FOREWORD

This service manual is written to familiarize you with the maintenance of your S4S and S6S 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.

The information contained in this manual applies to the engine model produced at the time of publication.

It should be noted that specifications and design may change due to improvements made thereafter.

For items other than those in this publication, refer to the operation manual for a unit on which the engine is mounted.

Service Manual
Mitsubishi SS-Series diesel engines
Version 08/2004

How to use this manual

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

   Clogged oil hole

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

   5 → 2 → 4 → 3 → 1

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

Notes, Cautions, Warnings, Dangers

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

⚠ DANGER — Indicates the most serious specific potential hazard resulting in serious bodily injury or death.

⚠ WARNING — Indicates a specific potential hazard resulting in bodily injury.

⚠ CAUTION — Indicates operating procedure, practice, etc., resulting in personal injury or damage to or destruction of engine.

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

Terms Used in This Manual

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

Assembly Standard	Indicates the dimension of a part, the dimension to be attained at the time of reassembly or the standard performance. The value is rounded to the nearest whole number needed for inspection and is different from the design value.
Nominal Value	Indicates the standard dimension of a part.
Repair Limit	A part which has reached this limit must be repaired.
Service Limit	A part which has reached this limit must be replaced.
Standard Clearance	Indicates the clearance to be obtained between mating parts at reassembly.

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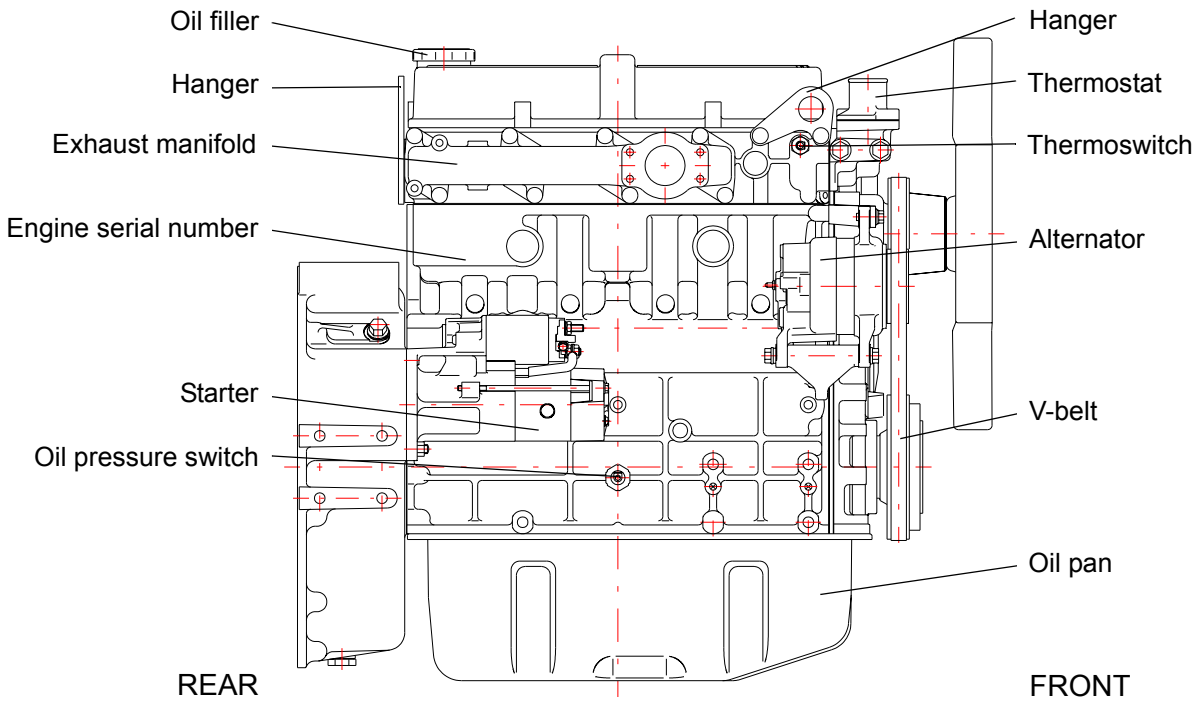
WORKSHOP TIPS

GENERAL

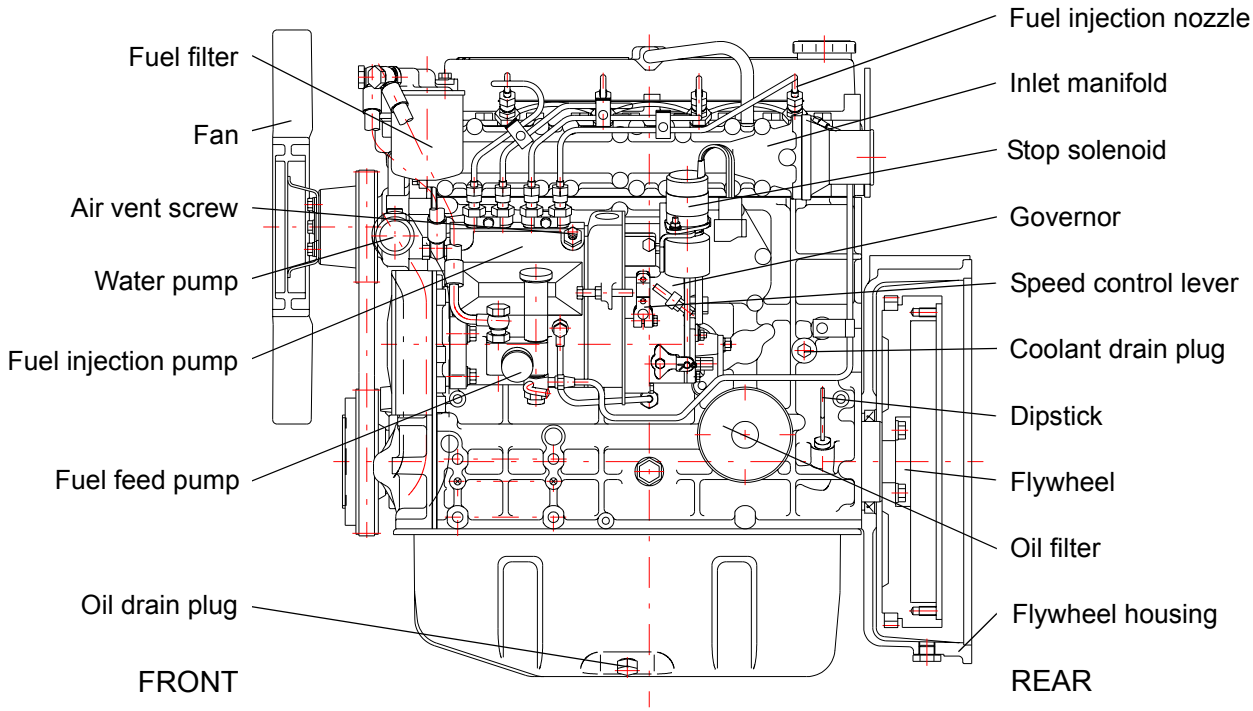
1 OUTLINE

1.1 External View

[S4S - Standard]



