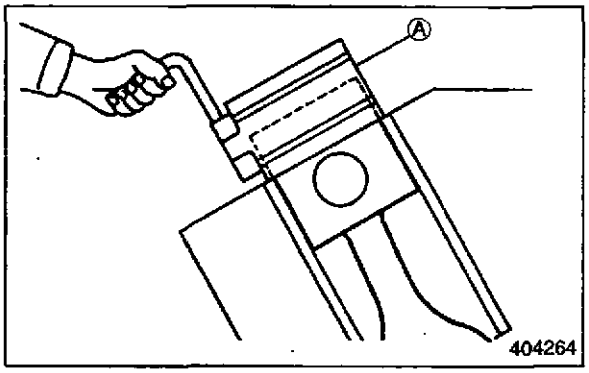
⚠WARNING

Do not pinch your finger between the oil ring and cylinder liner.

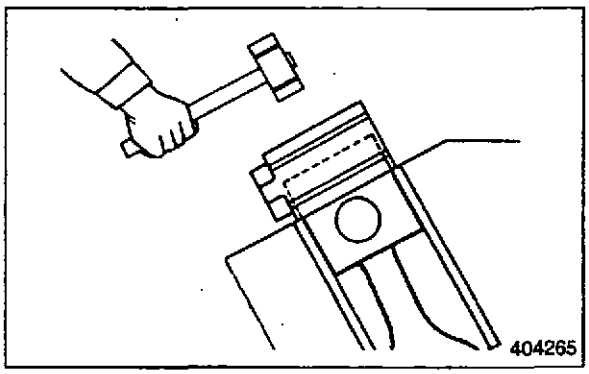
NOTE

Slowly insert the piston to avoid damaging it.

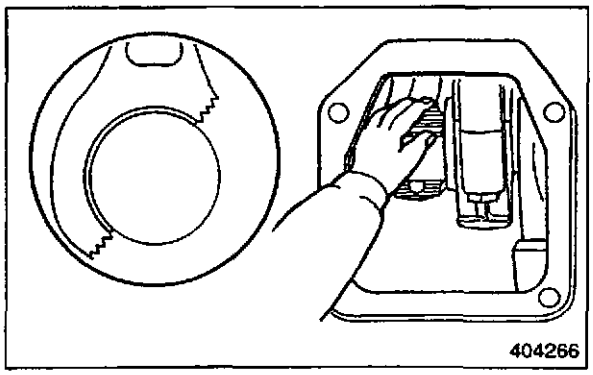
(d) After making sure that the piston ring gaps are positioned properly, coat the rings with engine oil, then clamp them, using the piston installer Ⓐ (37191-07100). At this time, coat the inside surface of the installer with engine oil.



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



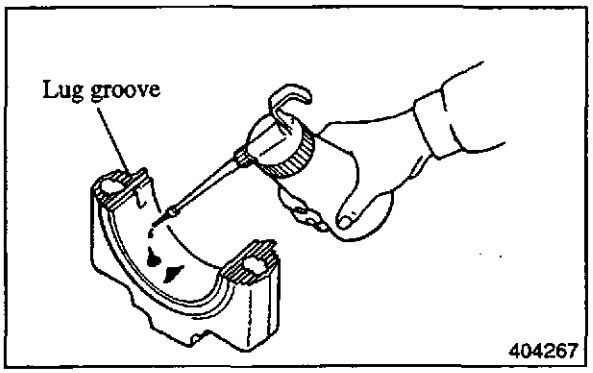
(f) By inserting your hand through the crankcase inspection hole, make sure that the upper shell of the metal is properly positioned in the large end of the connecting rod.



(6) Installing connecting rod cap bolts

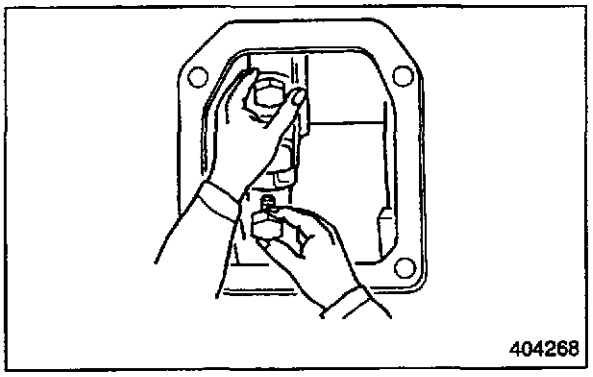
(a) Insert the connecting rod metal into the connecting rod cap along the ring groove.

(b) Coat the threads of the cap bolts and the inside surface of the lower shells of the connecting rod metal with engine oil.



(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 dropping the cap into the oil pan. Coat the threads of the bolts with engine oil, then tighten the bolts temporarily.

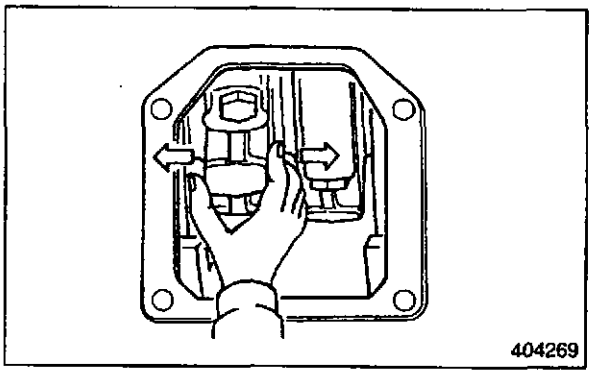
(d) With the cap bolts tightened temporarily, touch the joint between the cap and rod. Make sure that the cap is normally held in place, and tighten the bolts to the specified torque.



⚠CAUTION

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

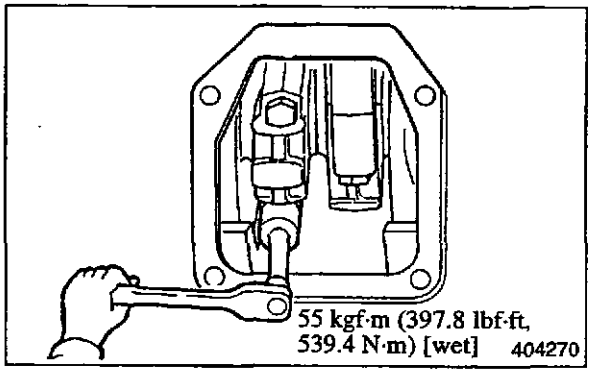
(e) Temporarily tighten the cap bolts of the rod installed later, then press it squarely toward the rod already installed by tapping. Move the large end of this rod in the thrust direction. Make sure that the rod has correct end play.



(f) Tighten the cap bolts to the specified torque.

NOTE

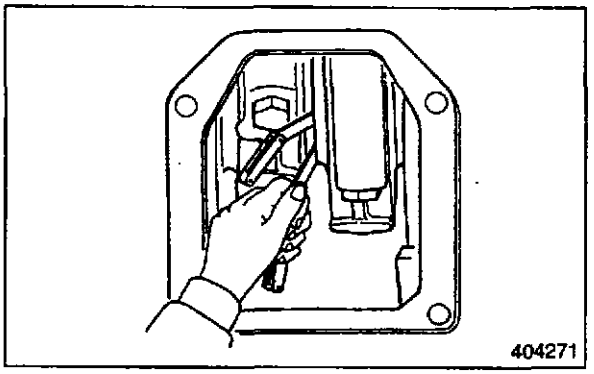
To tighten connecting rod cap bolts according to the angle method, tighten to 245 N·m {25 kgf·m}, then turn 60° more.



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

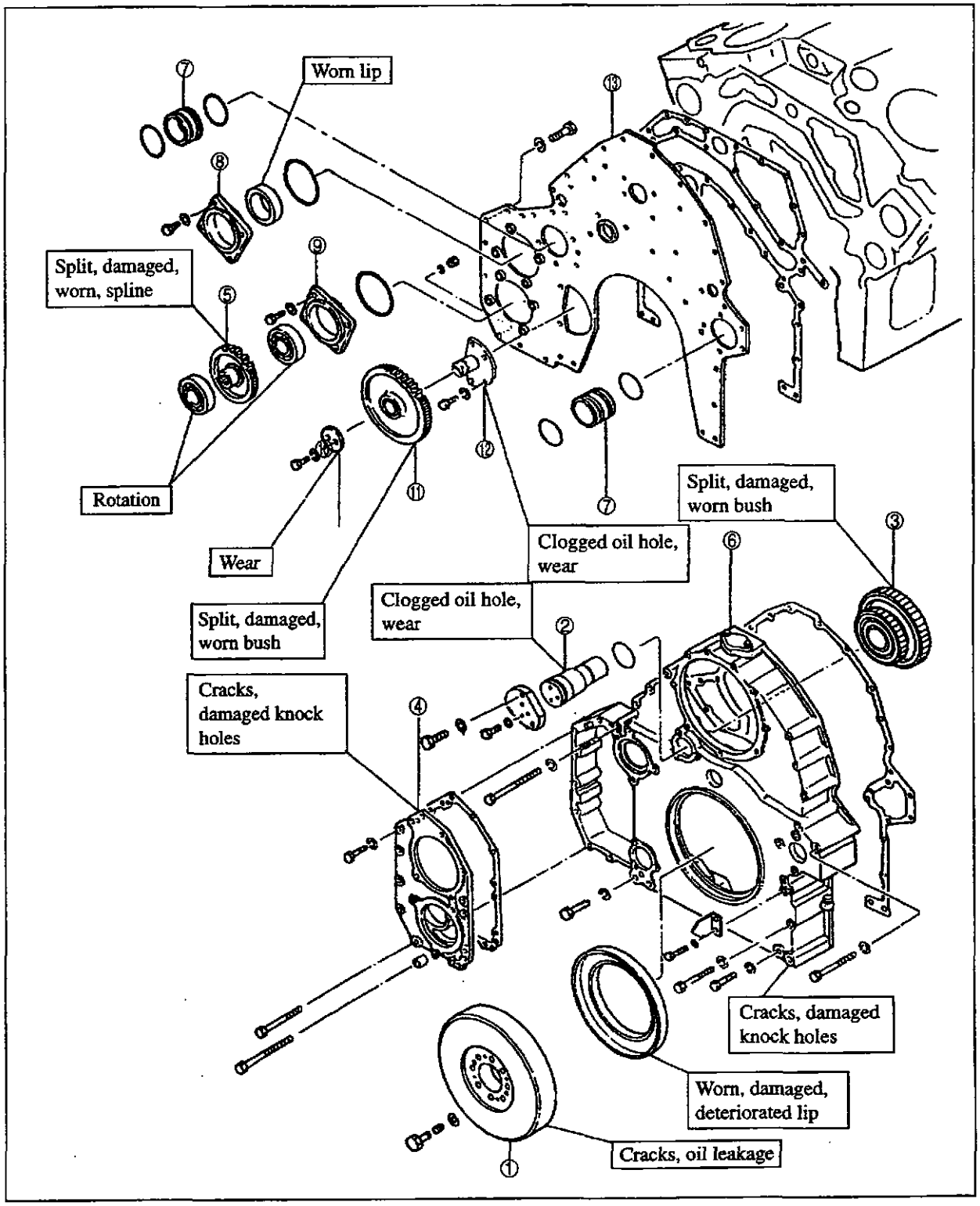
NOTE

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



3. Viscous Damper and Front Gear

3.1 Disassembly

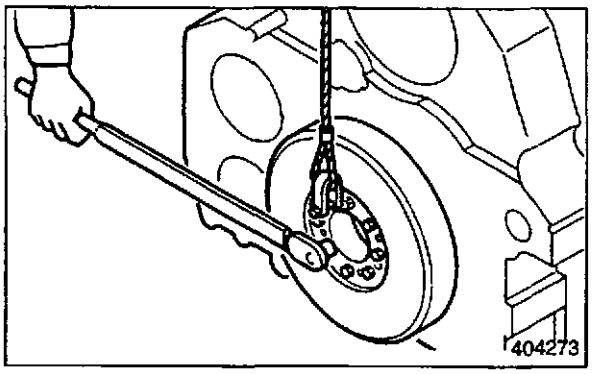


① Viscous damper
② Fan-drive idler shaft
③ Fan-drive idler gear
④ Plate
⑤ Oil pump gear
⑥ Front gear case
⑦ Water coupling
⑧ Water pump bearing cover
⑨ Oil pump bearing cover
⑩ Thrust plate
⑪ Idler gear
⑫ Idler shaft
⑬ Front plate

(1) Removing the viscous damper

(a) Attach a sling to the viscous damper. Unscrew the mounting bolts.
(b) Screw the two jacking bolts (M14 × 1.5-40 mm (0.06-1.58 in.)) into the holds uniformly, then remove the viscous damper.

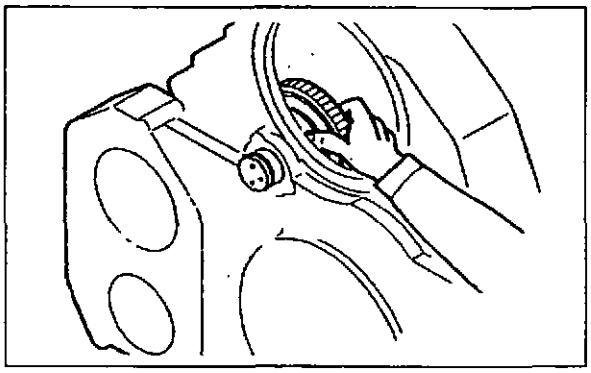
Weight: approx. 50 kg (110.2 lb)



(2) Removing the fan drive idler gear and idler shaft

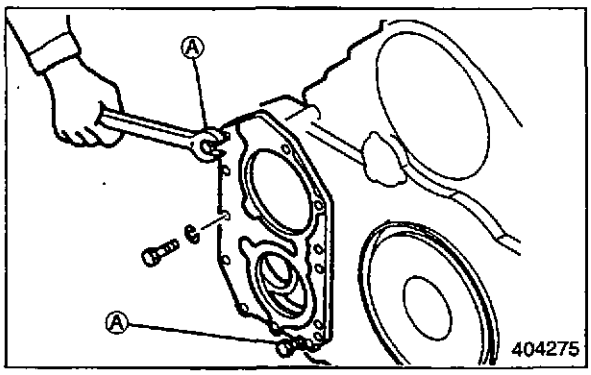
(a) Unscrew three gear case flange mounting bolts, three idler shaft mounting bolts and remove the gear case flange.

(b) Screw the idler shaft mounting bolt into the idler shaft, then pull it out.
When pulling it, grip the idler gear inside by hand to hold it.
After pulling the shaft out, remove the idler gear through the drive case mounting hole.



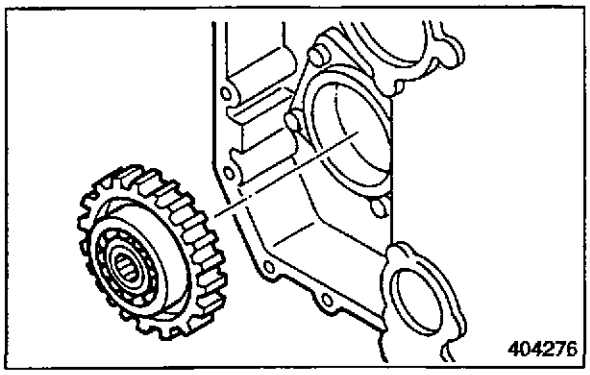
(3) Removing the oil pump and water pump mounting plate

Unscrew the mounting bolts of the plate.
Remove the plate by screwing the two jacking bolts Ⓐ (64362-68500: M12 × 1.25 (0.4925 in.)) uniformly into the plate.



(4) Removing the oil pump gear

Remove the oil pump gear, complete with the bearing.

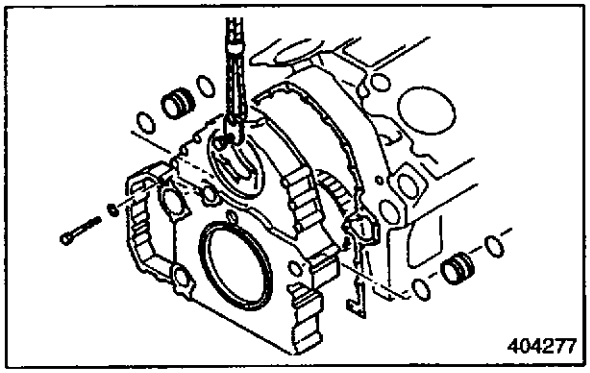


(5) Removing the front gear case

(a) Attach a sling to the front gear case.

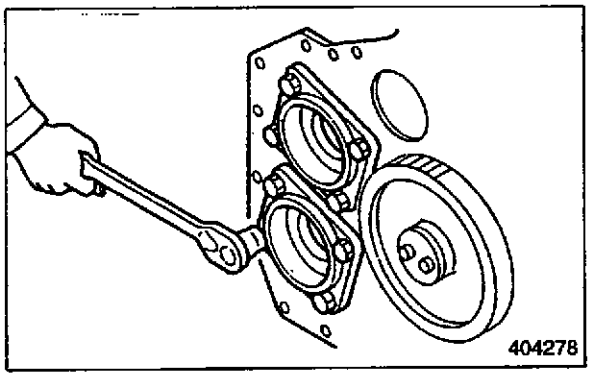
(b) Unscrew the front gear case mounting bolts. Remove the lifted gear case by sliding it until the gear case comes apart from the positioning dowel pin. Be careful not to damage the oil seal, or bend the pointer by hitting it.

Weight: 70 kg (154.3 lb) approx.



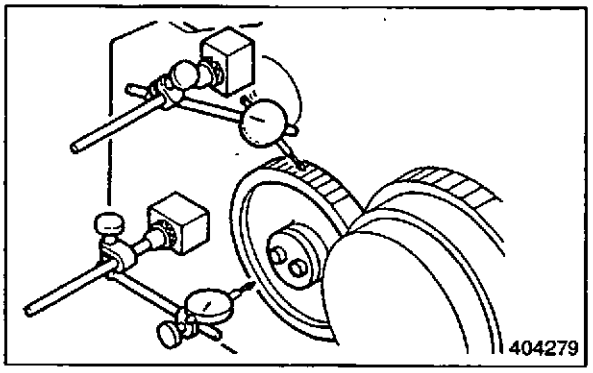
(6) Removing the oil pump and water pump bearing cover

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



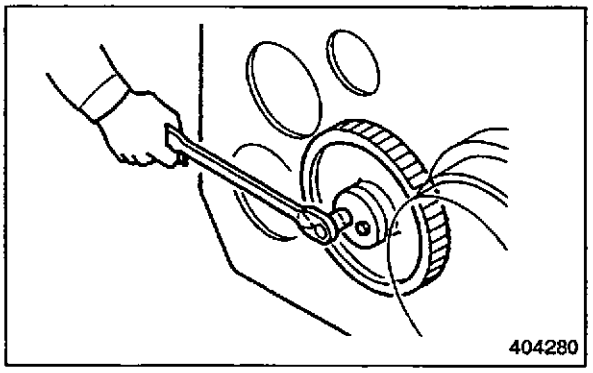
(7) Measuring backlash and end play of the idler gear

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



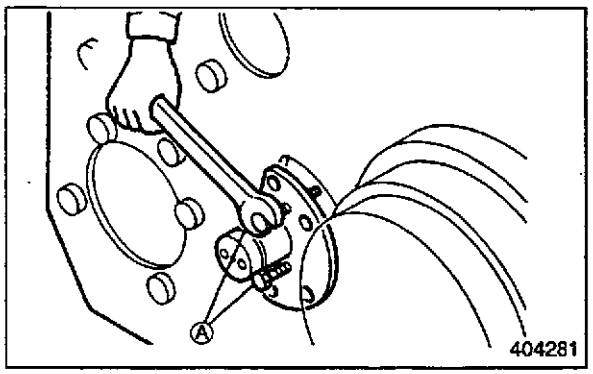
(8) Removing the idler gear

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



(9) Removing the idler shaft

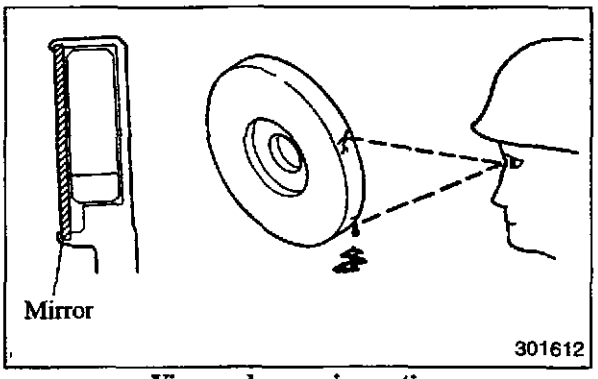
Do not remove the idler shaft unless it is needed. When needed, remove it by unscrewing the mounting bolts and screwing the two jacking bolts Ⓐ (M10 × 1.25 (0.49 in.)) uniformly.



3.2 Inspection and Repair

Viscous Damper Inspection

Check the viscous damper for cracks, deformations or cracks in the mirror plate, leakage of silicon oil, discolored or peeling paint due to excessive heat. Replace it with a new one after 8000 hours of service.



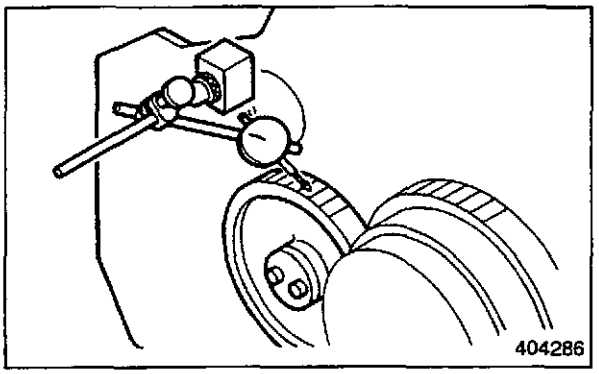
Viscous damper inspection

Measuring Backlash

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

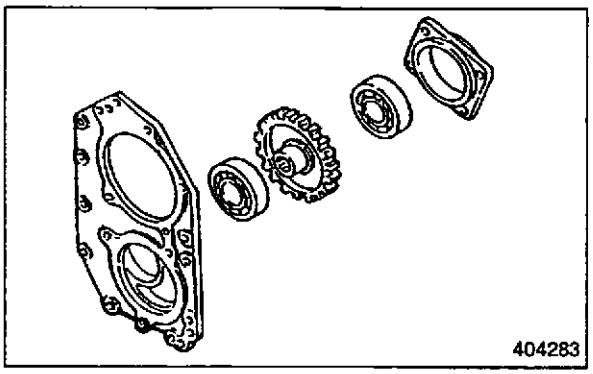
Unit: mm (in.)

Item	Standard Clearance	Service Limit
Backlash	0.12-0.18 (0.0047 to 0.0071)	0.50 (0.0197)



Measuring gear backlash

Oil Pump Drive: Bearing Bore Diameters



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

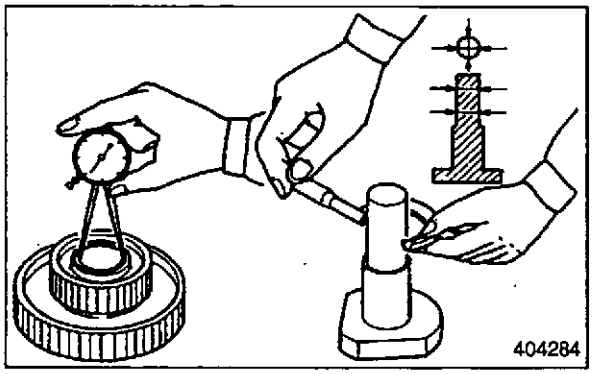
- Drive shaft and bearing
- Drive case and bearing
- Drive shaft and oil seal

Unit: mm (in.)

Item		Nominal Value	Assembly Standard
Cover bearing bore		ø110 (4.33)	110.000-110.035 (4.33071-4.33209)
Plate bearing bore		ø110 (4.33)	109.987-110.022 (4.33020-4.33157)
Bearing	Outside dia.	ø110 (4.33)	109.985-110.000 (4.33012-4.33071)
	Inside dia.	ø50 (1.97)	49.985-50.000 (1.96791-1.96850)
Gear shaft bearing bore		ø50 (1.97)	49.993-50.013 (1.96823-1.96902)

Idler Gears, Idler Gear Bushings, and Idler Gear Shafts

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



Measuring inside diameters for idler bushing and shaft

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

Unit: mm (in.)

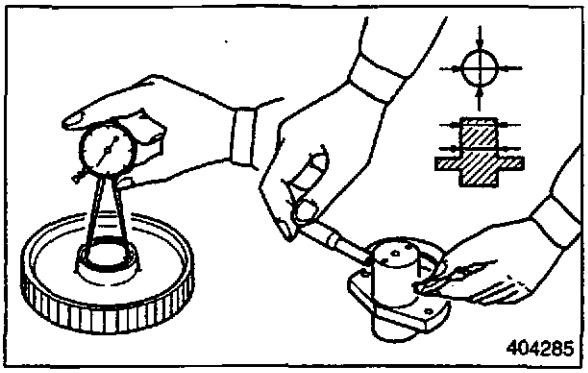
Item	Norminal Value	Assembly Standard	Service Limit
Idler gear bushing inside diameter	ø50 (1.97)	50.000-50.025 (1.96850-1.96949)	50.060 (1.97087)
Idler gear shaft diameter	ø50 (1.97)	49.950-49.975 (1.96654-1.96752)	49.900 (1.96457)

(2) 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	Norminal Value	Assembly Standard	Service Limit
Idler gear bushing inside diameter	ø50 (1.97)	50.000-50.025 (1.96850-1.96949)	50.060 (1.97087)
Idler gear shaft diameter	ø50 (1.97)	49.950-49.975 (1.96654-1.96752)	49.900 (1.96457)



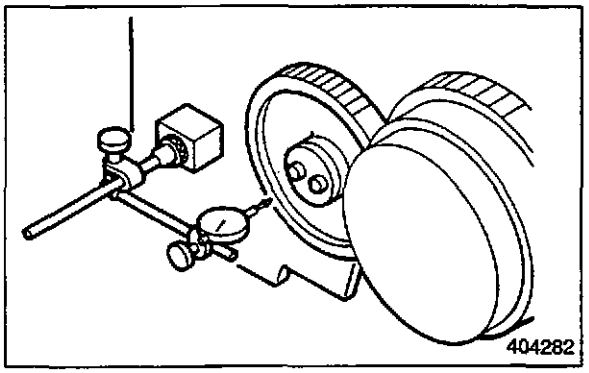
Measuring inside diameters for idler bushing and shaft

(3) Measuring idler gear end play

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

Unit: mm (in.)

Item	Standard Clearance	Repair Limit
Idler gear end play	0.2-0.4 (0.008-0.016)	0.6 (0.024)
Fan drive idler gear end play	0.25-0.75 (0.0098-0.0295)	1.2 (0.047)



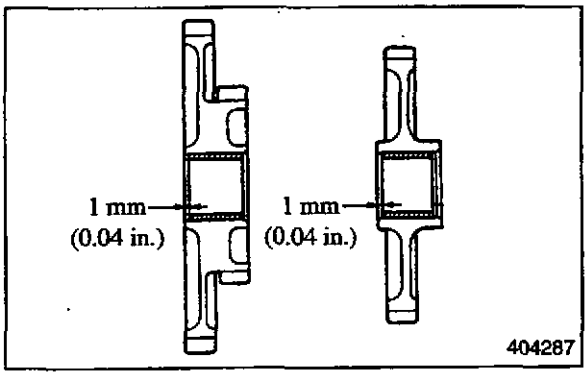
Measuring idler gear end play

(4) Replacing idler bushing

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

(b) Install a new bushing to the gear by pressing it until the end face of the bushing is 1 mm (0.04 in.) deeper than that of the gear boss.

(c) 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.) $\frac{1.6S}{\nabla\nabla\nabla}$.



Replacing idler bushing

3.3 Reassembly

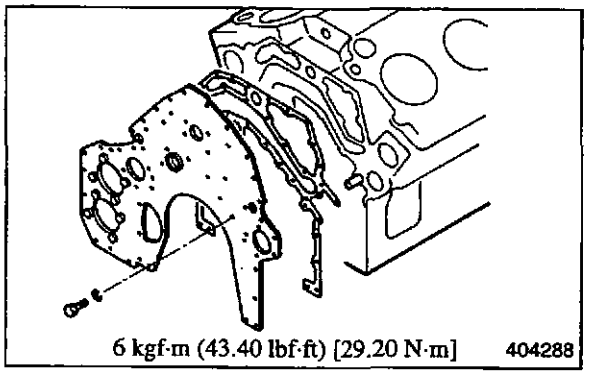
Reassembly is the reverse procedure of disassembly.

(1) Installing the front plate

(a) Apply sealant (HERDITE) 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.

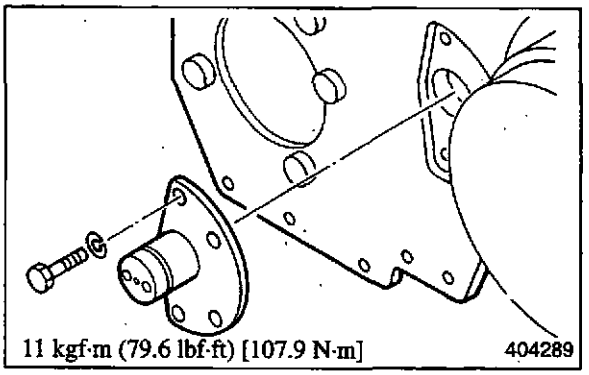
(c) Make sure that the lower end of the front plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



(2) Installing the idler shaft

(a) Insert the idler shaft using the guide bolts.

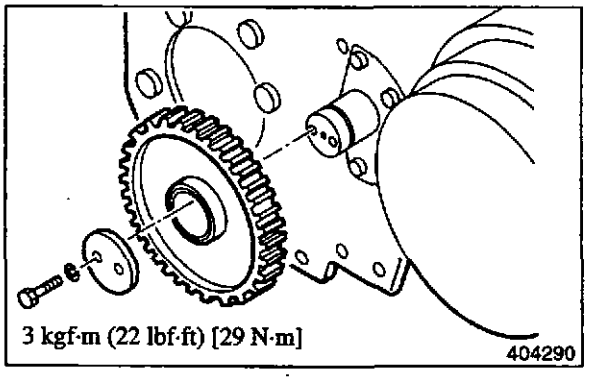
(b) Tighten the shaft mounting bolts to the specified torque.



(3) Installing the idler gear

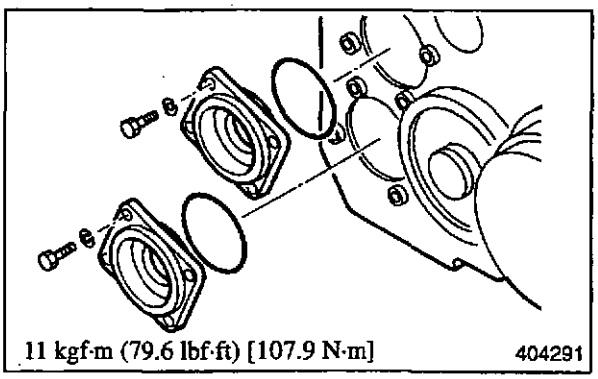
(a) Insert the idler gear into the shaft, and install the thrust plate.

(b) Install the thrust plate, then tighten the mounting bolts to the specified torque.



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

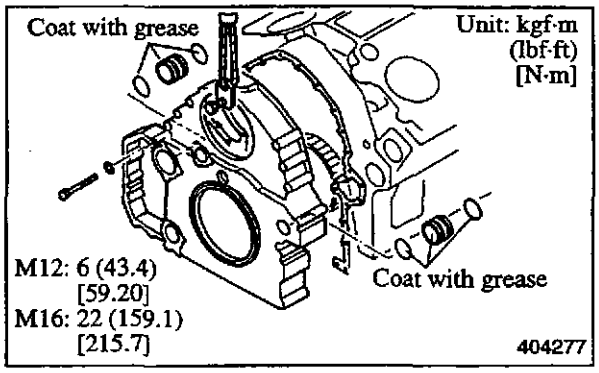
(a) Insert the bearing cover into the front plate, then tighten the cover mounting bolts to the specified torque.



(5) Installing the front gear case and pointer

(a) Apply a sealant (HERDITE) 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.



⚠CAUTION

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.

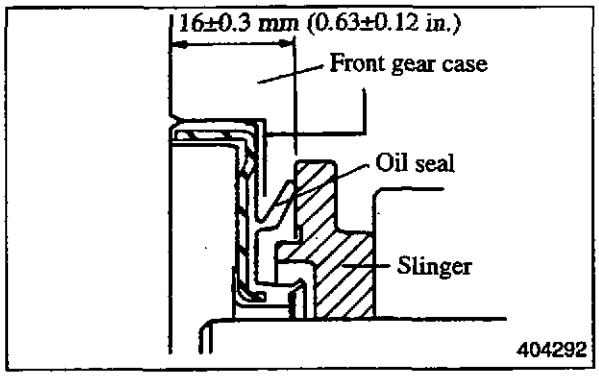
(d) Tighten the front cover mounting bolts uniformly to the specified torque.

(e) Make sure that the lower end of the front cover 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.

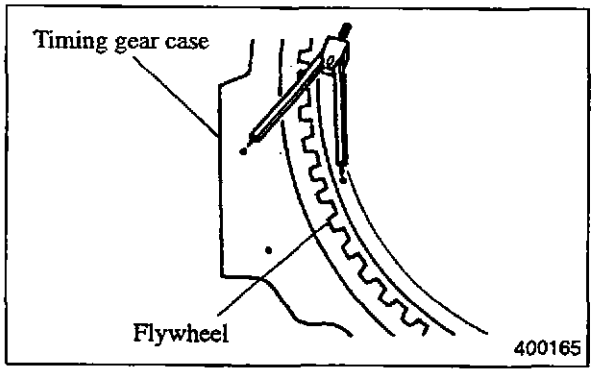
(g) Apply engine oil to the lip of the oil seal.

(h) Insert the oil seal to the slinger using the jig in position as shown in the figure (404292).



When the Pointer Is Out of Place

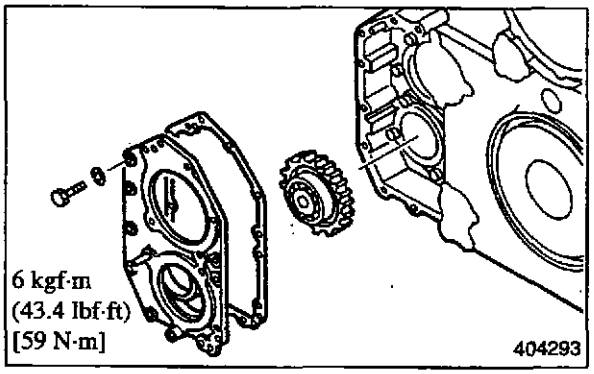
To determine the top dead center of No. 1 piston in compression stroke, bring the mark on the flywheel to the position where it is at the equal distances from the two marks punched on the timing gear case. When these marks are positioned at the equal distance from one another, No. 1 and No. 6 pistons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

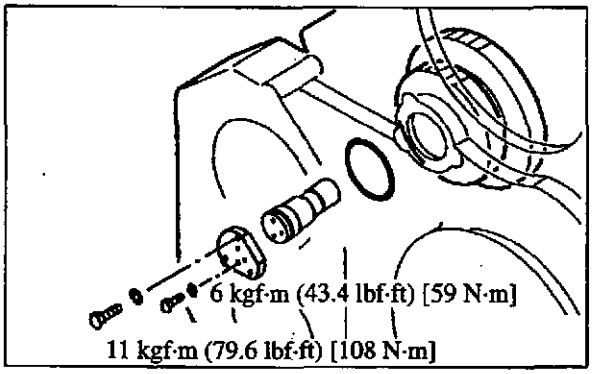
(a) Install the gear case flange to the idler shaft, and tighten the bolts to the specified torque.

(b) Install the idler gear through the drive case mounting hole with its smaller gear toward the front side.

(c) Insert the idler shaft. During installation, hold the gear center to align it with the center of the idler shaft hole.

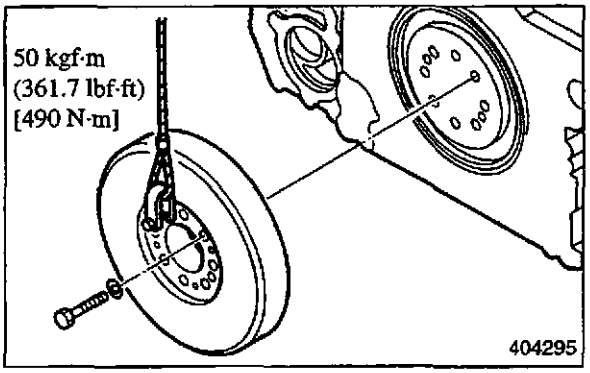
(d) Tighten the mounting bolts to the specified torque.

(e) Make sure that there is end play and backlash for the gear.



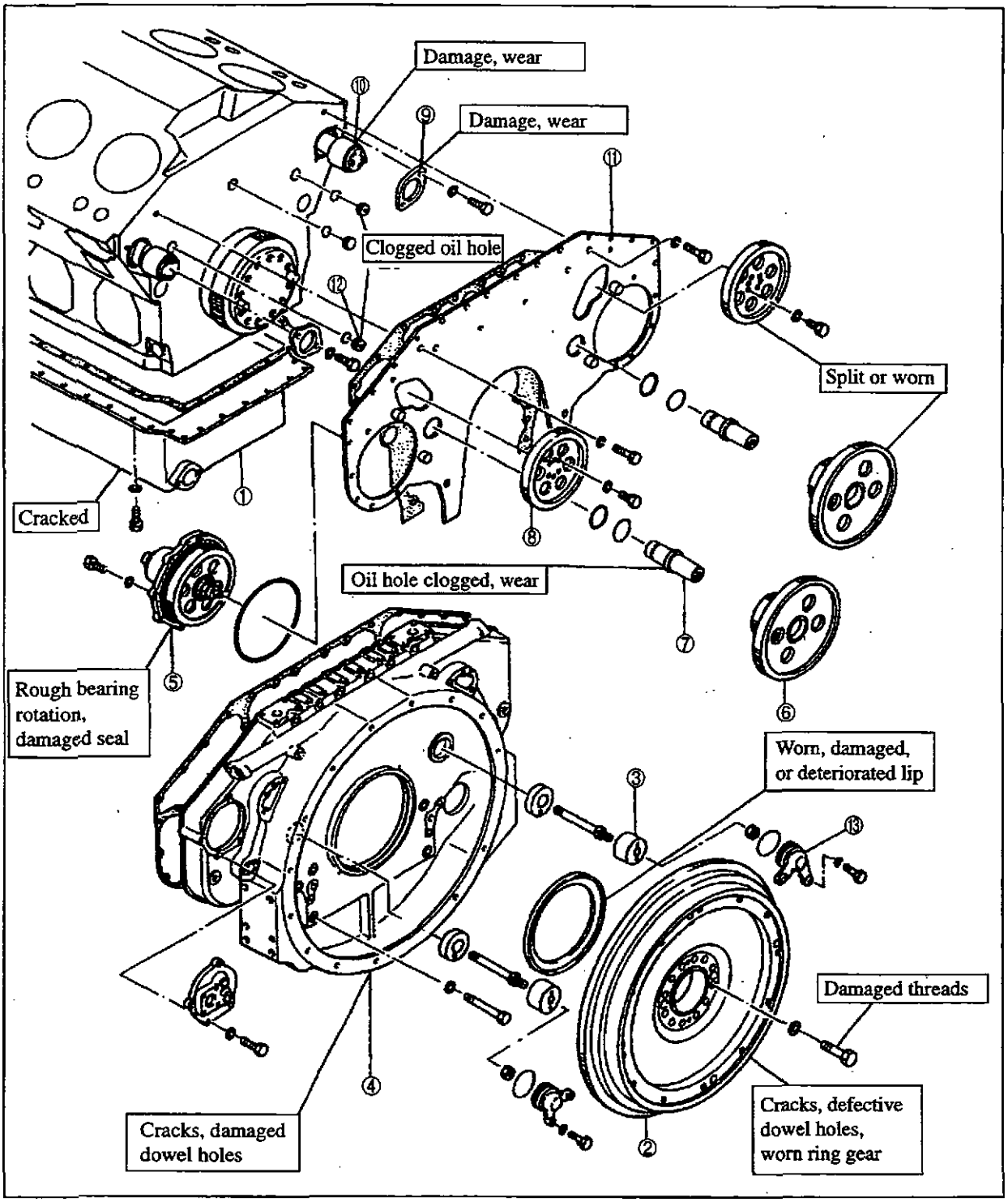
(8) Installing the viscous damper

Tighten the damper mounting bolts to the specified torque.



4. Flywheel, Timing Gears, and Camshaft

4.1 Disassembly



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

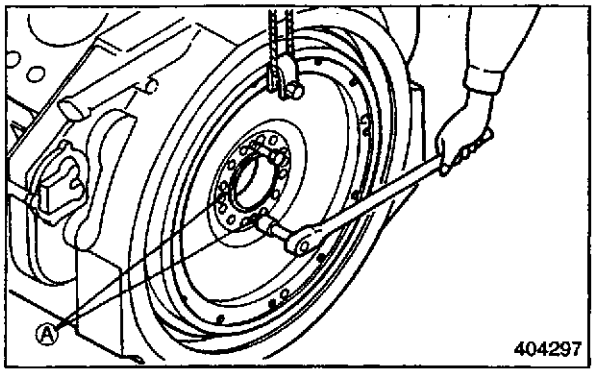
(1) Removing the flywheel

(a) Attach a sling to the flywheel.

(b) Unscrew the mounting bolts.

(c) Screw the two jacking bolts Ⓐ (64362-68500: M12 × 1.25 (0.49 in.)) into the holes in the flywheel evenly, then remove the flywheel.

Weight: approx. 138 kg (304.2 lb)



⚠CAUTION

(a) When you remove the flywheel, do not drop it or bump it against a hard object.

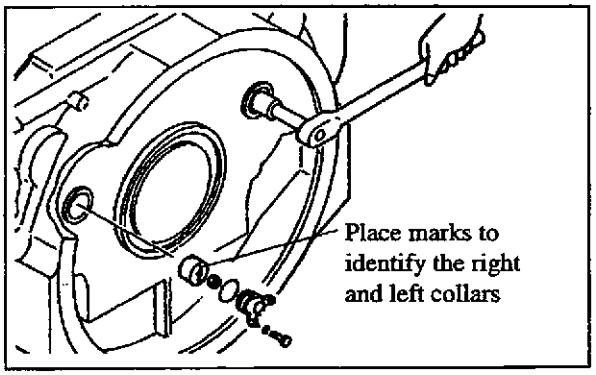
(b) The ring gear is bolt mounted to the flywheel. Do not remove the gear except when it has to be replaced.