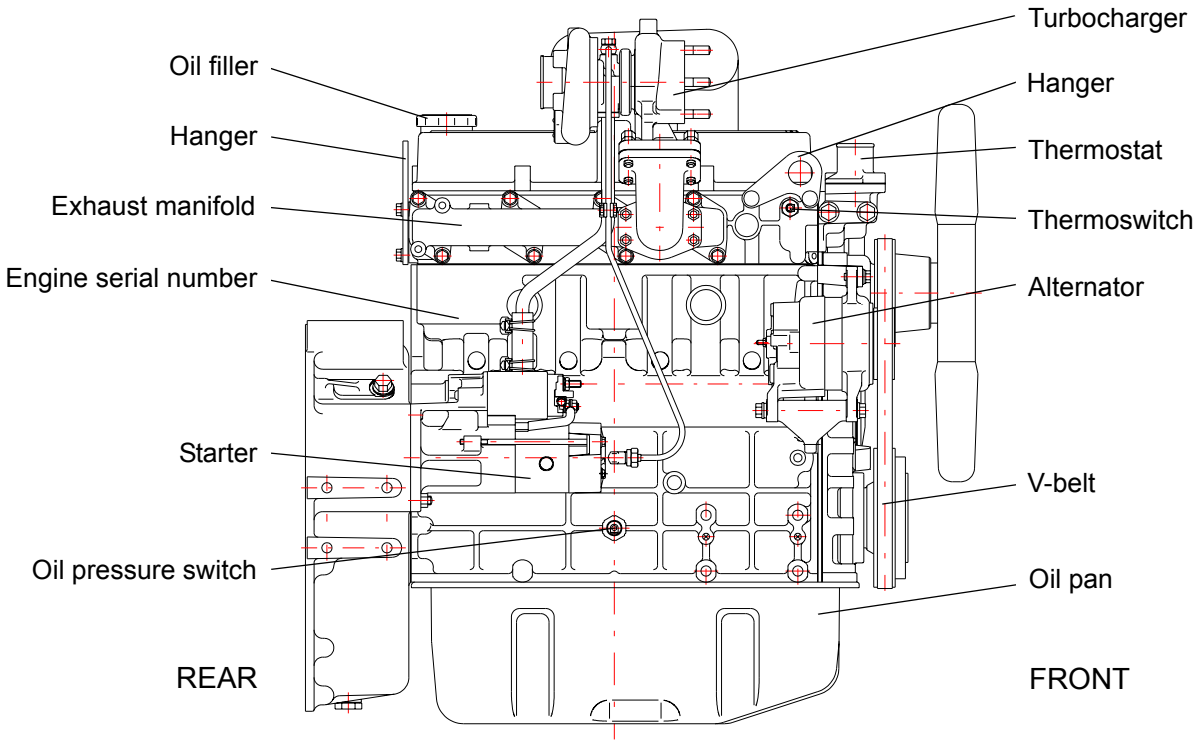
RIGHT SIDE VIEW



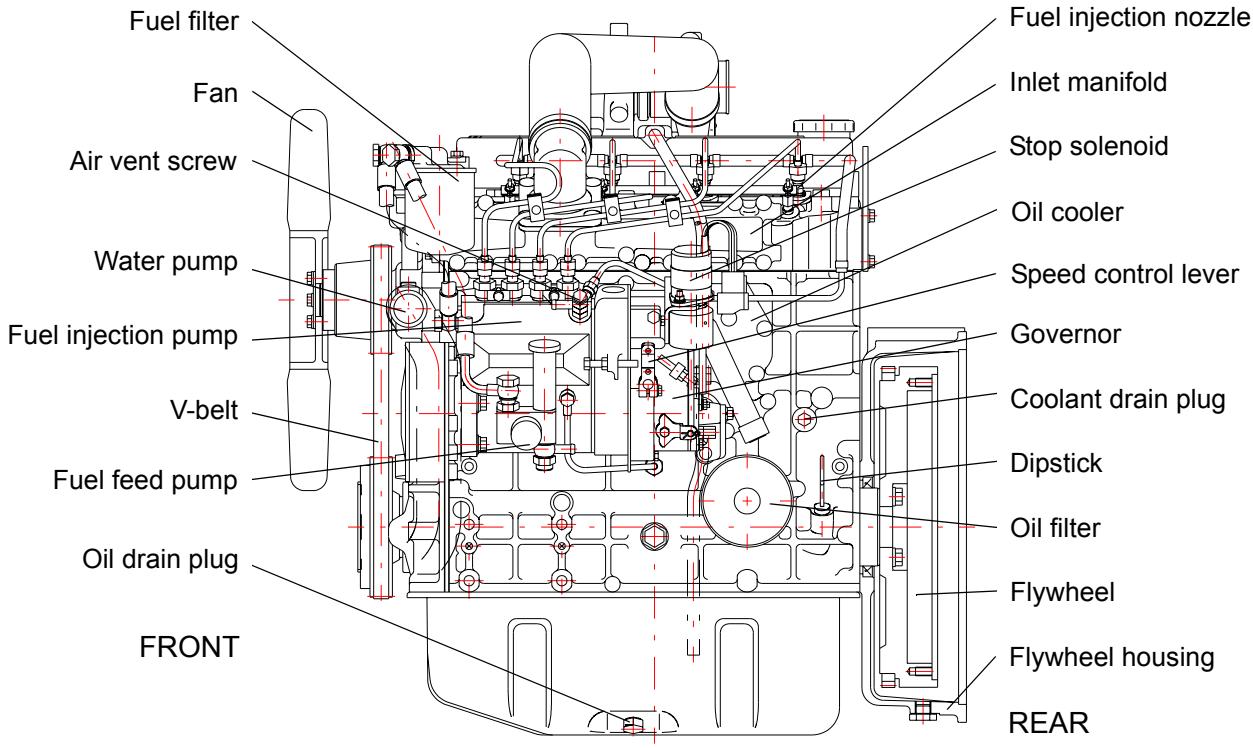
LEFT SIDE VIEW

Remark: Direction of rotation of this engine is counterclockwise as seen from flywheel side.

[S4S-DT - Standard]



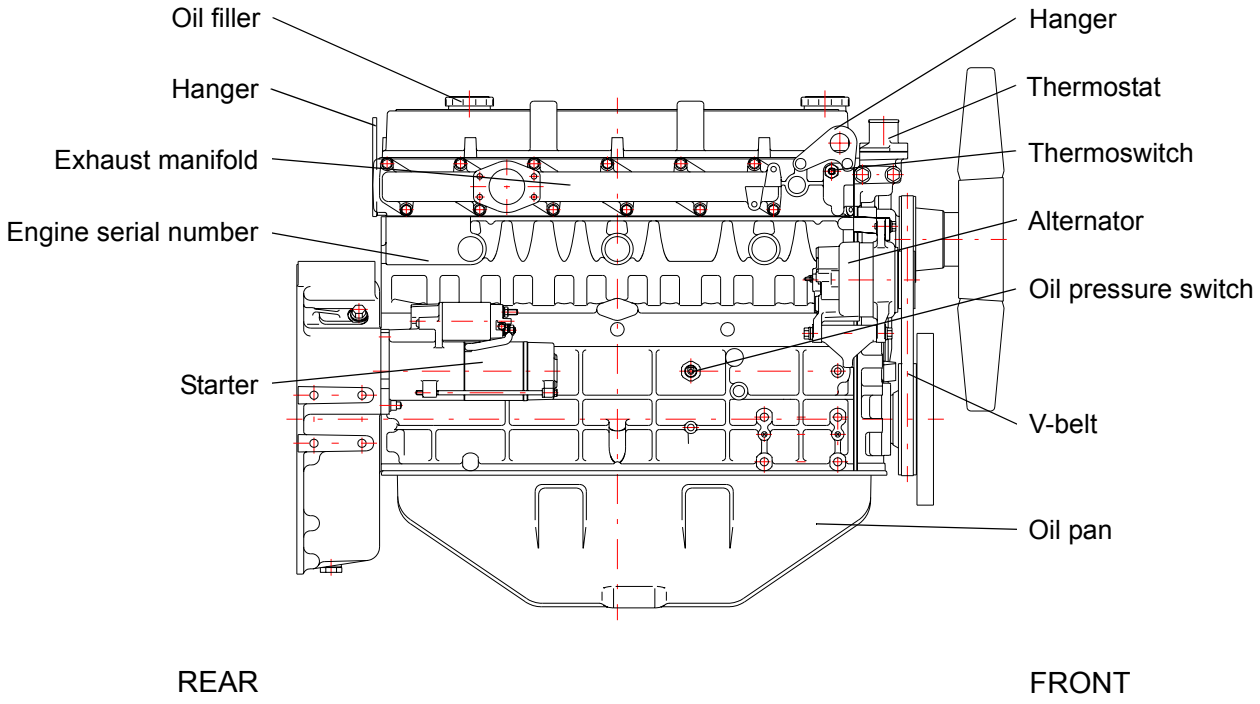
RIGHT SIDE VIEW



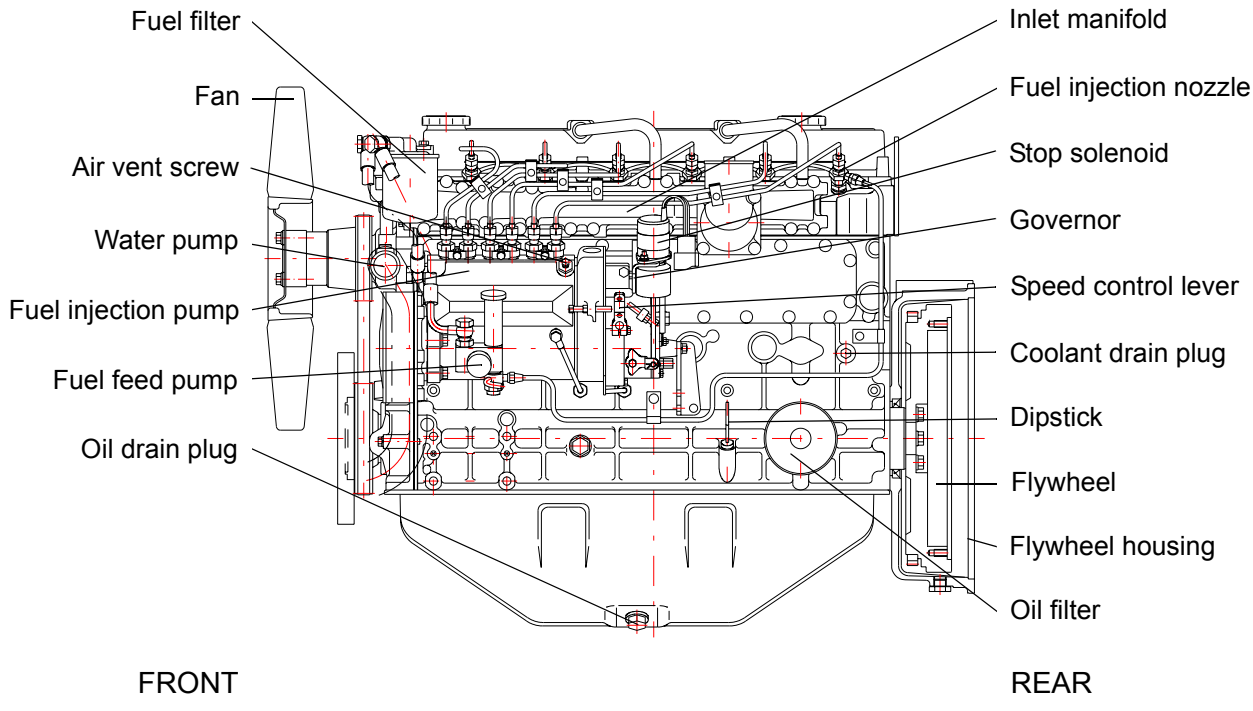
LEFT SIDE VIEW

Remark: Direction of rotation of this engine is counterclockwise as seen from flywheel side.

[S6S - Standard]