(2) Removing the idler shaft 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 bolt (M18 × 1.5 (0.49 in.)) through the thrust collar mounting bolt hole 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.

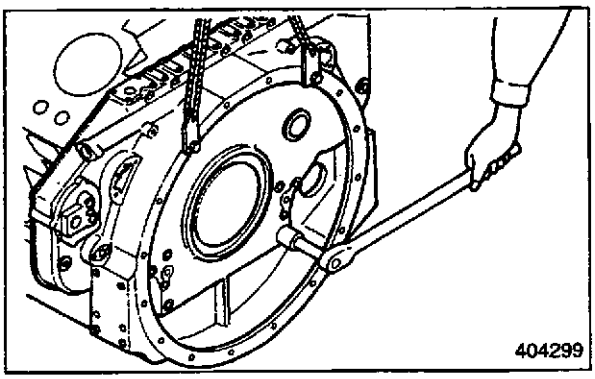
(3) Removing the timing gear case

(a) Attach slings to the timing gear case.

(b) Unscrew the mounting bolts.

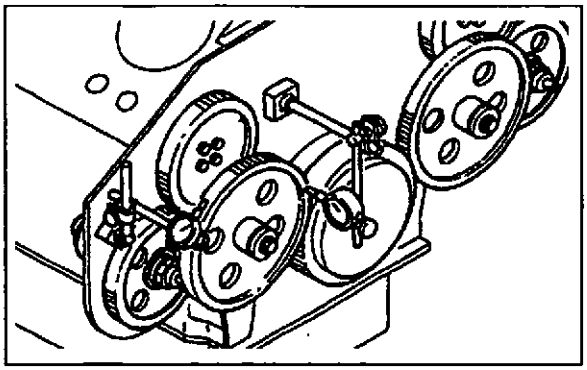
(c) Remove the timing gear case by lifting it up until it separates from the dowel pin. Do not damage the oil seal.

Weight approx. 150 kg (330.7 lb)



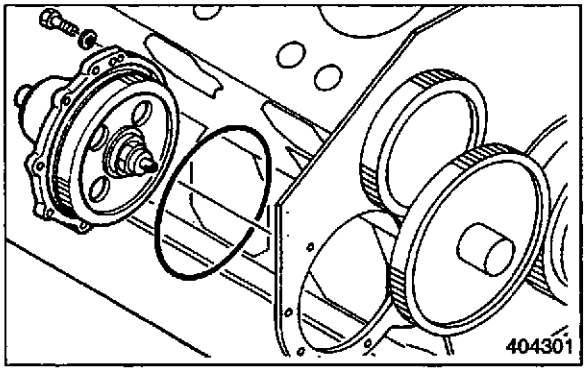
(4) Measuring backlash and end play

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



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

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



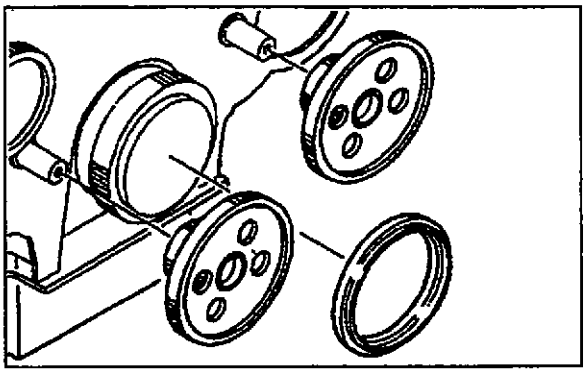
NOTE

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).

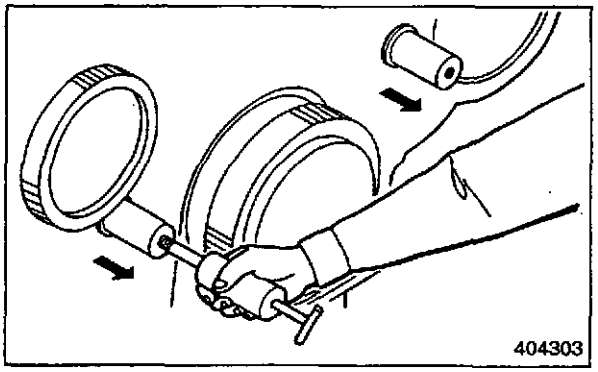


NOTE

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

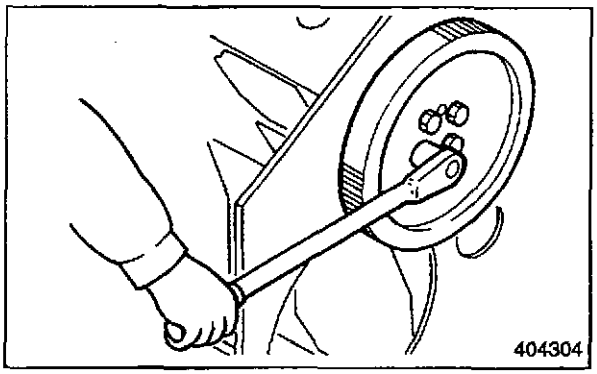
(7) Removing the idler shaft

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 (0.49 in.)).



(8) Removing camshaft gears

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



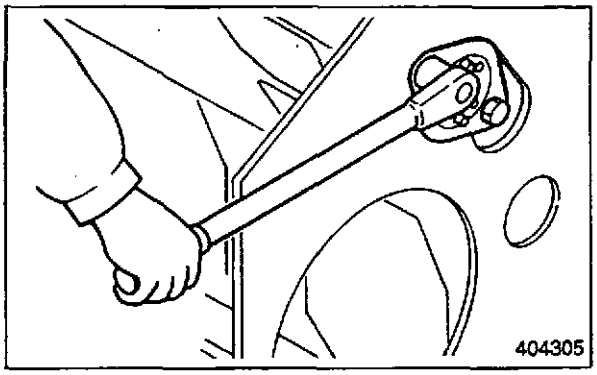
(9) Removing camshafts

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

Weight: approx. 35 kg (77.1 lb)

⚠CAUTION

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



4.2 Inspection and Repair

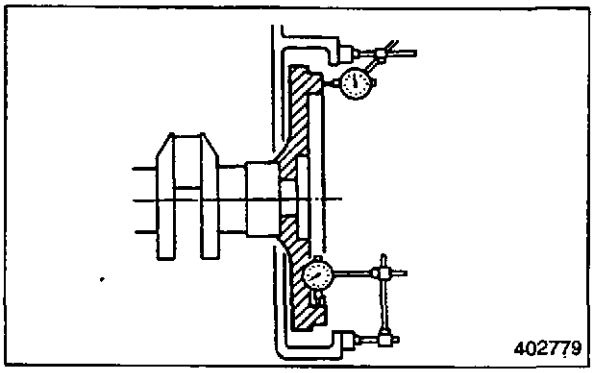
Flywheel and Ring Gear

Measure the flywheel face and radial runouts.

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

Unit: mm (in.)

Item		Assembly Standard
Flywheel	Face runout	0.336 (0.01323) max.
	Radial rout	0.13 (0.0051) max.



Measuring flywheel runout

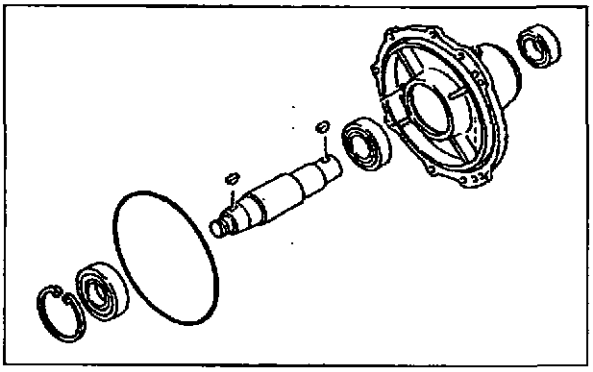
Injection Pump Drive Diameter and Inside Diameter of Bearings

(1) Check the bearing for smooth rotation. Replace the bearing if it rotates erratically or hums.

(2) Check the fit of the drive shaft in the bearing. Replace excessively worn parts.

(3) Check the fit of the bearing in the drive case. Replace excessively worn parts.

(4) Check the drive shaft and oil seal. Replace any defective parts.



Unit: mm (in.)

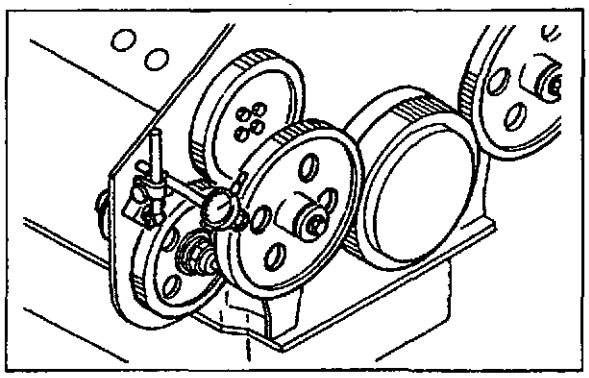
Item		Nominal Value	Assembly Standard
Bearing	Outside dia.	ø90 (3.54)	89.985-90.000 (3.93042-3.54331)
		ø100 (3.9)	99.985-100.000 (3.93042-3.93701)
	Inside dia.	ø45 (1.77)	44.988-45.000 (1.77118-1.77165)
		ø50 (1.97)	49.985-50.000 (1.96791-1.96850)
Drive shaft bearing dia.		ø45 (1.77)	45.002-45.013 (1.77173-1.77217)
		ø50 (1.97)	50.002-50.013 (1.96858-1.96902)

Timing Gears: Measuring Backlash

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

Unit: mm (in.)

Item	Standard Clearance	Repair Limit	Service Limit
Timing gear backlash	0.12-0.18 (0.0047-0.0071)	0.30 (0.0118)	0.50 (0.0197)



Measuring timing gear backlash

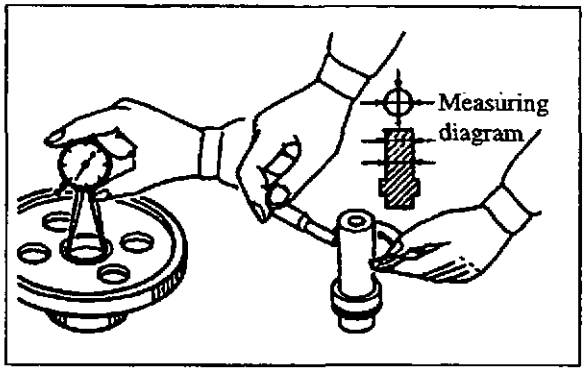
Idler Gears, Idler Gear Bushing, and Idler Gear Shafts

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

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

Unit: mm (in.)

Item	Norminal Value	Assembly Standard	Service Limit
Idler gear, bushing inside dia.	ø65 (2.56)	65.000-65.030 (2.55906-2.56024)	65.060 (2.56142)
Idler gear shaft dia.	ø65 (2.56)	64.951-64.970 (2.55713-2.55787)	64.900 (2.55512)



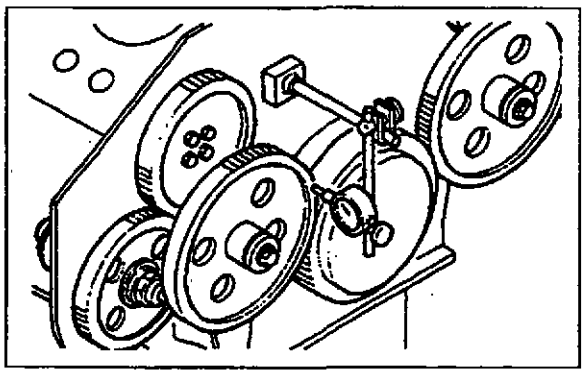
Measuring idler gear bushing and shaft

(2) Measuring idler gear end play

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

Unit: mm (in.)

Item	Standard Clearance	Repair Limit
Idler gear end play	0.3-0.6 (0.012-0.024)	1.0 (0.039)



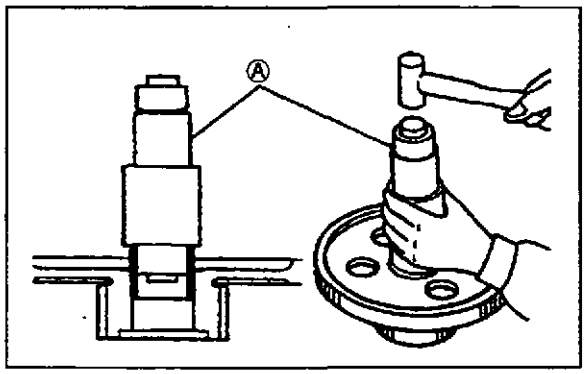
Measuring idler gear end play

(3) Replacing idler bushings

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

(b) Install a new bushing to the gear by pressing it until the end face of the bushing 1 mm (0.04 in.) deeper than that of the gear boss.

(c) After installing the bushing, be sure its inside diameter is within the assembly standard. If it is less than assembly standard, ream the bushing to the inside diameter of ø65 $^{+0.030}_{0}$ mm (2.56 $^{+0.001181}_{0}$ in.) $\frac{1.6S}{\nabla\nabla\nabla}$.



Replacing the idler gear bushing

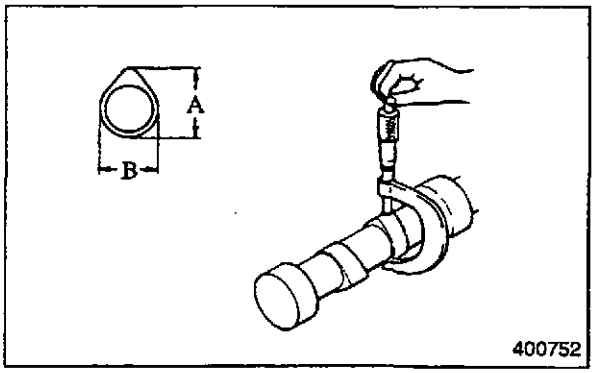
Camshafts and Camshaft Bushings

(1) Measuring cam lift

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

Unit: mm (in.)

Item	Assembly standard	Service Limit
Cam lift (A-B)	9.197-9.297 (0.36212-0.36605)	8.45 (0.3327)



Measuring cam lift

(2) Measuring camshaft runout

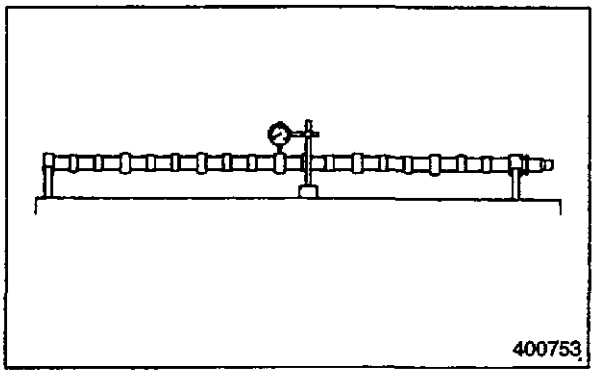
If the runout exceeds the repair limit, straighten the camshaft with a press, or replace it with a new one.

⚠CAUTION

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

Unit: mm (in.)

Item	Assembly Standard	Repair Limit
Camshaft runout	0.05 (0.002) max.	0.08 (0.0031)



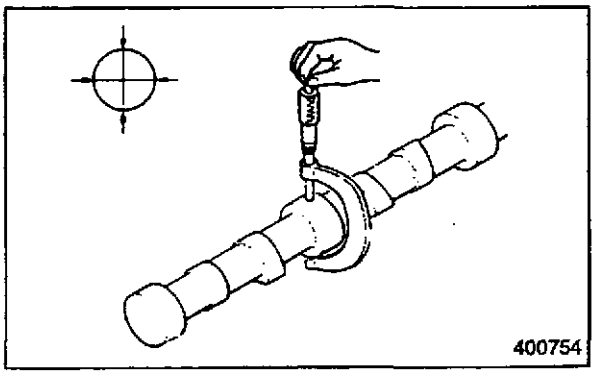
Measuring camshaft runout

(3) Measuring camshaft journal diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Camshaft journal dia.	ø84 (3.31)	83.92-83.94 (3.3042-3.3050)	83.87 (3.3022)



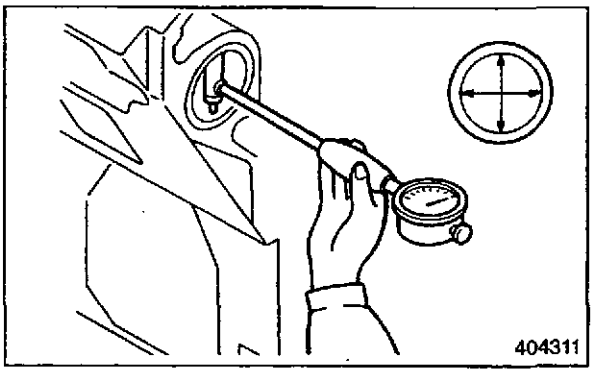
Measuring camshaft journal diameter

(4) Measuring camshaft bushing inside diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Camshaft bushing inside dia.	ø84 (3.31)	84.000-84.035 (3.30736-3.30874)	84.10 (3.31130)



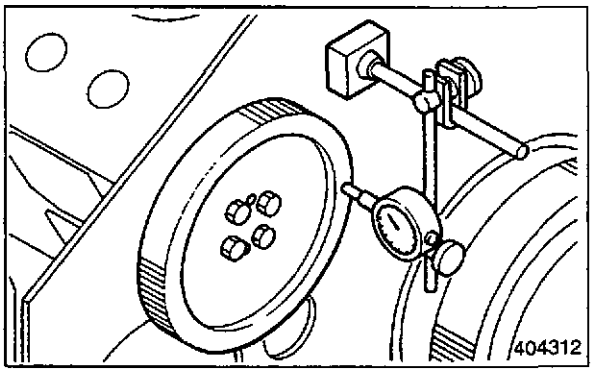
Measuring camshaft inside diameter

(5) Measuring camshaft end play

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

Unit: mm (in.)

Item	Standard Clearance	Service Limit
Camshaft end play	0.10-0.25 (0.0039-0.0098)	0.40 (0.0157)

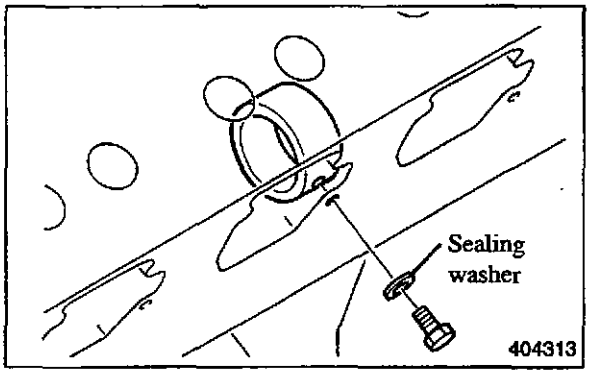


Measuring camshaft end play

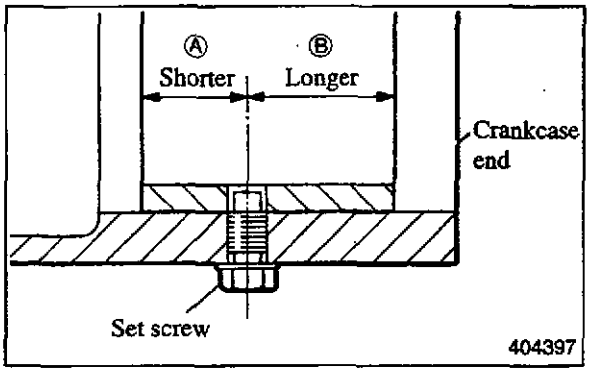
(6) Replacing camshaft bushings

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

Use a wide bushing as the bearing for the rear section, and insert it in the correct direction.



Replacing a camshaft bushing



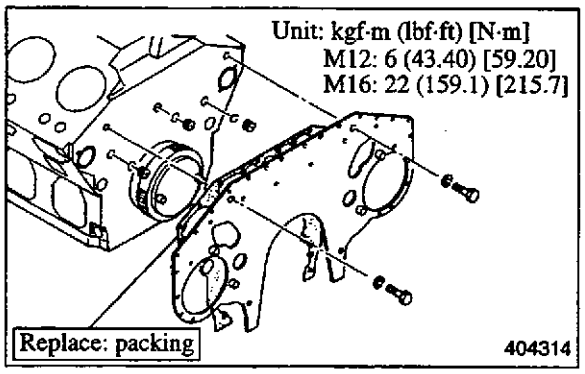
4.3 Reassembly

(1) Installing the rear plate

(a) Apply sealant (HERDITE) 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.

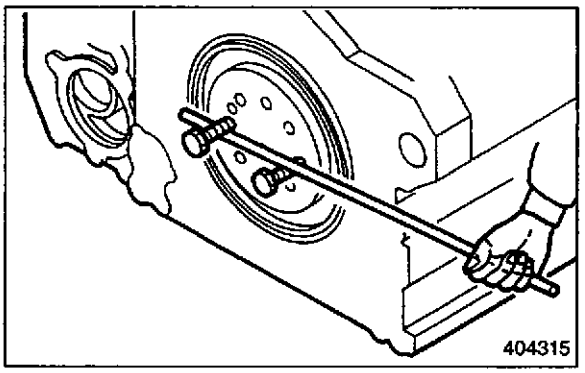
(c) Make sure that the lower end of the rear plate is flush with the bottom of the crankcase. Cut off the excess of the packing neatly along the edge of the plate.



(2) Cranking the engine

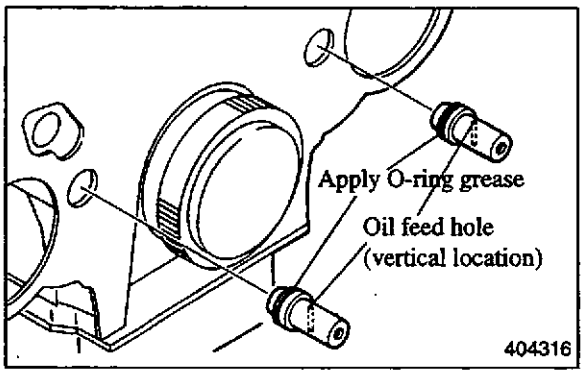
(a) Install the bolt to the viscous damper mounting hole (M22 × 1.5 (0.06 in.)).

(b) Using this bolt, 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).

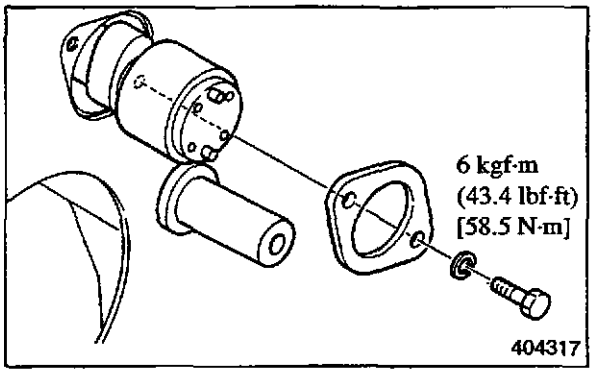


(4) Installing the camshafts (left and right)

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

(b) Tighten the thrustplate mounting bolt to the specified torque.

(c) Check and make sure that the camshaft turns smoothly.



NOTE

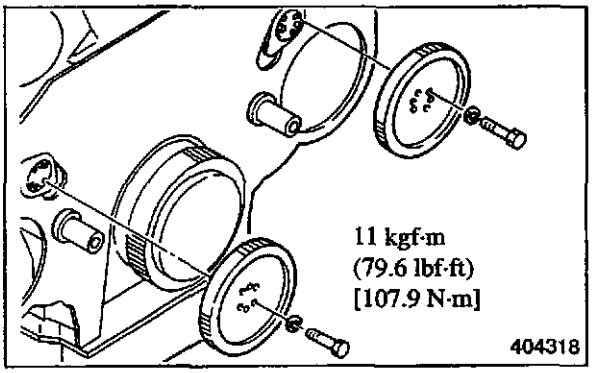
Do not mix the two different camshafts when you reassemble the engine.

(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.

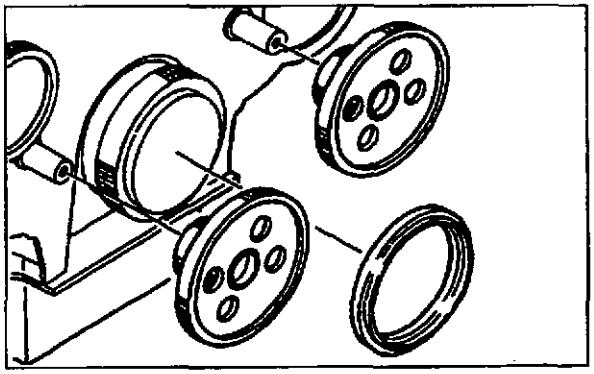
(c) After installing the camshaft gear, check that the gear rotates smoothly.



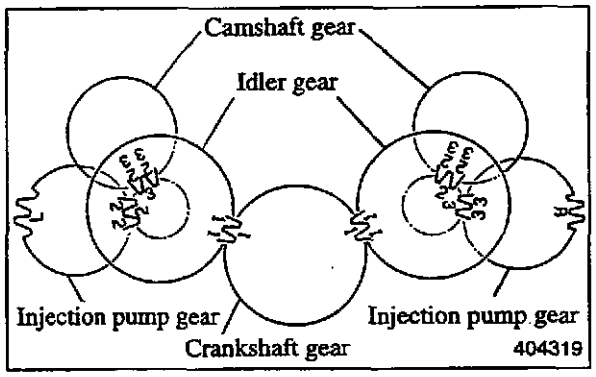
(6) Installing idler gears

(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 gear coincide with the figure shown on the right.



Timing gear train

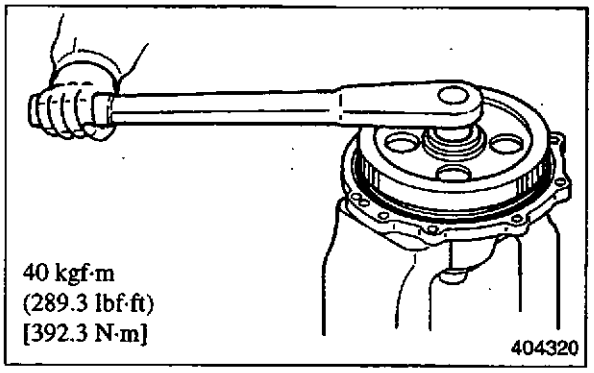
(7) Installing the injection pump drive

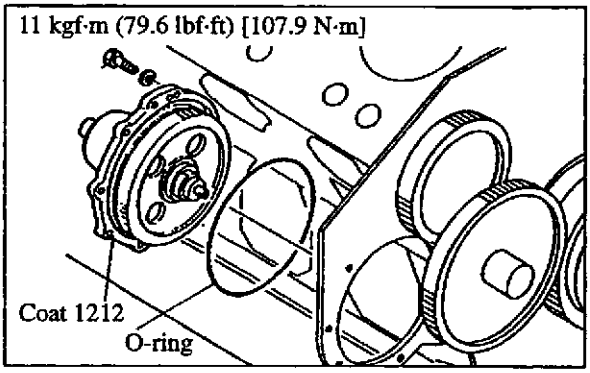
(a) Install the injection pump gear to the drive shaft, then tighten it to the specified torque.

(b) Fit the O-ring to the installation surface of the drive case.

(c) Install the injection pump drive to the rear plate by aligning its matching mark to that of the idler gear.

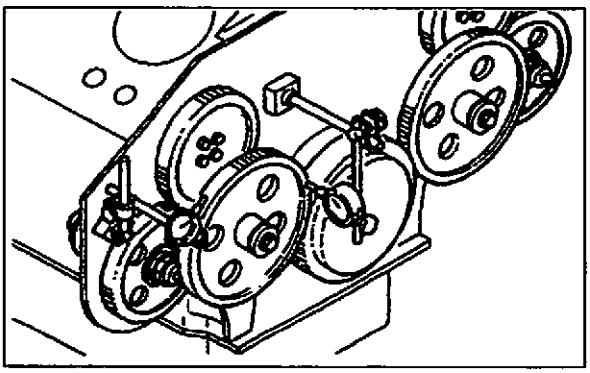
(d) Tighten the drive case mounting bolts to the specified torque.





(8) Inspecting and adjusting timing gears after installation

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



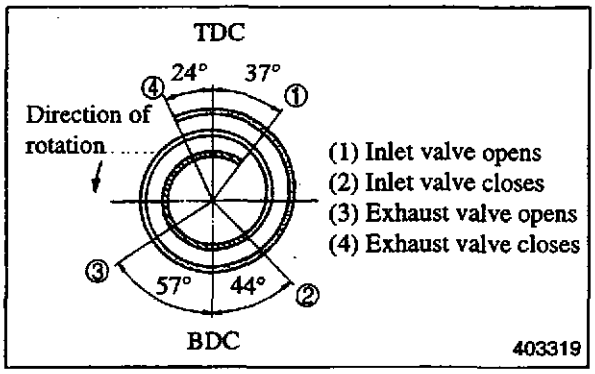
Inspecting Timing Gear Backlash and End Play

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

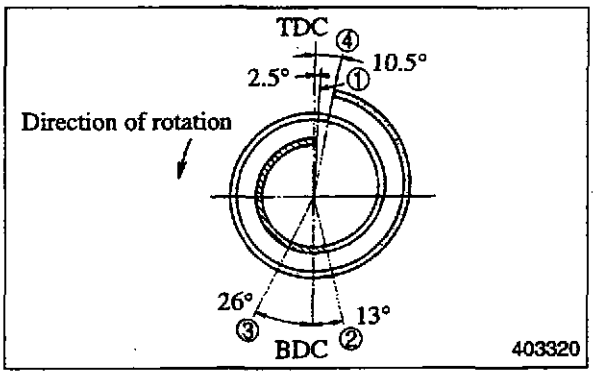
Inspecting Valve Timing

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 here.

Using a 2 mm (0.08 in.) feeler gauge, add 2 mm (0.08 in.) clearance to the inlet and exhaust valves of the No. 1 cylinder. Then insert a 0.05 mm (0.0019 in.) feeler gauge between to top of the bridge cap and rocker. Slowly turn the crankshaft to find the position where the feeler gauge is firmly gripped (the valve starts opening) and the position where the gauge 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

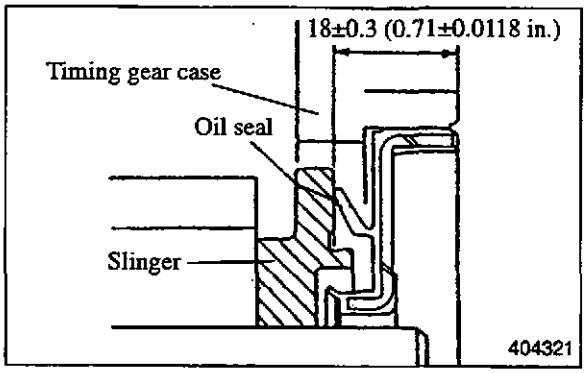
(a) Apply sealant (HERDITE) to the timing gear case surface. Place the packing in position. Apply the sealant on the placed packing. Cut off the excess of the packing neatly along the bottom surface of the crankcase.

(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 shown in the figure (404321).

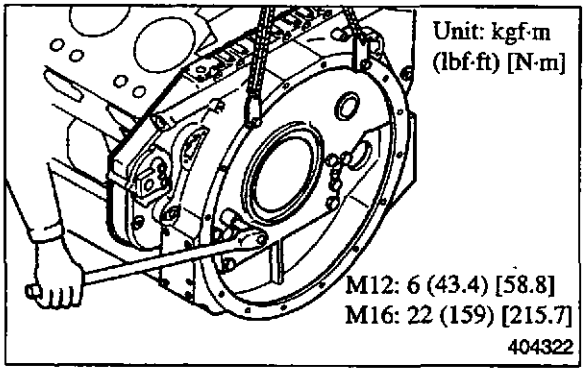


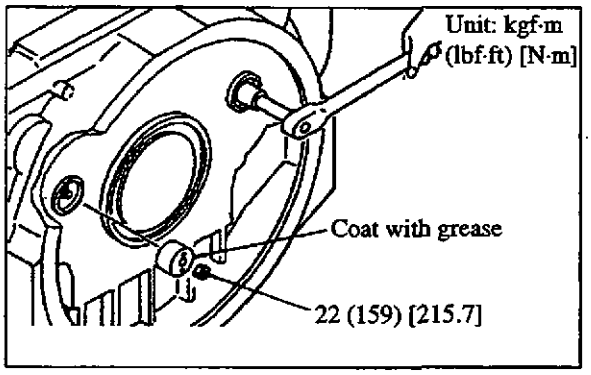
(10) Installing the idler shaft thrust collar

(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.

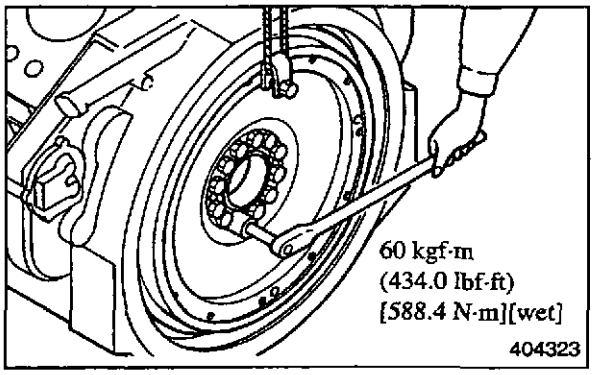




(11) Installing the flywheel

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

(b) Coat the threads and the bolt seat surface of the flywheel mounting bolts with engine oil, then tighten the bolts to the specified torque. Inspect the face and radial runouts of the flywheel.



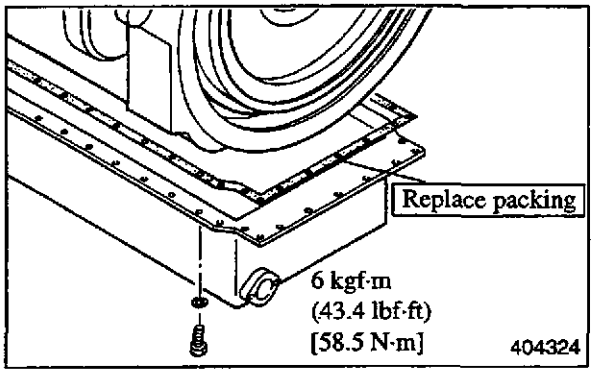
(12) Installing the oil pan

(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 (HERDITE) to the separated portions (4 locations).

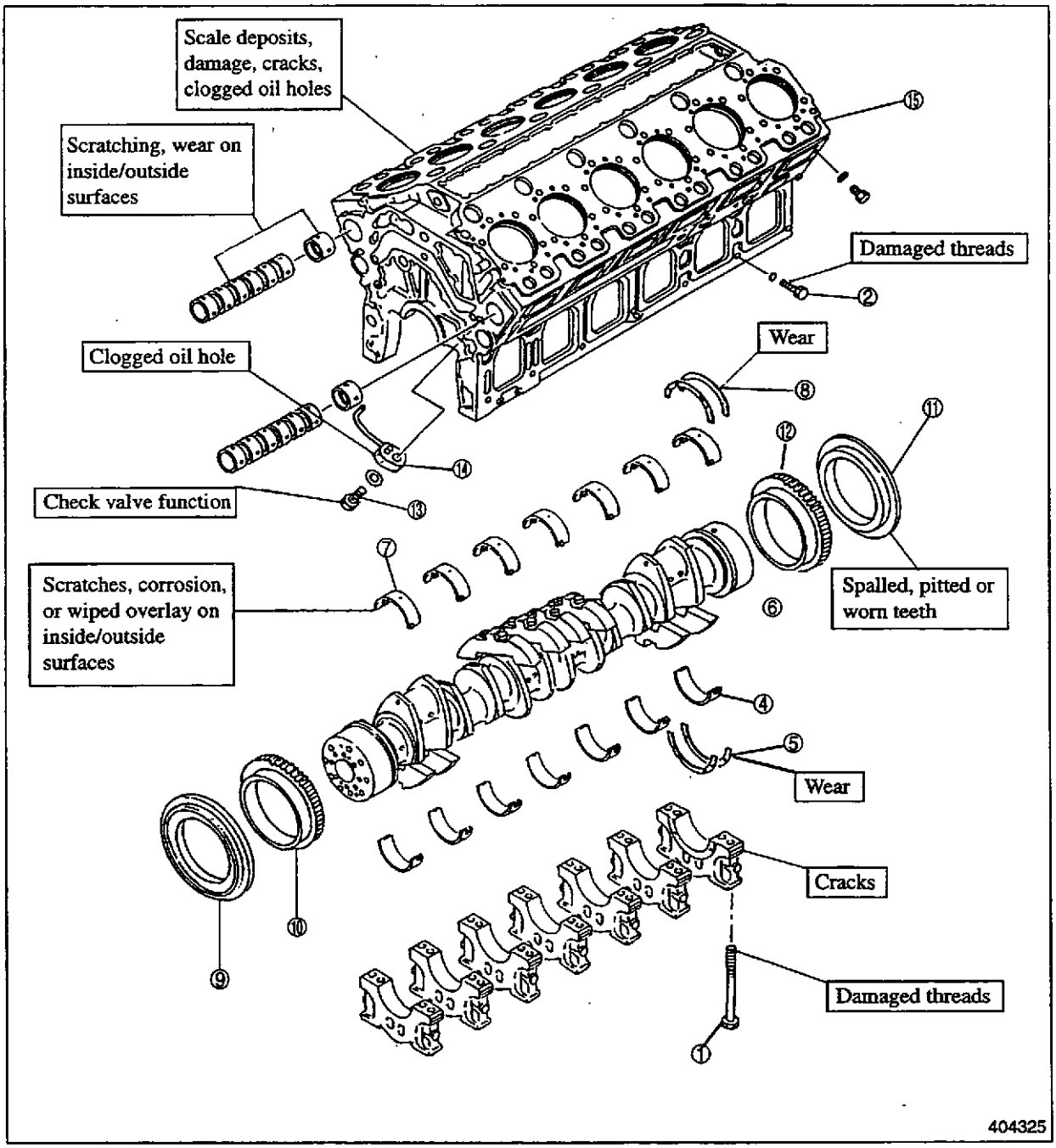
(c) Screw two guide bolts into the crankcase, then install the oil pan.

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



5. Crankcase, Crankshaft, and Main Metals

5.1 Disassembly

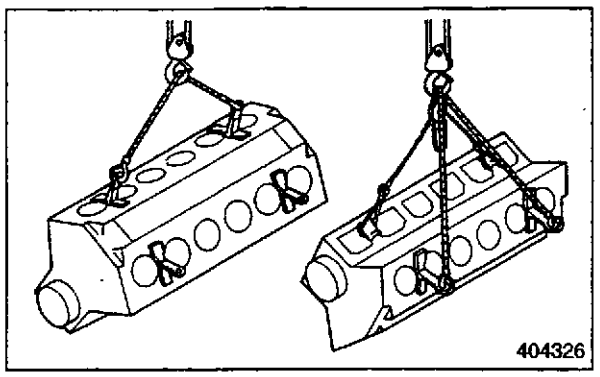


① Main metal cap bolt
② Side bolt
③ Main metal cap
④ Main metal (lower)
⑤ Thrust plate
⑥ Crankshaft
⑦ Main metal (upper)
⑧ Thrust plate
⑨ Slinger (front)
⑩ Crankshaft gear (front)
⑪ Slinger (rear)
⑫ Crankshaft gear (rear)
⑬ Check valve
⑭ Piston cooling nozzle
⑮ Crankcase

(1) Turning the crankcase upside down

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

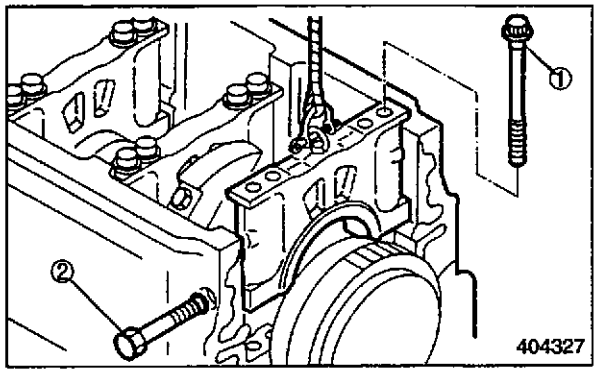
Crankcase and crankshaft weight: approx. 1800 kg (3.968 lb)



(2) Removing the main metal caps

(a) Unscrew the cap bolts ① and side bolts ②. Use a cap remover or a crane (eye bolt M12 × 1.25 (0.05 in.)) to remove the main metal caps.

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

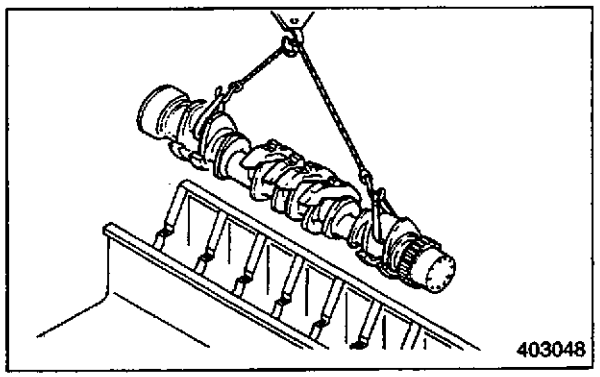


(3) Removing the crankshaft

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

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

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

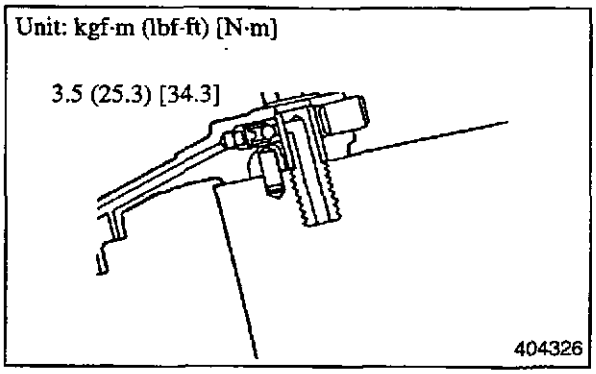


(4) Removing the piston cooling nozzles

Remove the nozzles only when the oil holes are clogged or defective.