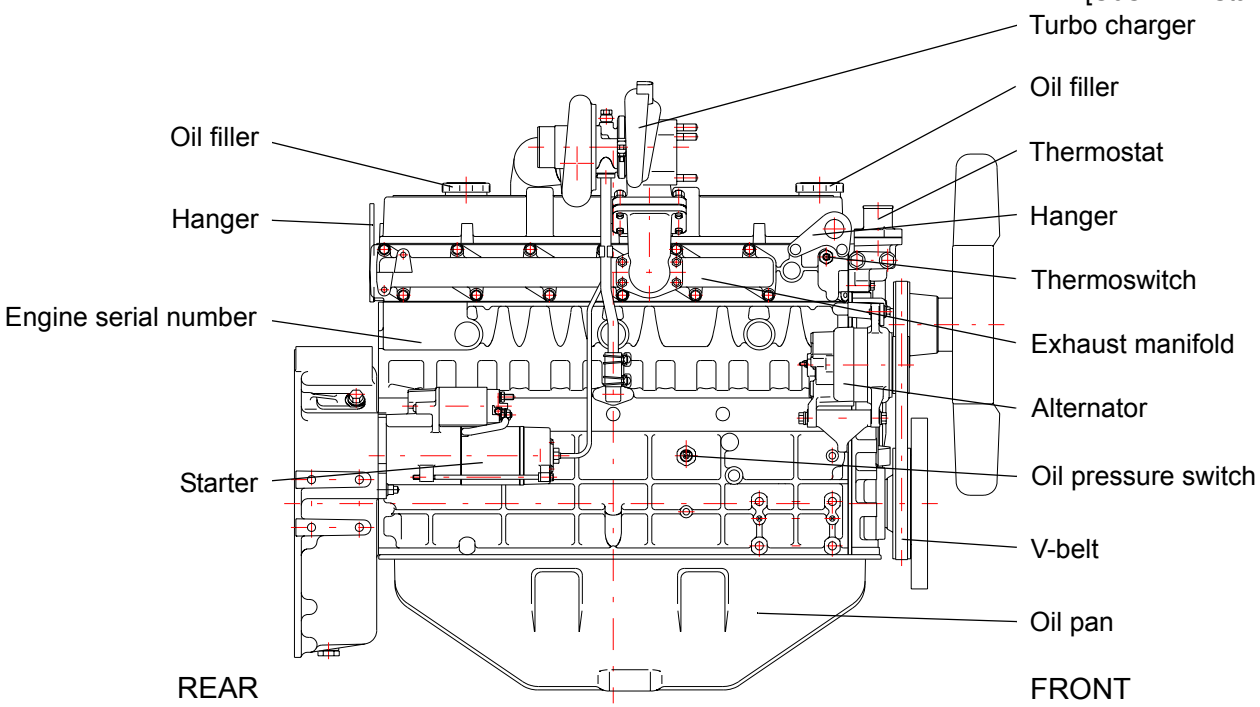
RIGHT SIDE VIEW



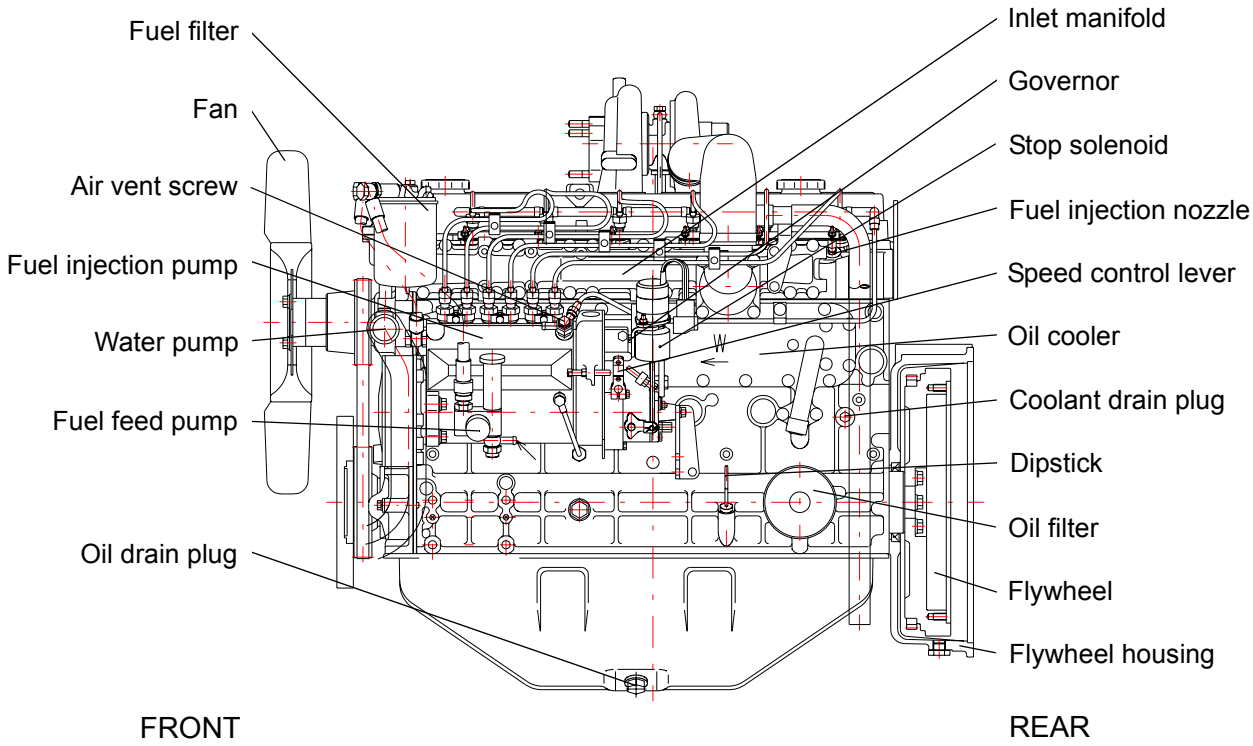
LEFT SIDE VIEW

Remark: Direction of rotation of this engine is counterclockwise as seen from flywheel side.

[S6S-DT - Standard]

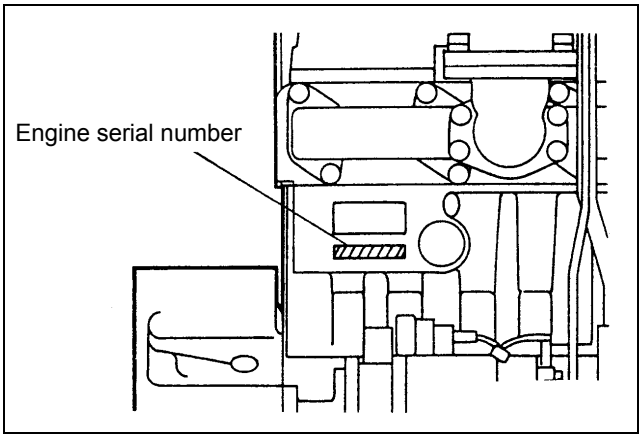


RIGHT SIDE VIEW



LEFT SIDE VIEW

Remark: Direction of rotation of this engine is counterclockwise as seen from flywheel side.



1.2 Engine Serial Number Location

The engine serial number is located on the side of the crankcase.

1.3 Engine Model and Application Codes

S 4 S - D T

S - Manufactured by Sagamihara Machinery Works

4 - Number of cylinders

S - Series code

D - Direct injection type

T - Equipped with turbocharger

2 SPECIFICATIONS

Model designation				S4S	S4S-DT
General	Type			Water-cooled, 4-stroke cycle	
	No. of cylinders - arrangement			4 - in line	
	Combustion chamber type			Swirl chamber	Direct injection
	Valve mechanism			Overhead	
	Cylinder bore x stroke mm [in.]			94 x 120 [3.70 x 4.72]	
	Piston displacement liter [cu in.]			3.331 [203]	
	Compression ratio			22 : 1	17 : 1
	Firing order			1 - 3 - 4 - 2	
	Direction of rotation			Counterclockwise as viewed from flywheel side	
	Dimension	Overall length mm [in.]		781 [30.7]	
		Overall width mm [in.]		593 [23.3]	
		Overall heigth mm [in.]		710 [28.0]	821 [32.3]
Engine main parts	Weigth (dry) kg [lb.]			245 [540]	250 [551]
	Type of cylinder sleeve			Intergral with cylinder block	
	No. of piston ring	Compression ring		2	
		Oil ring		1 (w/spring expander)	
	Valve timing	Inlet valve	Open	BTDC 30°	BTDC 18°
			Close	ABDC 50°	ABDC 54°
		Exhaust valve	Open	BBDC 74°	BBDC 66°
			Close	ATDC 30°	ATDC 22°
	Starting system			Electric-starter	
	Starting aid			Glow plugs	
Inlet and exhaust systems	Air cleaner	Type		Paper element	
	Turbocharger	Model		—	TD04HL

Model designation			S4S	S4S-DT
Lubrication system	Type		Force feed by oil pump	
	Engine oil	Specification	Class CD oil (API Service Classification)	
		Capacity (engine) liter [U.S. gal}	Approx. 10 [2.6] (Oil pan: 9 [2.4], Filter: 1 [0.3])	
	Oil pump	Type	Trochoid	
		Speed ratio to crankshaft	0.74	
		Capacity liter [U.S. gal]	28.6 [7.6] at 0.3 MPa (3 kgf/cm^2) discharge pressure of pump running at 2 230 rpm	
	Relief valve	Type	Piston valve	
		Opening pressure MPa (kgf/cm^2) [psi]	0.35 ± 0.05 (3.5 ± 0.5) [50 ± 7]	
	Oil Cooler	Type	—	Water-cooled multi-plate
	Oil filter	Type	Cartridge of paper element	
	Safety valve	Opening pressure MPa (kgf/cm^2) [psi]	—	1.1 (11) [156]
Cooling system	Refill capacity (engine water jacket) liter [U.S. gal.]		5.5 [1.5]	5 [1.3]
	Water pump	Type	Centrifugal	
		Speed ration to crankshaft	1.3	
		Capacity liter [U.S. gal.]/ min/rpm	160 [42.3] at 0.075 MPa [0.75 kgf/cm^2] discharge pressure of pump runnning at 3600 rpm	
	Fan belt	Type	Low-edge B type V-belt x 1	
	Thermostat	Type	Wax pellet	
		Valve opening temperature °C [°F]	76.5 ± 1.5 [170 ± 2.7]	
	Fan	Type	Pusher (PP)	
		No. of blade	6	
		Diameter mm [in.]	440 [17.3]	

Model designation			S4S	S4S-DT
Fuel system	Injection pump	Type	Bosch A	
		Diameter of plunger mm [in.]	7 [0.276]	9 [0.354]
	Feed pump	Type	Bosch, piston	
		Cam lobe lift mm [in.]	8 [0.315]	9 [0.354]
	Governor	Type	Bosch RSV, centrifugal	
	Injection nozzle	Type of nozzle	Bosch throttle	Bosch hole
		No. of spray orifice	1	4
		Diameter of spray orifice mm [in.]	1.0 [0.039]	0.28 [0.011] (for D/G) 0.24 [0.009] (for Power Unit)
		Spray angle	0°	155°
		Valve opening pressure MPa (kgf/cm^2) [psi]	11.77 (120) [1707]	17.65 (180) [2561]
	Fuel filter	Type	Cartridge of paper element	
Electrical system	Voltage - polarity		12V - ⊖ ground	
	Starter	Model	M008T75171	
		Type	Pinion shift	
		Output V - kW	12 - 2.2	
		No. of pinion teeth/flywheel ring gear teeth	10 / 122	
	Alternator	Type	3-phase, with rectifier	
		Output V - A	12 - 50	
		Working speed rpm	1000 to 18000	
		Rated output generating speed rpm	5000	
		Maximum permissible speed rpm	22000	
		Speed ratio to crankshaft	2.0	
	Glow plug	Type	Sheathed	
		Rated voltage - current V - A	Direct injection: 11 - 5.5 (30 sec. rating) Swirl chamber: 10.5 - 9.7 (30 sec. rating)	
	Stop solenoid (option)	Rated voltage V	12	
		Rated temp. °C [°F]	20 [68]	

Model designation				S6S	S6S-DT
General	Type			Water-cooled, 4-stroke cycle	
	No. of cylinders - arrangement			6 - in line	
	Combustion chamber type			Swirl chamber	Direct injection
	Valve mechanism			Overhead	
	Cylinder bore x stroke mm [in.]			94 x 120 [3.70 x 4.72]	
	Piston displacement liter [cu in.]			4.996 [305]	
	Compression ratio			22 : 1	17 : 1
	Firing order			1 - 5 - 3 - 6 - 2 - 4	
	Direction of rotation			Counterclockwise as viewed from flywheel side	
	Dimension	Overall length mm [in.]		1033 [40.7] SG type, 1029 [40.5] SP type	
		Overall width mm [in.]		593 [23.3]	626 [24.6]
		Overall heigth mm [in.]		748 [29.4]	896 [35.3]
Engine main parts	Weigth (dry) kg [lb.]			340 [750]	350 [772]
	Type of cylinder sleeve			Intergral with cylinder block	
	No. of piston ring	Compression ring		2	
		Oil ring		1 (w/spring expander)	
	Valve timing	Inlet valve	Open	BTDC 30°	BTDC 18°
			Close	ABDC 50°	ABDC 54°
		Exhaust valve	Open	BBDC 74°	BBDC 66°
			Close	ATDC 30°	ATDC 22°
	Starting system			Electric-starter	
	Starting aid			Glow plugs	
Inlet and exhaust systems	Air cleaner	Type		Paper element	
	Turbocharger	Model		—	TE06H

Model designation			S6S	S6S-DT
Lubrication system	Type		Force feed by oil pump	
	Engine oil	API Service Classification	CD	
		Refill capacity liter [U.S. gal}	Whole system: Approx. 12 liter [3.2 U.S. gal]; Oil pan: 11 liters [2.9 U.S. gal], Filter: 1 liters [0.3 U.S. gal]	
	Oil pump	Type	Trochoid	
		Speed ratio to crankshaft	0.74	
		Capacity liter [U.S. gal] / min	38.7 [10.2] at 0.3 MPa (3 kgf/cm^2) discharge pressure of pump running at 2 230 rpm	
	Oil pressure relief valve	Type	Piston valve	
		Opening pressure MPa (kgf/cm^2) [psi]	0.35 ± 0.05 (3.5 ± 0.5) [50 ± 7]	
	Oil Cooler	Type	—	Water-cooled multi-plate
	Oil filter	Type	Cartridge of paper element	
	Safety valve	Opening pressure MPa (kgf/cm^2) [psi]	—	1.1 (11) [156]
Cooling system	Refill capacity (engine water jacket) liter [U.S. gal.]		5.5 [1.5]	5 [1.3]
	Water pump	Type	Centrifugal	
		Speed ration to crankshaft	1.3	
		Capacity liter [U.S. gal.]/ min/rpm	160 [42.3] at 0.075 MPa [0.75 kgf/cm^2] discharge pressure of pump runnning at 3600 rpm	
	Fan belt	Type	Low-edge B type V-belt x 1	
	Thermostat	Type	Wax pellet	
		Valve opening temperature °C [°F]	76.5 ± 1.5 [170 ± 2.7]	
	Fan	Type	Pusher (PP)	
		No. of blade	7	
		Diameter mm [in.]	500 [19.7]	

Model designation			S6S	S6S-DT
Fuel system	Injection pump	Type	Bosch A	
		Diameter of plunger mm [in.]	7 [0.276]	9 [0.354]
	Feed pump	Type	Bosch, piston	
		Cam lob lift mm [in.]	8 [0.315]	9 [0.354]
	Governor	Type	Bosch RSV, centrifugal	
	Inspection nozzle	Type of nozzle	Bosch throttle	Bosch hole
		No. of discharge orifice	1	4
		Diameter of discharge orifice mm [in.]	1.0 [0.039]	0.28 [0.011] (for D/G) 0.24 [0.009] (for Pover Unit)
		Discharge angle	0°	155°
		Valve opening pressure MPa (kgf/cm^2) [psi]	11.77 (120) [1707]	17.65 (180) [2561]
	Fuel filter	Type	Cartridge of paper element	
Electrical system	Voltage - polarity		12V - ⊖ ground	
	Starter	Model	M008T50271	
		Type	Pinion shift	
		Output V - kW	12 - 3	
		No. of pinion teeth/flywheel ring gear teeth	10 / 122	
	Alternator	Type	3-phase, with rectifier	
		Output V - A	12 - 50	
		Working speed rpm	1000 to 18000	
		Rated output generating speed rpm	5000	
		Maximum permissible speed rpm	22000	
		Speed ratio to crankshaft	2.0	
	Glow plugs	Type	Sheathed	
		Rated voltage - current V - A	Direct injection: 11 - 5.5 (30 sec. rating) Swirl chamber: 10.5 - 9.7 (30 sec. rating)	
	Stop solenoid (option)	Rated voltage V	12	
		Rated temp. °C [°F]	20 [68]	

3 TIPS ON DISASSEMBLY AND REASSEMBLY

This service manual covers recommended procedures to be followed when servicing 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 positions or directions. Put on your own marks, if necessary, to aid reassembly.

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

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

3.2 Reassembly

1. Wash all engine parts, except oil seals, O-rings, rubber seals, etc. in cleaning solvent and dry them with compressed air.
2. Use only the correct tools and instruments.
3. Use only good quality lubricating oils and greases. Be sure to apply a coat of oil, grease, or sealant to parts as specified. (Refer to section 3, of Group 2, “Maintenance Standards”.)
4. Use a torque wrench to tighten parts when specified tightening torques are required. (Refer to section 2, of Group 2, “Maintenance Standards”.)
5. Replace all gaskets and packing. Apply appropriate amount of adhesive or liquid gasket when required.

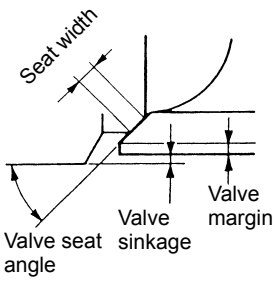
MAINTENANCE STANDARDS

4 MAINTENANCE STANDARDS TABLE

Unit: mm [in.]

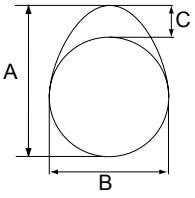
Group	Inspection Point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
General	Maximum rpm, (no-load)		According to engine specification				Adjust governor setting.
	Minimum rpm, (no-load)						
	Compression pressure MPa (kgf/cm^2) [psi]	DI		2.9 (30) [427] at 300 rpm	2.6 (27) [384]		Oil and water temp. 20 to 30°C [68 to 86°F]
		SC		3.2 (33) [469] at 300 rpm	2.8 (29) [413]		
	Engine oil pressure MPa (kgf/cm^2) [psi]		0.3 to 0.5 (3 to 5) [43 to 71] at 1500 rpm		0.15 (1.5) [21.3]		Oil temperature 70 to 90°C [158 to 194°F]
			0.1 (1) [14.2] or more at idling		0.05 (0.5) [7]		
	Valve timing		Inlet valves open Inlet valves close Exhaust valves open Exhaust valves closed		DI BTDC 18° ABDC 54° BBDC 66° ATDC 22° ±3° (crank angle)	SC BTDC 30° ABDC 50° BBDC 74° ATDC 30° ±3° (crank angle)	
	Valve clearance (cold)			0.25 [0.0098]			Bolt inlet and exhaust valves.
	Fuel injection timing						The timing for each model of engine varies according to its specification. Be sure to verify the timing by referring to the specifications of each model.
	V-belt deflection			12 [0.5], approx.			Push belt inward with thumb pressure and measure deflection.
Crankcase	Crankcase	Warpage of gasket contact surface		0.05 [0.0020] or less	0.20 [0.0079]		Regrind if warpage is minor.
	Cylinder	Inside diameter	94 [3.70]	94.000 to 94.035 [3.7008 to 3.7022]	94.200 [3.7087]	94.700 [3.7283]	Refinish cylinder to 0.25 [0.0098] or 0.50 [0.0197] oversize of normal value by honing and use the same oversize pistons and piston rings.
		Circularity		0.01 [0.0004] or less			
		Taper		0.015 [0.0006] or less			
	Main bearing	Clearance between bearing and journal		(0.050 to 0.110) ([0.0020 to 0.0043])	(0.200) ([0.0079])	–0.09 [–0.035] as journal diameter which is 78 [3.07]	If repair limit is reached, replace bearings. If it is exceeded, regrind journals and use undersize bearings. Bearing undersizes: 0.25 [0.0098] 0.50 [0.0197] 0.75 [0.0295]

DI: Direct injection
SC: Swirl chamber

Group	Inspection Point			Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Crankcase	Tappet bore	Inside diameter			14.000 to 14.018 [0.5512 to 0.5519]		14.100 [0.5551]	
		Clearance between tappet and bore			(0.016 to 0.052) ([0.0006 to 0.0021])	(0.080) ([0.0031])		If it exceeds the repair limit, replace tappets.
	Camshaft bore	Clearance between camshaft and journal	Front and middle		(0.070 to 0.118) ([0.0028 to 0.0047]) (without bushings)	(0.15) ([0.0059])		If it exceeds the repair limit, refinish bores and install bushings, or replace camshaft.
			Rear		(0.070 to 0.110) ([0.0028 to 0.0043]) (without bushings)			
					(0.040 to 0.119) ([0.0016 to 0.0047]) (with bushings)	(0.15) ([0.0059])		If it exceeds the repair limit, replace bushings. Ream if necessary.
Cylinder head	Cylinder head	Warpage of gasket contact surface			0.05 [0.0020] or less	0.20 [0.0079]		Regrind if warpage is minor
		Compressed thickness of gasket		1.2 [0.05]	±0.05 [±0.002]			
	Valve and valve guide	Diameter of valve stem	Inlet valve	8 [0.31]	7.940 to 7.955 [0.3126 to 0.3132]		7.900 [0.3110]	
			Exhaust valve		7.920 to 7.940 [0.3118 to 0.3126]		7.850 [0.3091]	
		Clearance between guide and stem	Inlet valve		(0.065 to 0.095) ([0.0026 to 0.0037])		(0.200) ([0.0079])	
			Exhaust valve		(0.080 to 0.115) ([0.0032 to 0.0045])			
		Height to top of valve guide		11.5 [0.45]	±0.1 [±0.004]			
	Valve seat	Angle		30°				
		Valve sinkage	Inlet valve	0.4 [0.016]	±0.1 [±0.004]		1.0 [0.039]	
			Exhaust valve	0.5 [0.020]				
		Width		1.4 [0.055]	±0.14 [±0.0055]		1.8 [0.071]	
		Valve margin			2.13 [0.0839]		Up to 1.83 [0.0720] by refacing	
	Valve spring	Free length		48.85 [1.92]			47.60 [1.87]	
		Squareness			1.5° or less			Squareness of ends with respect to center line
		Set length			43 [1.69]			
		Set force N (kgf) [lbf]			176 to 196 (18 to 20) [40 to 44]		147 (15) [33]	

Group	Inspection Point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Cylinder head	Rocker arm	Inside diameter of rocker bushing	19 [0.75]	19.010 to 19.030 [0.7484 to 0.7492]			
		Diameter of rocker shaft		18.980 to 19.000 [0.7472 to 0.7480]			
		Clearance between bushing and shaft		(0.010 to 0.050) ([0.0004 to 0.0020])	(0.070) ([0.0028])		
	Valve pushrod	Deflection		0.3 [0.012] or less			1/2 of dial indicator reading
Main moving parts	Crankshaft	Deflection		0.02 [0.0008] or less	0.05 [0.0020]		
		Journal diameter	78 [3.07]	77.955 to 77.970 [3.0691 to 3.0697]	77.850 [3.0650]	77.100 [3.0354]	
		Crankpin diameter	58 [2.28]	57.955 to 57.970 [2.2817 to 2.2823]	57.800 [2.2756]		
		Center to center distance between journal and crankpin	60 [2.36]	±0.04 [±0.0016]			
		Parallelism between journal and crankpin		Runout: 0.01 [0.0004] or less (over crankpin length)			
		Circularity of journal and crankpin		0.01 [0.0004] or less	0.03 [0.0012]		
		Taper of journal and crankpin					
		Fillet radius of journal and crankpin	3 [0.12]	±0.2 [±0.008]			
		End play	33 [1.30]	(0.100 to 0.264) ([0.0039 to 0.0104])	(0.300) ([0.0118])		If thrust plate clearance exceeds the repair limit, replace thrust plates. If it is exceeded, use oversize thrust plates. Thrust plate oversizes: 0.15 [0.0059] 0.30 [0.0118] 0.45 [0.0177]

Group	Inspection Point			Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Main moving parts	Piston	Outside diameter (at skirt)	Standard	94 [3.70]	93.955 to 93.985 [3.6990 to 3.7002]		93.770 [3.6917]	
			0.25 [0.0098] oversize		94.205 to 94.235 [3.7089 to 3.7100]		94.020 [3.7016]	
			0.50 [0.0197] oversize		94.455 to 94.485 [3.7187 to 3.7199]		94.270 [3.7114]	
		Protrusion	DI		0.05 to 0.45 [0.0020 to 0.0177]			Check bearing clearance.
			SC		–0.25 to 0.15 [–0.0098 to 0.0059]			
		Clearance between piston pin and bore			(0.000 to 0.016) ([0.0000 to 0.0006])		(0.050) ([0.0020])	
		Piston weight difference per engine			5 g [0.18 oz] or less			
	Piston ring	Clearance between groove and ring	No. 1 ring		(0.07 to 0.11) ([0.0028 to 0.0043])		(0.200) ([0.0079])	
			No. 2 ring	2.0 [0.079]	(0.045 to 0.085) ([0.0018 to 0.0034])		(0.150) ([0.0059])	
			Oil ring	4.5 [0.177]	(0.025 to 0.065) ([0.0010 to 0.0026])		(0.150) ([0.0059])	
		Clearance between ends	No. 1, 2 rings		0.30 to 0.50 [0.0118 to 0.0197]		1.50 [0.0591]	
			Oil ring					
	Piston pin	Diameter		30 [1.18]	29.994 to 30.000 [1.1809 to 1.1811]			
		Clearance between pin and bushing			(0.020 to 0.051) ([0.0008 to 0.0020])		(0.080) ([0.0032])	
	Connecting rod	Inside diameter of bushing		30 [1.18]	30.020 to 30.045 [1.1819 to 1.1829]			
		Bend and twist			0.10/100 [0.0039/ 3.94] or less	0.15 [0.0059]		
		Clearance between crankpin and connecting rod bearing			(0.030 to 0.090) ([0.0012 to 0.0035])		(0.200) ([0.0079])	
		End play		33 [1.30]	(0.15 to 0.35) ([0.0059 to 0.0138])		(0.50) ([0.020])	Replace connecting rod.
		Rod weight difference per engine			10 g [0.35 oz] or less			
	Flywheel	Flatness			0.15 [0.0059] or less	0.50 [0.020]		
		Face runout						
		Deflection			0.02 [0.0008] or less	0.05 [0.0020]		Straighten by cold working or replace.