NOTE

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



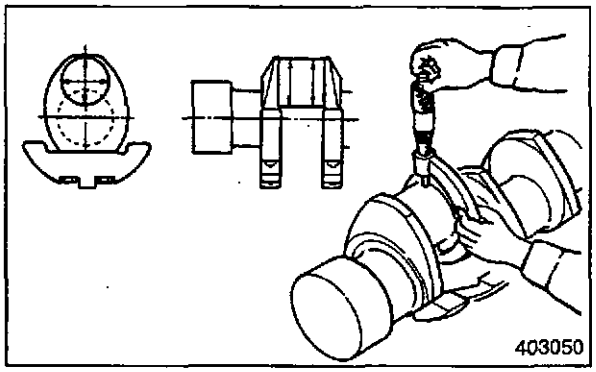
5.2 Inspecting and Repair

(1) Measuring crank pin and journal diameters

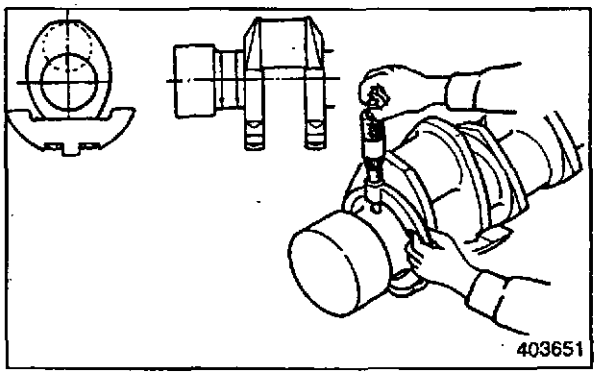
(a) Using a micrometer, measure the crank pin and journal diameters. If the diameter exceeds the repair limit, grind them to the next lower size: -0.25 mm, -0.50 mm, -0.75 mm, or-1.00 mm (-0.0098 in., -0.0197 in., -0.0295 in., -0.0394 in.).

(b) Measure the crank pins and journals to determine the amount of out-of-roundness and taper.

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



Measuring crank pin diameter



Measuring crank journal diameter

Unit: mm (in.)

Item			Nominal Value	Assembly Standard	Repair Limit
Crank pin dia.			ø125 (4.92)	–0.050 to –0.070 (–0.00197 to –0.00276)	–0.110 (–0.00433)
Journal dia.			ø170 (6.69)	–0.060 to –0.080 (–0.00236 to –0.00315)	–0.120 (–0.00472)
Pin, journal	Out of roundness			Dia. difference 0.01 (0.0004) max.	0.03 (0.00118)
	Taper			Dia. difference 0.02 (0.0008) max.	0.03 (0.00118)
	Fillet radius	Pin	7 (0.28)	$7.0\ ^{0}_{-0.2}$ $(0.28\ ^{0}_{-0.0079})$	
		Journal	8.5 (0.335)	$8.5\ ^{0}_{-0.2}$ $(0.335\ ^{0}_{-0.0079})$	
	Hardness			Hv >590	

Grinding dimensions for an undersize crankshaft

Unit: mm (in.)

Undersize		Finishing Dimension	Out of Roundness	Taper
Crankpin dia.	0.25 (0.0098)	124.68-124.70 (4.9091-4.9099)	Dia. difference 0.01 (0.0004) max.	Dia. difference 0.02 (0.0008) max.
	0.50 (0.0197)	124.43-124.45 (4.89922-4.90001)		
	0.75 (0.0295)	124.18-124.20 (4.88938-4.89017)		
	1.00 (0.0394)	123.93-123.95 (4.87954-4.88032)		
Journal dia.	0.25 (0.0098)	169 67-169.69 (6.68047-6.68126)	Dia. difference 0.01 (0.0004) max.	Dia. difference 0.02 (0.0008) max.
	0.50 (0.0197)	169.42-169.44 (6.67063-6.67142)		
	0.75 (0.0295)	169.17-169.19 (6.66079-6.66157)		
	1.00 (0.0394)	168.92-168.94 (6.65094-6.65173)		

(2) Grinding the crankshaft

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

When grinding the crank pins 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 crank pins and journals, and inspect them for cracks by conducting a magnalux (magnetic particle) test. After grinding, *finish the journals and crank pins to* $\phi \frac{0.8S}{\nabla\nabla\nabla}$.

(3) Measuring crankshaft end play

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

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

+ 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 plates will generally be sufficient.

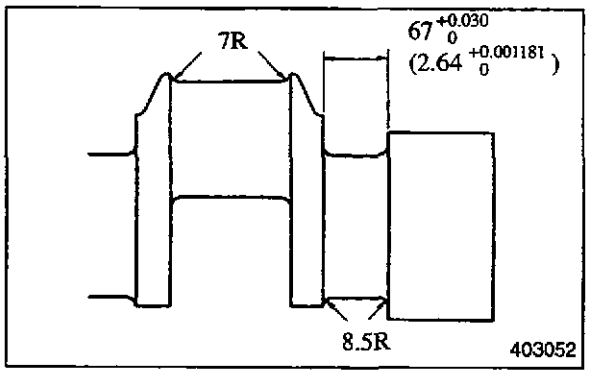
Unit: mm (in.)

Item	Standard Clearance	Repair Limit
Crankshaft end play	0.20-0.40 (0.0079-0.0157)	0.50 (0.0197)

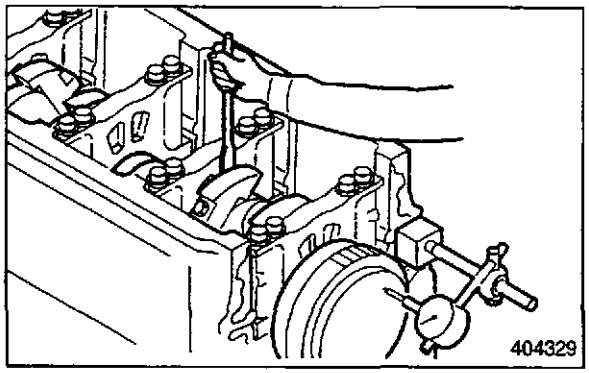
Crankshaft Journal Grinding Dimensions for Oversize Thrust Plates

Unit: mm (in.)

Item	Oversizes for Journal or Thrust Plates	Oversizes for Journal and Thrust Plates	Tolerance
+0.25 (0.0098) O.S	67.25 (2.6479)	67.50 (2.6577)	$+0.03\ 0$ $(^{+0.0012}_{0})$
+0.50 (0.0197) O.S	67.50 (2.6577)	68.00 (2.67739)	
+0.75 (0.0295) O.S	67.75 (2.6675)	68.50 (2.69707)	



Measuring thrust bearing journal length



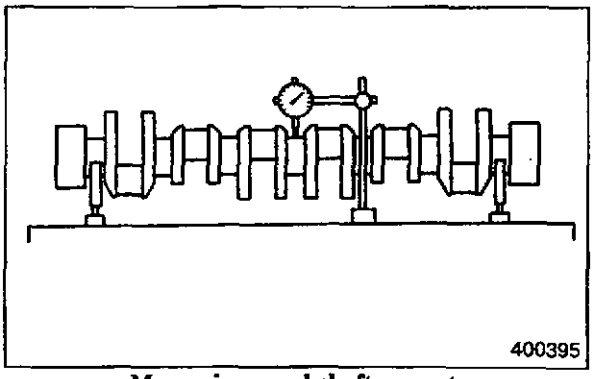
Measuring crankshaft end play

(4) Measuring crankshaft runout

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

Unit: mm (in.)

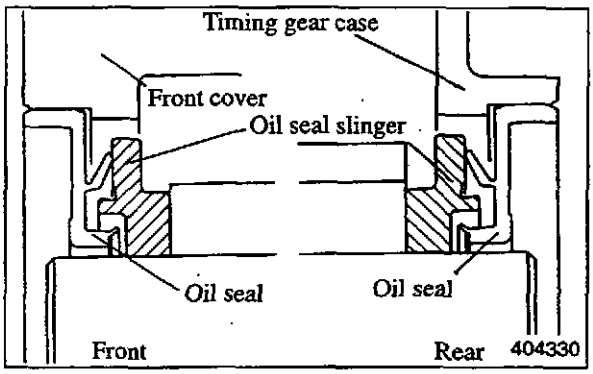
Item	Assembly Standard	Repair Limit
Crankshaft runout	0.04 (0.0016) max.	0.10 (0.0039)



Measuring crankshaft runout

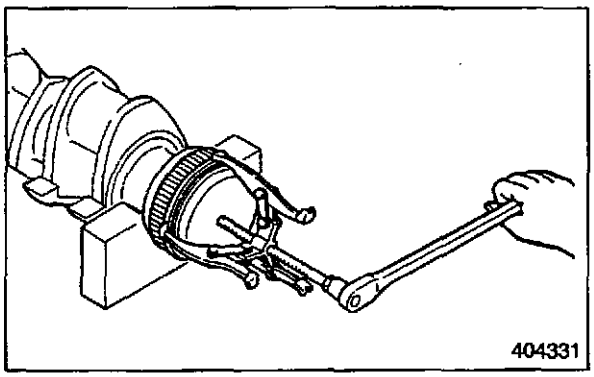
(5) Replacing the oil seal slinger

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



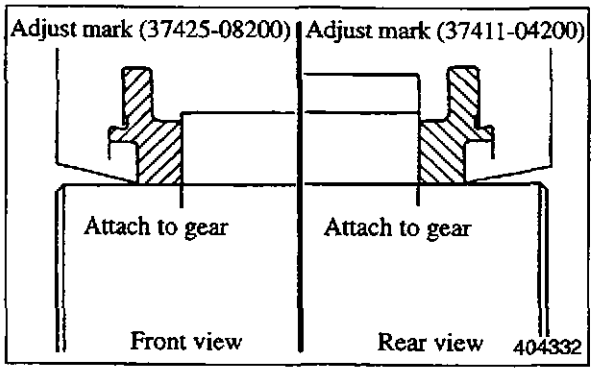
Removing the Slinger

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



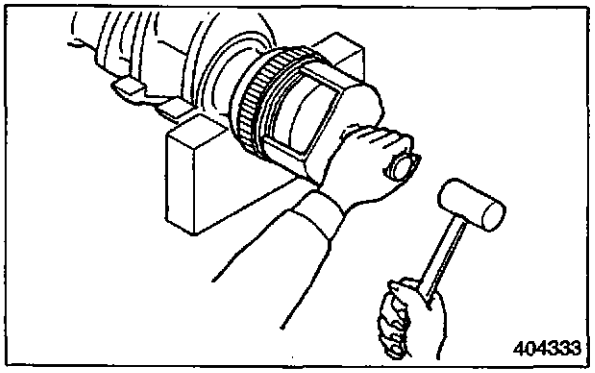
Slinger Installation

(a) Identify the front slinger and the rear slinger.



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

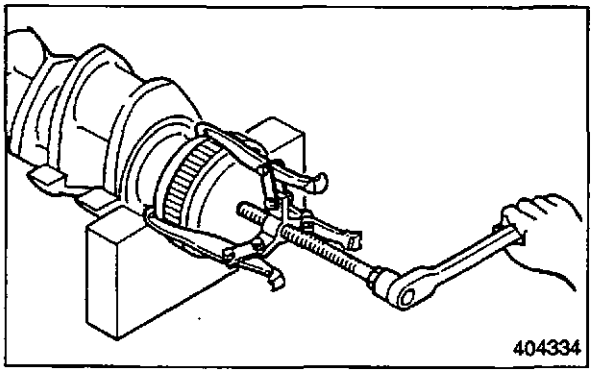
If the slinger has stopped before it touches the gear, tap the center or shoulder of the installer with a copper hammer.



(6) Replacing the crankshaft gear

Removing the Gear

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



NOTE

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

Installing the Gear

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

Front side: 0.106-0.171 mm (0.00417-0.00673 in.) Rear side: 0.274-0.358 mm (0.01079-0.01410 in.)

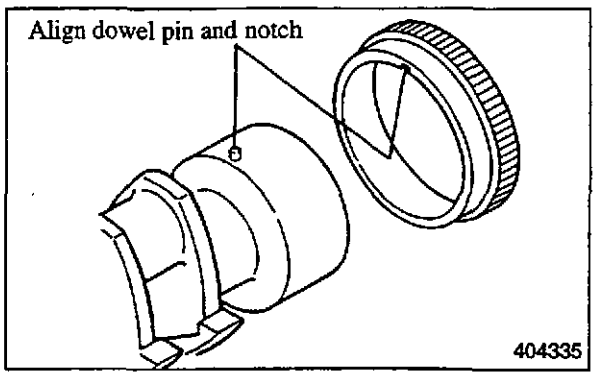
(b) Heat the gear to the range 180° to 200°C (356 to 392°F).

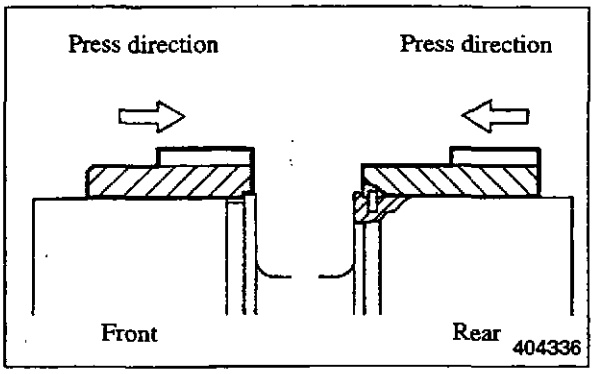
(c) Drive the rear crankshaft gear onto the crankshaft by tapping the end face of the gear lightly with a copper hammer. Be sure the crankshaft dowel pin enters the notch in the gear. The front crankshaft gear has no notch for alignment, so it can be driven onto the crankshaft at any position.

NOTE

(a) Install the gear to the crankshaft until it touches the collar.

(b) Do not mistake the direction of gear installation.

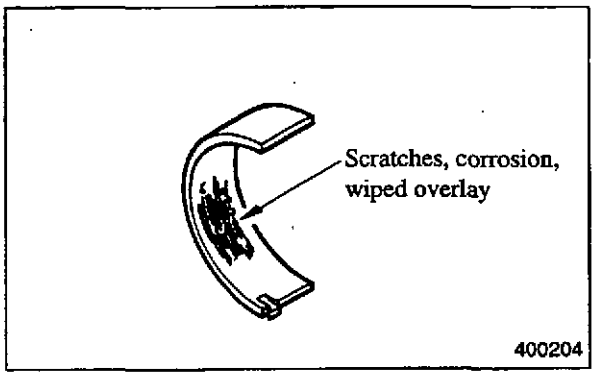




Main Bearing

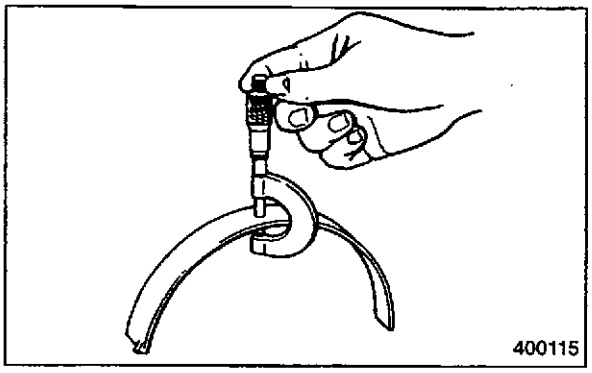
(1) Inspection

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



(2) Measuring metal thickness

Use a ball point micrometer to measure the center of each metal 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.



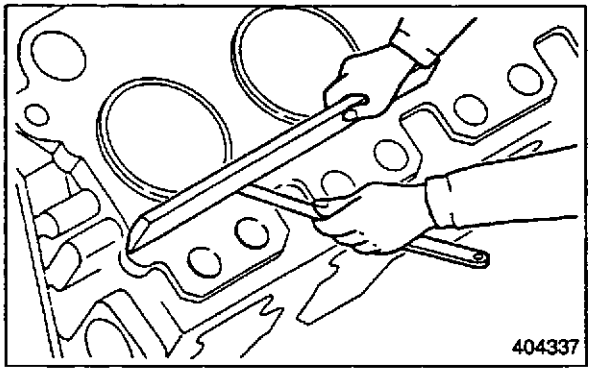
Measuring main metal thickness

Unit: mm (in.)

Item		Nominal Value	Assembly Standard	Service Limit
Main metal thickness (center)	STD	4.500 (0.177165)	4.467-4.480 (0.17588-0.17639)	4.425 (0.17423)
	-0.25 (0.0098)	4.625 (0.18210)	4.592-4.605 (0.18080-0.18131)	4.550 (0.17915)
	-0.50 (0.0197)	4.750 (0.18701)	4.717-4.730 (0.18572-0.18624)	4.675 (0.18407)
	-0.75 (0.0295)	4.875 (0.19195)	4.842-4.855 (0.19065-0.19116)	4.800 (0.18899)
	-1.00 (0.0394)	5.000 (0.19687)	4.967-4.980 (0.19557-0.19608)	4.925 (0.19391)

(3) Replacing main metals

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



Measuring crankcase gasketed surfaces

Crankcase

(1) Measuring gasketed surface warp

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

Unit: mm (in.)

Item	Assembly Standard	Repair Limit
Crankcase gasketed surface warpage	0.1 (0.004) max.	0.2 (0.008)

NOTE

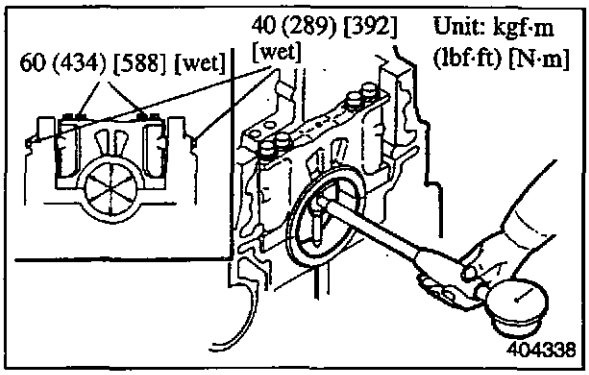
Do not grind the crankcase more than necessary to remove warpage. Excessive grinding can cause the piston protrusion to exceed assembly standard.

(2) Measuring main metal bore diameter

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

Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Main metal bore dia.	ø179 (7.05)	179.000-179.025 (7.08326-7.04881)	179.045 (7.04960)



Measuring main metal bore diameter

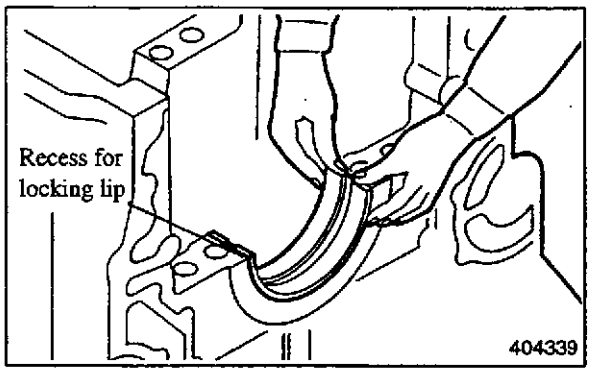
5.3 Reassembly

Reassembly is the reverse procedure of disassembly.

(1) Installing the main metal

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

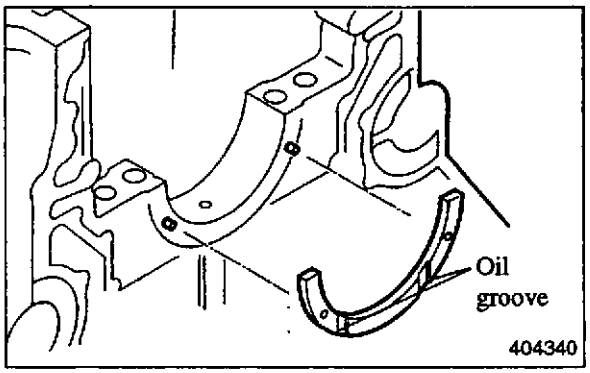
(b) Lightly coat the inside surface of the shells with engine oil.



(2) Installing thrust plates

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

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

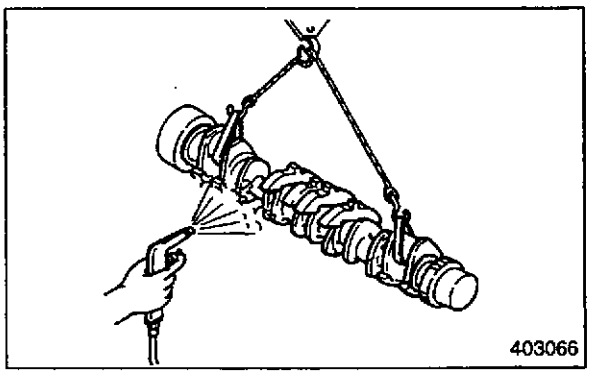


(3) Installing the crankshaft

(a) Wash the crankshaft with cleaning solvent, and dry it by applying a blast of pressurized air.

NOTE

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



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

(c) Lightly coat the journals with engine oil.

(4) Installing main metal caps

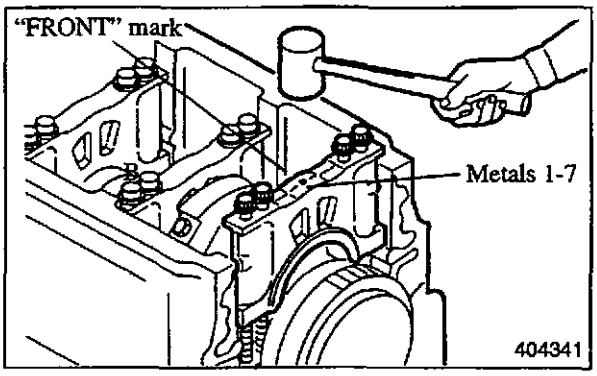
(a) Fit the lower shell of the metal to each metal cap.

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

(c) From the front side of the crankcase, metals 1 to 7 are stamped on the caps. Install the caps with these numbers on the front of the crankcase.

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

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

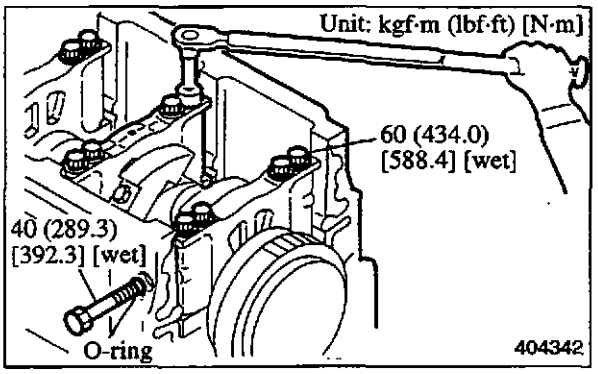


(5) Installing metal cap bolts

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

(b) Tighten the left and right side bolts alternately to the specified torque.

(c) Make sure that the crankshaft rotates smoothly.

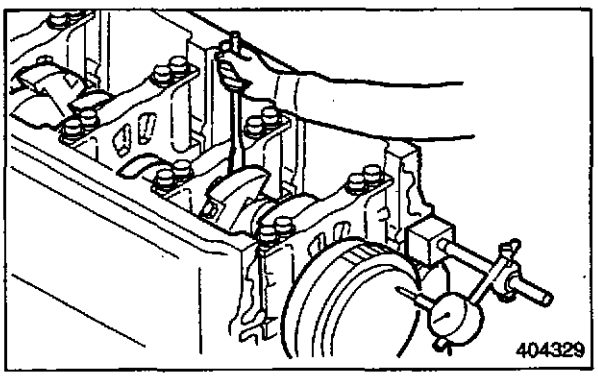


(6) Measuring crankshaft end play

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

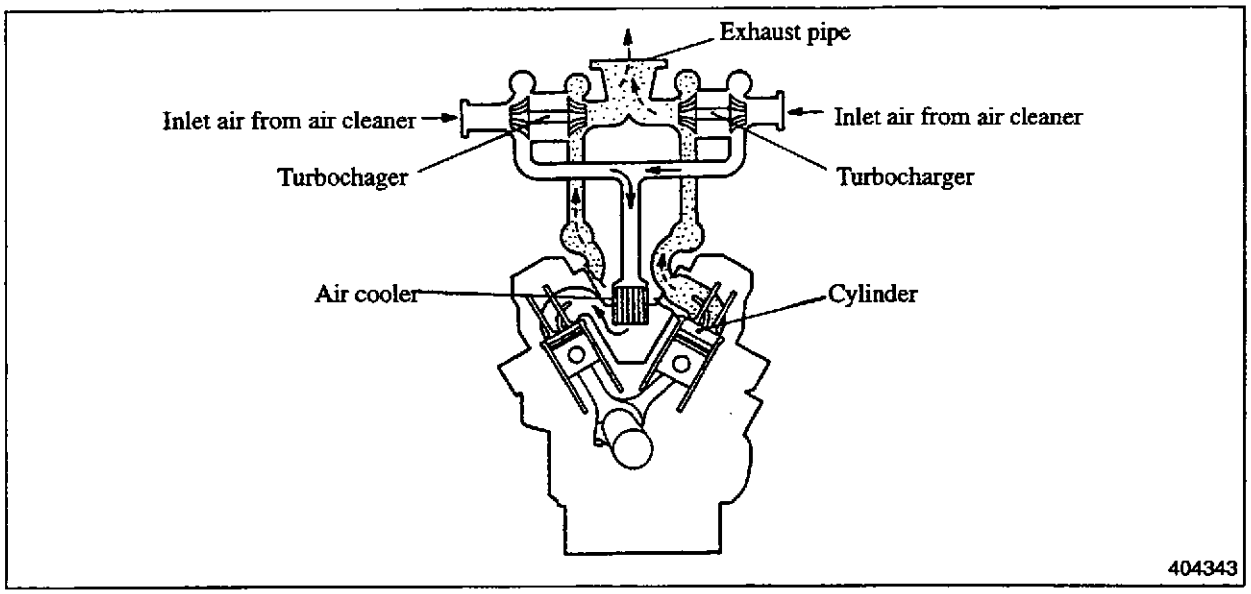
(b) After tightening the No. 7 cap bolts, make sure that the end play is correct.

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



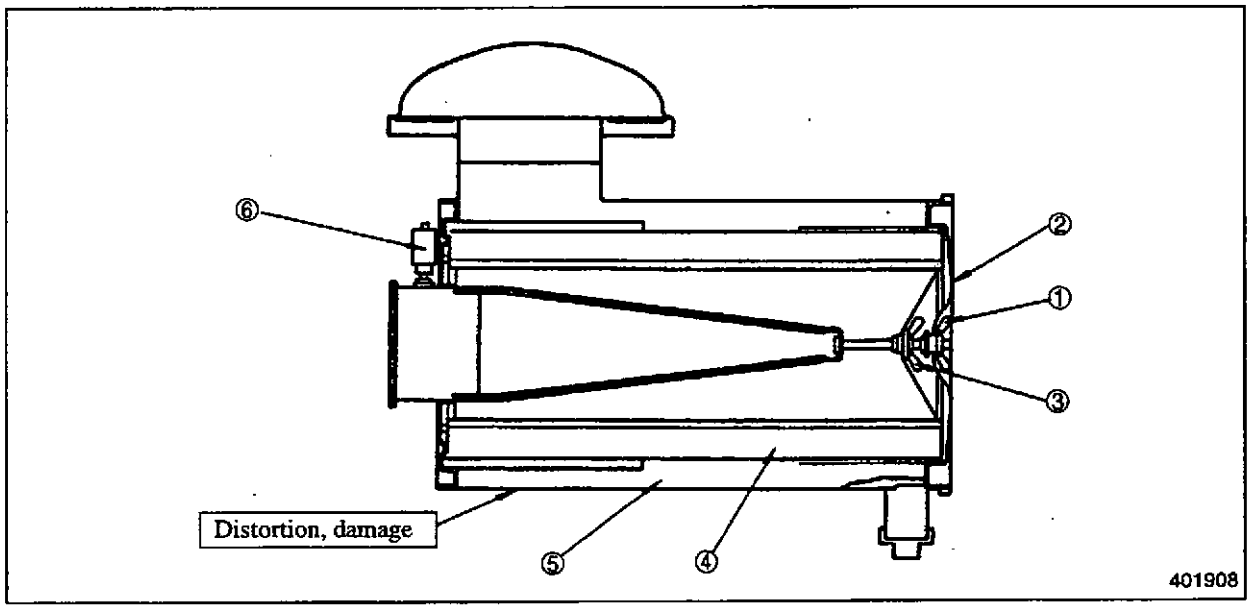
INLET AND EXHAUST SYSTEMS

1. Description



2. Air cleaners

Disassembly and Inspection



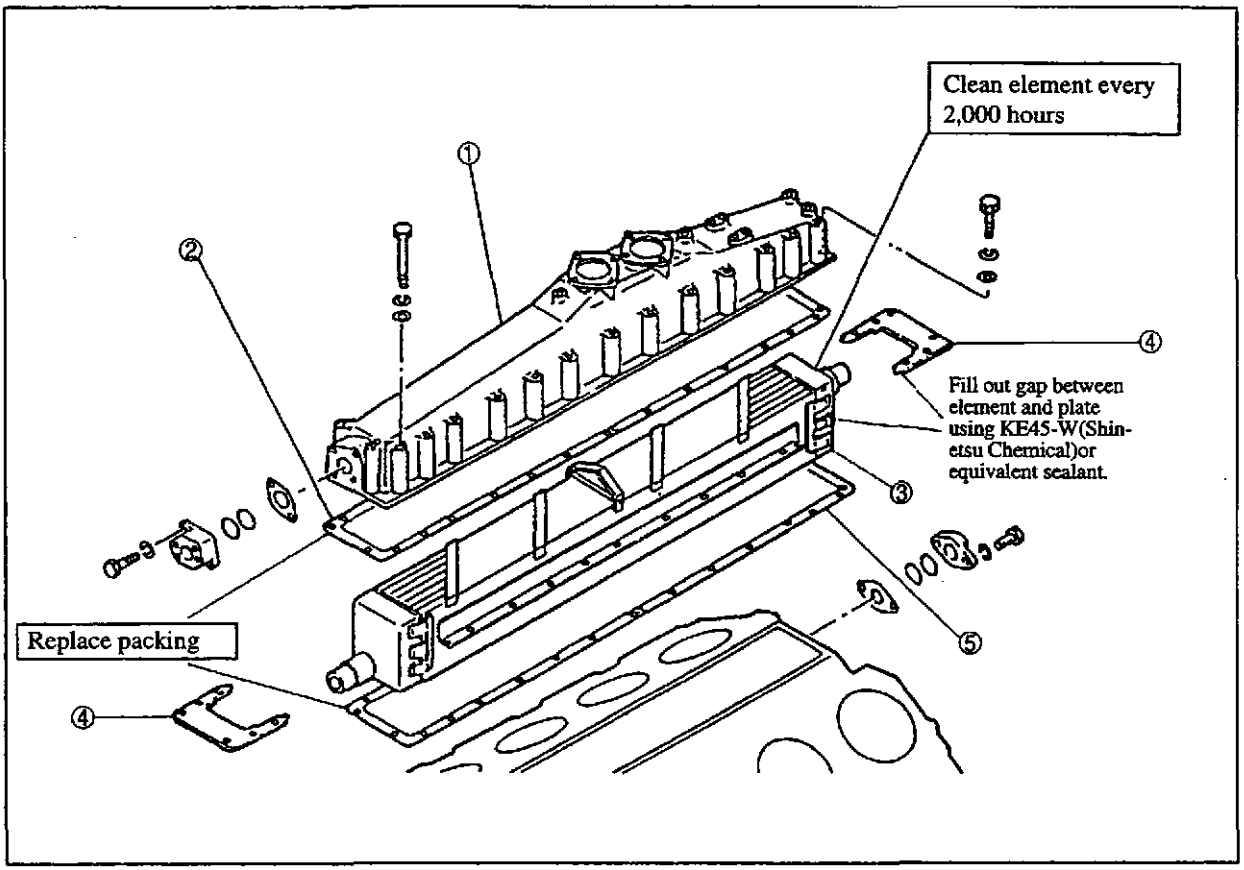
① Wing nut
② Cover
③ Wing nut
④ Element
⑤ Air cleaner body
⑥ Dust indicator

NOTE

When you remove the air cleaner for servicing, be sure to stop the engine and cover the air inlet port to prevent dirt from entering the engine.

3. Air Cooler

3.1 Disassembly

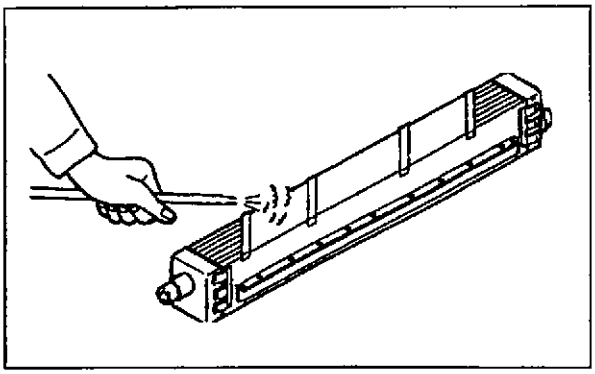


① Air cooler case
② Packing
③ Element
④ Plate
⑤ Packing

3.2 Inspection

(1) Cleaning air coolers

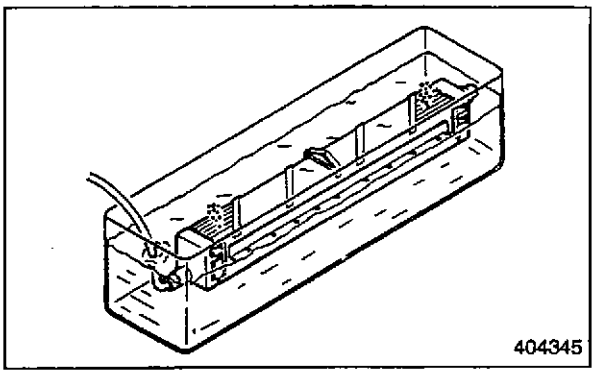
(a) Remove dirt built up from the air cooler by directing high pressure air of 3 to 5kgf/cm² (4.27 to 71.1 psi, 0.29 to 0.49 MPa) (maximum) in the direction opposite to air flow. Inspect the cooler for corrosion and cracks.



(b) Wash the fresh water or salt water pipes in water and caustic soda lime, then remove scale deposits by insering a 3 mm (1/8 in.) bar into each pipe.

(2) Inspecting air coolers for air tightness

Immerse the air cooler in water, then apply high pressure air of 4kgf/cm² (56.9 psi, 0.39 MPa) to the coolant side to inspect for air leaks.

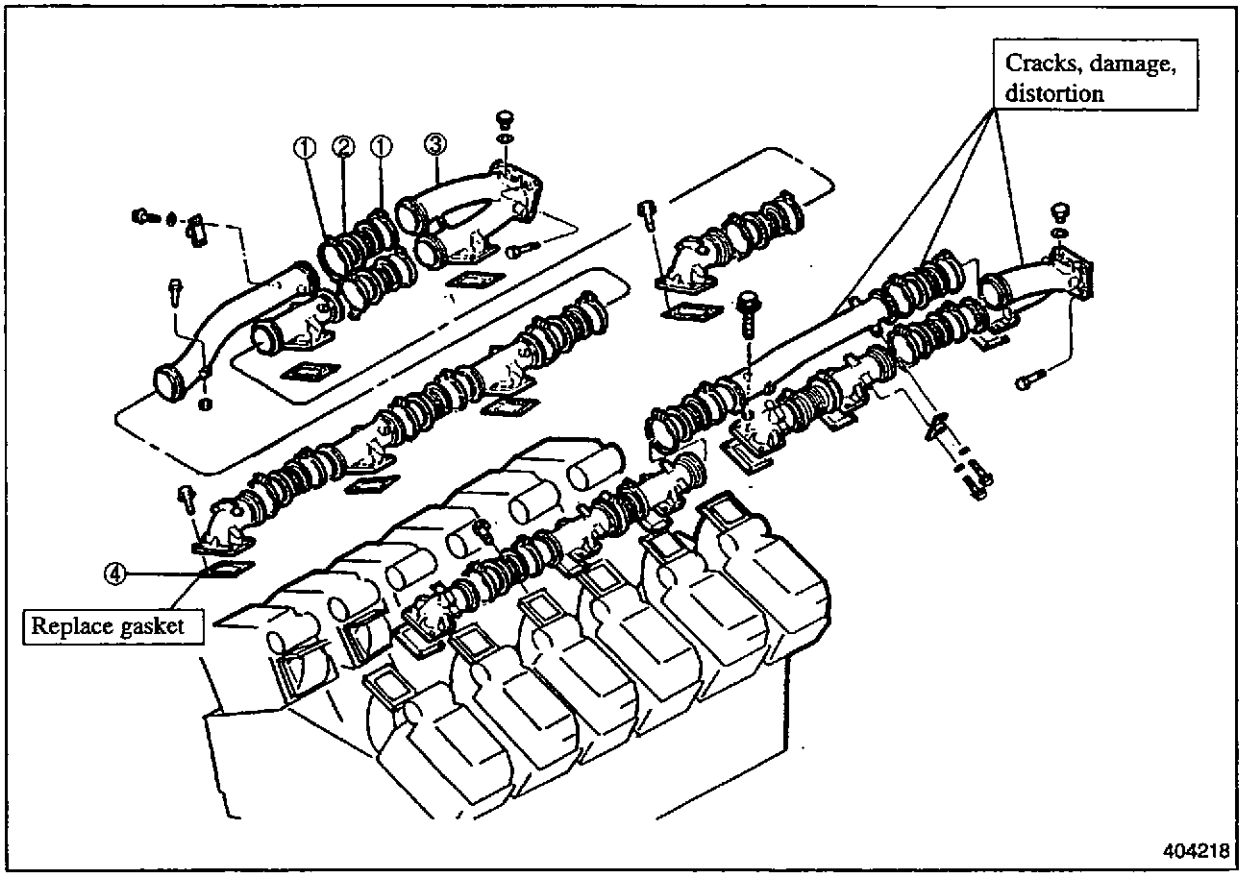


⚠CAUTION

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

4. Exhaust Manifold

Disassembly and Inspection



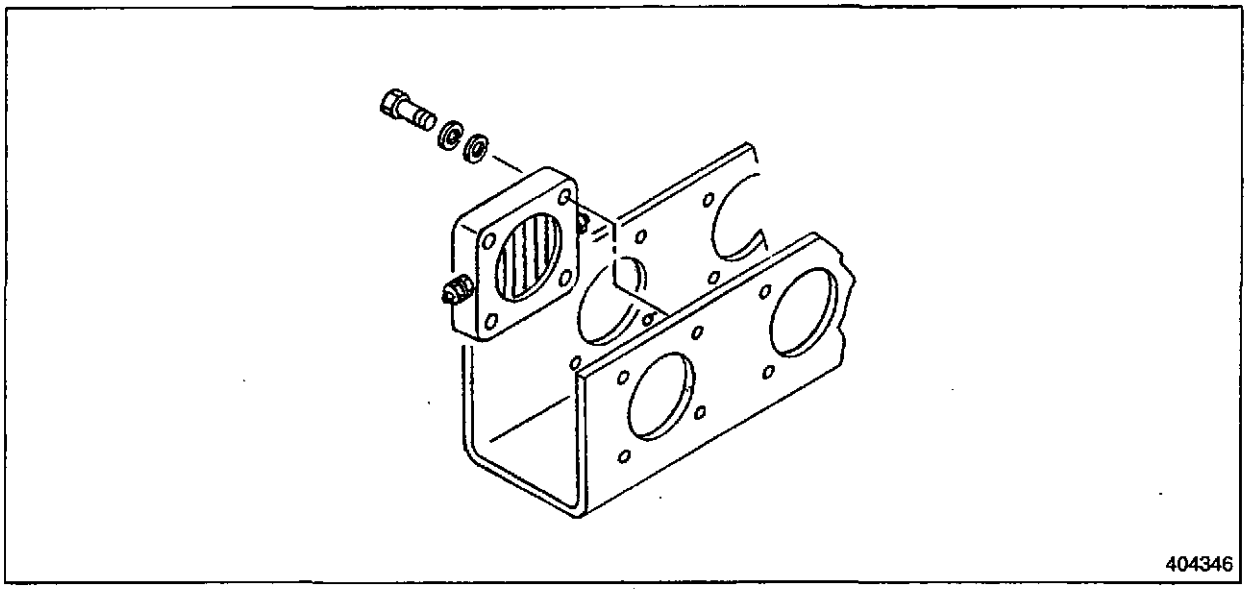
① Coupling
② Flexible joint
③ Exhaust manifold
④ Gasket

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.

5. Air Heater

5.1 Disassembly



1 Air heater assembly

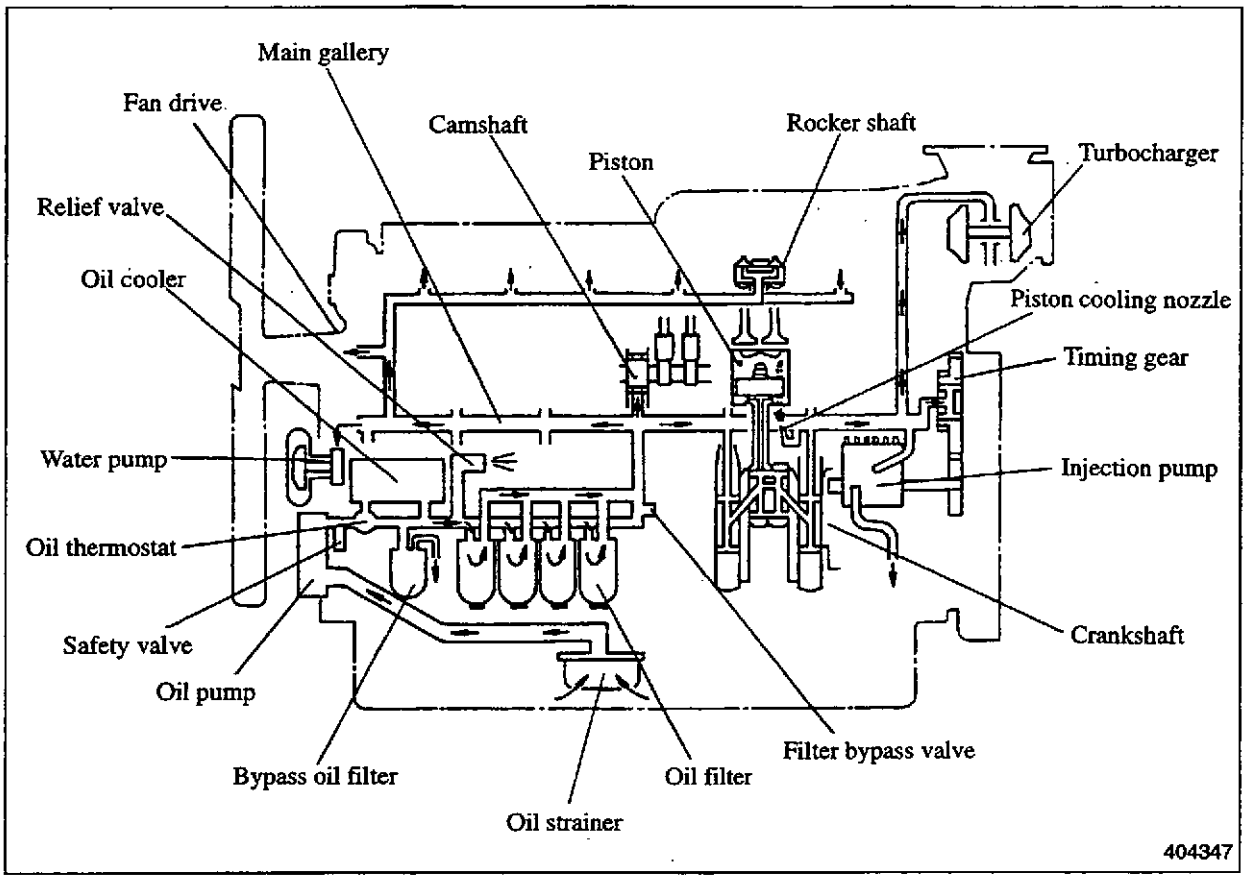
5.2 Inspection

(a) When the starter switch is set to "HEAT", use a galvanometer or an inspection lamp to check that electricity is flowing through the indicator, the relay switch, and air heater.