Group	Inspection Point				Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Timing gears	Camshaft	Cam lift C	Inlet valve	DI	A= $46.918^{+0.1}_{-0.3}$ [$1.8472^{+0.004}_{-0.012}$]	6.682 [0.2631]		6.182 [0.2434]	
				SC	A= $46.916^{+0.1}_{-0.3}$ [$1.8471^{+0.004}_{-0.012}$]	6.684 [0.2632]		6.184 [0.2435]	
			Exhaust valve	DI	A= $46.878^{+0.1}_{-0.3}$ [$1.8456^{+0.004}_{-0.012}$]	6.722 [0.2647]		6.222 [0.2450]	
				SC	A= $46.880^{+0.1}_{-0.3}$ [$1.8457^{+0.004}_{-0.012}$]	6.720 [0.2646]		6.220 [0.2450]	
		Journal diameter	No. 1, 2 (S4S) No. 1, 2, 3 (S6S)		54 [2.13]	53.94 to 53.96 [2.1236 to 2.1244]		53.90 [2.1220]	
			No. 3 (S4S) No. 4 (S6S)		53 [2.09]	52.94 to 52.96 [2.0842 to 2.0850]		52.90 [2.0827]	
		End play			5 [0.20]	(0.10 to 0.25) ([0.0039 to 0.0098])		(0.30) ([0.0118])	Replace thrust plates.
	Idler gear	Clearance between shaft and bushing				(0.009 to 0.050) ([0.0004 to 0.0020])		(0.100) ([0.0040])	Replace bushing.
		End play			30 [1.18]	(0.05 to 0.20) ([0.0020 to 0.0079])		(0.35) ([0.0138])	Replace thrust plates.
		Fit (interference) of bushing in crankcase bore			30 [1.18]	(0.035T to 0.076T) ([0.0014T to 0.0030T])			
	Backlash					(0.03 to 0.18) ([0.0012 to 0.0071])		(0.25) ([0.0098])	Replace gears.
Lubrication system	Oil pump	Clearance between outer rotor and case				(0.20 to 0.30) ([0.0012 to 0.0018])		(0.50) ([0.0197])	
		Diameter of main shaft (case side)			16 [0.63]	15.985 to 16.000 [0.6293 to 0.6299]			
		Diameter of main shaft (oil pump bushing side)			14 [0.55]	13.957 to 13.975 [0.5495 to 0.5502]			
		Clearance between main shaft and case				(0.032 to 0.074) ([0.0013 to 0.0029])		(0.15) ([0.0059])	Replace pump case or pump assembly.
		Clearance between main shaft and oil pump bushing				(0.025 to 0.111) ([0.0010 to 0.0044])		(0.200) ([0.0079])	Replace bushing or pump assembly.
		Clearance between outer and inner rotors				(0.13 to 0.15) ([0.0051 to 0.0059])		(0.20) ([0.0079])	
		Clearance between rotors and cover				(0.04 to 0.09) ([0.0016 to 0.0035])		(0.15) ([0.0059])	Replace cover or case.
	Relief valve		Valve opening pressure, MPa (kgf/cm^2) [psi]			0.35 ± 0.05 (3.5 ± 0.5) [50 ± 7]			
	Safety valve					1.1 (11) [156]			With oil cooler.
Cooling system	Thermostat	Temp. at which valve starts opening				76.5 ± 1.5°C [170 ± 2.7°F]			
		Temp. at which valve lift is more than 8 [0.3]				90°C [194°F]			

Group	Inspection Point			Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Fuel system	Injection nozzle	Valve opening pressure, MPa (kgf/cm^2) [psi]	DI	17.65 (180) [2560]	18.14 to 19.12 (185 to 195) [2632 to 2774]			Make shim adjustment. Pressure varies by 1 (10) [142] per 0.1 mm [0.004 in.] thickness of shim.
			SC	11.77 (120) [1706]	11.77 to 12.75 (120 to 130) [1707 to 1849]			
		Spray cone angle	DI	155°				Test by means of hand tester, using diesel fuel, at 20°C [68°F]. If discharge pattern is bad even after nozzle is washed in clean diesel fuel, replace nozzle tip.
			SC	0°				
		Oil tightness of needle valve seat		Seat shall hold a test pressure 2 MPa (20 kgf/cm^2) [284 psi] lower than valve opening pressure for 10 seconds.				Wash or replace nozzle tip.
Electrical system	Starter (12V - 2.2 kW)	Diameter of commutator		32 [1.26]			31.4 [1.24]	
		Runout of commutator		0.03 [0.0012]			0.1 [0.004]	
		Depth of commutator mold		0.4 to 0.6 [0.016 to 0.024]	0.2 [0.008] or less			
		Brush	Length	18 [0.71]			11 [0.43]	
			Spring force, N (kgf) [lbf]	30.4 to 38.2 (3.1 to 3.9) [6.8 to 8.6]			19.6 (2.0) [4.4]	
		Thrust clearance of pinion shaft		0.5 [0.020]	0 or more			
		Pinion clearance		0.5 to 2.0 [0.020 to 0.079]				

No-load characteristics			Locked characteristics			Magnetic switch
Voltage, V	Current, A	Speed, rpm	Voltage, V	Current, A	Torque N·m (kgf·m) [lbf·ft]	Switch-in voltage V
11	130 or less	3800 or more	3	1120 or less	31.36 (3.2) [23.1] or more	8 or less

Group	Inspection Point		Nominal Value	Assembly Standard (Standard Clearance)	Repair Limit (Clearance)	Service Limit (Clearance)	Remark
Electrical system	Starter (12V - 3 kW)	Diameter of commutator	38.7 [1.52]			38.1 [1.50]	
		Runout of commutator	0.03 [0.0012]			0.1 [0.004]	
		Depth of commutator mold	0.4 to 0.6 [0.016 to 0.024]	0.2 [0.008] or less			
		Brush – Length	17 [0.67]			11 [0.43]	
		Brush – Spring force, N (kgf) [lbf]	33.3 to 45.1 (3.4 to 4.6) [7.5 to 10.1]			17.7 (1.8) [4.0]	
		Thrust clearance of pinion shaft	0.5 [0.020]	0 or more			
		Pinion clearance	0.5 to 2.0 [0.020 to 0.079]				

No-load characteristics			Locked characteristics			Magnetic switch
Voltage, V	Current, A	Speed, rpm	Voltage, V	Current, A	Torque N·m (kgf·m) [lbf·ft]	Switch-in voltage V
11	180 or less	3800 or more	2	1050 or less	25.0 (2.55) [18.4] or more	8 or less

Alternator	Brush spring force, N (gf) [lbf]		3.0 to 4.2 (310 to 430) [0.7 to 0.9]		2.1 (210) [0.5]	
	Brush heigth		18.5 [0.73]		7 [0.28]	
	Resistance in slip rings		2.4Ω			At 20°C [68°F].

5 TIGHTENING TORQUES

5.1 Important Bolts and Nuts

Description	Thread Dia. x Pitch (M-thread)	Width across flats, mm	Tightening Torque			Remark
			N·m	kgf·m	lbf·ft	
Cylinder head	M12 x 1.75	19	113 to 123	11.5 to 12.5	83 to 90	
Rocker cover	M8 x 1.25	12	10.0 to 13.0	1.0 to 1.3	7.23 to 9.40	
Rocker shaft brackets	M8 x 1.25	12	10.0 to 20.0	1.0 to 2.0	7.23 to 14.5	
Main bearing caps	M14 x 2	22	98 to 108	10.0 to 11.0	72 to 80	
Connecting rod caps	M10 x 1.25	14	49.0 to 59.0	5.0 to 6.0	36.2 to 43.4	
Flywheel	M12 x 1.25	17	78.5 to 88.3	8.0 to 9.0	57.9 to 65.1	
Camshaft thrust plate	M8 x 1.25	12	10.0 to 13.0	1.0 to 1.3	7.23 to 9.40	
Front plate	M8 x 1.25	12	10.0 to 13.0	1.0 to 1.3	7.23 to 9.40	
Timing gear case	M8 x 1.25	12	10.0 to 13.0	1.0 to 1.3	7.23 to 9.40	
Crankshaft pulley	M30 x 1.5	46	480 to 500	49 to 51	354 to 369	
Idler gear thrust plate	M10 x 1.25	14	29.0 to 39.0	3.0 to 4.0	21.7 to 28.9	
Oil pan	M8 x 1.25	12	10.0 to 13.0	1.0 to 1.3	7.23 to 9.40	Press product
Oil pan	M8 x 1.25	12	27.5 to 33.4	2.8 to 3.4	20.3 to 24.6	Cast oil pan for agricultural tractor
Rear plate	M10 x 1.25	14	54.0 to 65.7	5.5 to 6.7	39.8 to 48.5	Agricultural tractor use
Oil pan drain plug	M14 x 1.5 M20 x 1.5	22 24	34.0 to 44.0 73.0 to 83.0	3.5 to 4.5 7.5 to 8.5	25.3 to 32.5 54.2 to 61.5	
Fuel injection nozzle glands (direct injection type)	M8 x 1.25	12	21.0 to 23.0	2.0 to 2.4	14.5 to 17.4	
Fuel injection nozzles (swirl chamber type)	M20 x 1.5	21	53.0 to 64.7	5.4 to 6.6	39.1 to 47.7	
Fuel injection pump delivery valve holders		22	34.0 to 39.0	3.5 to 4.0	25.3 to 28.9	
Fuel leak-off pipe nut	M12 x 1.5	17	20.6 to 24.5	2.1 to 2.5	15.2 to 18.1	
Fuel injection pump gear (distribution type)	M14 x 1.5	22	76.5 to 86.3	7.8 to 8.8	56.4 to 63.7	
Fuel injection pump gear (in-line, swirl chamber type) (in-line, direct injection type)	 M12 x 1.75 M14 x 1.5	 19 22	 58.8 to 68.6 83.4 to 98.0	 6.0 to 7.0 8.5 to 10.0	 43.4 to 50.6 61.5 to 72.3	
Glow plug (swirl chamber type) (direct injection type) (terminal)	 M10 x 1.25 M12 x 1.25 M4 x 0.7	 12 12 8	 15.0 to 20.0 20.0 to 30.0 1.0 to 1.5	 1.5 to 2.0 2.0 to 3.0 0.10 to 0.15	 10.8 to 14.5 14.5 to 21.7 0.72 to 1.08	
Exhaust Manifold (bolt only) (with spacer)	 M8 x 1.25 M8 x 1.25	 12 12	 27.5 to 33.3 15.0 to 22.0	 2.8 to 3.4 1.5 to 2.2	 20.3 to 24.6 10.8 to 15.9	
Oil pressure relief valve	M22 x 1.5	27	44.1 to 53.9	4.5 to 5.5	32.5 to 39.8	
Safety valve or blind plug	M18 x 2	24	64.0 to 74.0	6.5 to 7.5	47.0 to 54.2	
Coolant drain plug	1/4 – 18NPTF	14	35.3 to 43.1	3.6 to 4.4	26.0 to 31.8	