(b) Confirm that it takes 40-50 seconds for the indicator lamp to come on after setting the starter switch to "HEAT". If the interval is too short, or the indicator lamp does not come on, use a tester to check the indicator and the air heater for a short or broken connection.

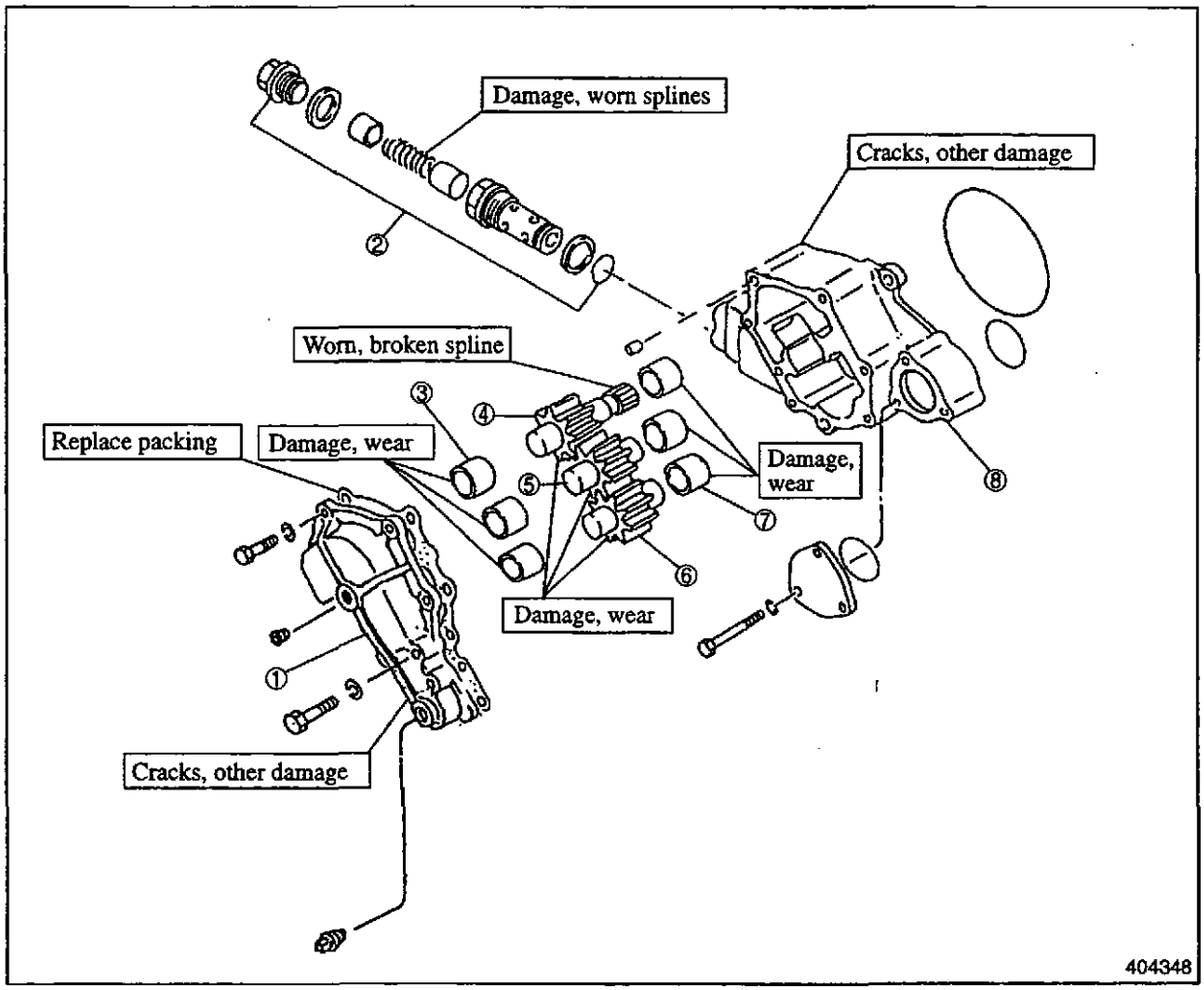
LUBRICATION SYSTEM

1. Description



2. Oil Pump and Safety Valve

2.1 Disassembly



① Oil pump cover
② Safety valve assy.
③ Bushing
④ Drive gear
⑤ Driven gear
⑥ Driven gear
⑦ Bushing
⑧ Oil pump case

2.2 Inspection

(1) Measuring drive gear and driven gear backlash

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

Unit: mm (in.)

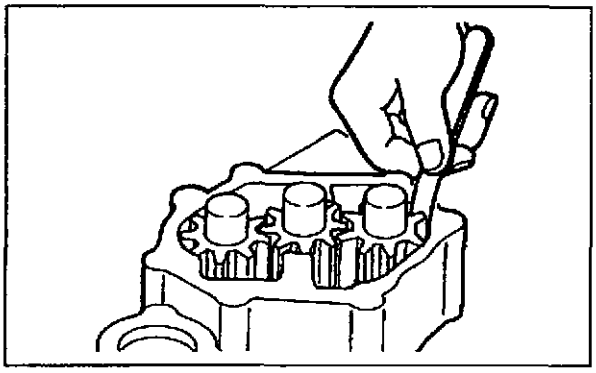
Item	Standard Clearance	Service Limit
Drive gear and driven gear backlash	0.10-0.20 (0.0039-0.0079)	0.4 (0.016)

(2) Measuring pump gear tip clearance

Use a fealer gauge 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
Drive gear and driven gear clearance	ø60 (2.36)	0.100-0.148 (0.00394-0.00583)	Tip clearance: 0.35 (0.0138)



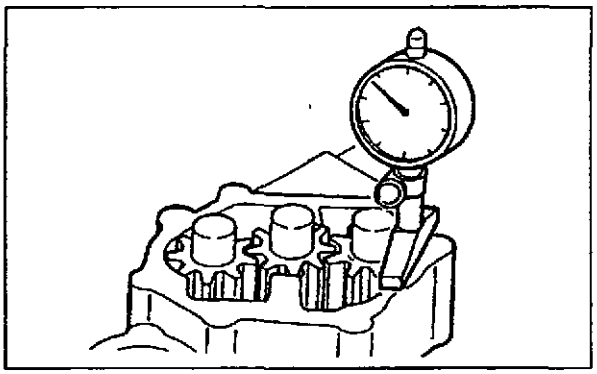
Measuring drive gear tip clearance

(3) Measuring pump gear end clearance

Use a dial gauge 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
Pump gear end clearance	72.5 (2.8546)	0.040-0.116 (0.00157-0.0046)	0.21 (0.0083)



Measuring drive gear end clearance

NOTE

Remove the cover mounting packing (0.04mm ((0.0016 in.)) thick) when you measure.

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

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

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

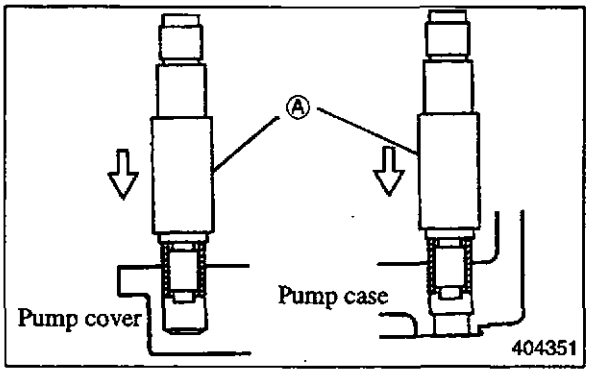
Unit: mm (in.)

Item	Nominal Value	Assembly Standard	Service Limit
Drive shaft diameter	ø30 (1.18)	29.887-29.900 (1.17665-1.17717)	29.840 (1.17480)
Driven shaft diameter	ø30 (1.18)	29.947-29.960 (1.17911-1.17963)	29.920 (1.17805)
Bushing inside diameter	ø30 (1.18)	30.000-30.021 (1.18120-1.18203)	30.055 (1.18337)

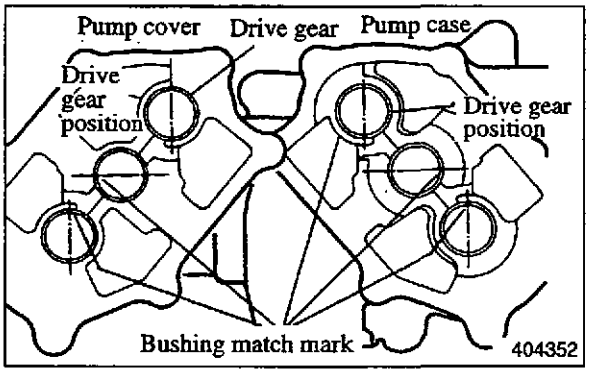
(5) Replacing oil pump bushings

(a) Remove the oil pump bushing as needed. If the oil pump busing insertion is too tight to remove it, replace it with the case or cover assembly.

(b) When you install the pump cover bushing, take the bushing joint position as shown in the right figure. (Do not align with the lubrication oil groove.)

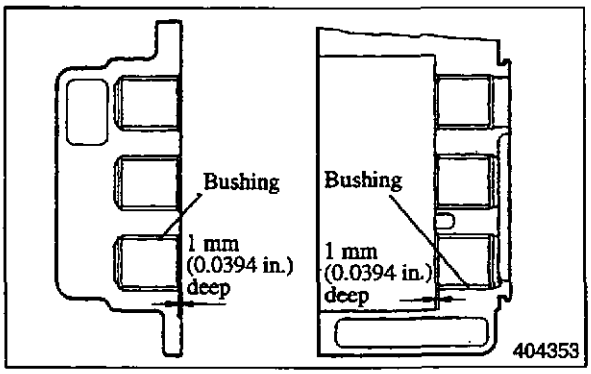


Oil pump bushing match mark positions



(c) Using the oil pump bushing installer Ⓐ, insert the bushing to the position shown in the right figure.

(d) After you press a new bushing into position, finish its inside diameter to ø 30H7 $^{+0.021}_{0}$ mm. (ø1.18H0.28 $^{+0.00083}_{0}$ in.) VVV .

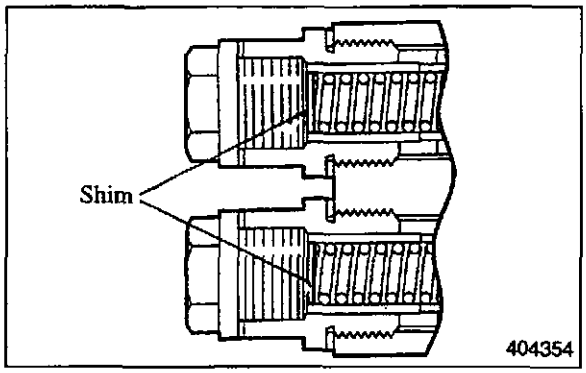


Installing oil pump bushing

(6) Inspecting the safety valve

(a) Check the valve spring of the oil pump safety valve for deterioration. If excessive deterioration or wear is found, replace the valve spring.

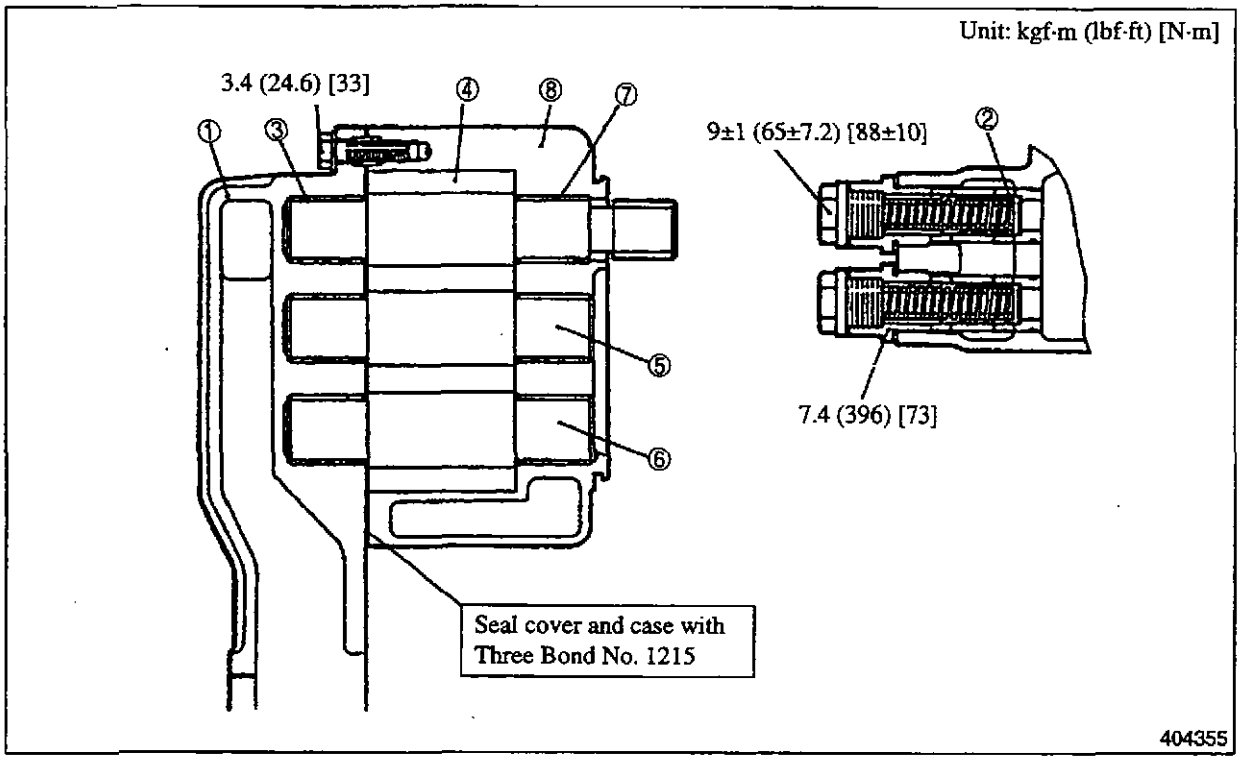
(b) Measure the valve opening pressure. If the pressure is higher or lower than the assembly standard, increase or decrease the thickness of shim inserted between the spring and spring cap nut. The thickness of the shim will vary 1 mm (0.0394 in.) for every 1kgf/cm² (14.2 psi, 0.098 MPa).



Unit: mm (in.)

Item	Assembly Standard	Service Limit
Safety valve opening pressure kgf/cm² (psi) [MPa]	13±1.3 (185±18.5) [1.27±0.13]	
Safety valve spring length under test force /test force mm (in.)/kgf (lbf) [N]	65.8/34.8 (2.59)/(76.720) [359]	66.4/30.0 (2.59)/66.138) [314]

2.3 Reassembly



Reassembly Order

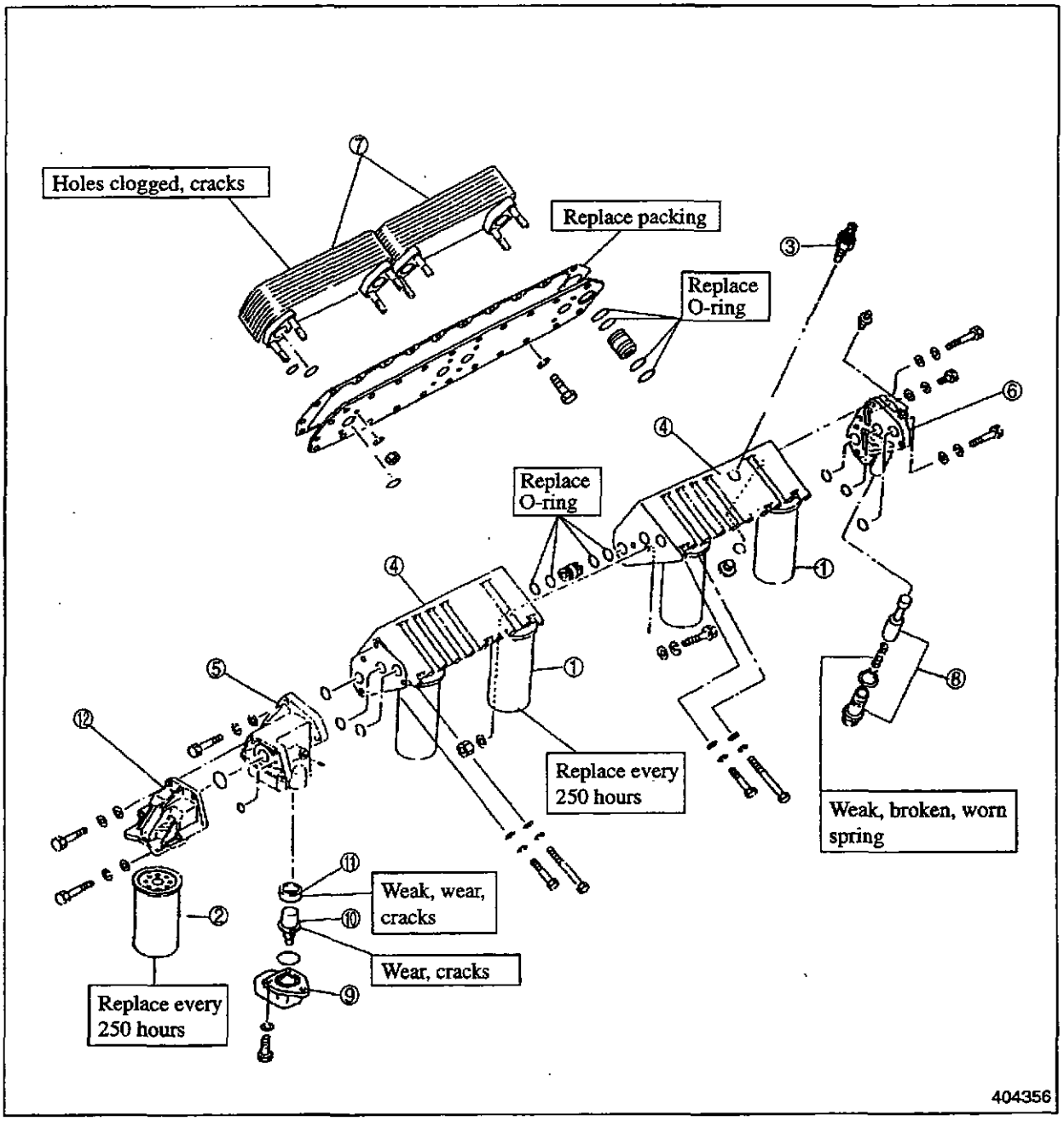
① → ③ ↓
⑧ → ⑦ → ④ → ⑤ → ⑥ → ②

NOTE

During reassembly, apply anti-seizing agent (grease containing molybdenum disulfide) to all sliding surfaces. When installing valve assemblies, apply engine oil to O-rings.

3. Oil Filter Assembly

3.1 Disassembly

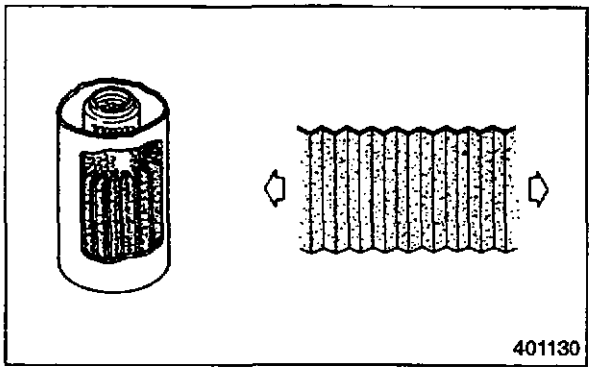


① Full flow oil filter element
② Bypass oil filter element
③ Oil filter alarm
④ Filter bracket assy.
⑤ Adaptor A assy.
⑥ Adaptor B assy.
⑦ Air cooler element
⑧ Relief valve assy.
⑨ Connector
⑩ Oil thermostat
⑪ Thermostat seal
⑫ Bracket

3.2 Inspection

(1) Inspecting the oil filter

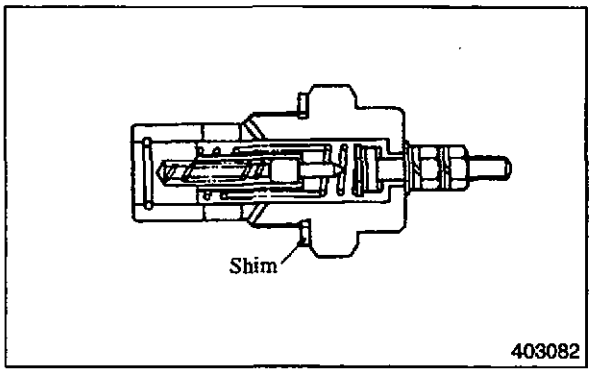
When you replace the paper element, sample about 500cm³ (30.5 cu.in.) of oil and check for metal particles. If any metal particles are found, unfold the pleats of element and check the color and shape of the particles trapped in the pleats to identify the cause.



(2) Inspecting the oil filter alarm

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

(b) If the lamp lighting pressure is not within the assembly standard, adjust it by inserting shims. For the thickness of a shim, 1 mm (0.039 in.) corresponds to a change in pressure of 0.07 kgf/cm² (0.996 psi, 0.007 MPa).



Unit: kgf/cm² (psi) [MPa]

Item	Assembly Standard
Oil filter alarm lamp lighting pressure	$1.5\ ^{+0.3}_{0}$ $(21.3\ ^{+4.27}_{0})$ $[0.15\ ^{+0.03}_{0}]$

(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 gauge.

(b) Warm up the engine until the oil temperature rises to 70-90°C (158-194°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 1 kg/m² (0.0014 psi, 0.0000098MPa).

Unit: kgf/cm² (psi) [MPa]

Item	Assembly Standard
Set pressure (max. speed)	5-6.5 (71.12-92.46) [0.49-0.64]
Relief valve opening pressure	5.2 ± 0.2 (74 ± 2.8) [0.51 ± 0.02]

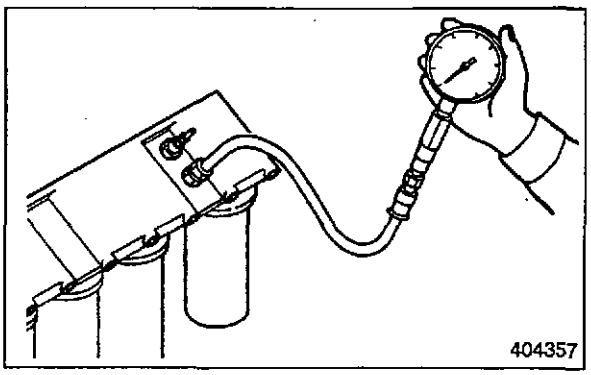
NOTE

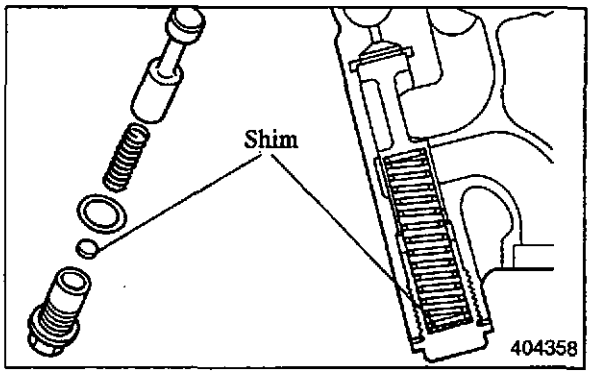
The measured oil pressure might be above the set pressure when oil temperature is low, but it returns to the set pressure when oil temperature rises.

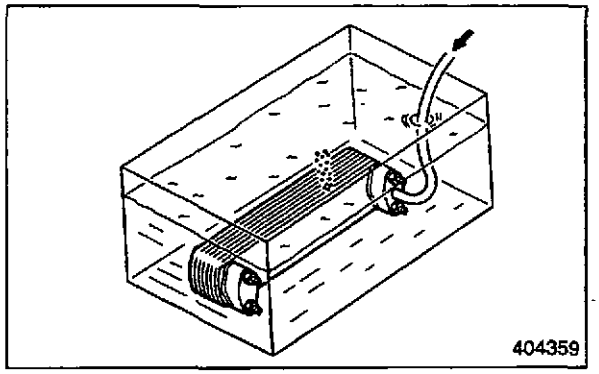
(e) If adjustment with shims is not effective, replace the relief valve and spring.

(4) Inspecting the left side oil cooler

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



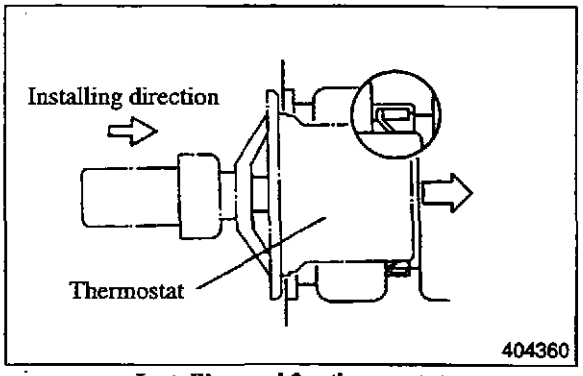




(5) Inspection the left side thermostat

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

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

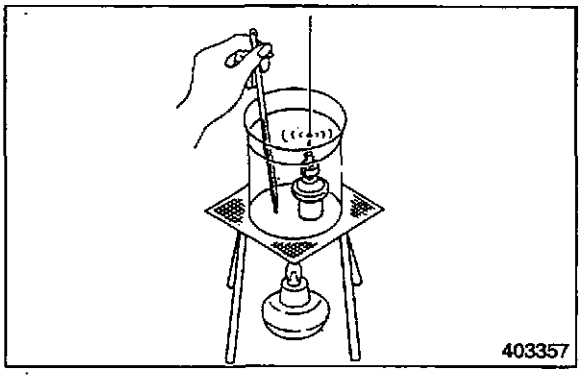


Installing seal for thermostat

(c) Operation testing

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
Temperature for valve opening	80-84°C (176-183.2°F)
Temperature for 11 mm (0.43 in.) valve lift	95°C (203°F)



NOTE

(a) Stir the oil in the beaker with a stick to maintain an even temperature during the test.
(b) At reassembly, be sure to place the thermostat in the correct position by ascertaining the valve opening temperature stamped on its mounting flange.

3.3 Reassembly

Reassembly is the reverse procedure of disassembly.

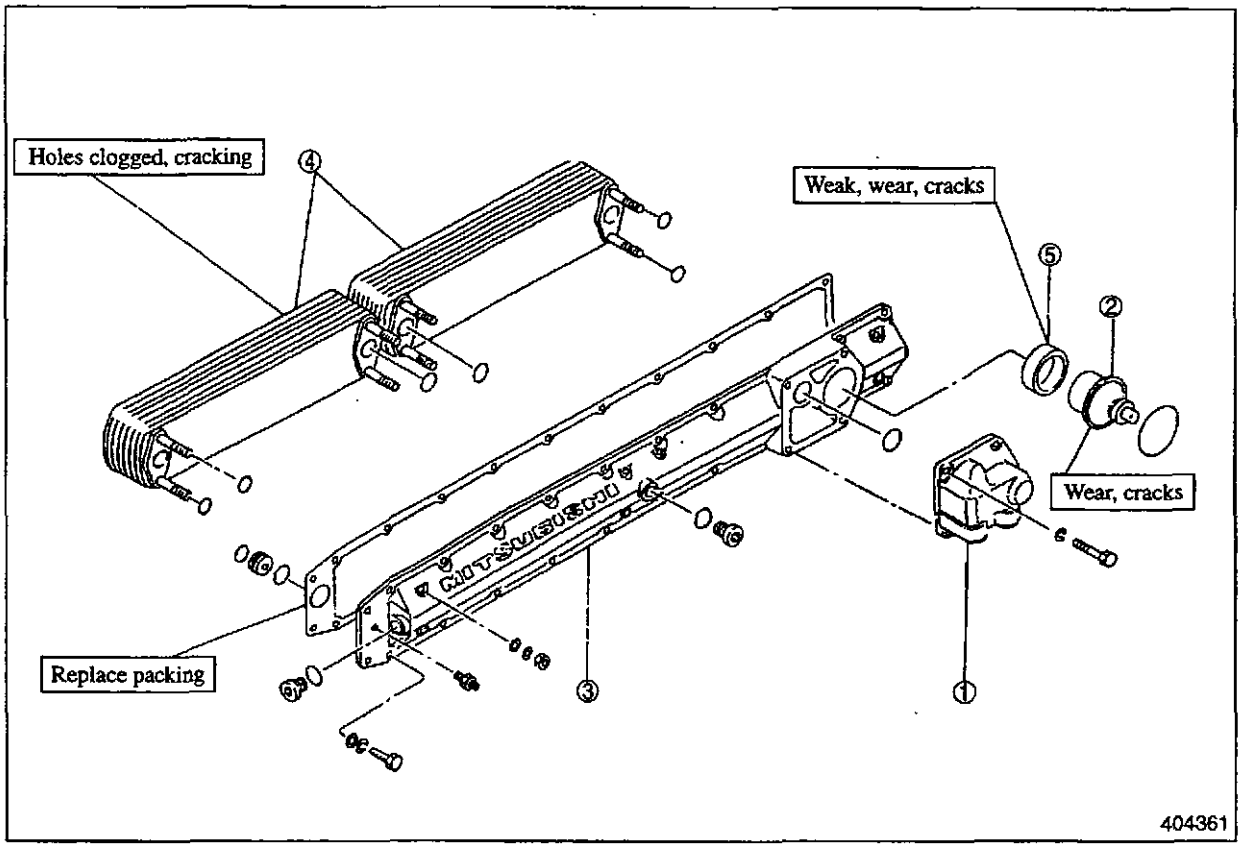
(1) Replace packing and O-rings during reassembly.

(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 complete with its bracket.

4. Right Side Oil Cooler and Oil Thermostat

4.1 Disassembly



① Connector
② Oil thermostat
③ Oil cooler
④ Oil cooler element
⑤ Thermostat

4.2 Inspecting the oil cooler element and oil thermostat

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

4.3 Reassembly

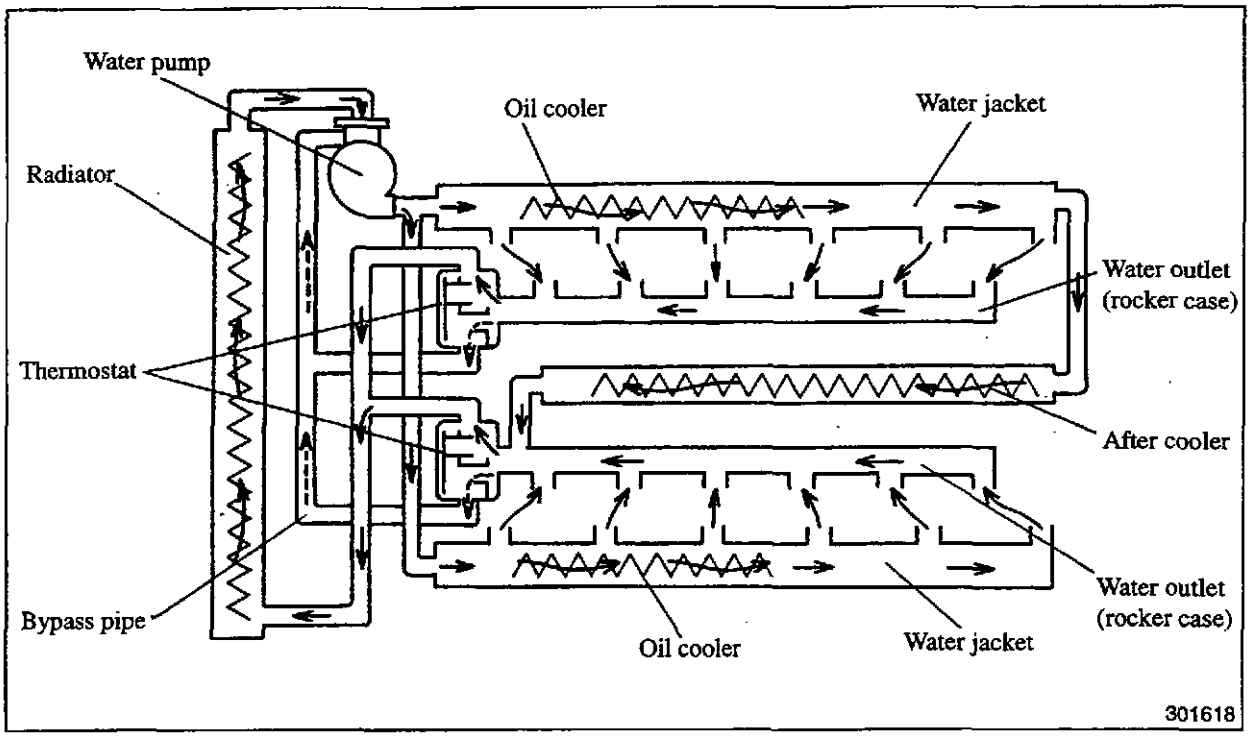
Reassembly is the reverse procedure of disassembly.

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

(2) Before reassembly, clean the oil paths of the oil cooler cover, etc. by flushing them with oil then blowing them with compressed air.

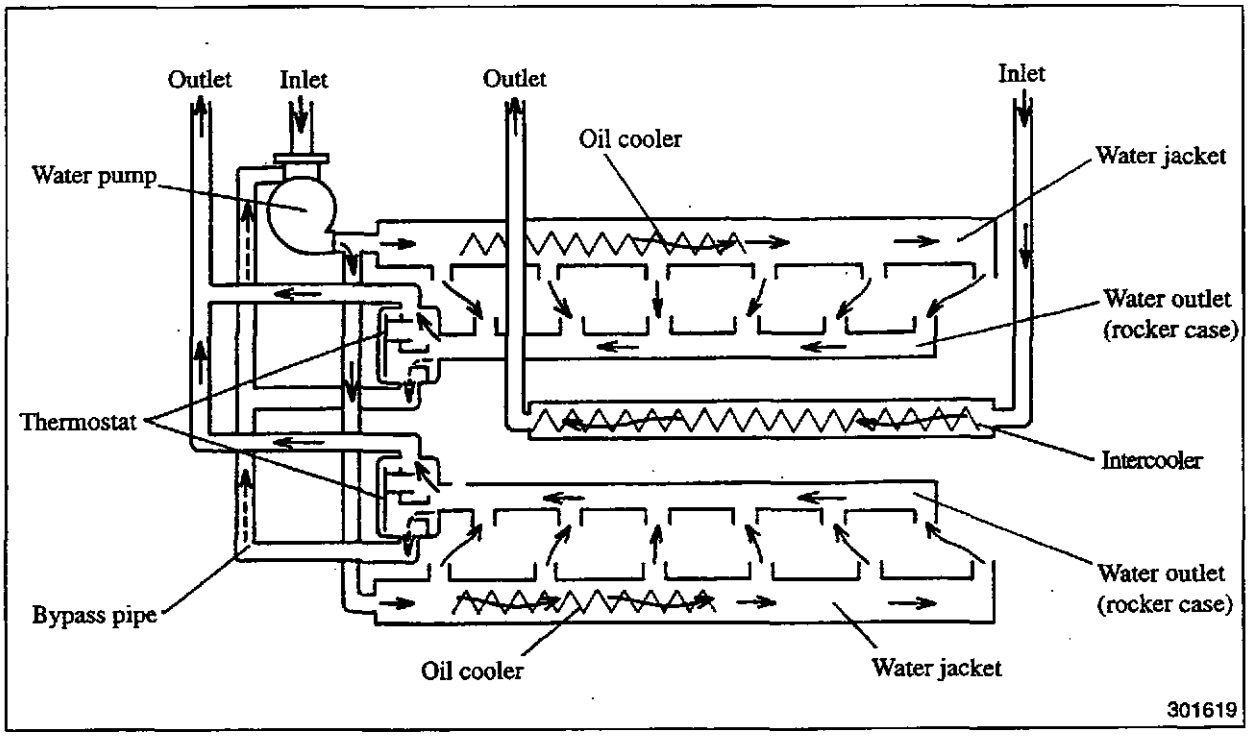
COOLING SYSTEM

1. Cooling System with a Radiator



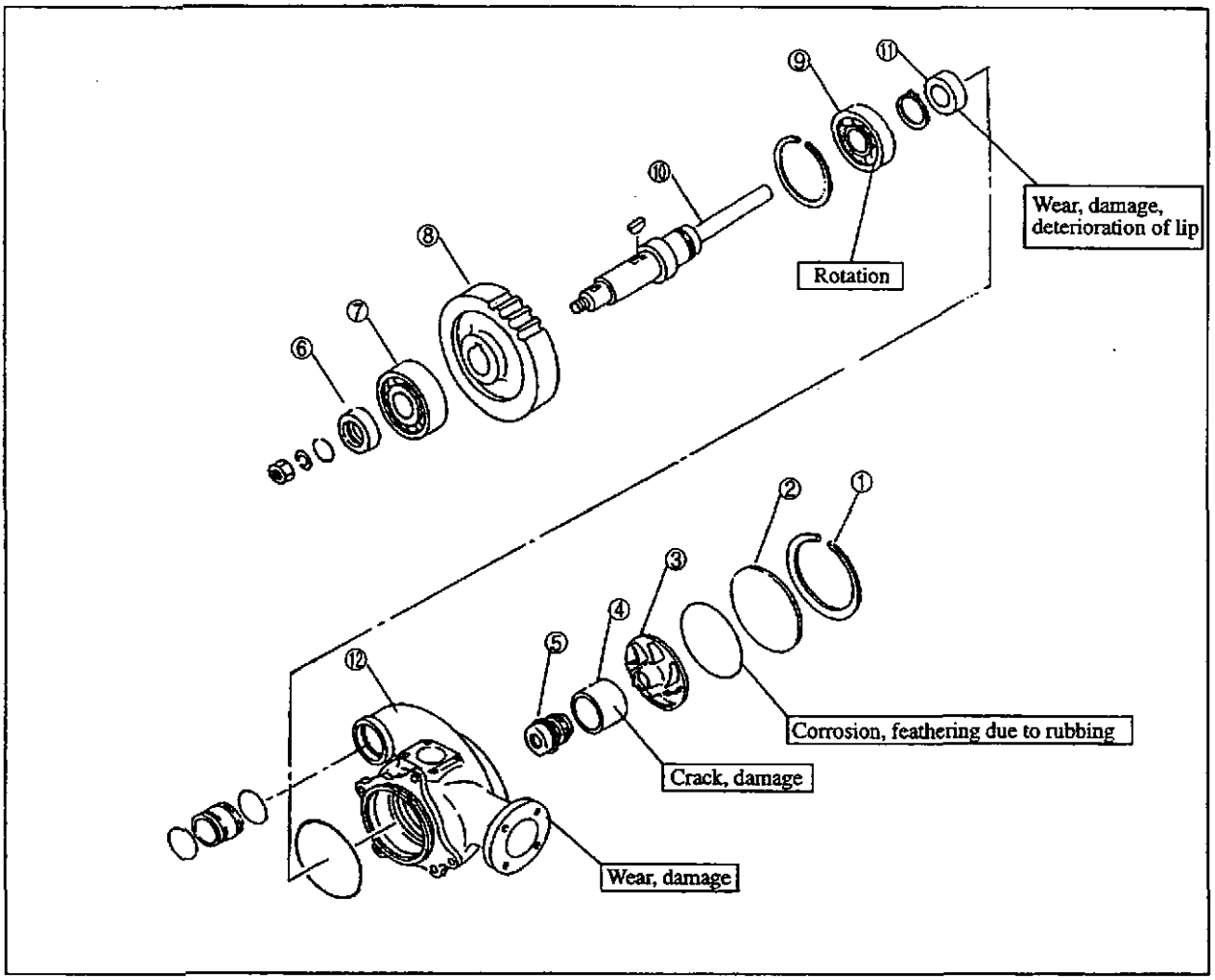
2. Cooling System with a Remote Water Supply

Two-circuit cooling (parallel piping) PTK



3. Water Pump

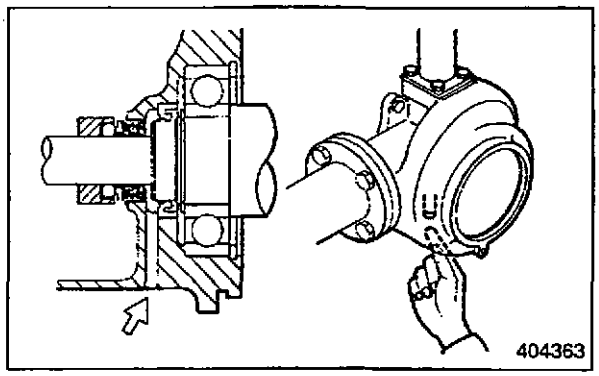
3.1 Disassembly



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

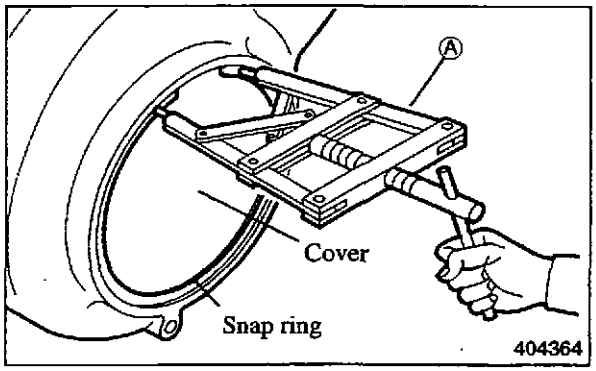
(1) Inspecting the wear pump on the engine

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.

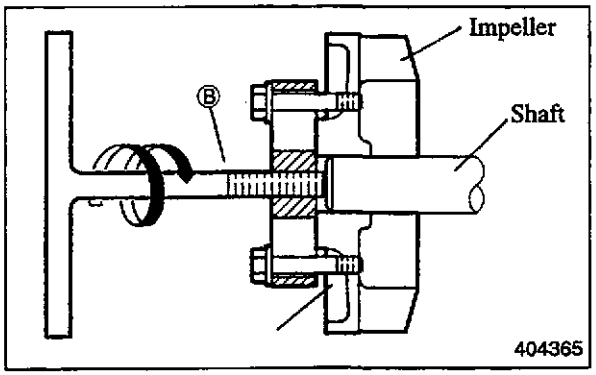


(2) Removing the impeller

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



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



Removing the impeller

(3) Removing the water pump shaft

(a) Remove the oil seal sleeve.

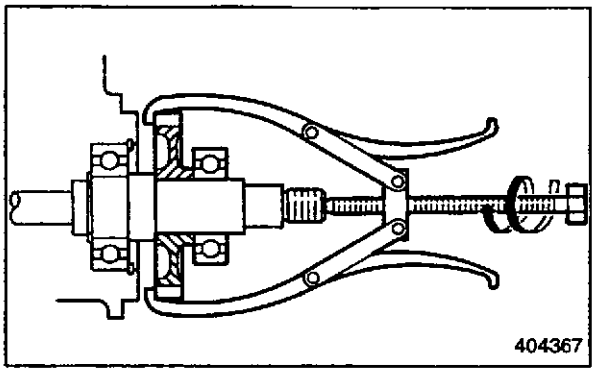
(b) Remove the gear, complete with the bearing with the gear puller.

(c) Remove the snap ring of the impeller side ball bearing.

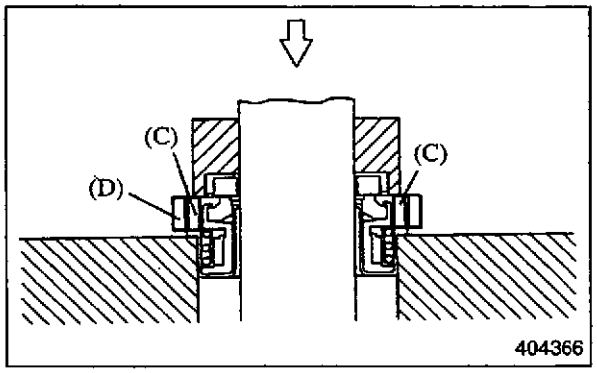
(d) Insert the two half rings (C) of the ring remover (37791-03400) between the unit seal and the pump case as shown in the figure (404366).

(e) Fit the outer ring (D) to the outside of the half rings in such a way that they do not fall free.

(f) Recieve the pump case and pull out the edge face on the side of the shaft impeller by pushing with a hand press in the direction of the arrow mark as shown in the figure (404366).



Removing the gear



3.2 Inspection

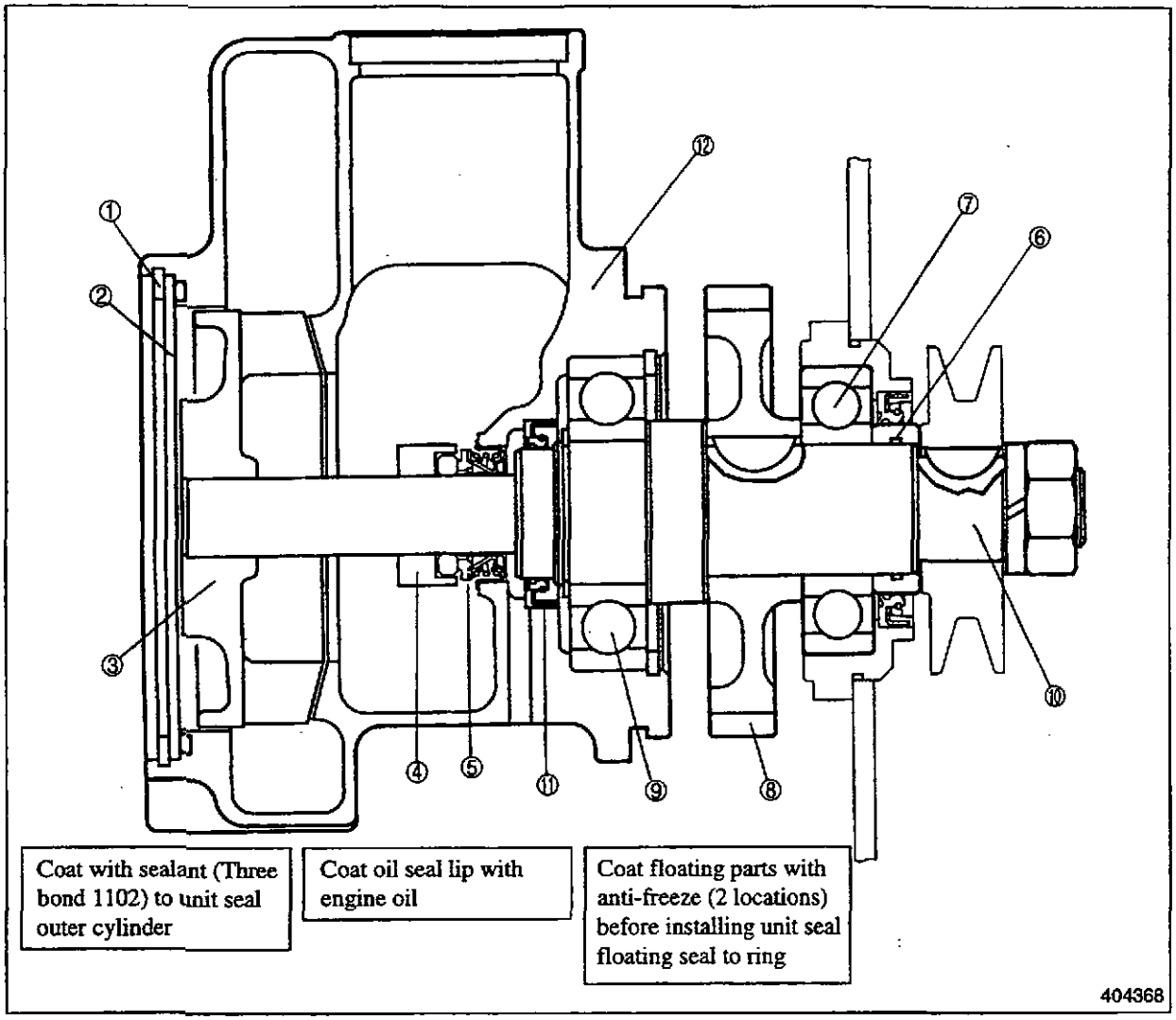
Water pump

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 worn, replace it.

Unit:mm (in.)

Item		Nominal Value	Assembly Standard
Inside diameter of pump case bearing		ø120 (4.72)	119.987-120.022 (4.72429-4.72488)
Inside diameter of cover to which the bearing outer race is fitted		ø110 (4.33)	110.005-110.040 (4.7240-4.33264)
Bearing	Diameter	ø120 (4.72)	119.982-120.000 (4.72370-4.72441)
		ø110 (4.33)	109.985-110.000 (4.33012-4.33071)
	Inside diameter	ø55 (2.17)	54.985-55.000 (2.16476-2.16535)
		ø50 (1.97)	49.985-50.000 (1.96791-1.96850)
Diameter of pump shaft on which bearing inner race is fitted		ø55 (2.17)	55.011-55.024 (2.16579-2.16630)
		ø50 (1.97)	50.011-50.024 (1.96894-1.96945)

3.3 Reassembly



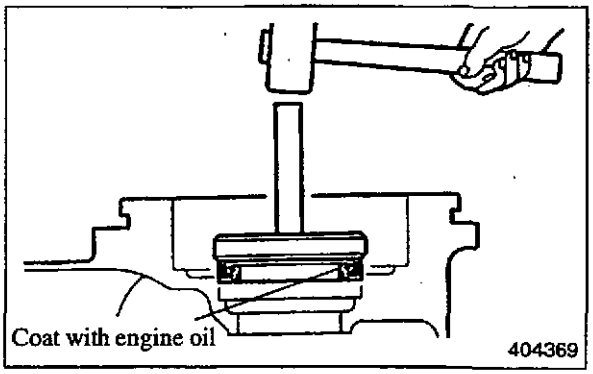
Reassembly Sequence

⑫ → ⑪ → ⑤ ┐
⑩ → ⑨ ┘→ ⑧ → ⑦ → ⑥ → ④ → ③ → ② → ①

NOTE

Replace all O-rings and oil seals and unit seals at reassembly.

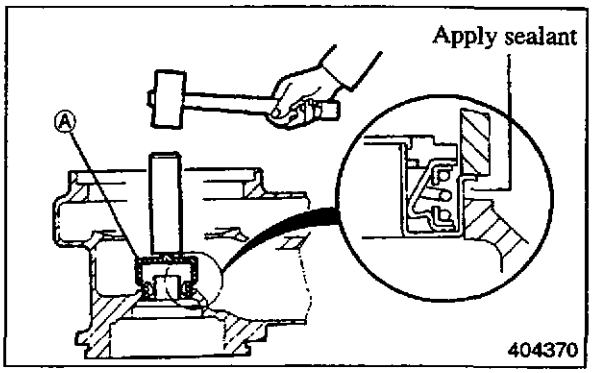
(1) With the oil seal installer, press in the oil seal. Apply engine oil to the oil seal lip.



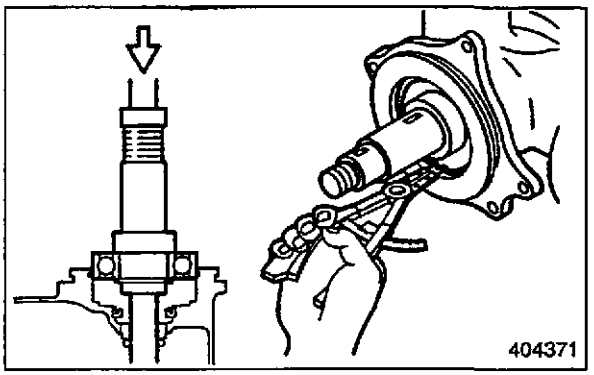
(2) Use the unit seal installer Ⓐ (37191-06300) to press in the unit seal.
Replace the unit seal if it has been removed during reassembly.

NOTE

Install the unit seal after coating with sealant (three-bond 1102) to seal the outer ring.



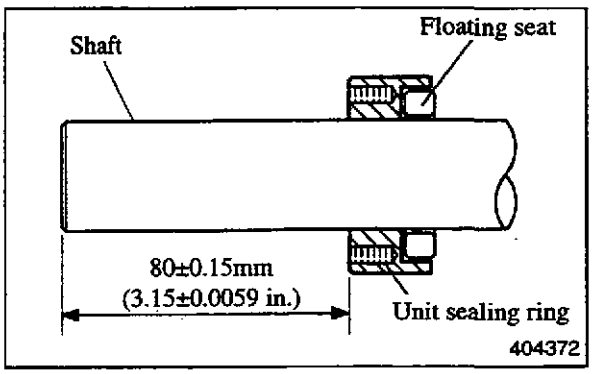
(3) Use a press to press in the impeller-side pump shaft, complete with ball bearings into the case. Install the snap ring with its gap down.



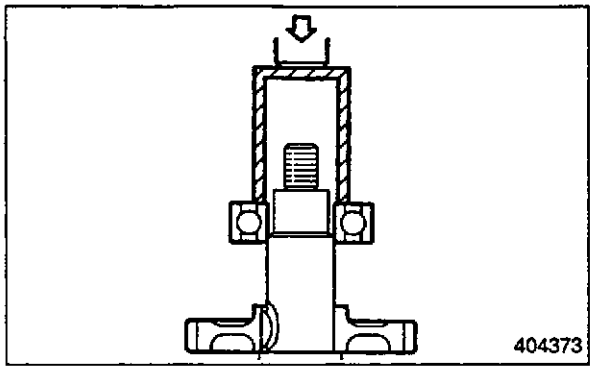
(4) With a press, press in the unit seal ring, complete with the unit seal floating seat using the ring installer (37791-03300).

NOTE

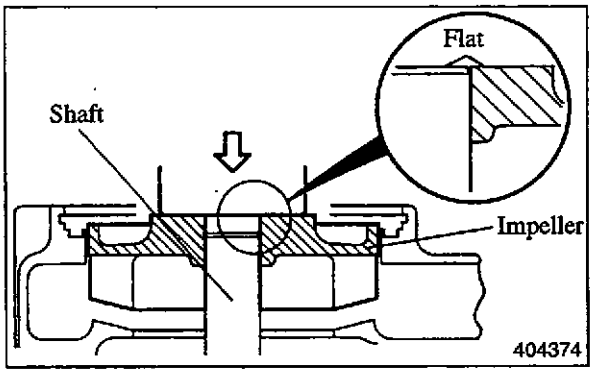
Before installation, coat with anti-freeze the floating parts at two locations.



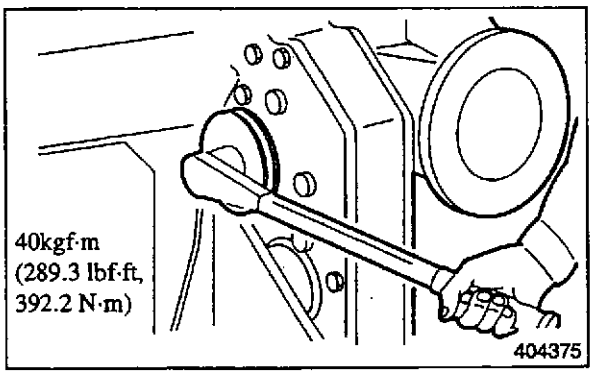
(5) Insert the gear into the shaft by matching the key. Press in the nut side of the ball bearing.



(6) Press in the impeller. The impeller's boss end and pump shaft end should form a flat surface.

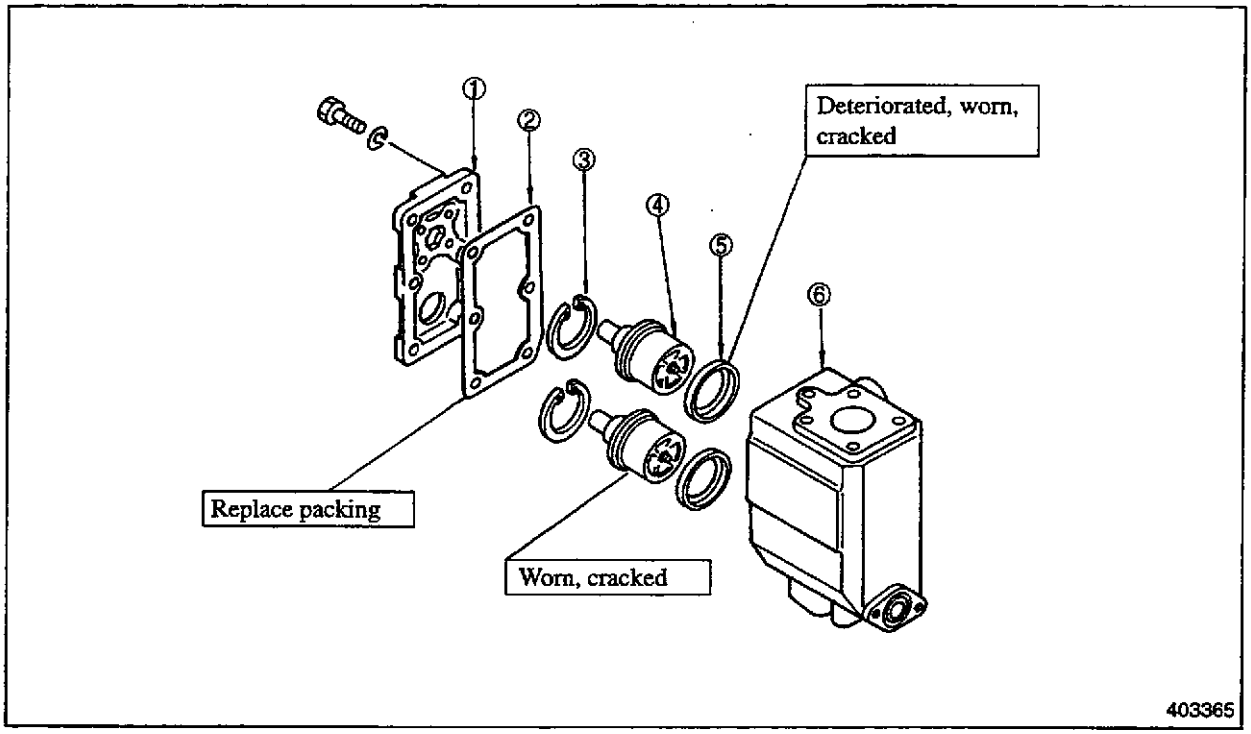


(7) After installing the water pump assembly, install the alternator pulley and tighten the nut to the specified torque.



4. Thermostats

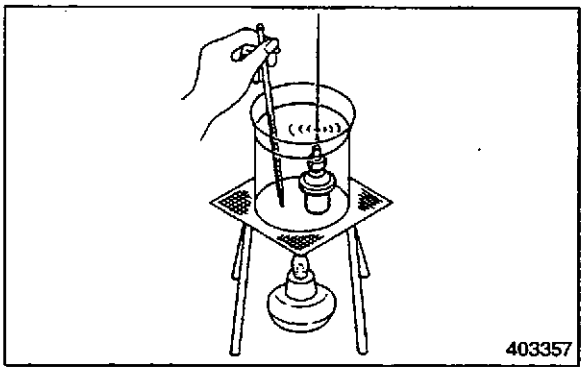
4.1 Disassembly



① Thermostat cover
② Packing
③ Snap ring
④ Thermostat
⑤ Thermostat seal
⑥ Thermostat case

4.2 Inspection

Place the thermostat in a water tub, and test it for by heating the water to raise the water temperature. Test the temperature where the valve should start opening and where the valve shaft should be 11 mm (0.4 in.) or more. If the valve falls to operate properly, replace the thermostat.



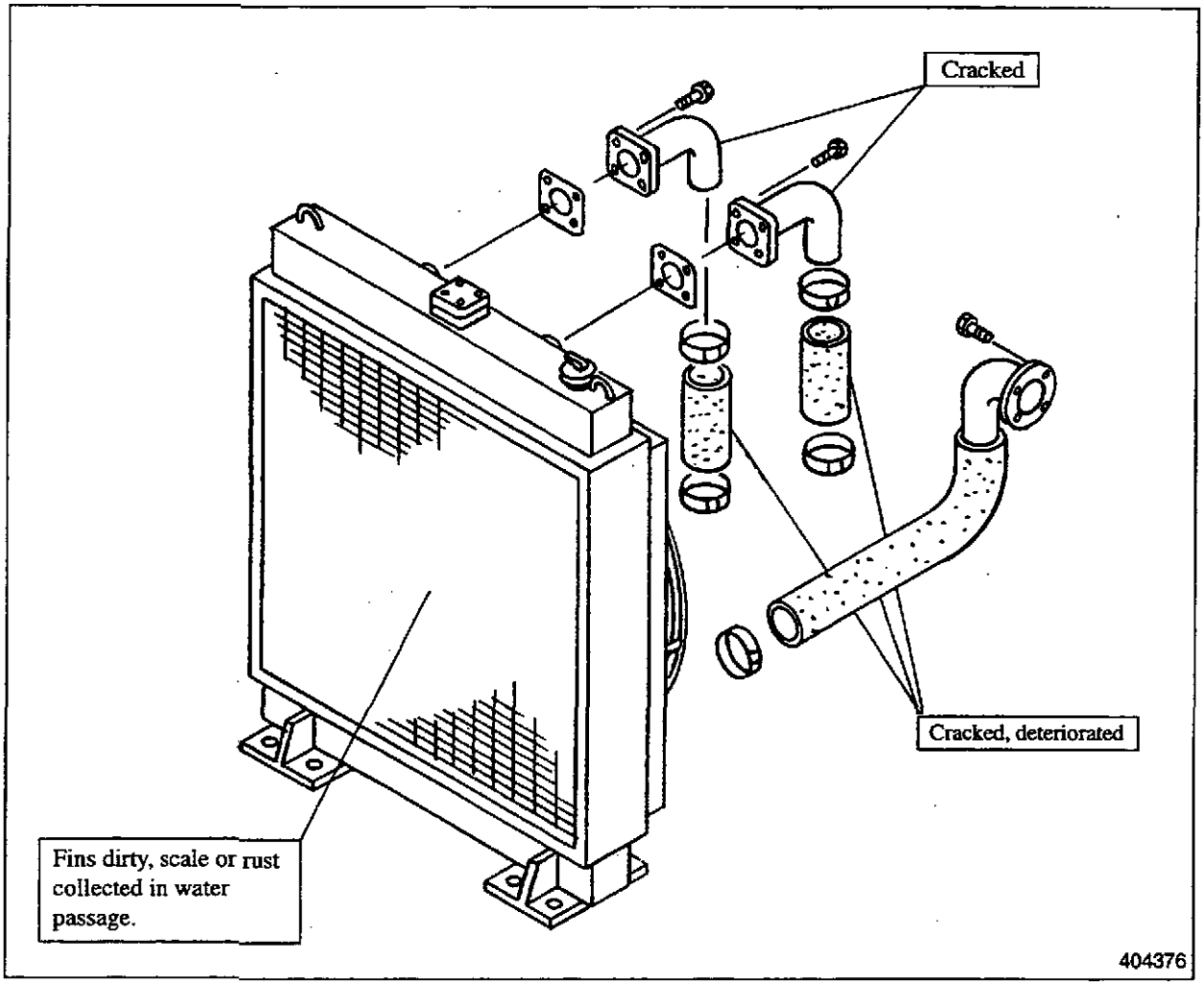
Item	Assembly Standard
Temperature where valve should start opening	71±2°C (160±3.6°F)
Valve lift of 11 mm	85°C (185°F)

NOTE

(a) Stir the heated water during the test to maintain an even temperature.
(b) At reassembly, place the thermostat in the correct position by ascertaining the valve opening temperature stamped on it mounting flange.

5. Radiator

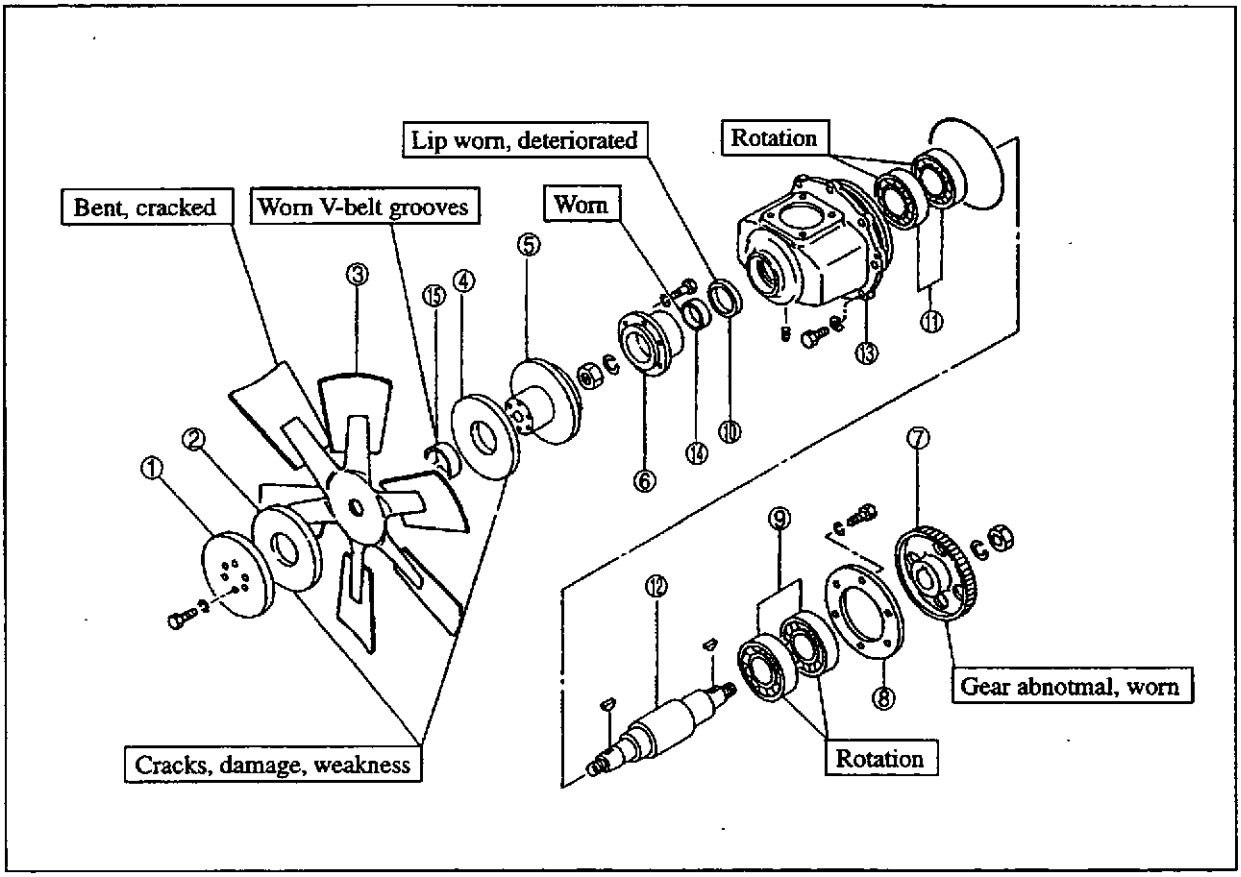
Inspection



(1) Inspect the radiator for dirt, scale, or rust in the water passages, the clean if necessary.
(2) Check the rubber hose and hose clamp. Replace them if any damage or deterioration is found.

6. Fan drive

6.1 Disassembly



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

⚠CAUTION

If one the fan blades is broken, this can cause excessive vibration and weaken the opposite blade. Carefully inspect each blade for cracks or warping.

6.2 Inspection

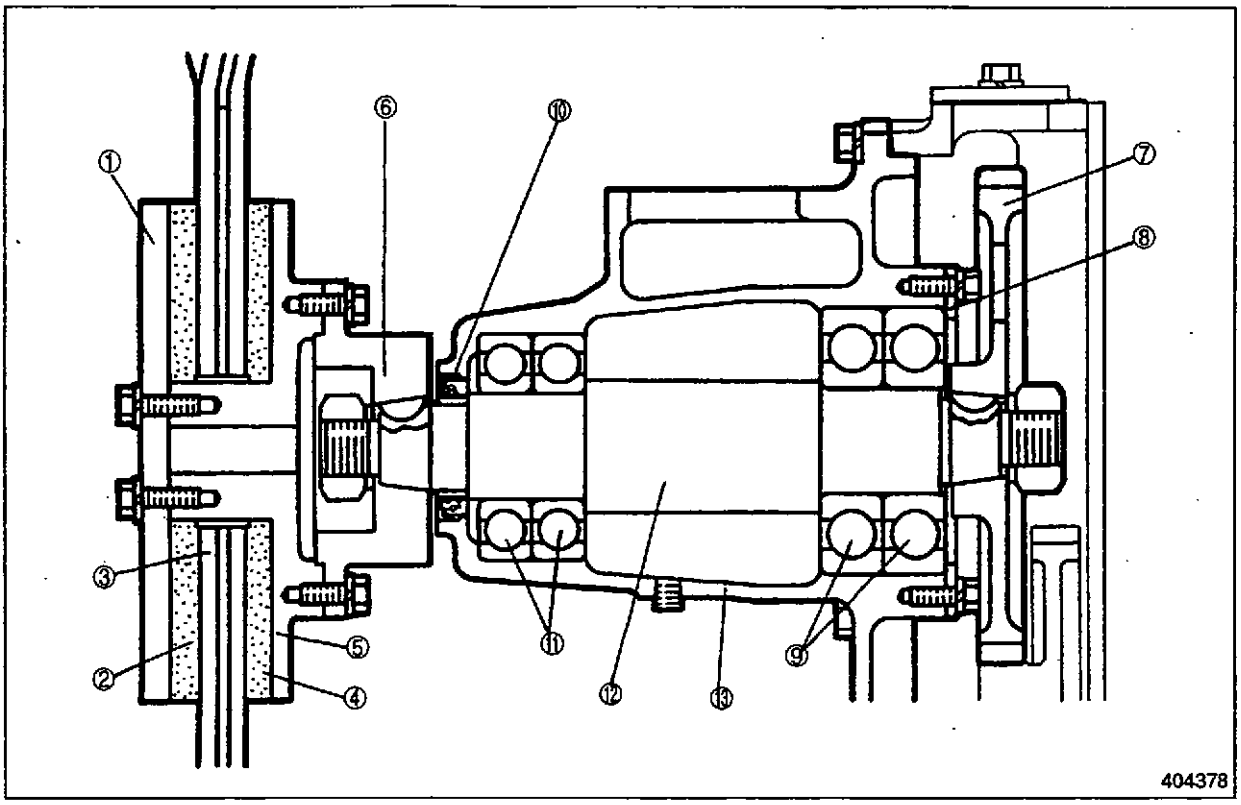
(1) Measure the inside diameter of the bracket to which the bearing outer race is fitted.
Measure the diameter of the shaft to which the bearing inner race is fitted. If the bearing, shaft, or bracket is worn, replace it.

Unit: mm (in.)

Item		Nominal Value	Assembly Standard
Inside diameter of bracket bore to which bearer race is fitted		ø140 (5.51)	139.986-140.026 (5.51172-5.51329)
		ø120 (4.72)	119.987-120.022 (4.72429-4.72488)
Bearing	Diameter	ø120 (4.72)	119.982-120.000 (4.72370-4.72441)
		ø110 (4.33)	109.985-110.000 (4.33012-4.33071)
	Inside diameter	ø55 (2.17)	54.985-55.000 (2.16476-2.16535)
Diameter of shaft on which bearing inner race is fitted		ø55 (2.17)	55.002-55.015 (2.16561-2.16612)

(2) Check the fan bushing for wear and damage and replace it anything abnormal is found.
(3) Check the friction rubber for deterioration, cracks, or damage. Replace it if necessary.

6.3 Reassembly

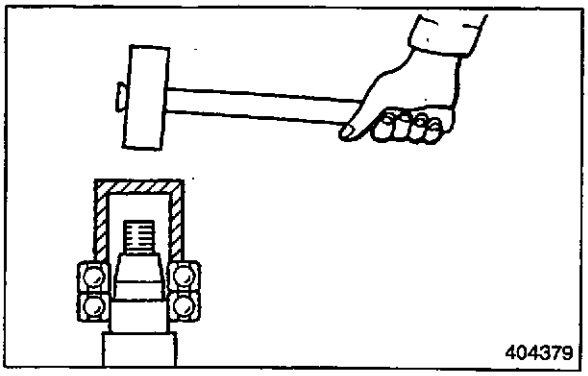


Reassembly Sequence

⑪ → ⑩ → ⑨ → ③ → ② → ①

⑧ → ⑦ → ⑥ → ⑤ → ④ → ③ → ② → ①

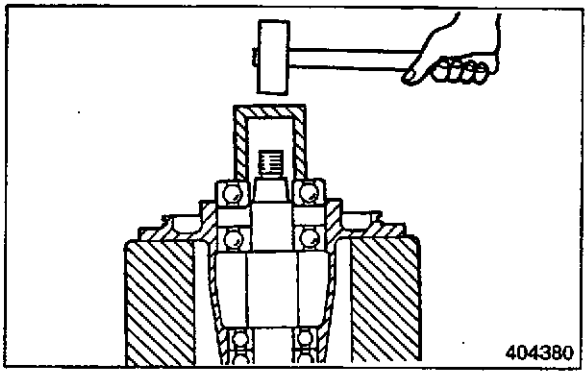
(1) Use a bearing installer to press the bearing onto the shaft. Press the oil seal to the case.



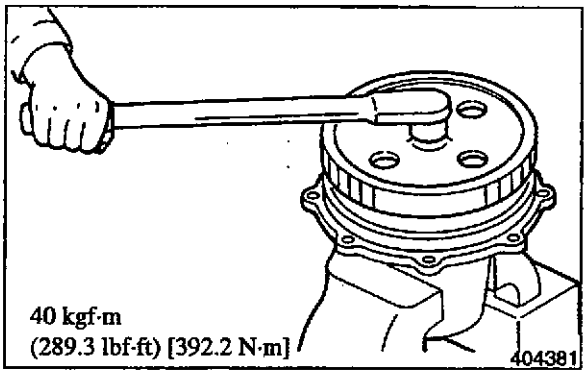
NOTE

Apply engine oil to the oil seal lip before installation.

(2) Press the shaft into the bracket. Use a bearing installer to press the bearings to the shaft and bracket. Install the thrust plate.



(3) Insert the gear onto the shaft, then tighten the nut to the specified torque.

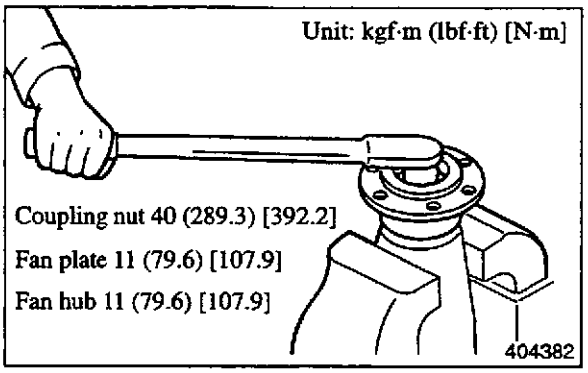


(4) Installing the fan

(a) Match the key to insert the coupling to the shaft, then the nut to the specified torque.

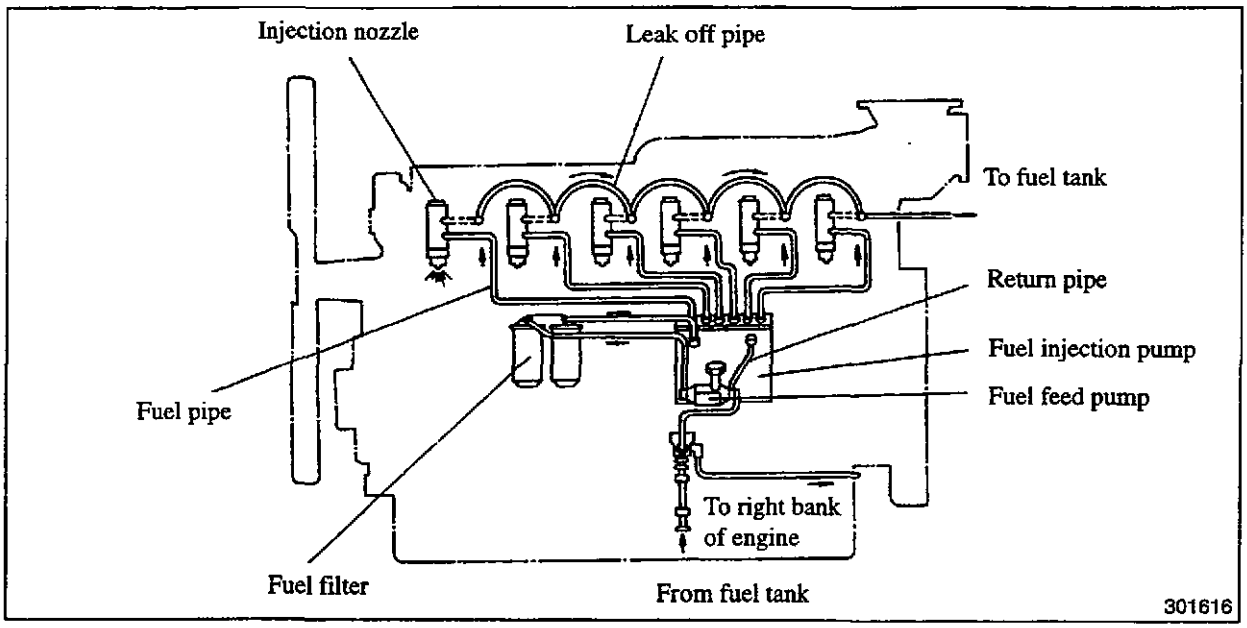
(b) Tighten the coupling and the fan hub mounting bolt to the specified torque.

(c) Insert the friction rubber, the fan bushing, and the fan to the shaft, then tighten the fan plate mounting bolt to the specified torque.