Description	Thread Dia. x Pitch (M-thread)	Width across flats, mm	Tightening Torque			Remark
			N·m	kgf·m	lbf·ft	
Fuel injection pipe nuts	M12 x 1.5	19	26.5 to 32.4	2.7 to 3.3	19.5 to 23.9	
Fuel return pipe nuts	M10 x 1.25	14	17.7 to 21.6	1.8 to 2.2	13.0 to 15.9	
Oil pump gear	M10 x 1.25	14	28.0 to 38.0	2.9 to 3.9	21.0 to 28.2	
Overheat warning unit (thermoswitch)	M16 x 1.5	19	20.6 to 24.5	2.1 to 2.5	15.2 to 18.1	
Starter terminal B	M8 x 1.25	12	9.81 to 11.8	1.0 to 1.2	7.23 to 8.68	
Plug	M16 x 1.5	24	39.2 to 49.0	4.0 to 5.0	28.9 to 36.2	Cylinder head
Balancer	M8 x 1.25	12	27.5 to 33.4	2.8 to 3.4	20.3 to 24.6	
Fuel injection pump feed pipe (flare)	M12 x 1.0	17	16.0 to 23.0	1.6 to 2.3	11.6 to 16.6	
Fuel injection pump eye bolt	M14 x 1.5	22	15.0 to 20.0	1.5 to 2.0	10.8 to 14.5	
Fuel injection pump overflow valve		17	15.0 to 20.0	1.5 to 2.0	10.8 to 14.5	
Oil level sensor	1 – 1/ 16 – 12	24	49.0 to 58.8	5.0 to 6.0	36.2 to 43.4	

5.2 Standard Bolts

Thread Diameter (mm)	Torque					
	4T			7T		
	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
M6	2.94 to 4.90	0.3 to 0.5	2.17 to 3.62	7.89 to 9.80	0.8 to 1.0	5.79 to 7.23
M8	9.80 to 12.7	1.0 to 1.3	7.23 to 9.40	14.7 to 21.6	1.5 to 2.2	10.8 to 15.9
M10	17.7 to 24.5	1.8 to 2.5	13.0 to 18.1	29.4 to 41.2	3.0 to 4.2	21.7 to 30.4
M12	29.4 to 41.2	3.0 to 4.2	21.7 to 30.4	53.9 to 73.5	5.5 to 7.5	39.8 to 54.2

5.3 Standard Studs

Thread Diameter (mm)	Torque (tap end)					
	For driving in aluminum materials			For driving in ferrous materials		
	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
M8	4.90 to 5.90	0.50 to 0.60	3.62 to 4.34	11.8 to 13.7	1.2 to 1.4	8.68 to 10.1
M10	12.7 to 14.7	1.3 to 1.5	9.40 to 10.8	21.6 to 25.5	2.2 to 2.6	15.9 to 18.8

5.4 Standard Plugs

Thread Diameter	Torque					
	For aluminum materials			For ferrous materials		
	N·m	kgf·m	lbf·ft	N·m	kgf·m	lbf·ft
NPTF 1/16	4.90 to 7.85	0.5 to 0.8	3.62 to 5.79	7.85 to 11.8	0.8 to 1.2	5.79 to 8.68
PT 1/8	7.85 to 11.8	0.8 to 1.2	5.79 to 8.68	14.7 to 21.6	1.5 to 2.2	10.8 to 15.9
PT 1/4, NPTF 1/4	19.6 to 29.4	2.0 to 3.0	14.5 to 21.7	34.3 to 44.1	3.5 to 4.5	25.3 to 32.5
PT 3/8	—	—	—	53.9 to 73.5	5.5 to 7.5	39.8 to 54.2

Remarks:

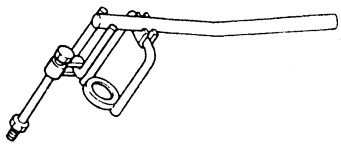
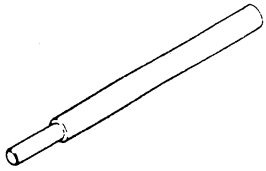
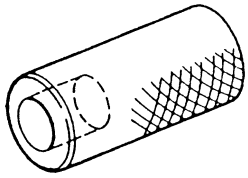
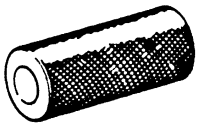
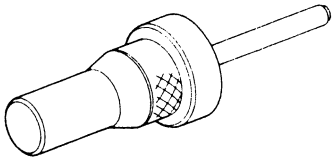
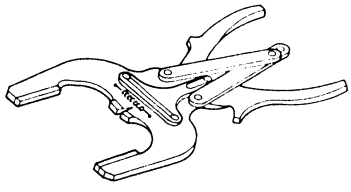
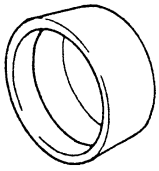
1. The torque values shown above are for the bolts with spring washers.
2. Do not apply any oil to the bolt threads.

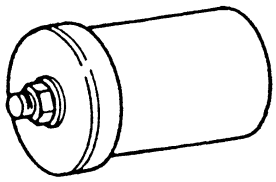
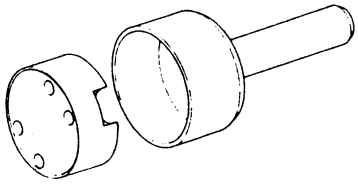
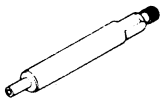
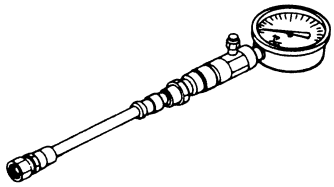
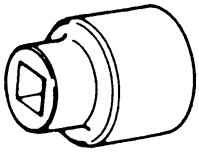
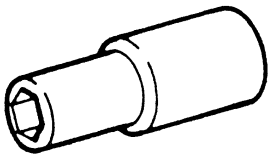
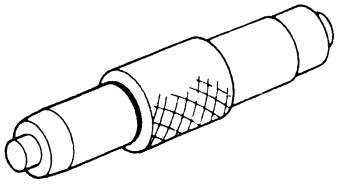
6 SEALANTS AND LUBRICANTS TABLE

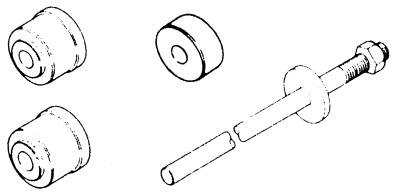
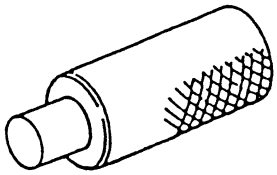
Apply to	Mating part	Sealant or Lubricant	How to Use
Oil pan	Crankcase	Three Bond 1207C	Apply to seal.
Rear bearing cap seat on crankcase	Rear bearing cap	Three Bond 1212	Apply to corners before installing cap.
Side seals	Crankcase rear bearing cap	Three Bond 1212	Apply to side seals.
Cylinder head coolant hole plug	Cylinder head	Three Bond 1386D	Apply to plug hole.
Crankcase coolant hole plug	Crankcase	Three Bond 1386D	Apply to plug hole.
Crankcase oil hole plug	Crankcase	Three Bond 1386D	Apply to plug hole.
Return oil hole blind plug or pipe of crankcase	Crankcase	Three Bond 1344	Apply to blind plug or pipe.
Crankshaft threads	Crankshaft pulley nut	Three Bond 1212	Apply to crankshaft thread before tightening nut.

SPECIAL TOOLS

7 SPECIAL TOOL LIST

Tool name	Part No.	Shape	Use
Valve spring pusher	30691-04500		Valve spring removal/installation
Valve guide remover	32A91-00300		Valve guide removal
Valve guide installer	32A91-00100		Valve guide installation
Stem seal installer	32A91-10200		Valve stem installation
Valve seat insert caulking tool	Inlet valve: 36791-00200 Exhaust valve: 34491-03020		Valve seat installation
Piston ring pliers	31391-12900		Piston ring removal/installation
Piston installer	34491-00200		Piston installation

Tool name	Part No.	Shape	Use
Idler shaft puller	MH061077		Idler gear shaft removal
Oil seal sleeve installer set	30691-13010		Crankshaft rear oil seal sleeve installation
Gage adaptor	32A91-01100 (direct injection)		Compression pressure measurement
Gage adaptor	30691-21100 (swirl chamber)		Compression pressure measurement
Compression gage	33391-02100		Compression pressure measurement
Turning socket	58309-73100		Engine turning
Socket	34491-00300		Camshaft thrust plate and rocker bracket installation
Connecting rod bushing puller	MH061236		Connecting rod bushing removal/ installation

Tool name	Part No.	Shape	Use
Camshaft bushing installer set	30691-00010		Camshaft bushing removal/ installation
Oil pump bushing installer	32A91-00400		Oil pump bushing installation

OVERHAUL INSTRUCTIONS

8 DETERMINATION OF OVERHAUL TIMING

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

1. Decreased power
2. Increased fuel consumption
3. Increased engine oil consumption
4. Increased blow-by gas volume through the breather due to abrasion at the cylinder liner and the piston ring
5. Gas leakage due to poor seating of the inlet and the exhaust valves
6. Starting problems
7. Increased noise from engine parts
8. Abnormal color of exhaust gas from engine after warm-up

Any one or a combination of these symptoms may indicate that engine overhaul is required. Of the items listed above some are not directly related to the necessity of engine overhaul. Items (2) and (6) are more likely to be affected substantially by

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

Item (4) above, however, requires special consideration because decreased pressure due to wear at the cylinder liner and the piston ring is one of the most obvious signs that the engine requires overhauling.

The most effective way to make a decision is by testing the compression pressure; other factors are to be considered secondarily.