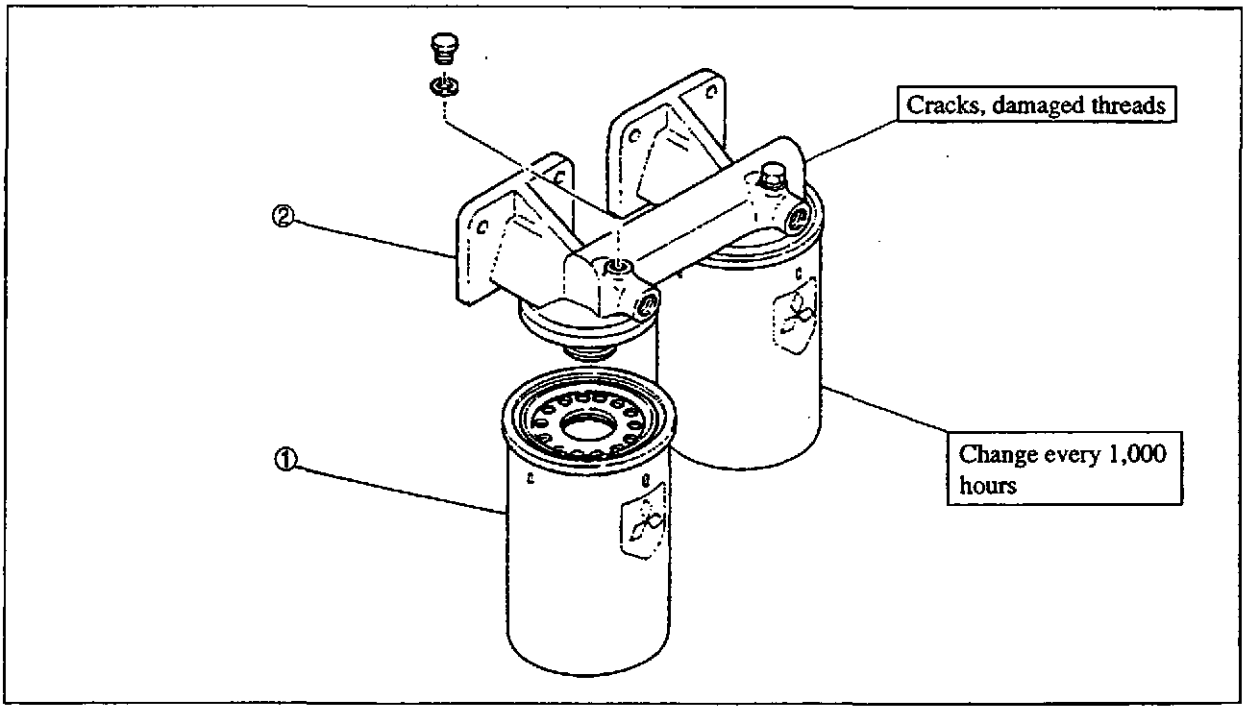
FUEL SYSTEM

1. Description



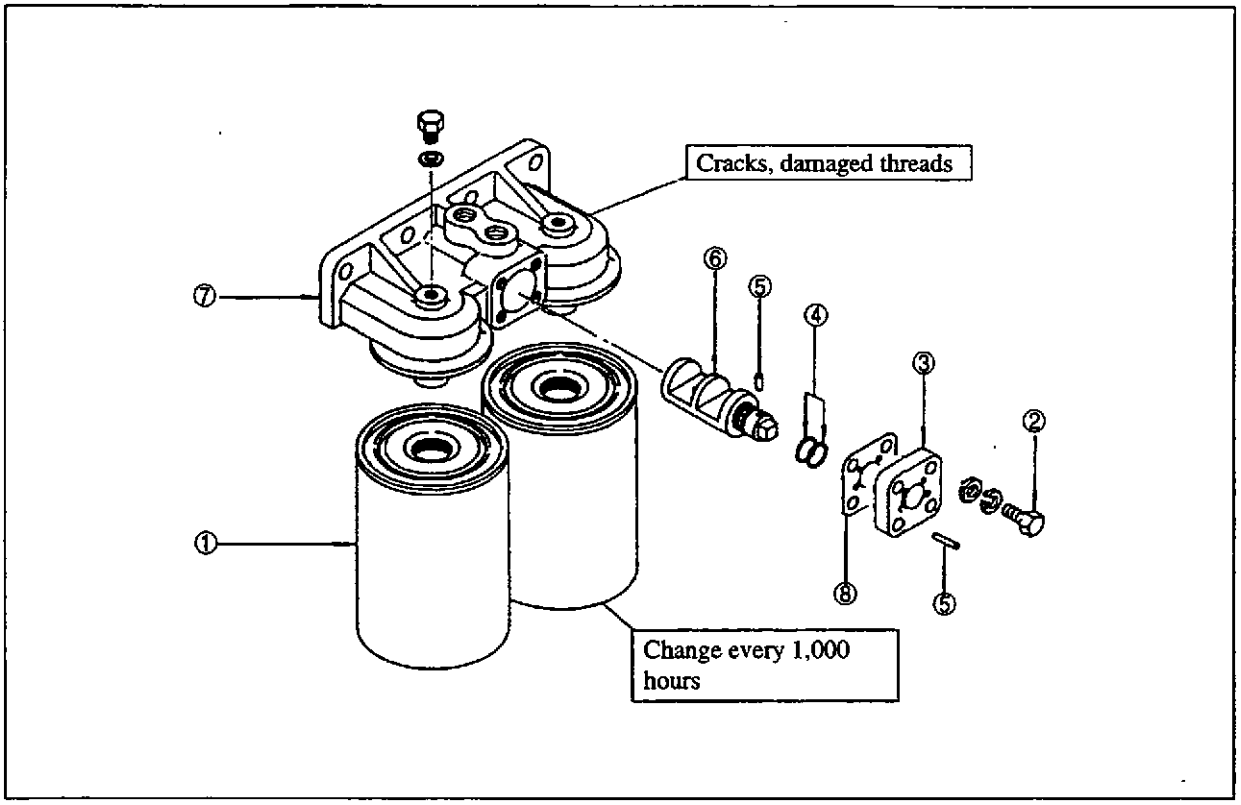
2. Fuel Filters

2.1 Disassembly and Inspection



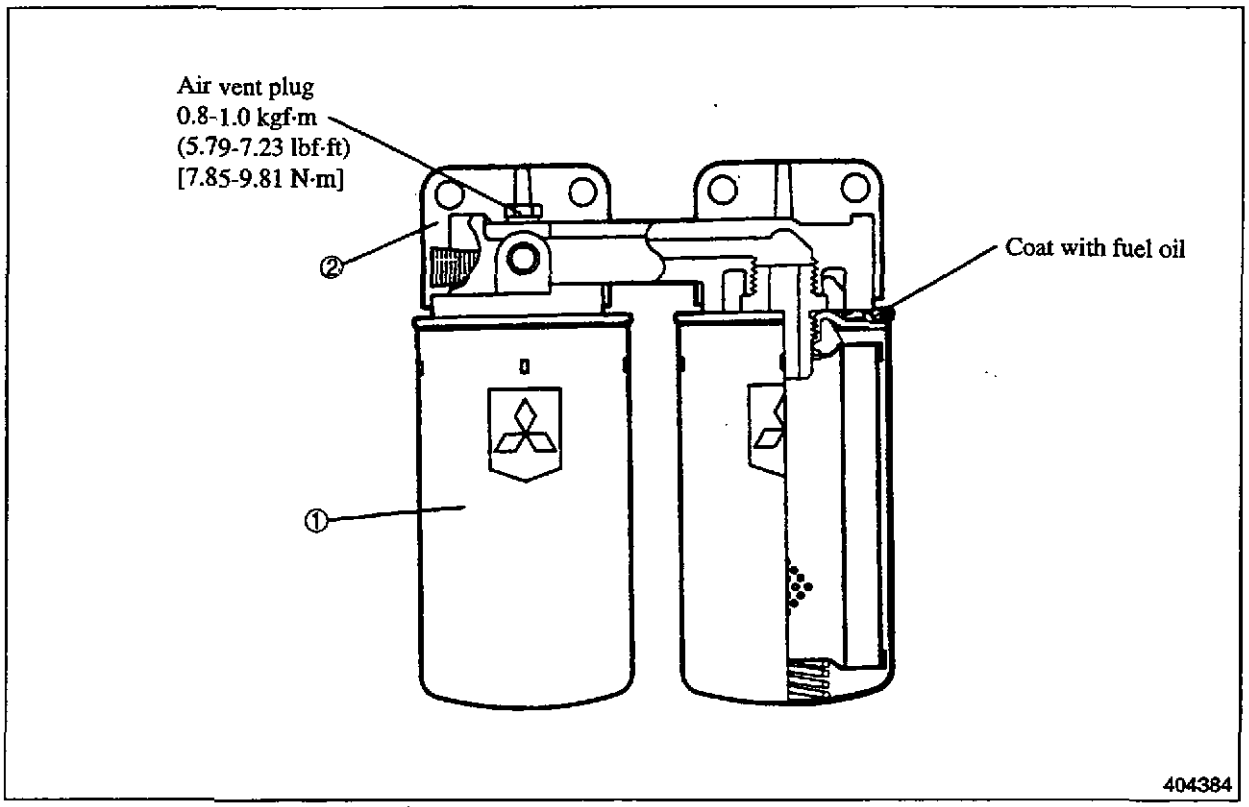
① Element ② Fuel filter bracket

Switchable Type



① Element
② Bolt
③ Cover
④ O-ring
⑤ Pin
⑥ Cock
⑦ Fuel filter bracket
⑧ Gasket

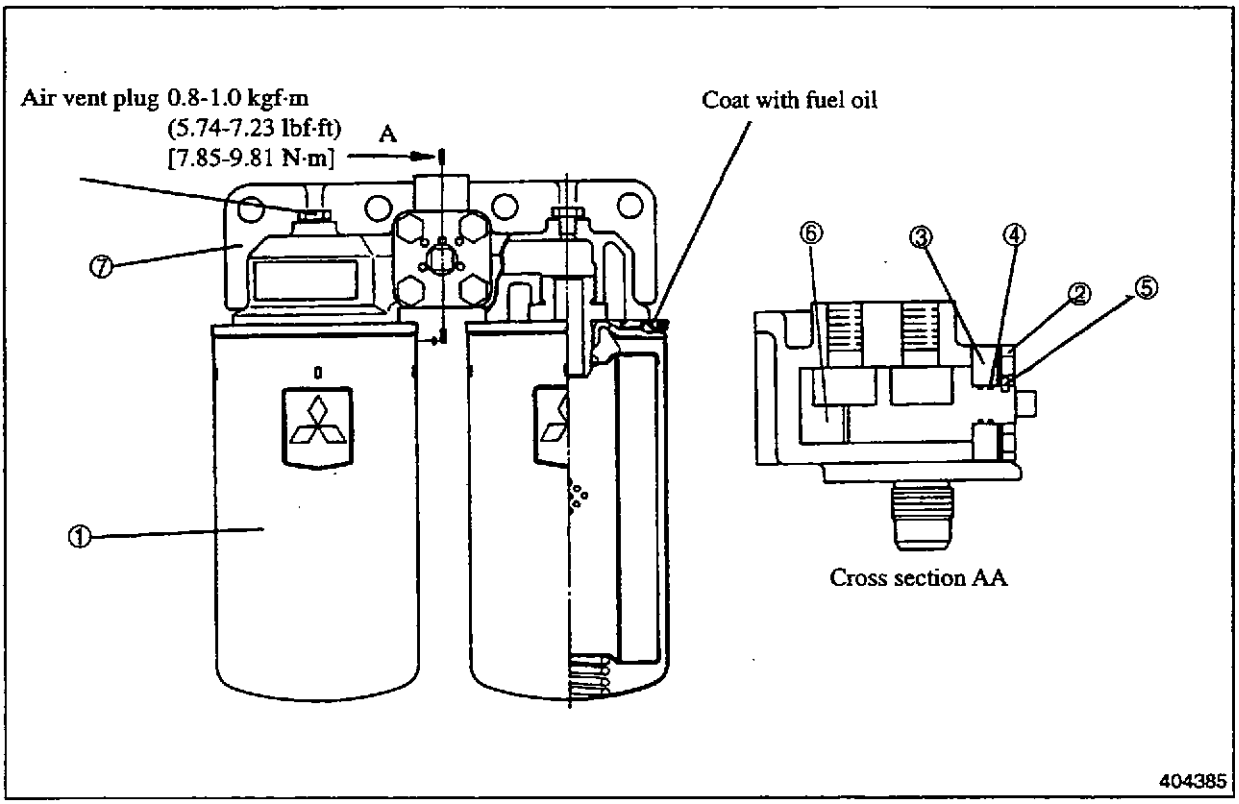
2.2 Reassembly



Reassembly Sequence

② → ①

Switchable Type



Reassembly Sequence

⑦ → ⑤ → ④ → ⑥ → ③ → ② → ①

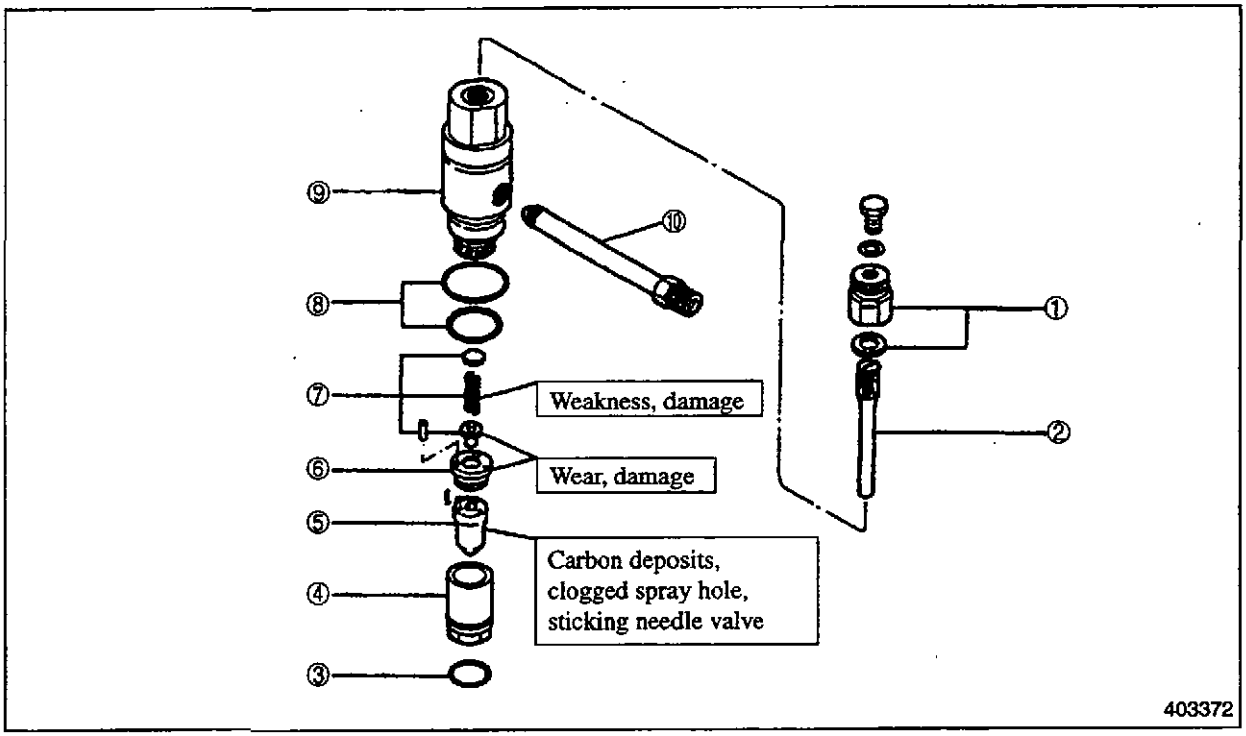
To install the cartridge, clean the mounting surface and apply fuel oil to the gasket. After bringing the gasket into contact with the sealing surface of the bracket, tighten the cartridge with your hand about to one turn (Do not use a filter wrench. Do not use the filter if it is dented or scratched, since such surface flaws can result in filter damage.)

⚠CAUTION

After installing the fuel filter on the engine, start the engine, then confirm that the filters are not leaking.

3. Fuel Injection Nozzles

3.1 Disassembly



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

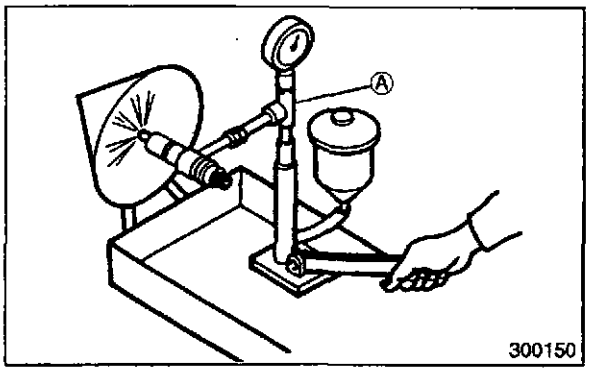
3.2 Inspection and Adjustment

(1) Injection Pressure

(a) Install the nozzle on the tester Ⓐ (41091-01500). 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: kgf/cm² (psi) [MPa]

Item	Assembly Standard
Injection pressue (Valve opening pressure)	350-355 (4979-5050) [34.3-34.8]



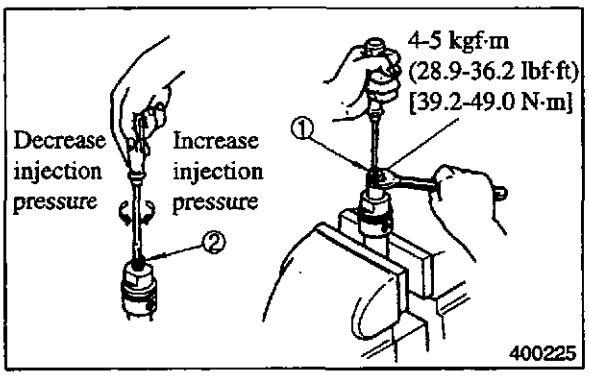
⚠WARNING

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.

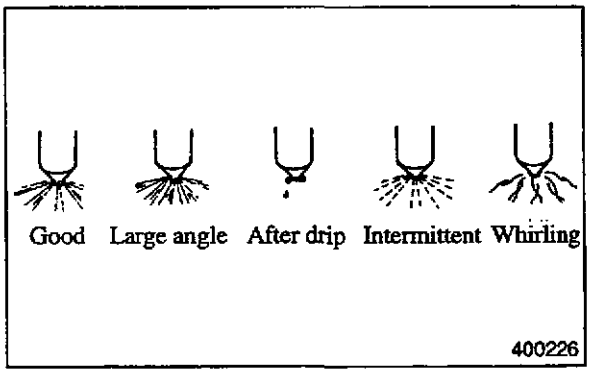
(c) After completing the adjustment, tighten the jam nut and the cap nut to the specified torque.

(d) Re-check the injection pressure to be sure that it is correct.



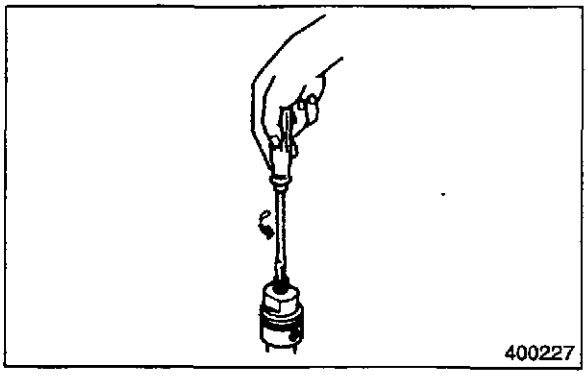
(2) Spray pattern

(a) When you are testing the injection pressure, inpsect 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.



Spray patterns

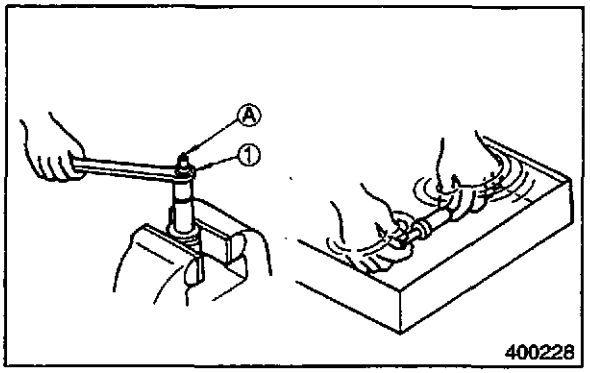
(b) When tested on the nozzle tester, the nozzle should spray fuel from its ten holes at the same time in a straight cone of 160 degrees. The spray should consist of finely atomized fuel particles without any large droplets. The spray should terminate with no dripping at the top.


400227

(3) Washing or replacing the nozzle tip

(a) The nozzle tip is spring loaded. Remove the cap nut and with a screwdriver, loosen the adjusting screw until it can be loosened by hand.

(b) Loosen the retaining nut ①, remove the nozzle tip and wash the needle valve and body.



400228

⚠CAUTION

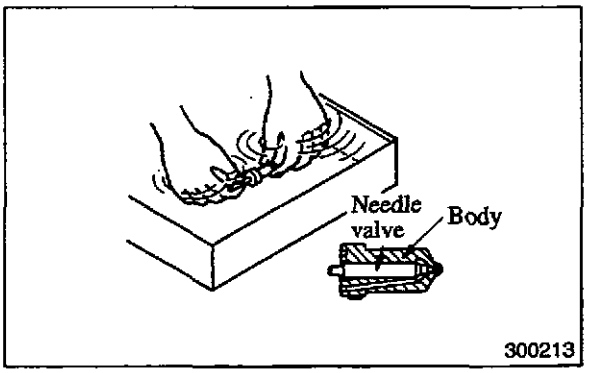
When pulling out the nozzle tip, do not damage the tip Ⓐ.

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

⚠CAUTION

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

(d) Tighten the retaining nut to the specified torque.



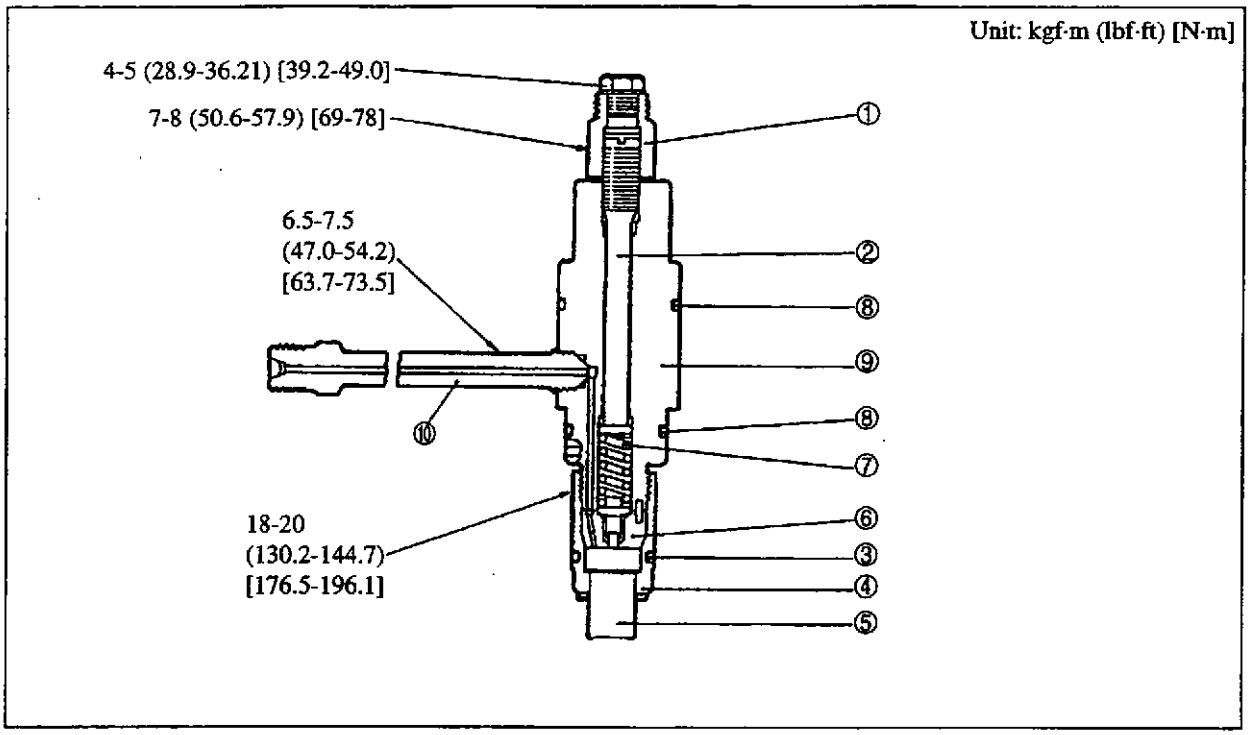
300213

(e) If the spray pattern is still bad after the nozzle has been adjusted and cleaned, replace the nozzle tip.

NOTE

New nozzle tips are coated with vaseline to preserve them. Wash them twice, first in gasoline then in diesel fuel before you inslall them.

3.3 Reassembly



Reassembly Sequence

⑨ → ③ → ⑧ → ⑦ → ⑥ → ⑤ → ④ → ⑩ → ② → ①

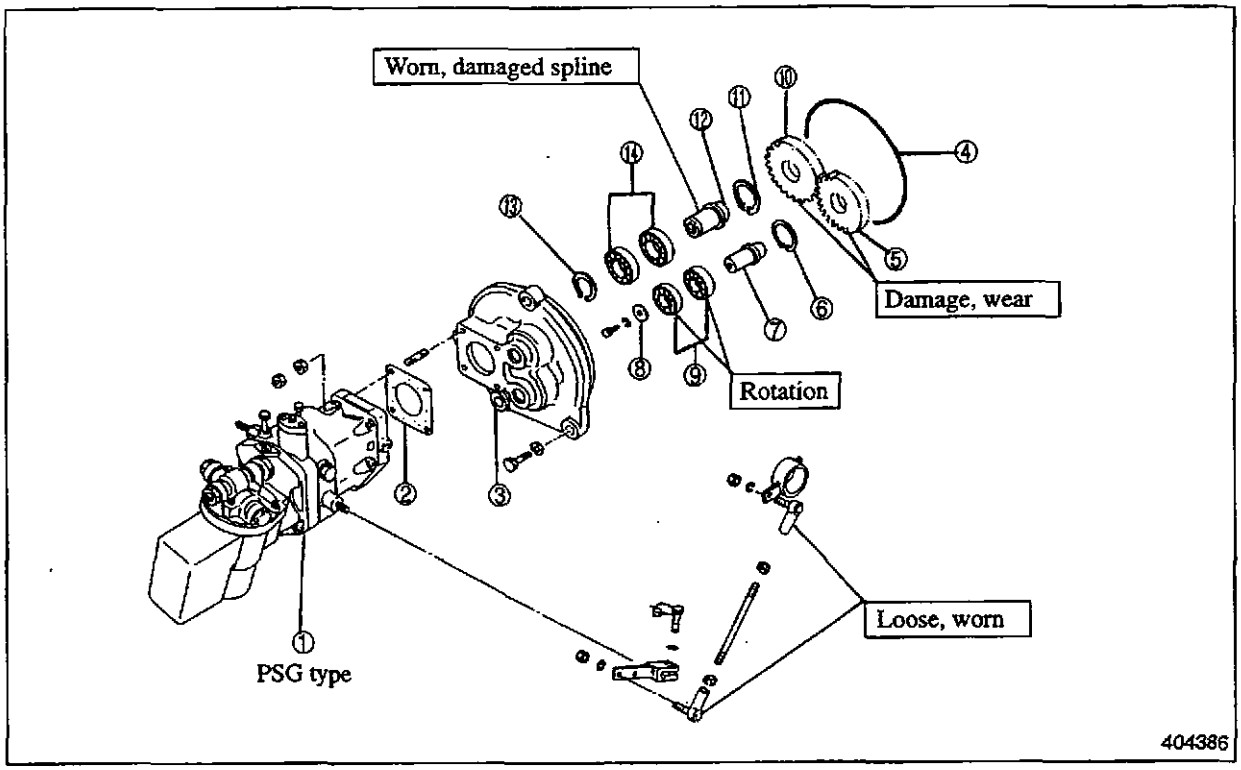
⚠CAUTION

Tighten the retaining nut ④ only as far as the specified torque. Excessive torque on the retaining nut, the needle will not operate smoothly, causing discoloration of exhaust gas and sticking.

4. Woodward Governor Drive and Governor Link

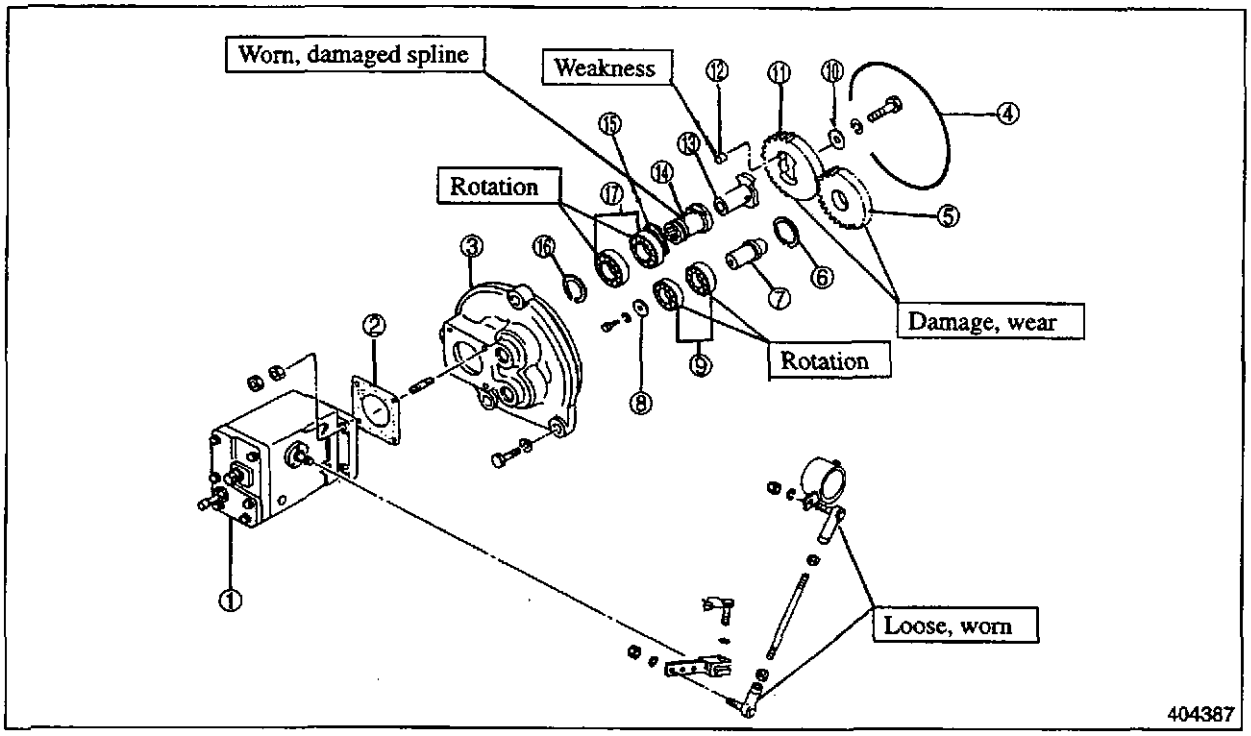
4.1 Disassembly

PSG, EG-3P Governors



① Woodward governor (PSG)
② Packing
③ Drive case
④ O-ring
⑤ Idler gear
⑥ Snap ring
⑦ Idler shaft
⑧ Washer
⑨ Bearing
⑩ Drive gear
⑪ Snap ring
⑫ Drive shaft
⑬ Snap ring
⑭ Bearing

EG-B2P Governors



① Woodward governor (EG-B2P)
② Packing
③ Drive case
④ O-ring
⑤ Idler gear
⑥ Snap ring
⑦ Idler shaft
⑧ Washer
⑨ Bearing
⑩ Washer
⑪ Drive gear
⑫ Gear rubber
⑬ Drive shaft
⑭ Drive shaft
⑮ Snap ring
⑯ Snap ring
⑰ Bearing

4.2 Inspection

Rotate each bearing to check rotation. Replace the bearing if its rotation is not smooth.

Check the fit of the bearings on the drive shaft, and idler shaft. Replace the shaft or bearings if they are worn.

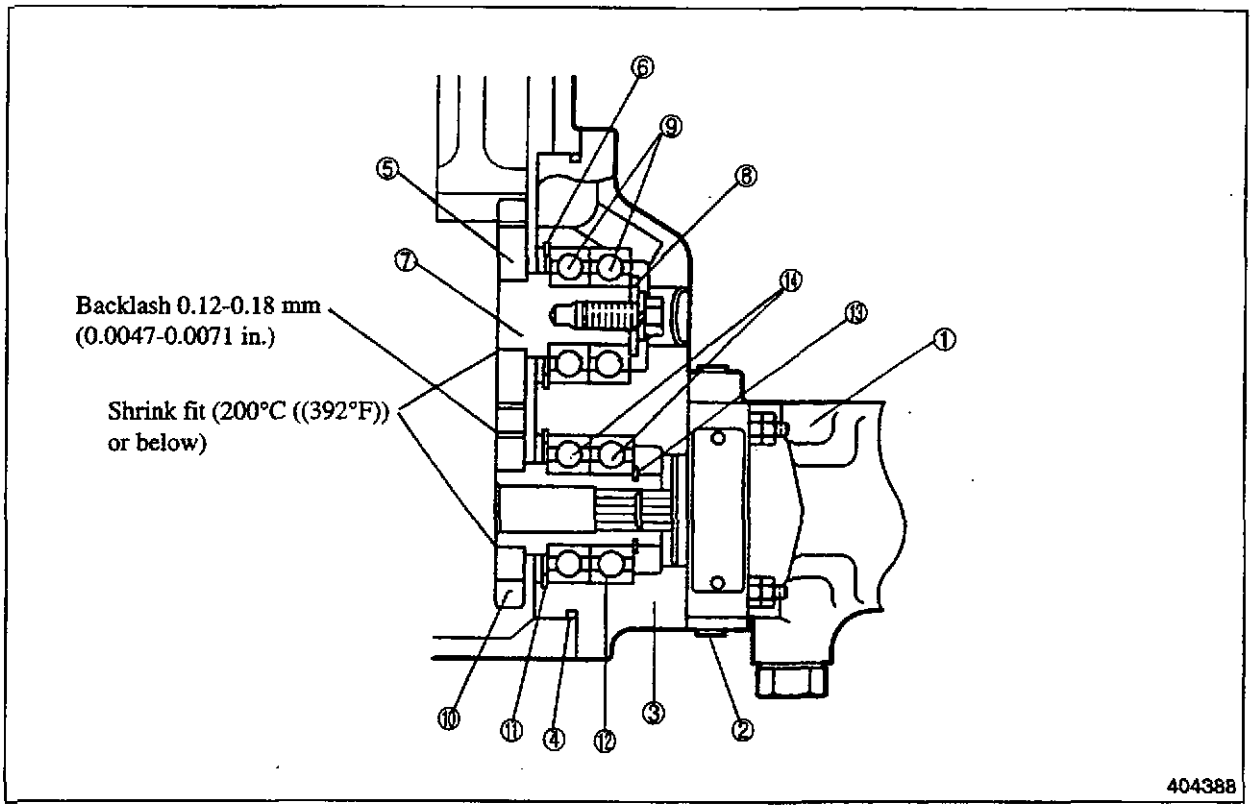
Check the fit of the bearings in the drive case and drive cover. Replace worn parts.

Unit:mm (in.)

Item		Nominal Value	Assembly Standard
Bearing inside diameter for case drive shaft		ø52 (2.05)	51.988-52.018 (2.04694-2.04812)
Bearing for drive shaft	Outside dia.	ø52 (2.05)	51.987-52.000 (2.04673-2.04724)
	Inside dia.	ø25 (0.98)	24.990-25.000 (0.98386-0.98425)
Drive shaft outside dia. for bearing		ø25 (0.98)	25.002-25.011 (0.98441-0.97477)
Bearing inside dia. for case idler shaft		ø47 (1.85)	46.989-47.014 (1.85011-1.85110)
Bearing for idler shaft	Outside dia.	ø47 (1.85)	46.989-47.000 (1.84996-1.85039)
	Inside dia.	ø20 (0.79)	19.990-20.000 (0.78701-0.78740)
Idler shaft outside dia. for bearing		ø20 (0.79)	20.002-20.011 (0.78755-0.78790)
Drive shaft outside dia for bearing		ø26 (1.02)	26.035-26.048 (1.02508-1.02560)
Drive gear inside dia.		ø26 (1.02)	26.000-26.013 (1.02371-1.02422)
EG-B2P drive shaft outside dia. for gear		ø29 (1.14)	28.959-28.980 (1.14021-1.14104)
EG-B2P drive gear inside dia.		ø29 (1.14)	29.00-29.04 (1.1418-1.1434)
Idler shaft outside dia. for gear		ø24 (0.94)	24.035-24.048 (0.94634-0.94685)
Idler gear inside dia.		ø24 (0.94)	24.000-24.013 (0.94496-0.94547)

4.3 Reassembly

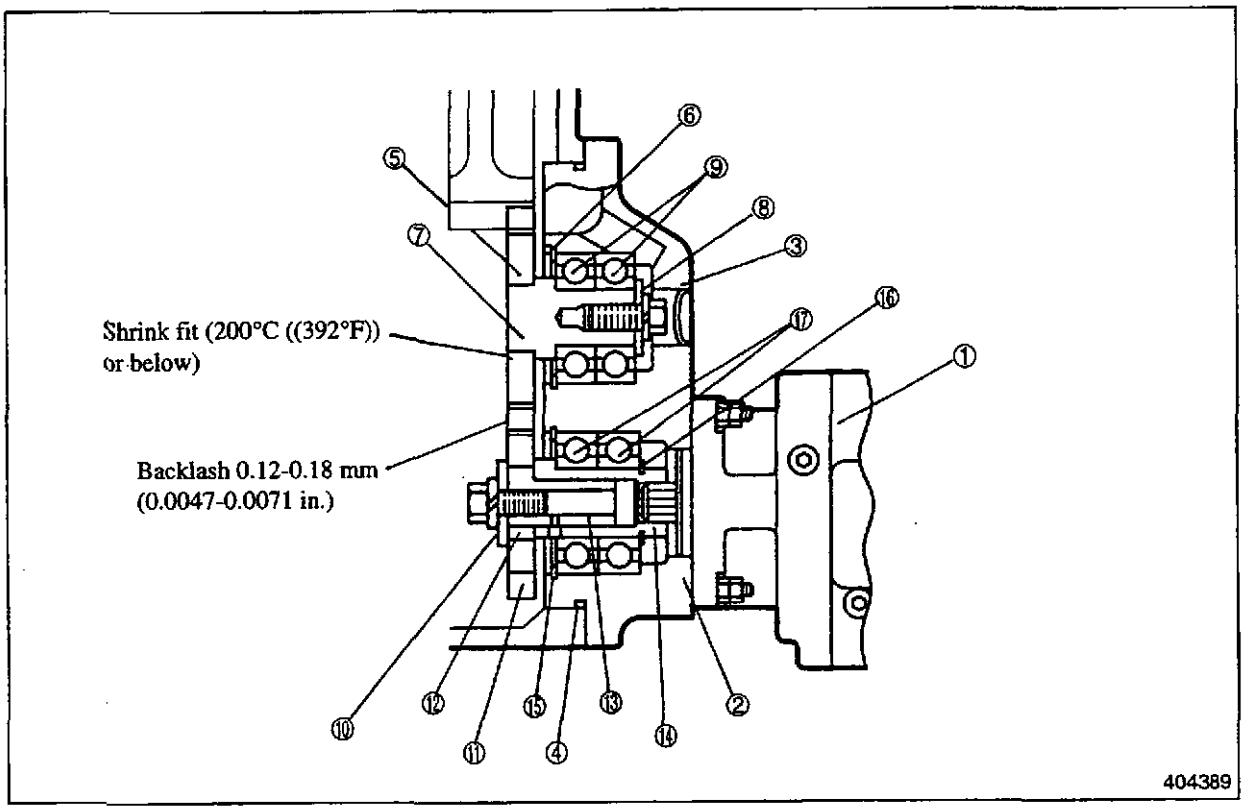
PSG, EG-3P Governor



Reassembly Sequence

⑫ → ⑬ → ⑮ → ⑭
③ → ⑪ → ⑩ → ⑧ → ⑥ → ④ → ② → ①
⑦ → ⑨ → ⑤

EG-B2P Governor



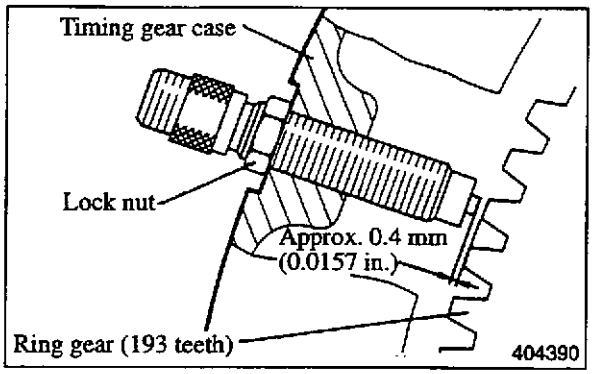
Reassembly Sequence

⑦ → ⑨ → ⑧ → ③ → ⑥ → ⑤ → ⑮ → ⑪ → ⑫ → ⑩ → ④ → ② → ①
⑬ → ⑭ → ⑰ → ⑯

Installing Pick-up

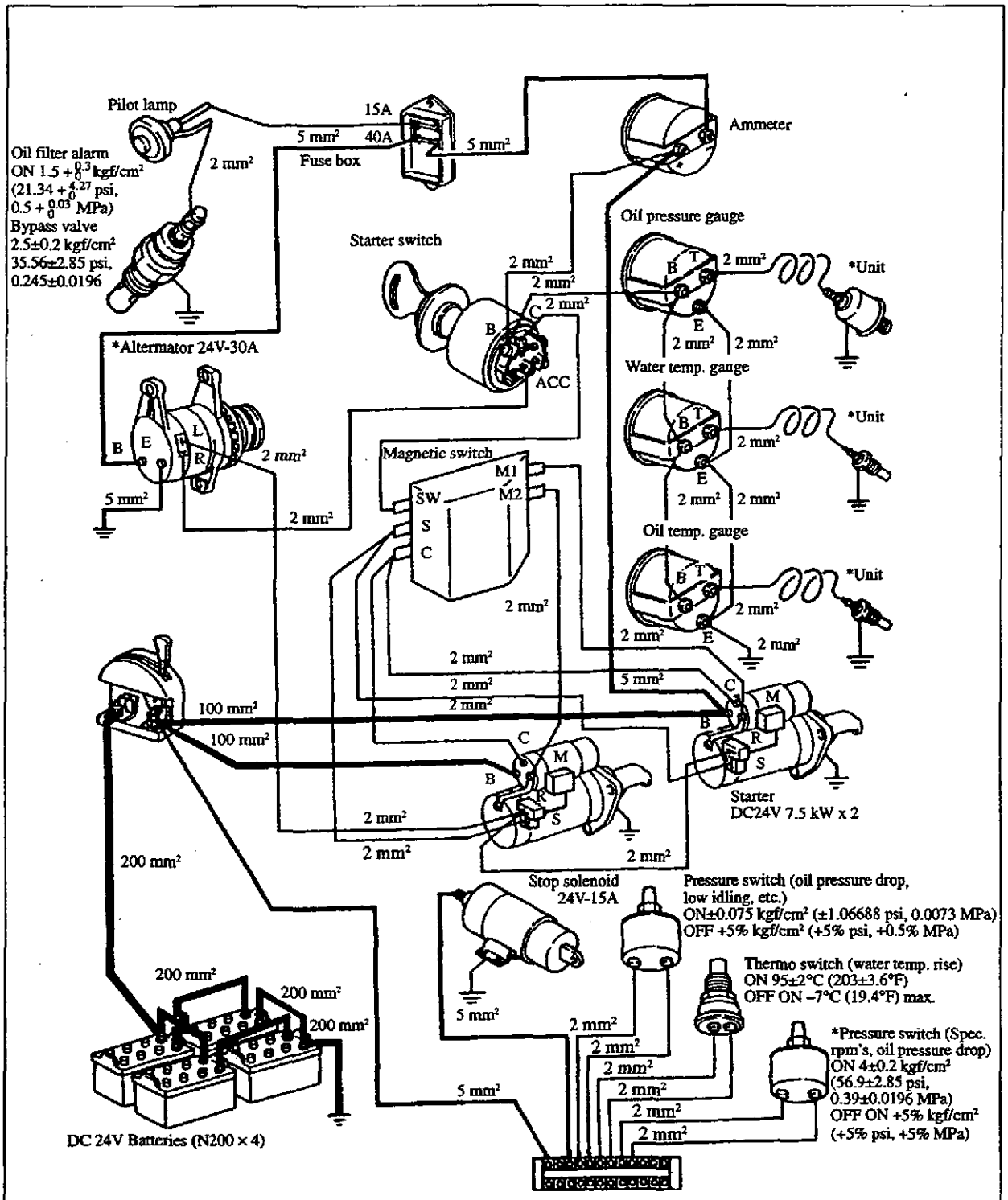
(a) Rotate the engine with the turning gear and position a tooth of the ring gear at the center of the pick-up.

(b) Screw in the pick-up gently until the tip of the pick- up touches the tooth of the gear.
Draw it back about 1/4 of a rotation then fix the lock nut.



ELECTRICAL SYSTEM

1. Electrical System Outline



Remarks:

(a) Circuit above is for the standard model. However, specifications and applications may vary with the type of engine.

(b) Circuit wiring is to be prepared in the field.

(c) Items marked with an asterisk (*) belong to the engine. Unmarked items are to be supplied individually.

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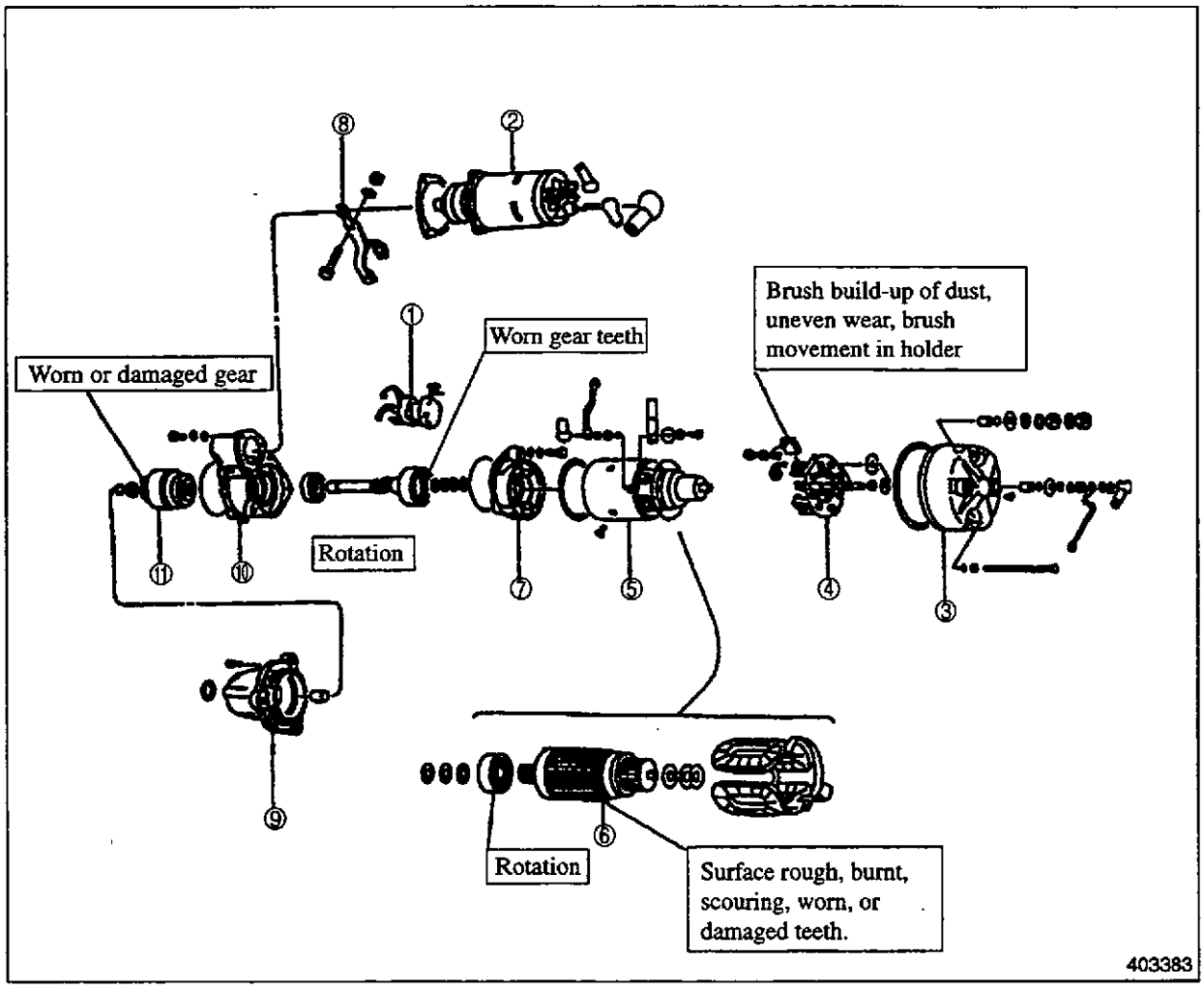
Wiring Diagram

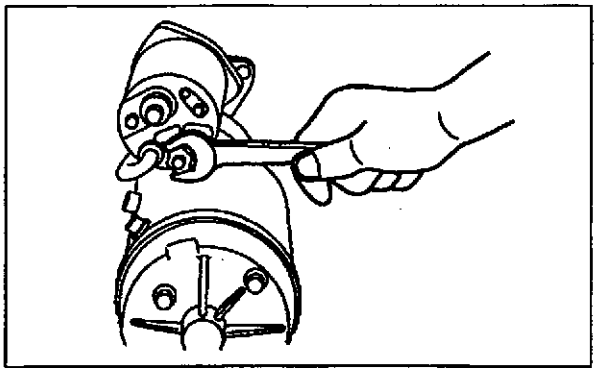
2. The Starter

2.1 Disassembly

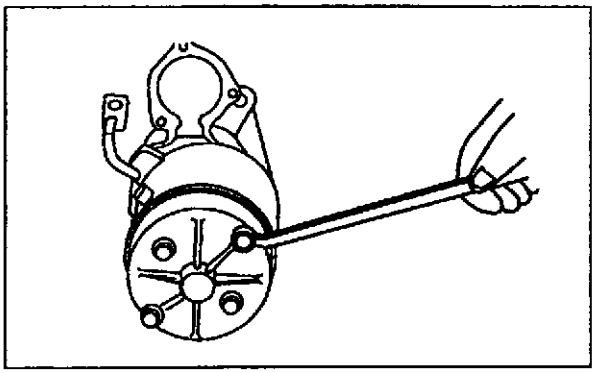


① Safety magnetic switch
② Magnetic switch assy.
③ Rear bracket
④ Brush holder assy.
⑤ Yoke assy.
⑥ Armature assy.
⑦ Center bracket
⑧ Lever assy.
⑨ Front bracket
⑩ Pinion case
⑪ Pinion clutch assy.