9 TESTING THE COMPRESSION PRESSURE

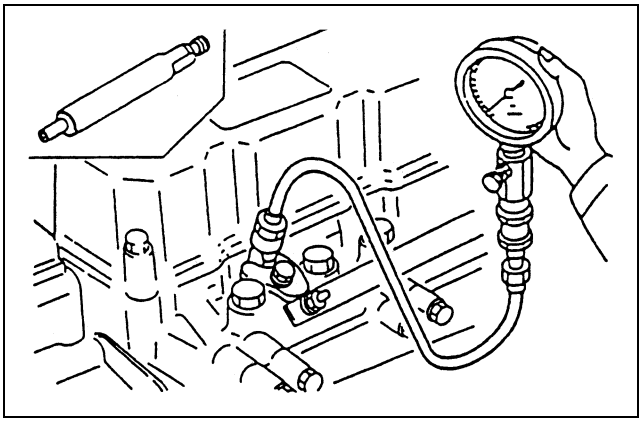


Figure 1 Measuring compression pressure (direct injection pump)

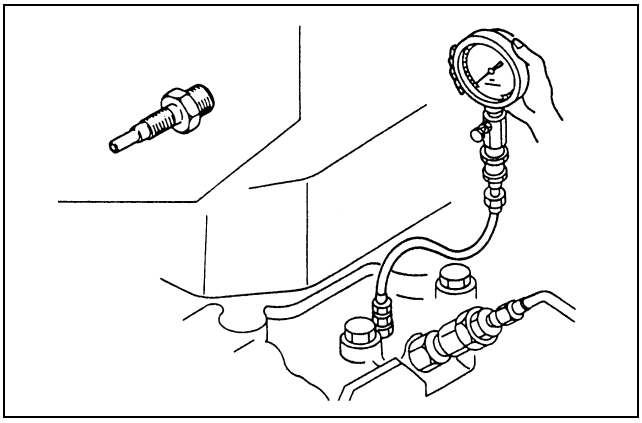


Figure 2 Measuring compression pressure (swirl chamber type)

1. Remove the injection nozzle from the cylinder head where the compression pressure is to be measured.
2. On the direction injection type engine, attached gage adaptor (32A91–01100) to the cylinder, and connect the compression gage (33391–02100) to the adaptor.
   On the swirl chamber type engine, attach the gage adaptor (30691–21100) to the cylinder, and connect the compression gage (33391–02100) to the adaptor.
3. Crank the engine by means of the starter, with the governor stop lever pulled (the fuel supply shut off), and read the compression gage indication when the engine 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 few cylinders, and presume the compression on the remaining cylinders.
b. Compression pressure varies with engine speed. Check engine speed when measuring the compression pressure.

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

Item		Assembly Standard	Service Limit
Compression pressure	Direct injection	2.9 (30) [427]	2.6 (27) [384]
	Swirl chamber	3.2 (33) [469]	2.8 (29) [413]

NOTE

Measure the compression pressure with the engine running at 300 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 new piston rings, valve seats, etc. Pressure will drop gradually by the wear of parts.

ADJUSTMENTS, BENCH TEST, PERFORMANCE TESTS

10 ADJUSTMENTS

10.1 Valve Clearance

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

Unit: mm [in.]

Item		Assembly Standard
Valve clearance (cold setting)	Inlet	0.25 [0.0098]
	Exhaust	

1. Inspection

   1) Inspect the valve clearance in the injection sequence. To check, turn the crankshaft by the specified crank angle in the normal direction to bring the piston to the top dead center of the compression stroke.

Injection sequence		Crank angle
S4S	1 - 3 - 4 - 2	180°
S6S	1 - 5 - 3 - 6 - 2 - 4	120°

   2) Put socket (58309–73100) and ratchet handle on the crankshaft pulley nut and turn the crankshaft in the normal direction (clockwise as seen from the front end).

Unit: mm [in.]

Width across flats of crankshaft pulley nut	46 [1.81]

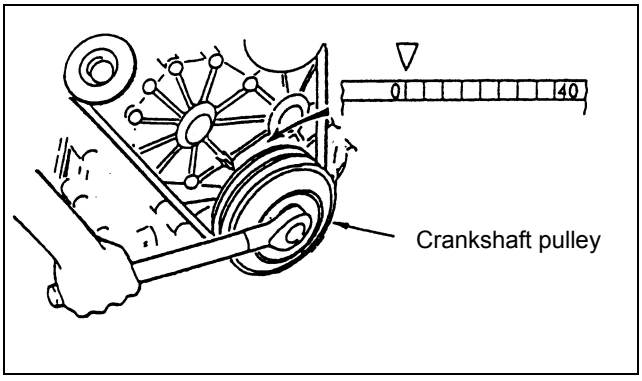


Figure 3 Checking valve clearance (turning)

   3) The top dead center on compression stroke of No.1 piston is identified by the timing mark “0” (on the crankshaft pulley) being aligned with the pointer on the gear case. With the piston so positioned, both the inlet and exhaust valve rocker arms are not being pushed up by their pushrods.
   4) Insert a feeler gage in between the rocker arm and valve cap, and check the clearance.

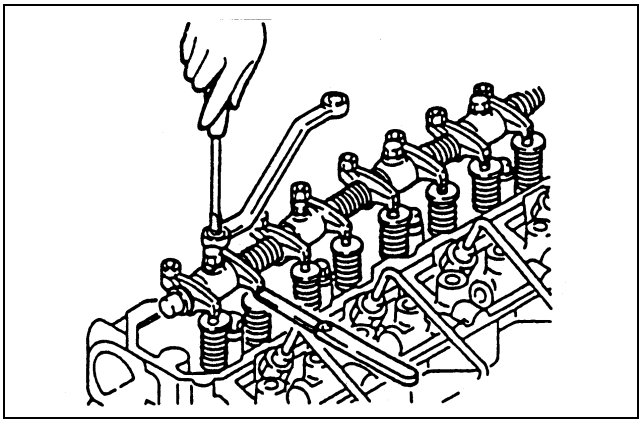


Figure 4 Adjusting valve clearance

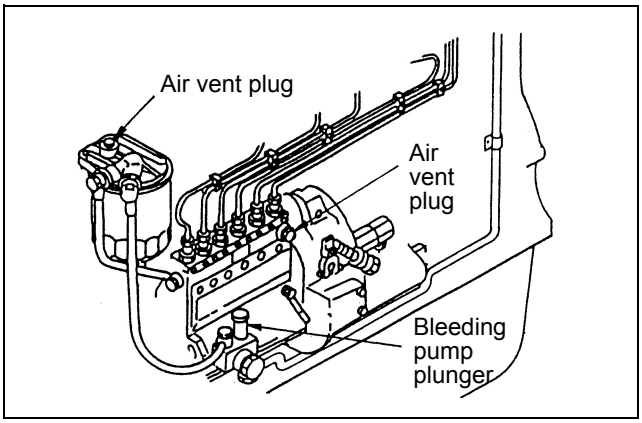


Figure 5 Bleeding fuel system

2. Adjusting

    1) Loosen the lock nut of the adjusting screw. Adjust the clearance by turning the screw in either direction to the extent that the gage is slightly gripped between the rocker arm and valve cap.
    2) After adjusting the clearance, tighten the lock nut. Inspect the clearance again and make sure that it is correct.

10.2 Fuel System Bleeding

1. Fuel filter

    1) Loosen air vent plug on the fuel filter by turning it about 1.5 rotations.
    2) Unlock bleeding pump plunger by turning it counterclockwise, and operate the pump.
    3) Tighten the air vent plug when the fuel flows without bubbles.

2. Fuel injection pump

    1) Loosen air vent plug on the injection pump by turning it 1.5 rotations
    2) Unlock bleeding pump plunger by turning counterclockwise, and operate the pump.
    3) Tighten the air vent plug when the fuel flows without bubbles.

⚠ DANGER

When fuel overflows from the air vent plug, wipe thoroughly with a cloth. Spilled fuel is a fire hazard.

NOTE

If the vent plug is tightened before the bleeding pump plunger is locked, fuel pressure acts on the feed pump, making it difficult to restore the plunger.

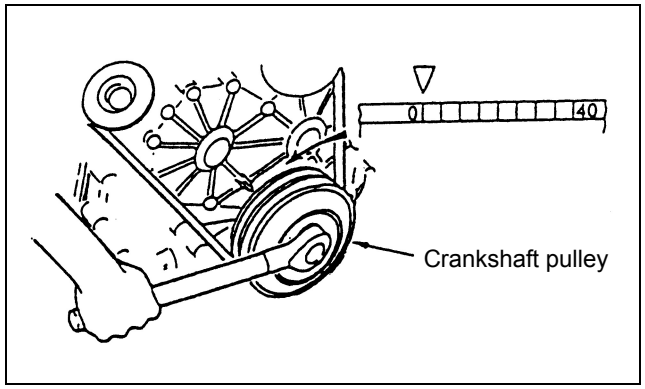


Figure 6 Finding top dead center on compression stroke

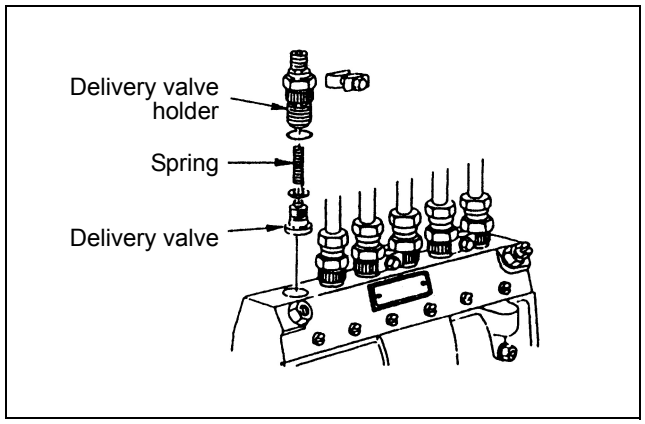


Figure 7 Checking injection timing (1) (Removing delivery valve)

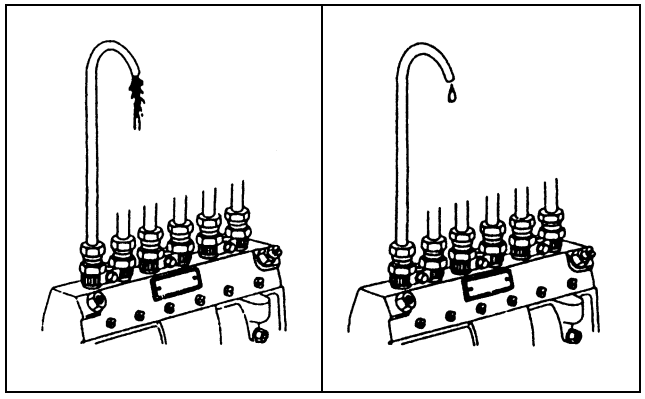


Figure 8 Checking injection timing (2)

10.3 Fuel Injection Timing

The injection timing varies according to the output, speed and specifications of the engine. Be sure to verify the timing by referring to the specifications.

1. Bringing the No.1 cylinder piston to the top dead center on compression stroke

    1) Put socket (58309–73100) on the crankshaft pulley nut and turn the crankshaft in the normal direction (clockwise as seen from the front end).
    2) Stop turning the crankshaft when the timing the mark “0” on the crankshaft pulley is aligned with the pointer.
    3) Push down on the inlet and exhaust valve rocker arms for the No.1 cylinder to make sure they are not being pushed up by the pushrods (the inlet and exhaust valves have some clearance).