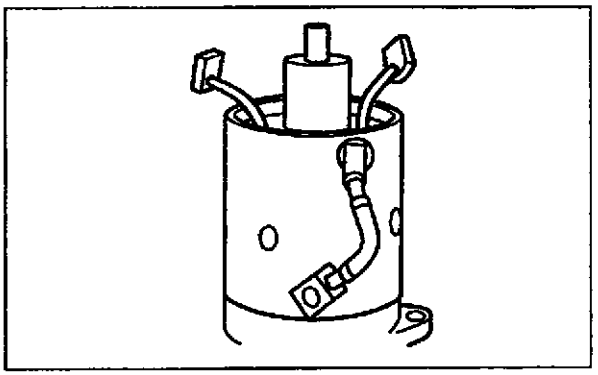
(1) After removing the safety switch, remove the lead wire, and then the magnetic switch assembly.



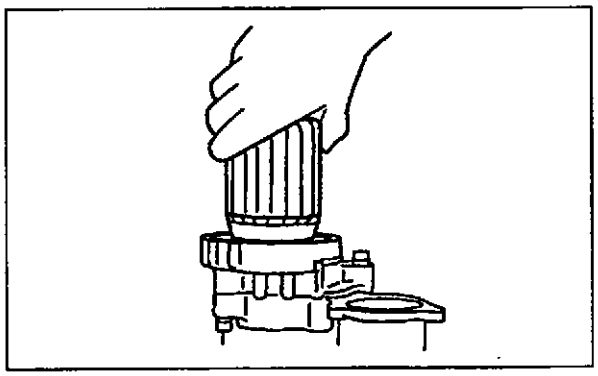
(2) Unscrew the through bolts and the brush holder mounting screws, then remove the rear bracket.



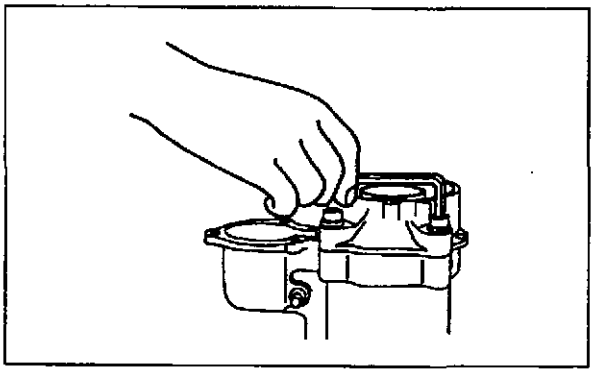
(3) Remove the brushes from the brush holder assembly, then remove the yoke.



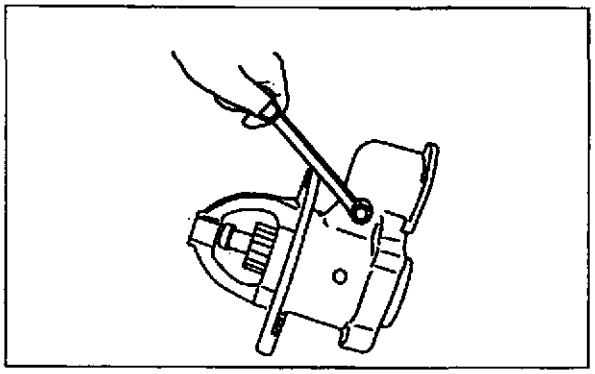
(4) Pull out the armature assembly.



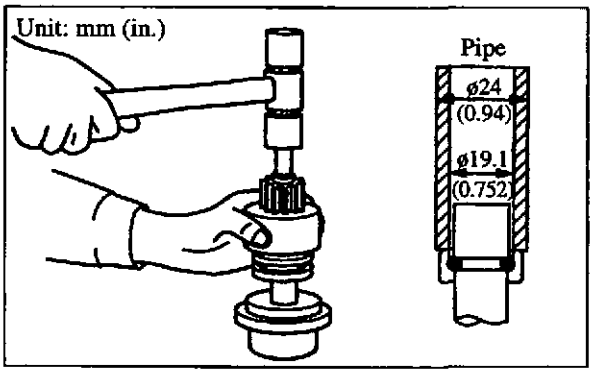
(5) Remove the center bracket.



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

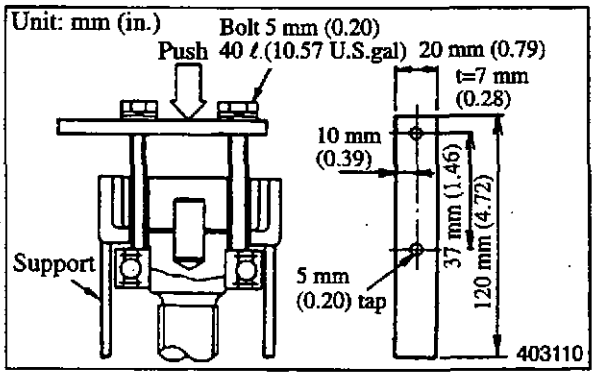


(7) Using a jig, remove the pinion stopper, then remove the overrunning clutch from the pinion shaft.



NOTE

To remove the shaft bearing for replacement, use a bearing puller like the one shown in the illustration.



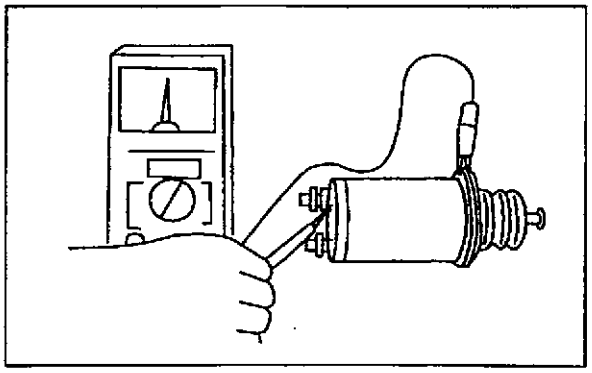
Pinion shaft bearing puller

2.2 Inspection and Repair

Magnetic Switch

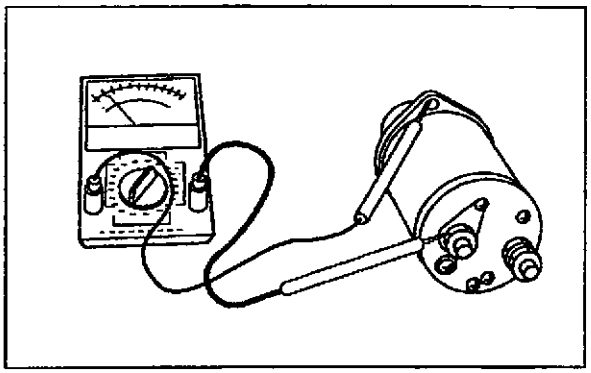
(1) Testing the magnetic switch coil

(a) Test the pressure coil and holding coil for an open ciruit. The coils are open-circuited if there is no continuity between the M terminal of the magnetic switch and the case.



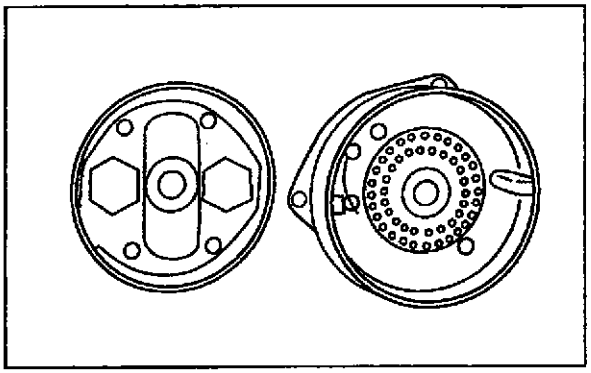
Resistance: 1.16 ohms (approx.)

(b) Apply voltage of 24 volts between the M terminal of the magnetic switch and the case. Now 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.



⚠CAUTION

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.

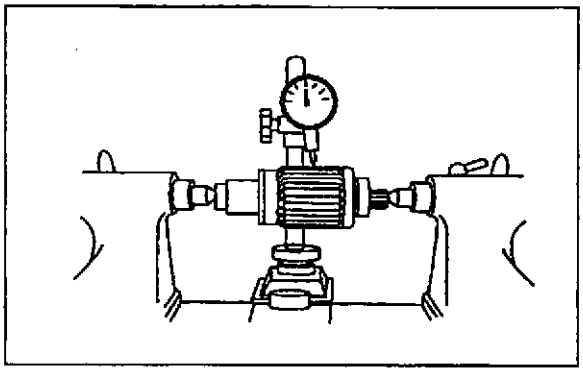
Armature

(1) Measuring the armature shaft for runout

Measure the runout with a dial gauge. If the runout exceeds the assembly standard, repair or replace the armature.

Unit: mm (in.)

Item	Assembly Standard
Armature shaft runout	0.05 (0.0020)

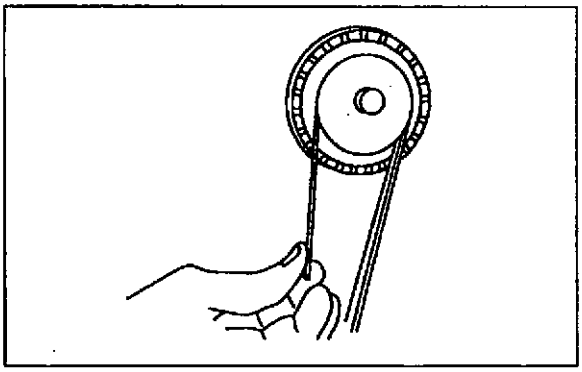


(2) Inspecting the commutator

(a) Check the condition of the commutator surface. If it is rough, polish it with #400-#600 sandpaper.
Check the commutator for runout with a dial gauge. Replace the commutator if the runout exceeds the service limit.

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Commutator runout	below 0.06 (0.002)	0.10 (0.0039)

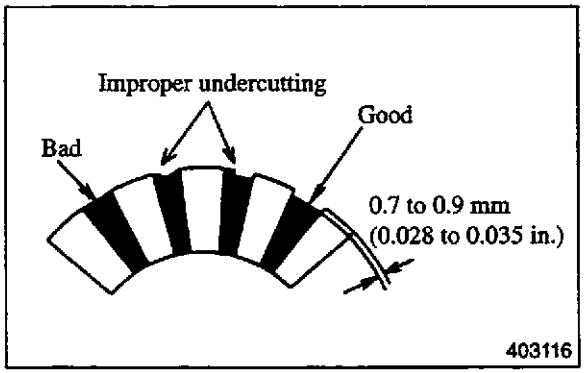


(b) Measuring the mica depth

Use a depth gauge to measure the depth of each mica undercut. If the depth exceeds the repair limit, re-condition the mica.

Unit: mm (in.)

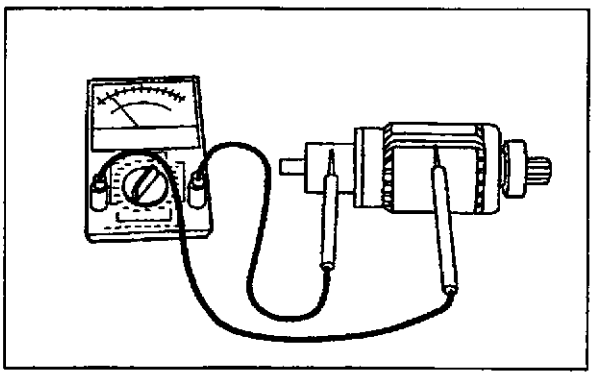
Item	Assembly Standard	Repair Limit
Commutator mica depth	0.7-0.9 (0.028-0.035)	0.2 (0.0079)



(3) Testing the armature

(a) Use a growler to test the armature for short circuits. If the hacksaw blade vibrates against the core, replace the armature.

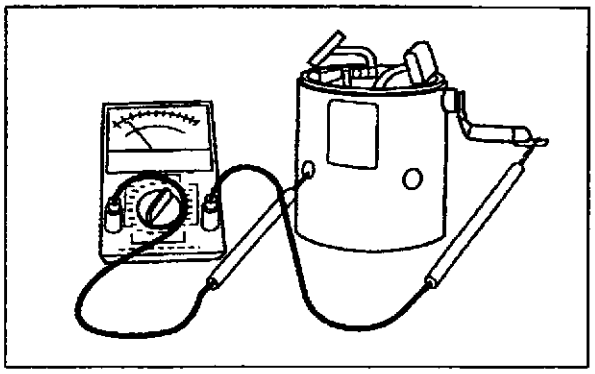
(b) If there is continuity between the commutator and shaft, replace the armature.



Field coil

(1) Testing for open circuits

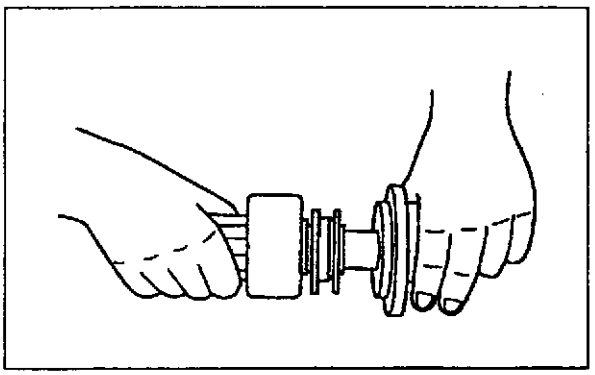
If there is no continuity between the M terminal of the field coil and the lead wire on the brush side, replace the field coil.



Overruning 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

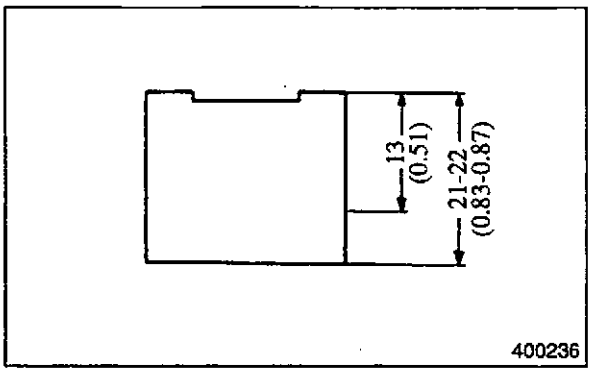
Do not immerse the overruning clutch in cleaning solvent to clean it. Immersion in cleaning solvent will cause grease inside the clutch to run out, causing clutch parts to seize when operating.

Brushes

(1) Inspecting for wear

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Brush height	21-22 (0.83-0.87)	13 (0.51)



(2) Testing brush spring tension

Unit: kgf (lbf) [N]

Item	Assembly Standard	Service Limit
Brush spring tension	4.0-4.5 (8.8-9.9) [39.2-44.1]	4.0 (8.8) [39.2] maximum

Safety Switch

Connect the safety switch shown in the illustration, and check the starter and safety switch operations.

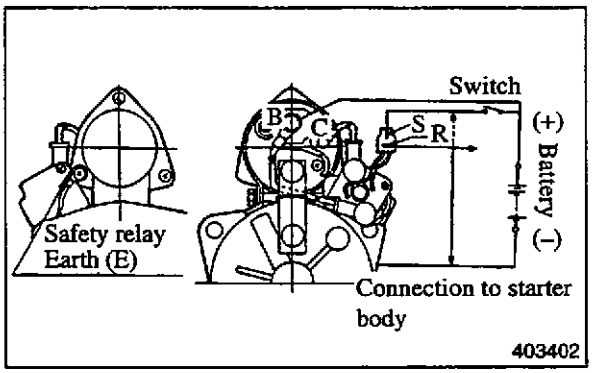
(1) Connect the R terminal to the battery minus (–) side.

(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.

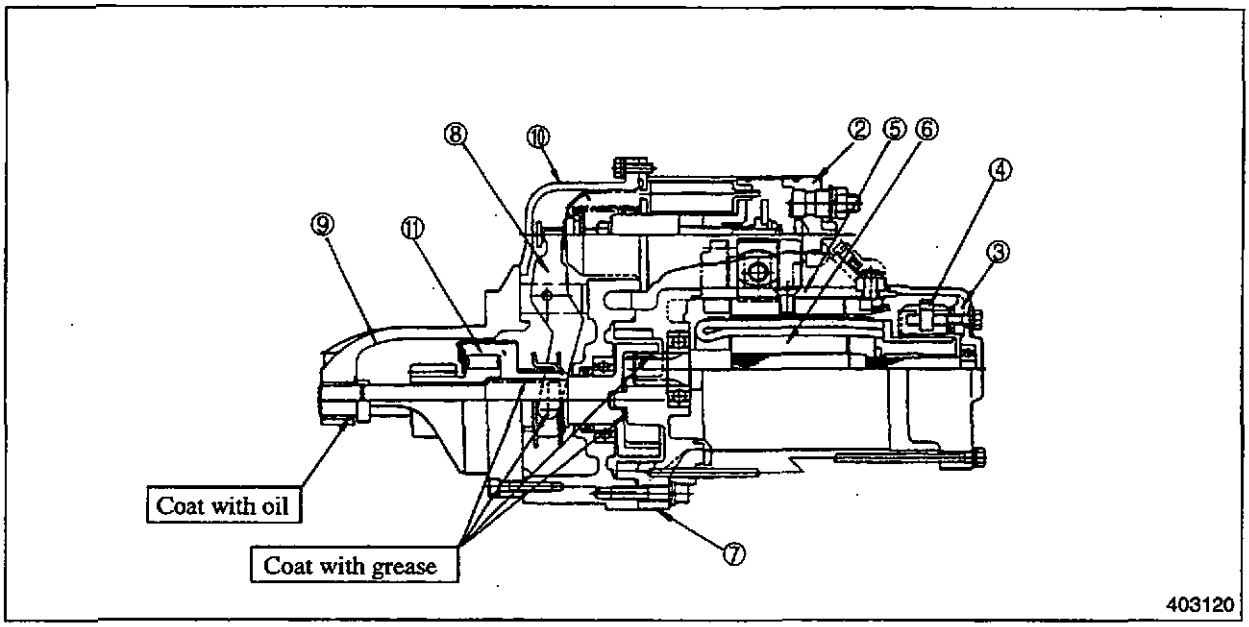
⚠CAUTION

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



2.3 Reassembly

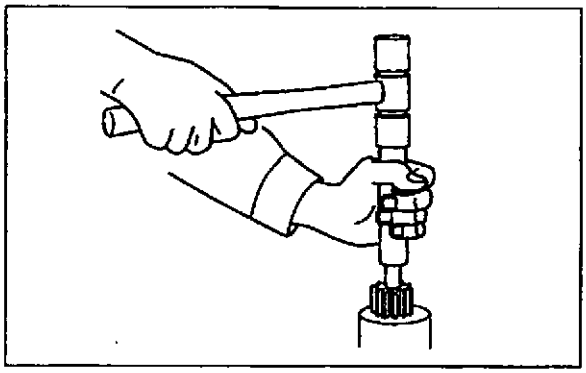
Reassembly Order



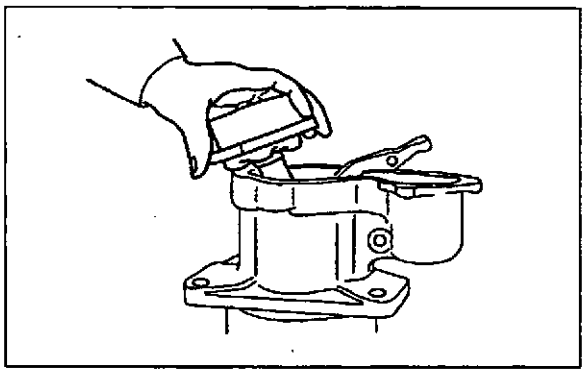
Reassembly Sequence

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

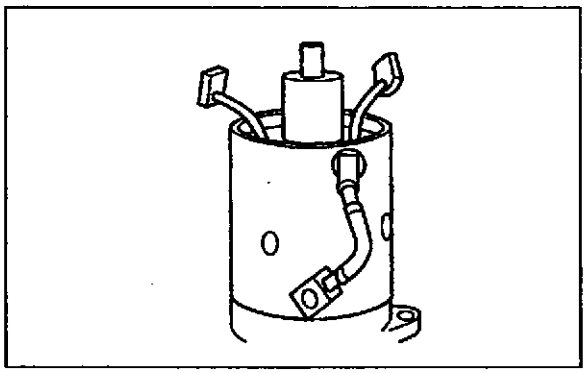
(1) Install the center bracket, overrunning clutch, and pinion stopper to the pinion shaft. Insert the shaft in position by tapping it with a plastic hammer.



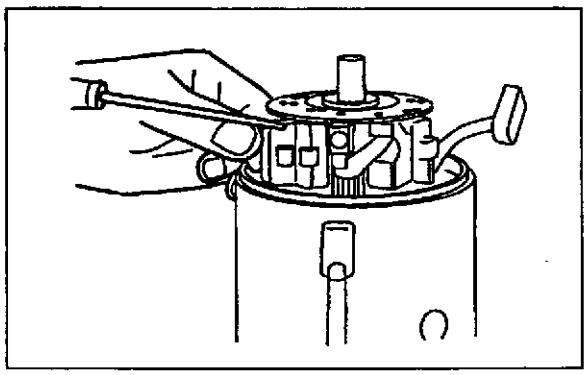
(2) Install the shift lever and pinion shaft to the front bracket by aligning the matching mark on the shift lever.



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

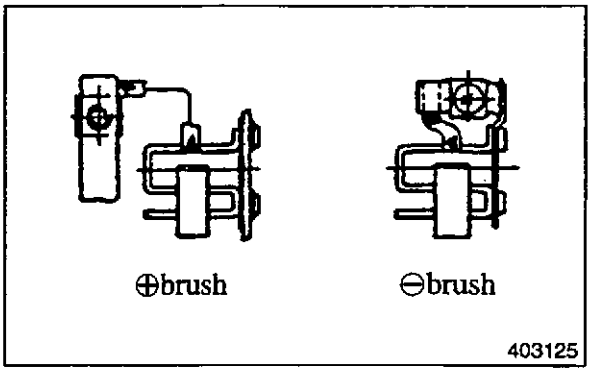


(4) Install the brushes and brush holders.

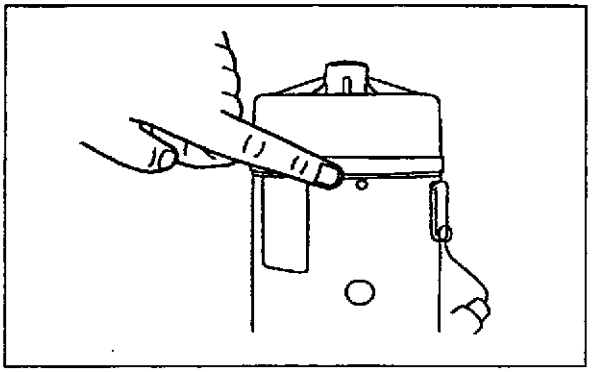


NOTE

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.

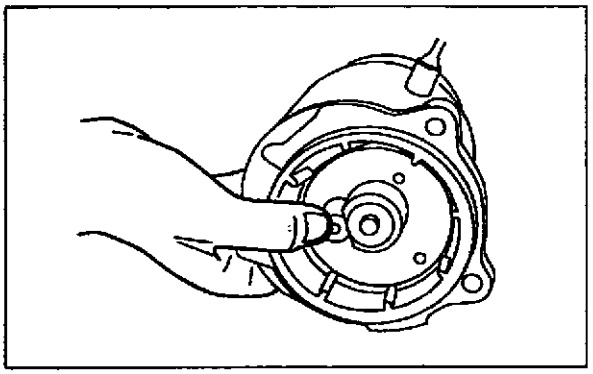


(6) Measure the end play of the armature. If the end play exceeds the assembly standard, adjust it on the rear side.

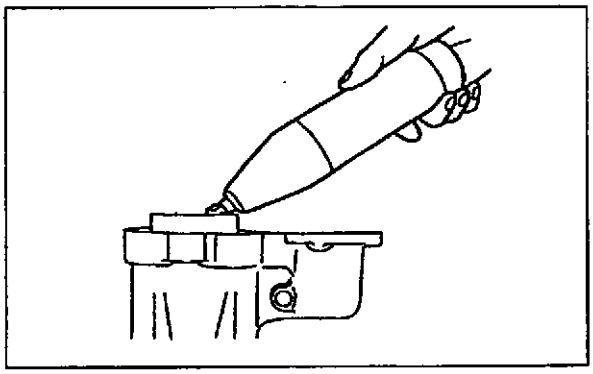
Test the motor to make sure that the voltage is below 24 volts and the current below 90 amperes.

Unit: mm (in.)

Item	Assembly Standard
Armature end play	0.2-0.6 (0.008-0.024)



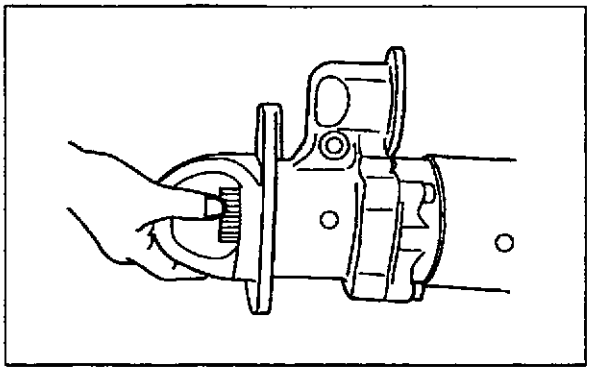
(7) Liberally coat the internal gear with grease, then install the pinion shaft to the gear.



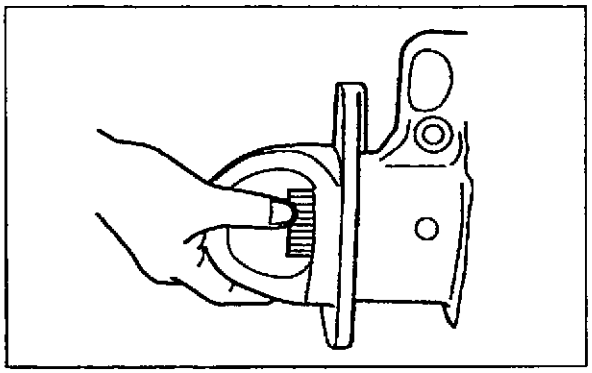
(8) Measure the end play of the pinion shaft. If the end play exceeds the assembly standard, adjust it on the internal gear side.

Unit: mm (in.)

Item	Assembly Standard
Pinion shaft end play	0.2-0.6 (0.008-0.024)

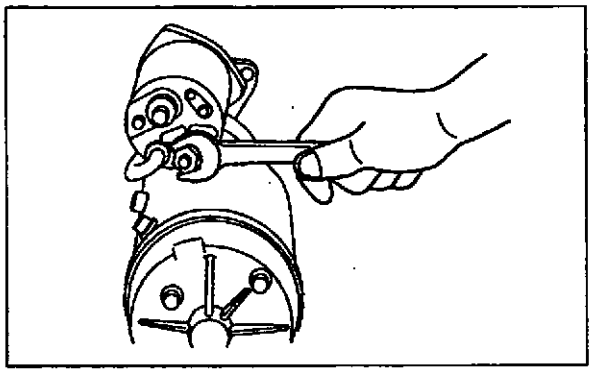


(9) Install the magnetic switch. Apply a voltage of 24 volts between the C and E terminals. Connect the lead wire and energize the circuit between the M and E terminals (within 1 second). After the pinion has shifted, measure how much the pinion returns. If the measurement is not 1.5 to 5 mm (0.06 to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



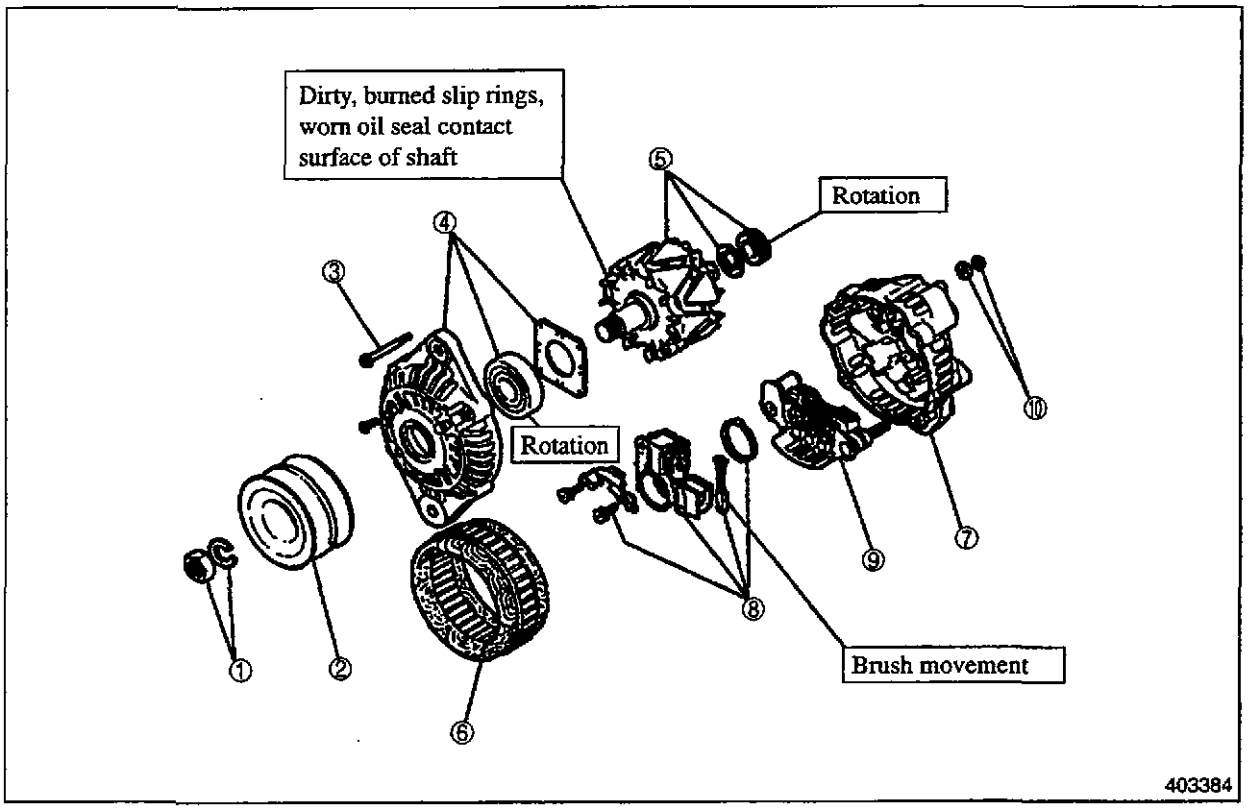
(10) Secure the lead wire.

(11) Install the safety switch.



3. The Alternator

3.1 Disassembly



① Nut, washer
② Pulley
③ Screw
④ Front bracket assy.
⑤ Rotor assy.
⑥ Stator
⑦ Rear bracket
⑧ Regulator assy.
⑨ Rectifier assy.
⑩ Set nut

3.2 Inspection and Repair

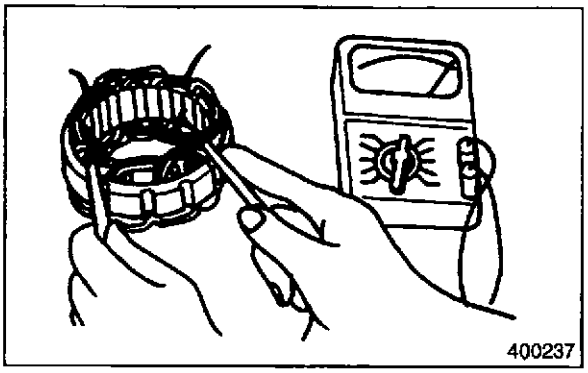
(1) Stator

(a) Testing the stator coil for open circuits

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

(b) Testing the stator coil for grounding

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



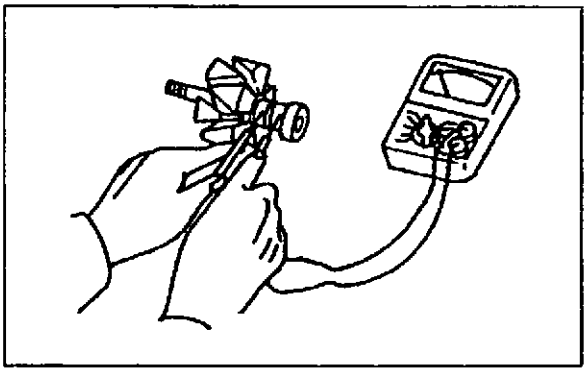
(2) Rotor

(a) Testing the rotor coil for open circuits

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

(b) Testing the rotor coil for grounding

If there is continuity between the slip rings and shaft (or core), replace the rotor.



(c) Measure the slip ring outside diameter

Using calipers, measure the outside diameter of each slip ring. If the diameter exceeds the service limit, replace the slip ring.

Unit: mm (in.)

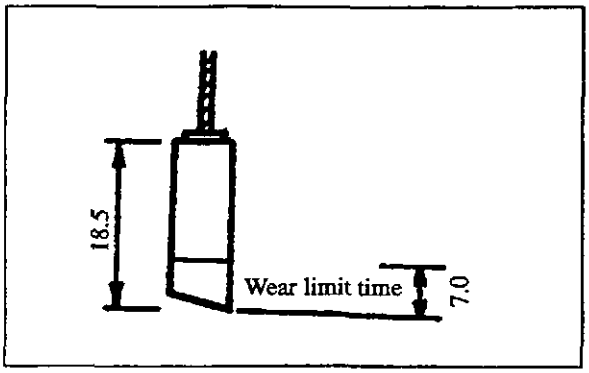
Item	Assembly Standard	Service Limit
Slip ring outside diameter	40.8-41.2 (1.606-1.622)	40.6 (1.599)

(3) Brushes and brush springs

(a) Brush wear

Unit: mm (in.)

Item	Assembly Standard	Service Limit
Brush height	18.5 (0.728)	11.5 (0.453)



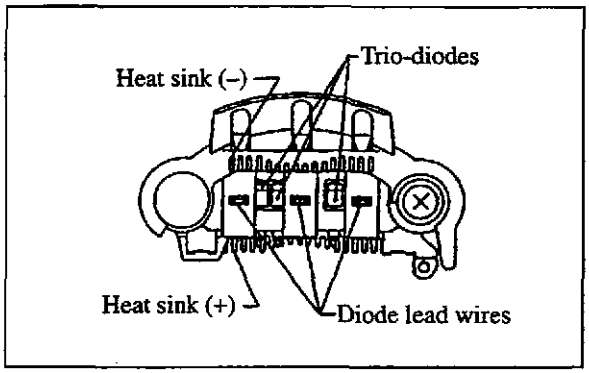
(b) Brush spring tension

Unit: gf (lbf) [N]

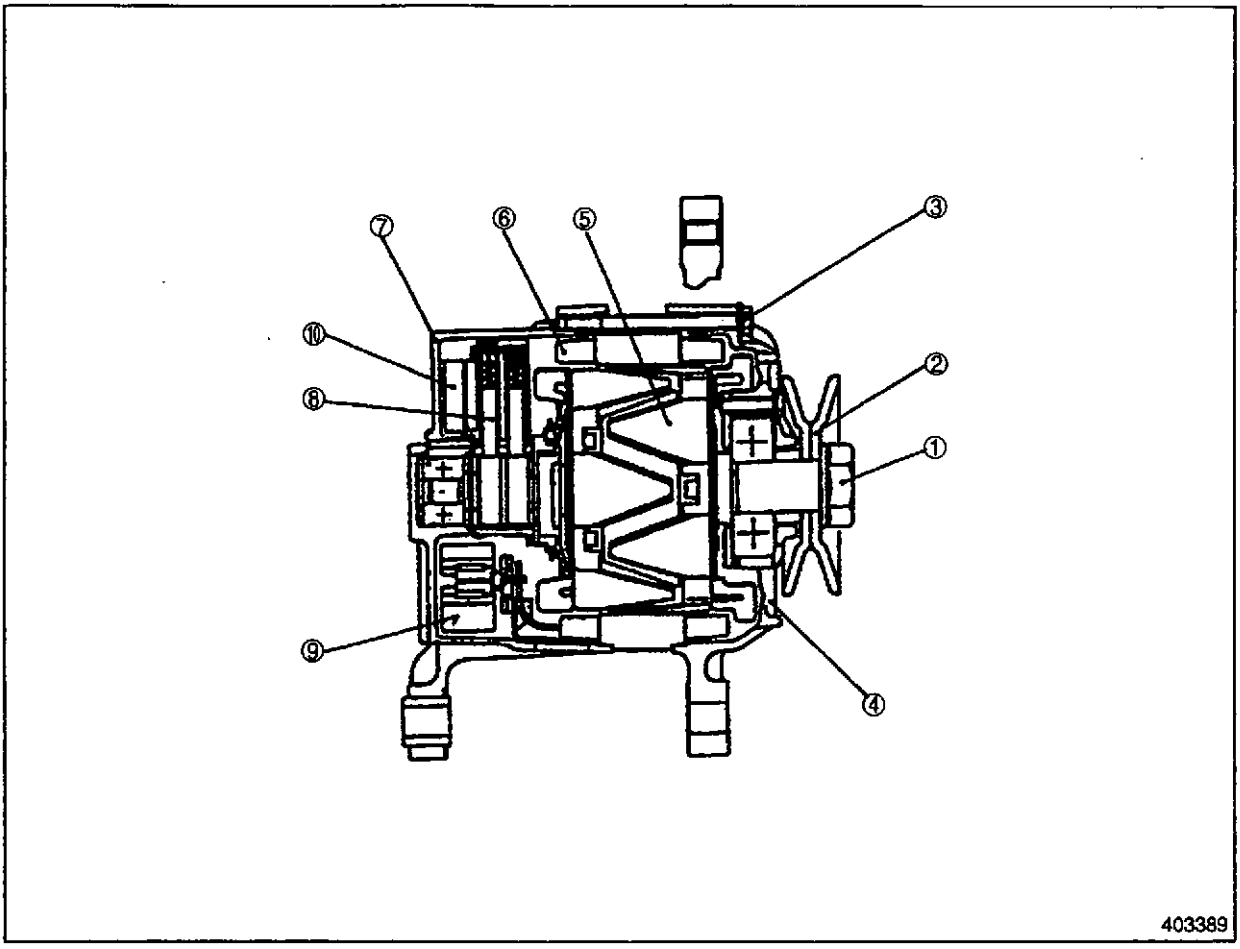
Item	Assembly Standard	Service Limit
Brush spring tension	320-440 (0.70-0.97) [3.1-4.3]	200 (0.45) [2.0]

(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 to 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.



3.3 Reassembly

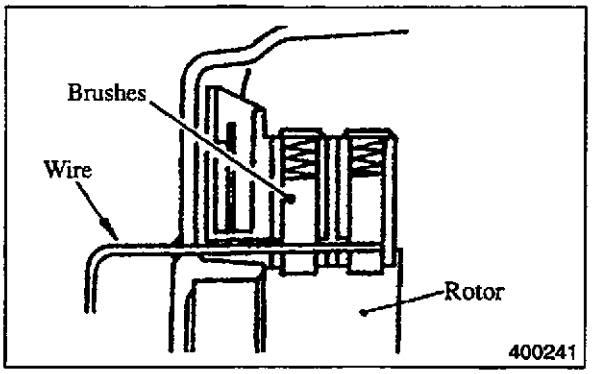


Reassembling Sequence

⑦ → ⑩ → ⑨ → ⑧ → ⑥ → ⑤ → ④ → ③ → ② → ①

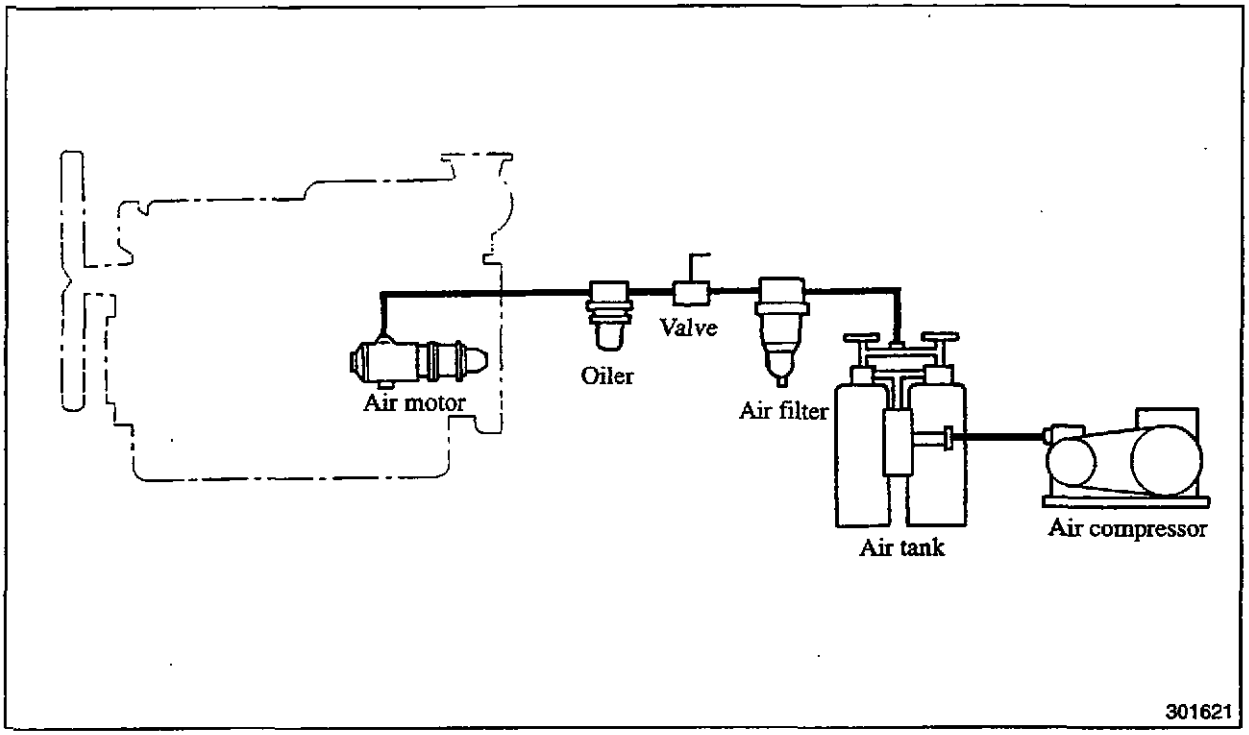
(1) Installing the brushes

Use a push wire to install the brushes in the brush holder as shown in the figure on the right. Install the rotor. Be sure to remove the push wire when you are finished.



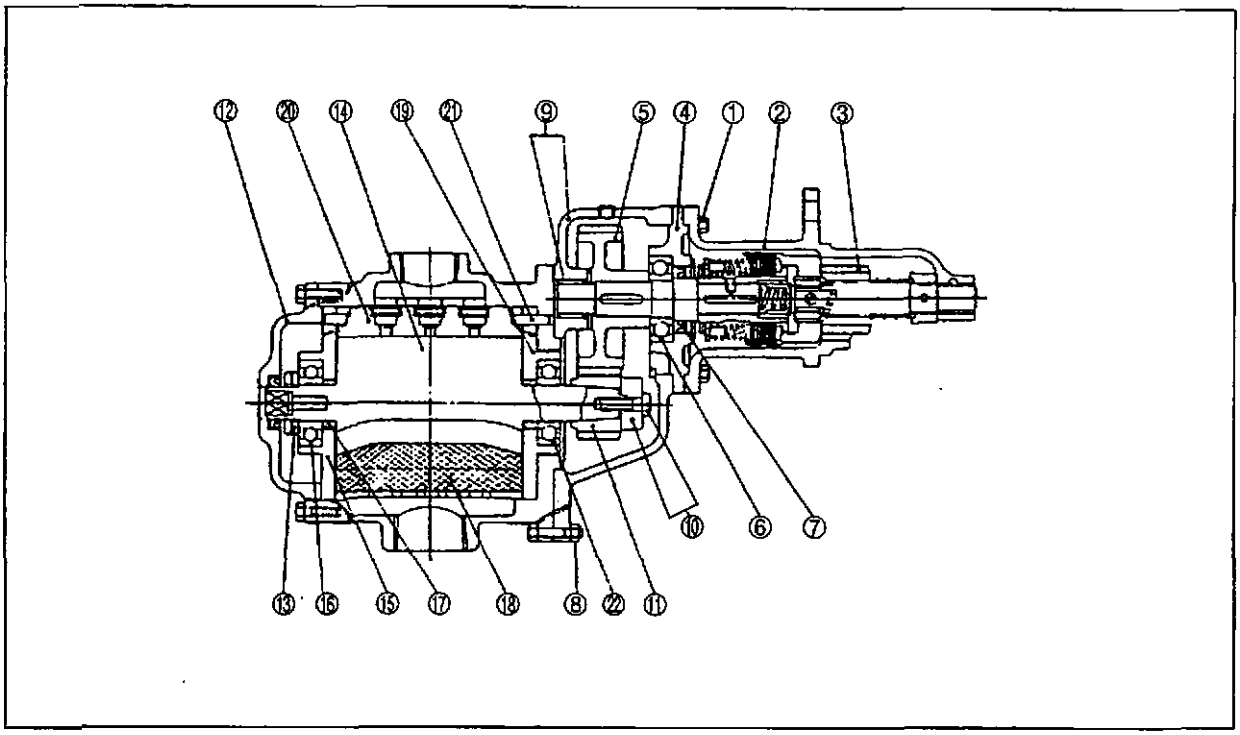
AIR START SYSTEMS

1. Air Motor System



2. Air Motor

2.1 Disassembly and Reassembly



① Bolt
② Pinion case
③ Clutch assy.
④ Gear case cover
⑤ Driven gear
⑥ Bearing
⑦ Oil seal
⑧ Nut
⑨ Gear case, needle roller bearing
⑩ Bolt, washer
⑪ Drive gear
⑫ Upper cover
⑬ Bearing retaining nut
⑭ Rotor
⑮ Cylinder upper cover
⑯ Ball bearing
⑰ Rotor adjusting ring
⑱ Vane
⑲ Cylinder lower cover
⑳ Cylinder
㉑ Dowel pin
㉒ Ball bearing

NOTE

Do not remove the rotor adjusting ring from the rotor.

Reassembly Sequence

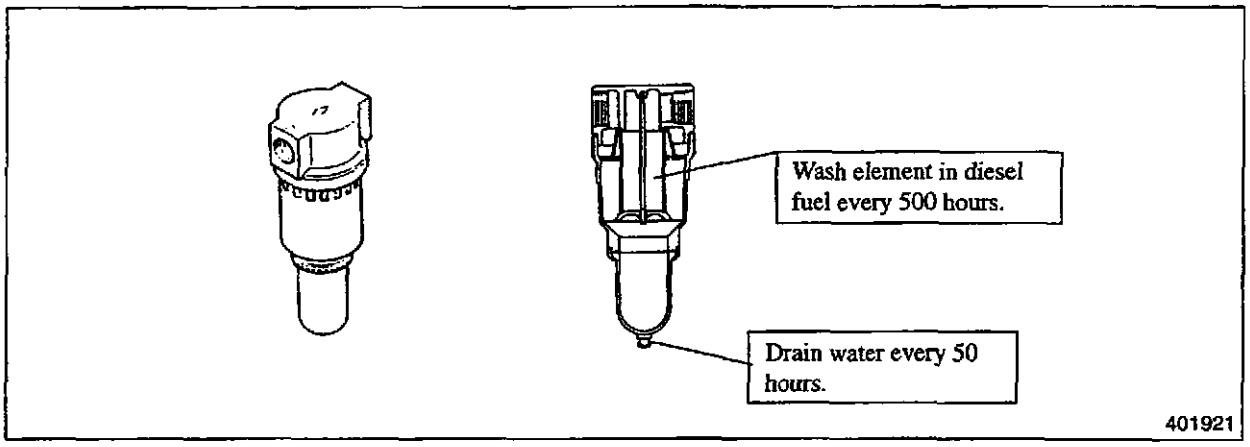
⑲ → ㉒ → ⑭ → ⑱ → ⑰ → ⑳ → ⑮ → ⑯ → ⑬ → ㉑ → ⑫ → ⑪ → ⑩ → ⑨ → ⑧ → ①
④ → ⑥ → ⑦ → ③ → ⑤ → ②

2.2 Inspection

Wash and inspect the air motor parts for wear or damage. Replace defective parts. The clutch assembly and pinion assembly should be replaced as a unit.

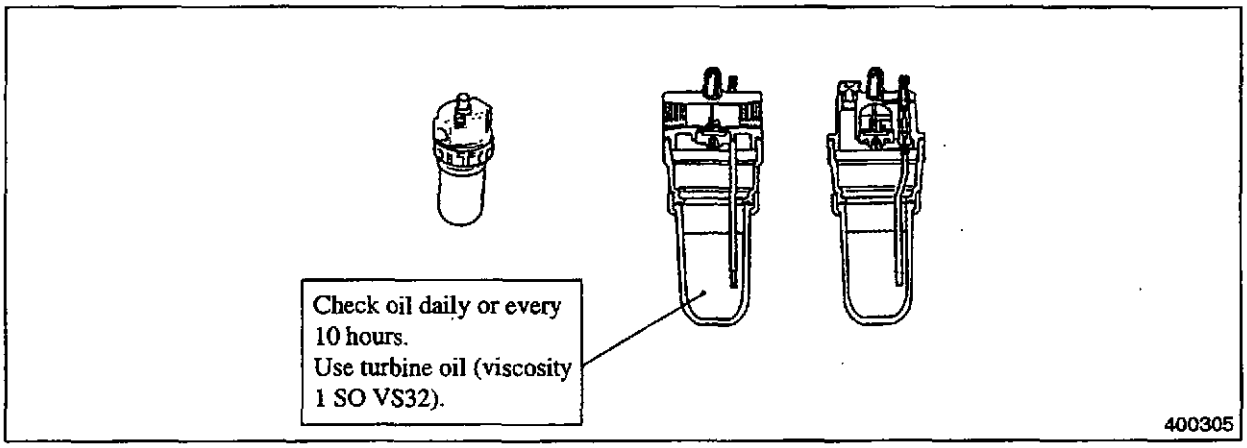
3. Air Filter

Inspection



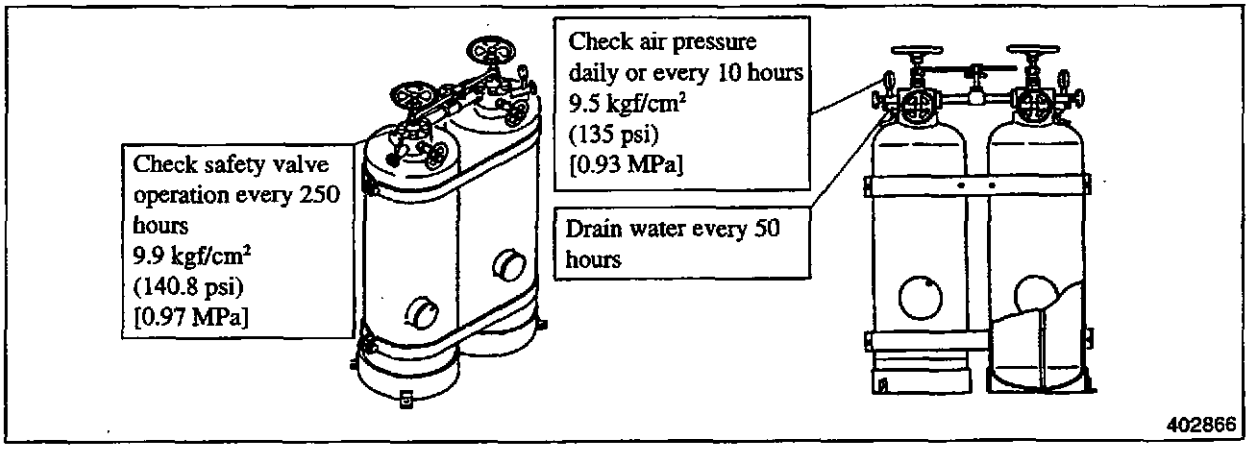
4. Oiler

Inspection

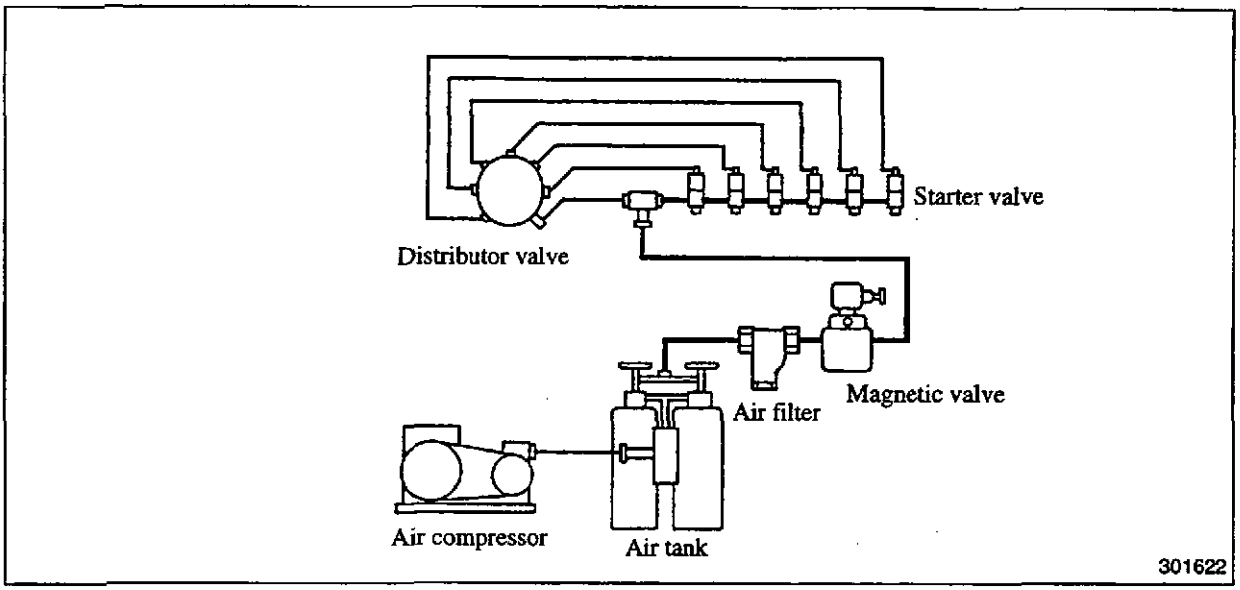


5. Air Tank (For Air Motor System)

Inspection

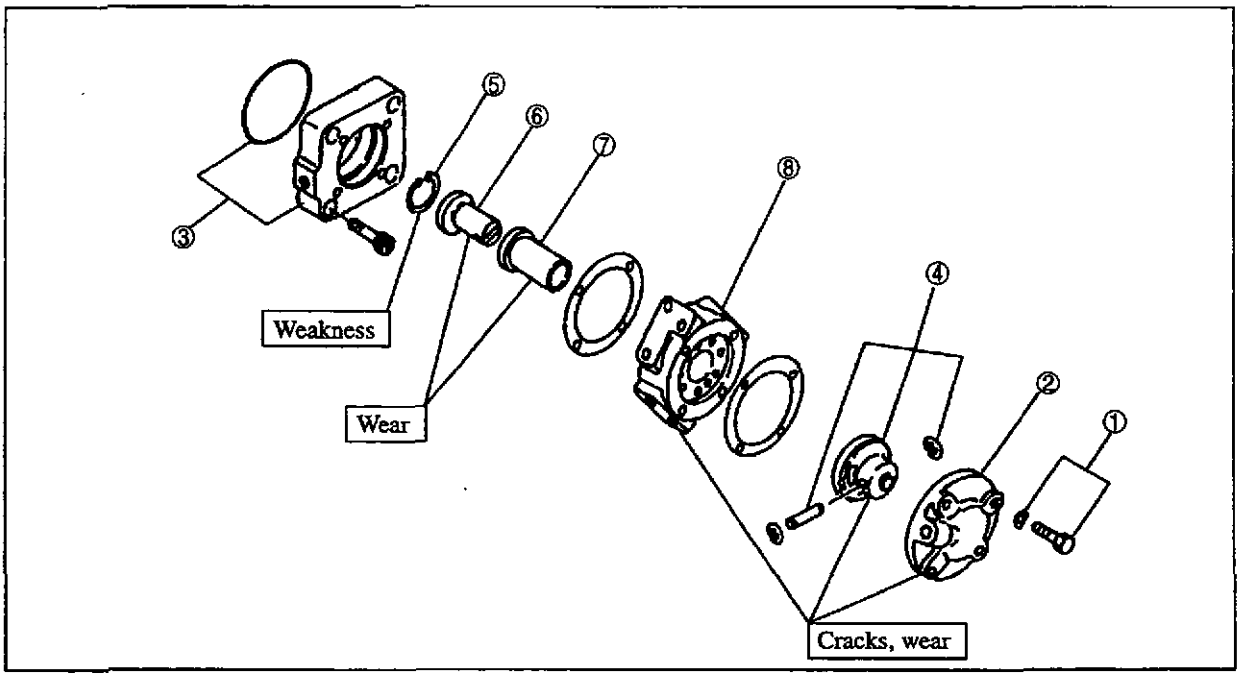


6. Direct Air Start System



7. Distributor Valve

7.1 Disassembly



① Bolt, spring washer
② Case cover, packing
③ Distributor spacer, O-ring
④ Lock pin, distributor valve, E-ring
⑤ Snap ring
⑥ Distributor shaft
⑦ Bushing
⑧ Distributor case

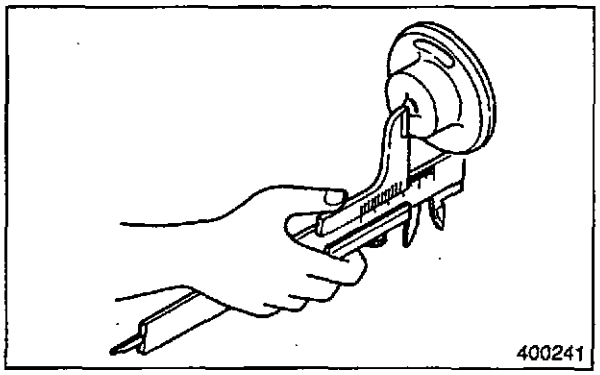
7.2 Inspection

(1) Measuring distributor valve height

If the height exceeds the service limit, replace the valve.

Unit: mm (in)

Item	Assembly Standard	Service Limit
Distributor valve height	21.5±0.1 (0.85±0.004)	21 (0.83)

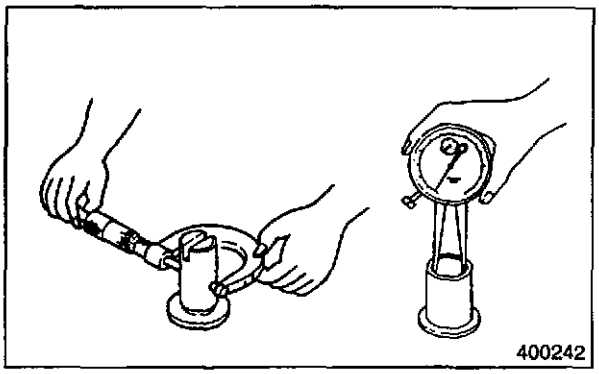


(2) Measuring distributor shaft clearance in the bushing

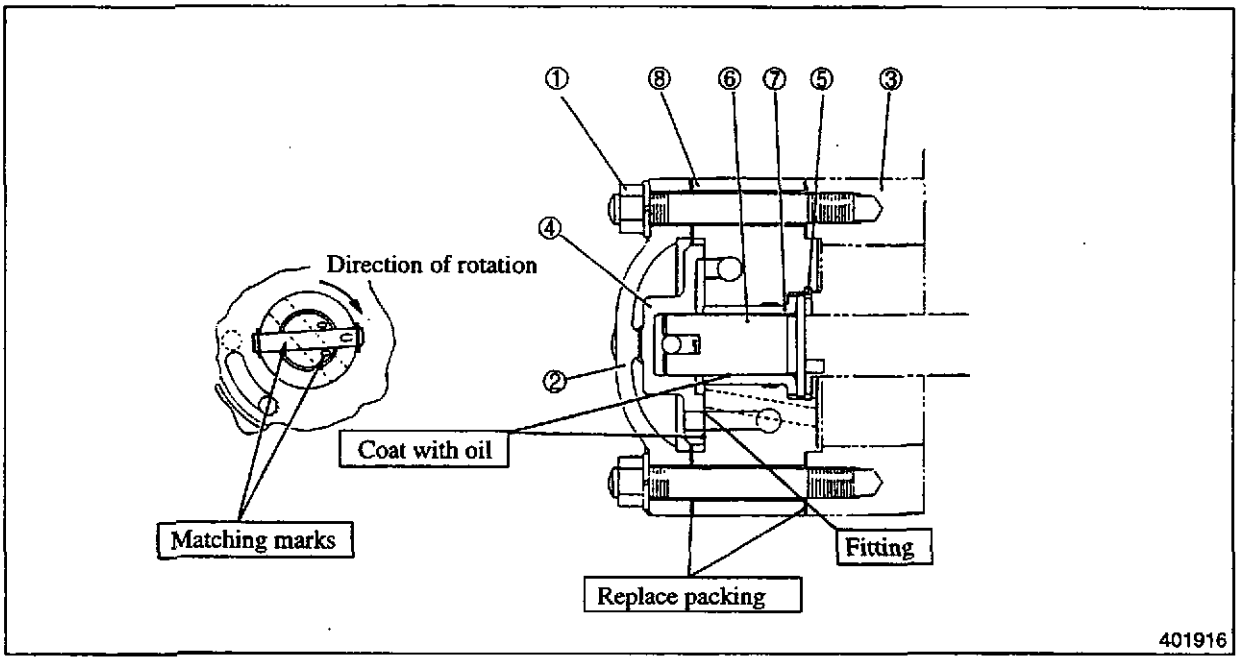
Measure the diameter of the shaft and the inside diameter of the bushing to determine the clearance. If the clearance exceeds the service limit, replace the bushing.

Unit: mm (in.)

Item	Standard Clearance	Repair Limit
Distributor shaft clearance in bushing	0.050-0.091 (0.00197-0.00359)	0.300 (0.01182)



7.3 Reassembly

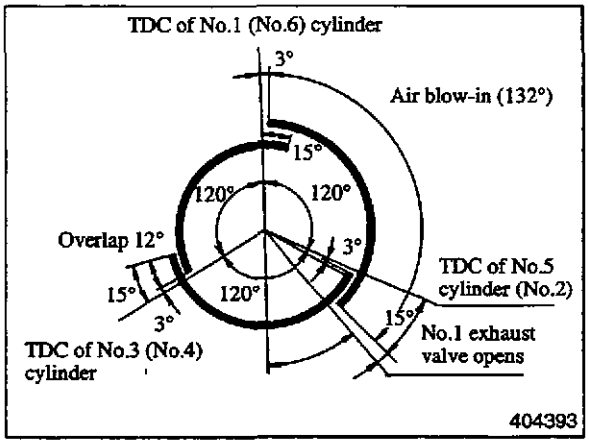


Reassembly Sequence

⑧ → ⑦ → ⑥→ ⑤ → ④ → ③ → ② → ①

NOTE

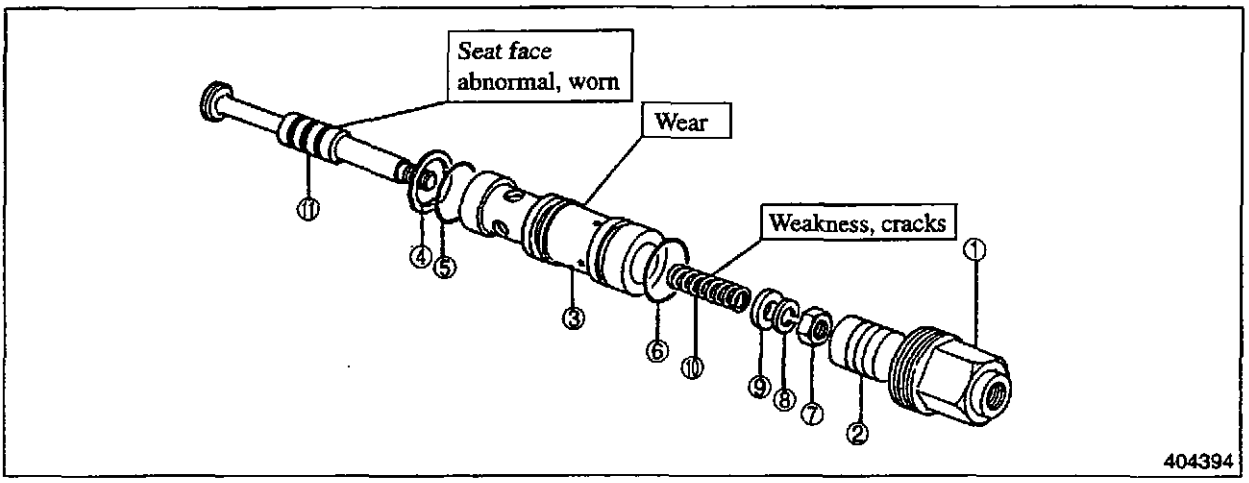
When reassembling and installing the distributor valve, be sure to align the matching marks. If the marks are not aligned, the valve timing (at which air is blown into the cylinders) could be off by 360°, resulting in a failure to start the engine.



Start air blow-in timing diagram (Crank angle)

8. Starter Valves

8.1 Disassembly

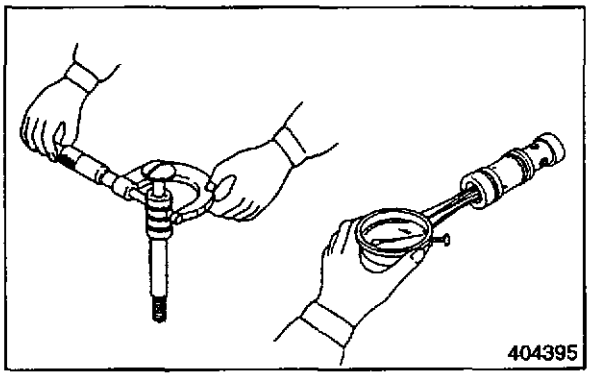


① Cap nut
② Starter valve piston
③ Starter valve guide
④ Starter valve gasket
⑤ O-ring
⑥ O-ring
⑦ Nut
⑧ Spring washer
⑨ Retainer
⑩ Spring
⑪ Starter valve

8.2 Inspection

(1) Measuring starter valve clearance in the guide

Using a micrometer and dial caliper gauge, measure the clearance. If the clearance exceeds the service limit, replace the parts.

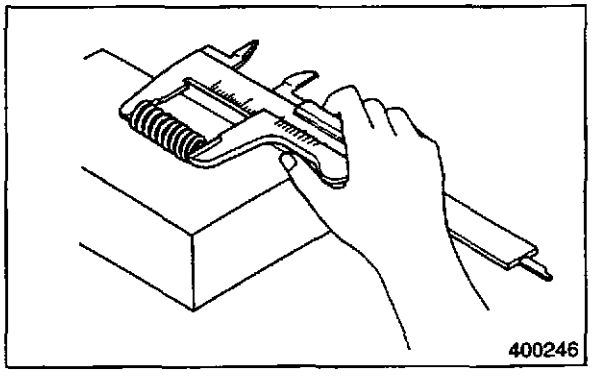


Unit: mm (in.)

Item	Nominal Value	Standard Clearance	Service Limit
Starter valve clearance in guide	ø15 (0.59)	0.016-0.052 (0.00063-0.00205)	40.6 (1.598)

(2) Measuring valve spring length

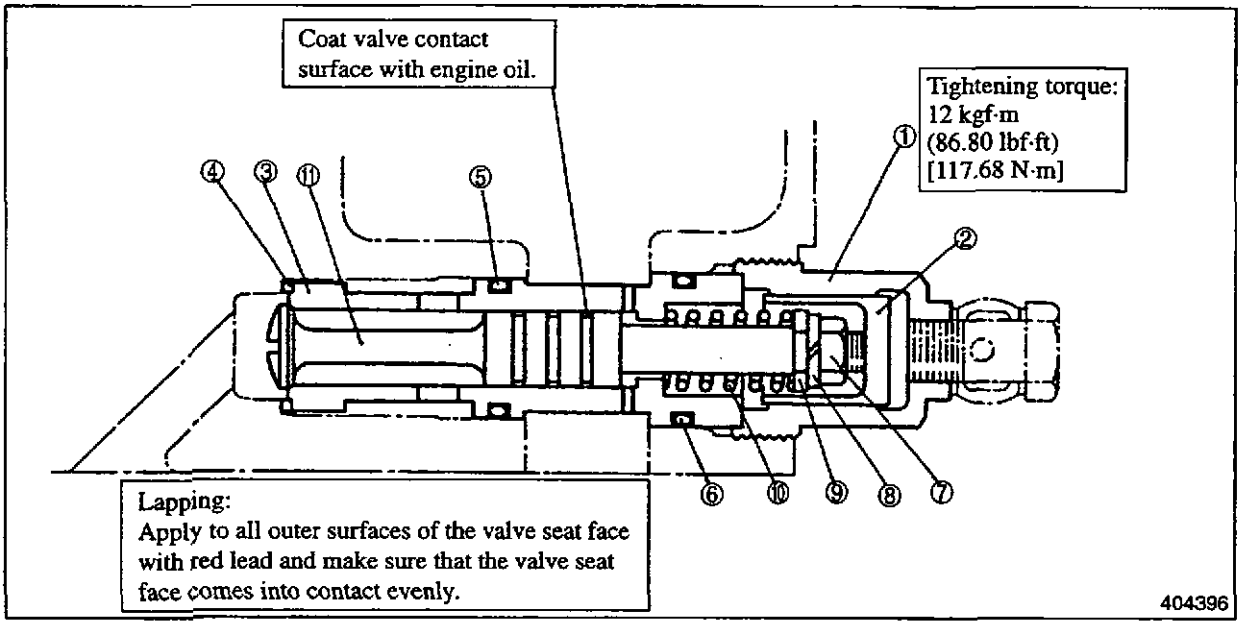
Use calipers to measure the free length. If the free length exceeds the service limit, replace the spring.



Unit: mm (in.)

Item	Assembly Standard	Service Limit
Valve spring free length	36 (1.42)	34 (1.34)

8.3 Reassembly

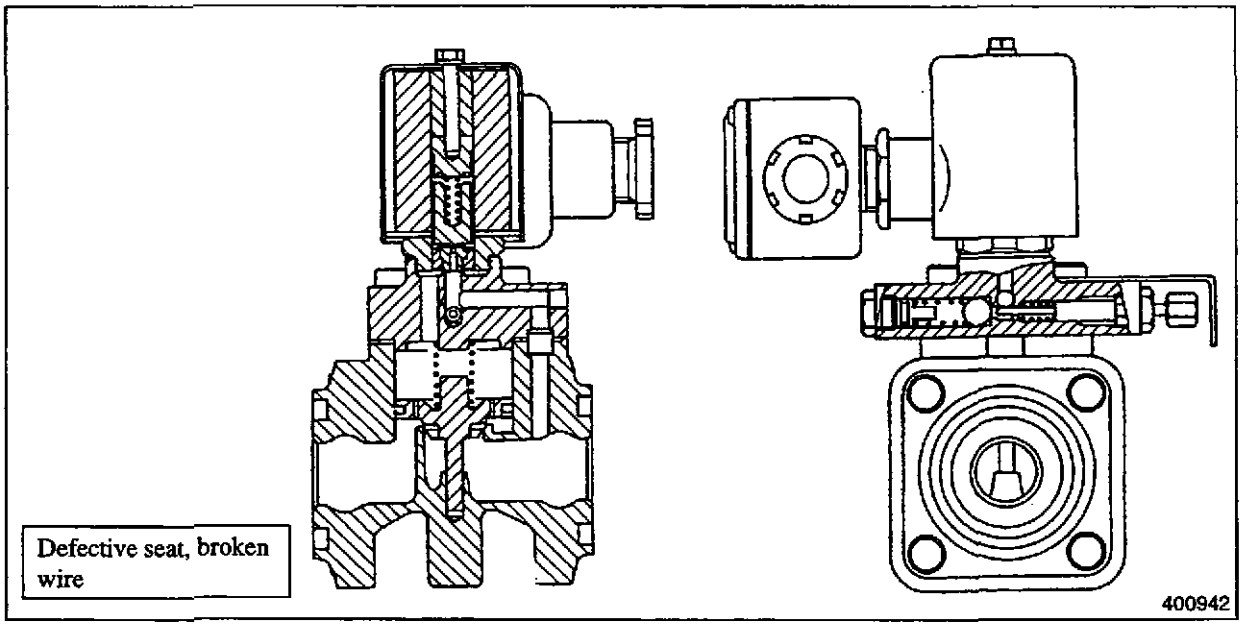


Reassembly Sequence

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

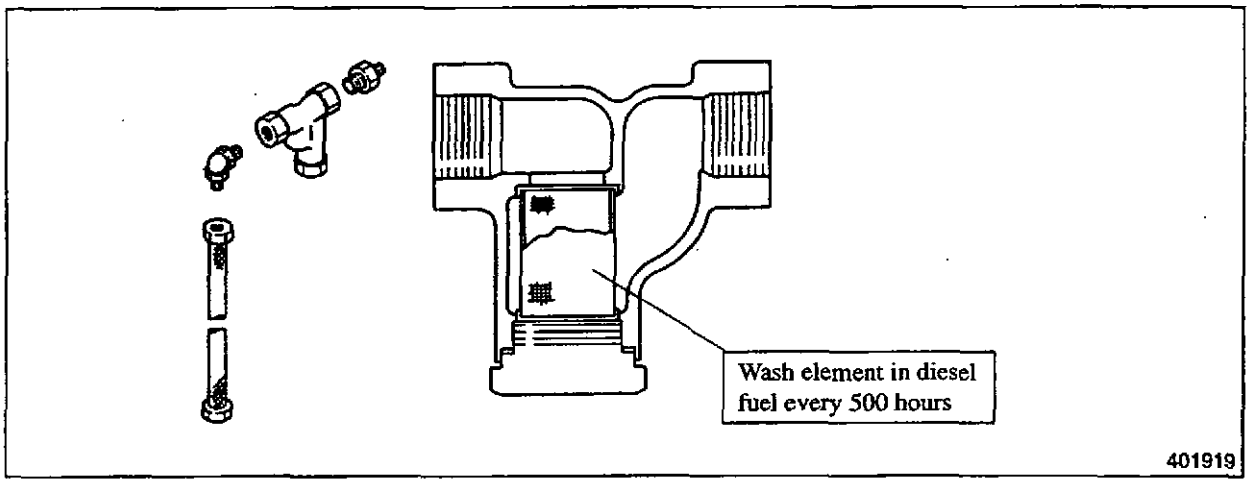
9. Magnetic Valve

Inspection



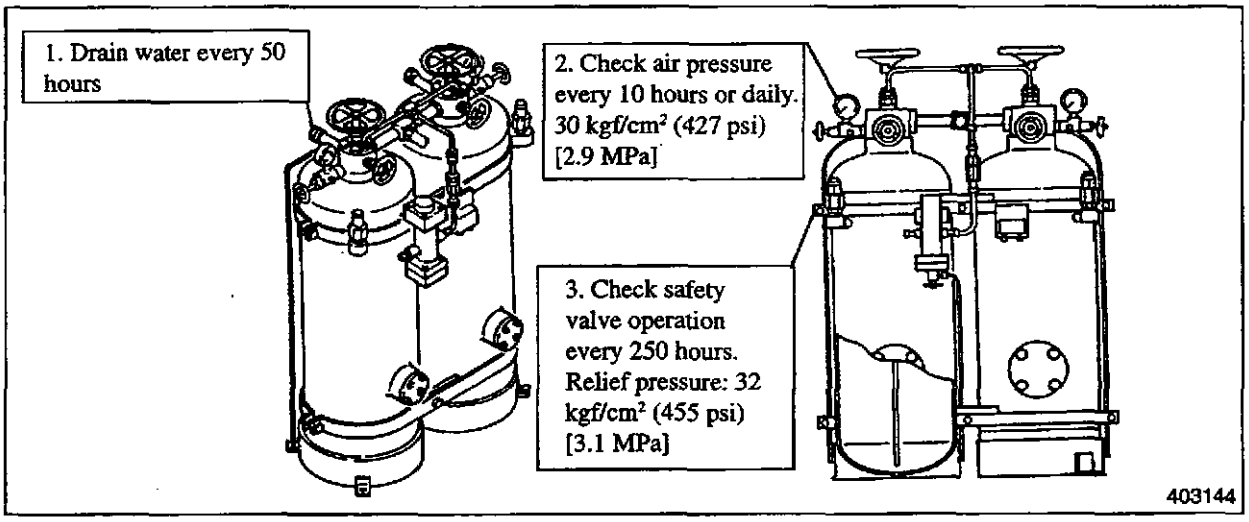
10. Air Strainer

Inspection



11. Air Tank (For a Direct Air Start System)

Inspection



WORKSHOP TIPS

1. Precautions for Disassembly and Reassembly

1.1 Oil Seals

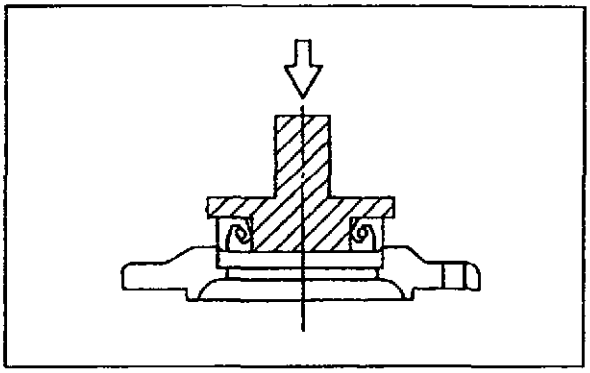
When installing oil seals, carefully observe the following points.

(1) Driving oil seals into housings

(a) Check the seal lip for damage, and be sure to position correctly with respect to the oil compartment.

(b) Apply a small amount of grease to the surface of the oil seal to be fitted into the housing bore.

(c) Use an oil seal driver to guide the seal lip squarely. To avoid damage to the oil seal and leaking, never hammer on it directly.

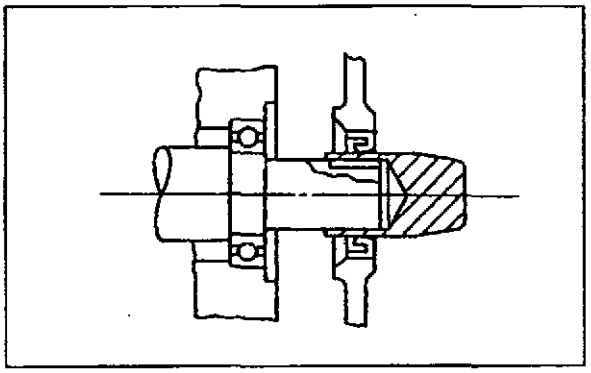


Oil seal driver

(2) Driving oil seals onto shafts

(a) Apply a thin coat of grease to the oil seal lip.

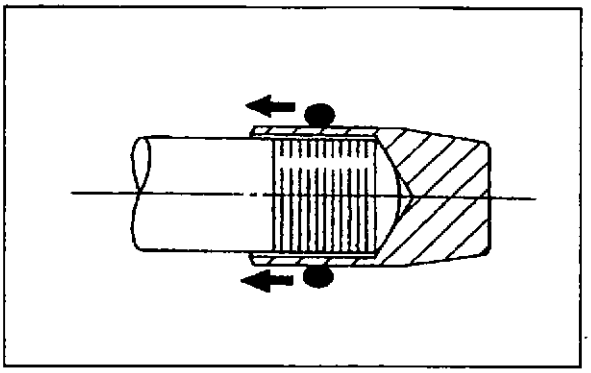
(b) Use an oil seal guide of the type shown when driving the oil seal over the stepped portion, splines, threads, or key way to prevent damage to the oil seal lip.



Oil seal guide

1.2 O-Rings

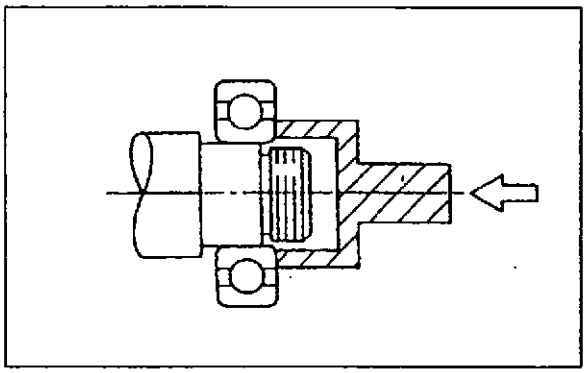
Use an O-ring guide to install an O-ring over stepped parts, splines, threads, or key way to prevent damage to the ring. Apply a thin coat of grease to the O-ring before installation.



O-ring guide

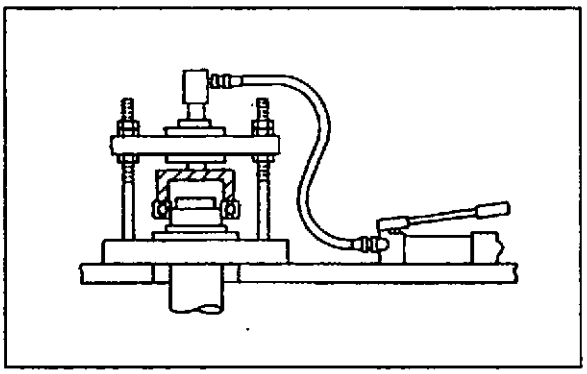
1.3 Bearings

(1) When installing a rolling bearing, be sure to push the inner or outer race by which the bearing is fitted. Be sure to use a bearing driver like the one shown.



Bearing driver

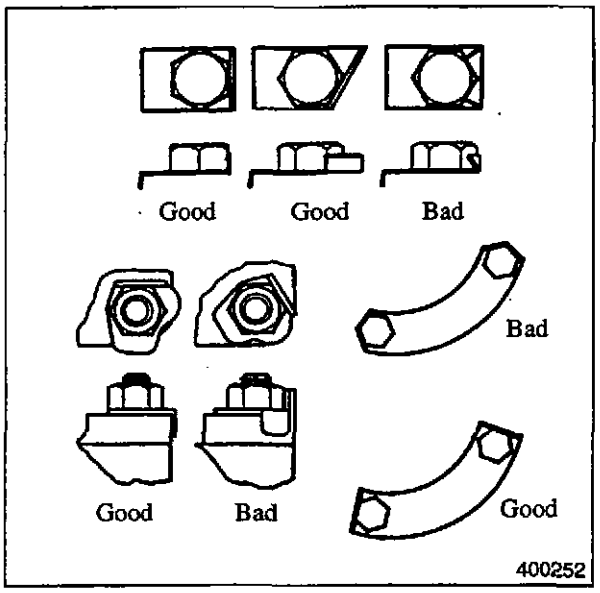
(2) Whenever possible, use a press to minimize shock to the bearing and to assure proper installation.



Bearing installation with a press

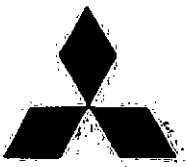
1.4 Lock Plates

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



1.5 Split pins and spring pins

Generally, split pins are to be replaced at disassembly. 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.



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