2. Checking injection timing

    1) Remove delivery valve holder from the No.1 plunger of the injection pump. Remove delivery valve and spring from the holder. Restore the holder to the pump.
    2) Connect a spare injection pipe to the No.1 plunger, with its free end held downward so that you can observe the fuel flow from that end.
    3) Turn the crankshaft to bring the No.1 piston to 60° position before top dead center on compression stroke.
    4) While operating the priming pump to allow the fuel to flow from the injection pipe, slowly turn the crankshaft in the normal direction. Stop turning the crankshaft when the fuel flow stops.
    5) Make sure the timing mark on the crankshaft pulley is aligned with the pointer.

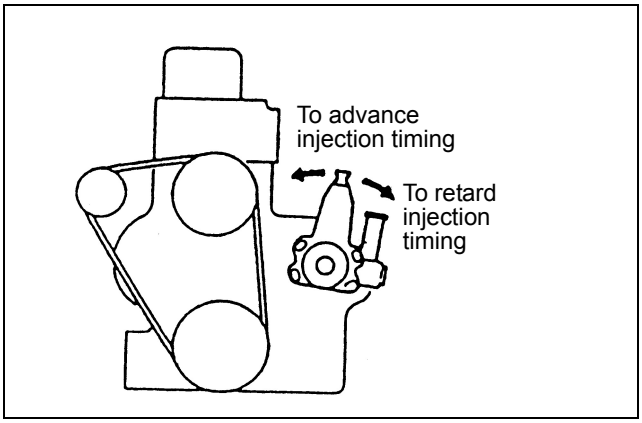


Figure 9 Adjusting injection timing (1)

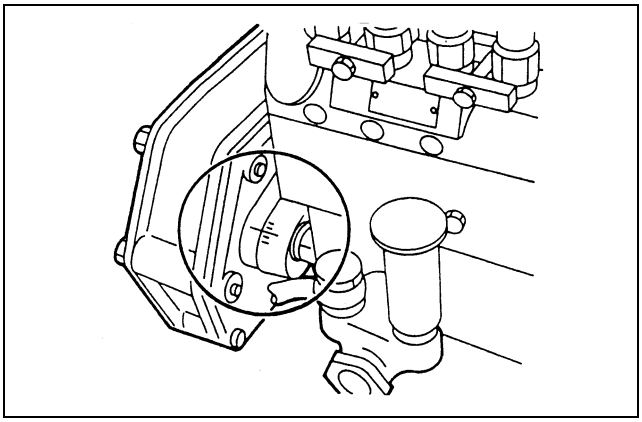


Figure 10 Adjusting injection timing (2)

3. Adjusting injecting timing

   1) If the injection timing is retarded, move the injection pump toward the crankcase. If the timing is advanced, move the pump away from the crankcase.

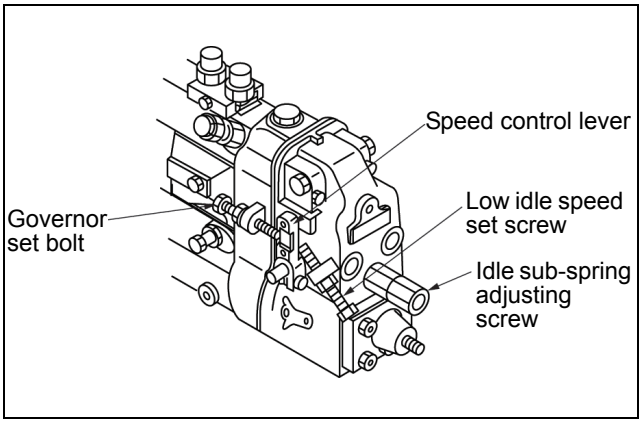
   2) One graduation of the scale on the injection pump coupling changes the timing by 6° in terms of crank angle.

10.4 No-load Minimum (Idling) Speed and Maximum Speed Setting

⚠ CAUTION

a. The no-load minimum (idle) speed and maximum speed are set for each engine on the test bench at the factory. The set bolts are sealed. These settings are to be inspected and adjusted at our authorized service shop only.
b. After adjusting the governor by breaking the seals, be sure to re-seal all visible stoppers, making them appear as if they were sealed at the factory.
c. When inspecting and adjusting these settings, be on standby to operate the engine stop lever manually in the event of engine overrun.

For inspection and adjustment, warm up the engine thoroughly until the coolant and oil temperature are above 70°C [158°F].



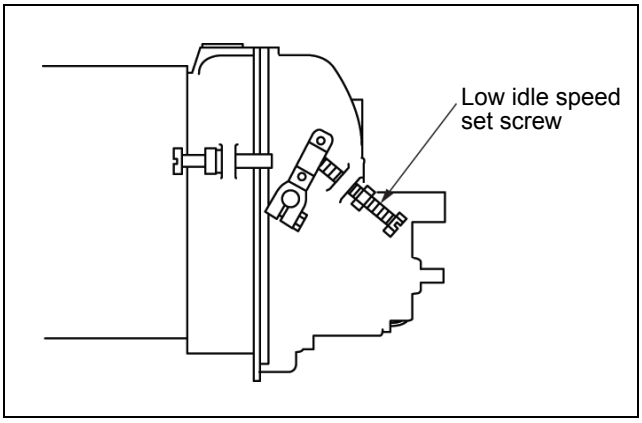


Figure 11 Setting no-load minimum (idle) speed

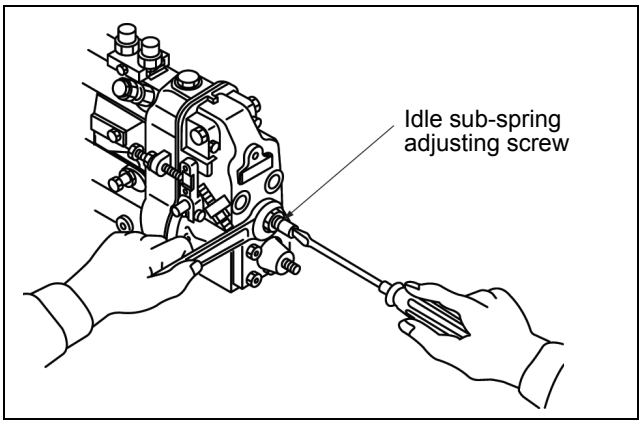


Figure 12 Setting idle sub-spring adjusting screw

1. Starting engine

   1) Pull speed control lever to the high speed side. Operate the starter switch to crank the engine.
   2) The engine will fire up at 150 rpm of cranking speed. When the engine fires, hold the engine speed between 800 and 1000 rpm.
   3) When the engine runs with a steady speed, move the speed control lever back to the idle speed position.

2. Setting no-load minimum (idle) speed

   1) Hold the speed control lever at the position for no-load minimum (idle) speed and set low idle speed set screw.

⚠ CAUTION

If a critical speed (the speed at which the engine excessively vibrates due to torsional resonance) might exist, shift the setting to a lower or higher idle speed level.

   2) The engine speed will increase when the low idle speed set screw is turned clockwise.
   3) If the engine speed tends to fluctuate, turn idle sub-spring adjusting screw clockwise to bring this spring into slight contact with the tension lever for eliminating fluctuation.

⚠ CAUTION

Tightening the idle sub-spring adjusting screw is likely to cause the engine to overspeed when the load is removed during operation. Be sure to tighten this adjusting screw just enough to eliminate the unstable condition.

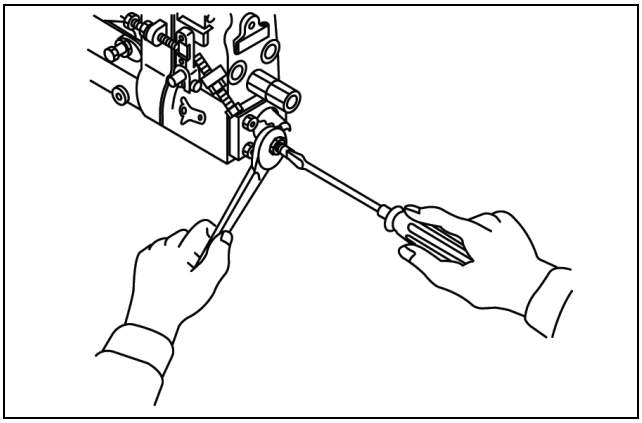


Figure 13 Setting rack (maximum output)

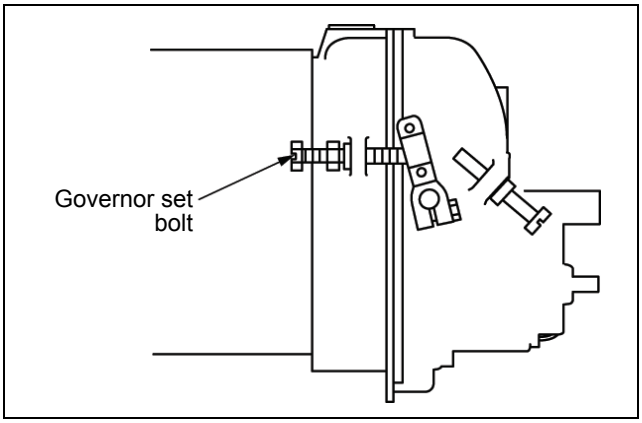


Figure 14 Setting governor (maximum speed)

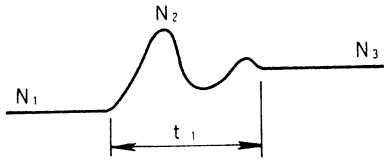
3. Setting rack (maximum output)

   1) Hold the speed control lever at the position for the indicated output and speed.
   2) Under this condition, check to be sure that the engine is running in a steady state.
   3) With the engine running in a steady state, adjust the full-load stopper bolt. Tighten or loosen this bolt to find out the position where the engine delivers the rated output.
   4) After adjusting the stopper bolt, back it off slowly while observing the speed. Stop backing off the stopper bolt just when the engine speed begins to decrease from the rated level and secure it in that position with its lock nut.
   5) At this time, the speed control lever should be in the maximum speed position.
   6) Turning the full-load stopper bolt clockwise will increase the injection quantity (engine output), and vice versa.

4. Setting governor (maximum speed)

   1) Apply full load to the engine and hold the speed control lever at the position for the indicated maximum speed.
   2) Set governor set bolt (maximum speed set bolt) at the position for the indicated speed.

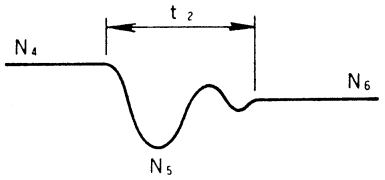
Speed regulation upon removing load



Instantaneous speed regulation (%)	Steady-state speed regulation (%)
$\frac{N_2 - N_1}{N_1} \times 100$	$\frac{N_3 - N_1}{N_1} \times 100$

N_1 = initial speed, rpm, before load is removed
N_2 = highest speed, rpm, during transitional period
N_3 = speed, rpm, at which the engine settles after load is removed
t_1 = stabilization time

Speed regulation upon applying load



Instantaneous speed regulation (%)	Steady-state speed regulation (%)
$\frac{N_4 - N_5}{N_4} \times 100$	$\frac{N_4 - N_6}{N_4} \times 100$

N_4 = initial speed, rpm, before load is removed
N_5 = highest speed, rpm, during transitional period
N_6 = speed, rpm, at which the engine settles after load is removed
t_2 = stabilization time

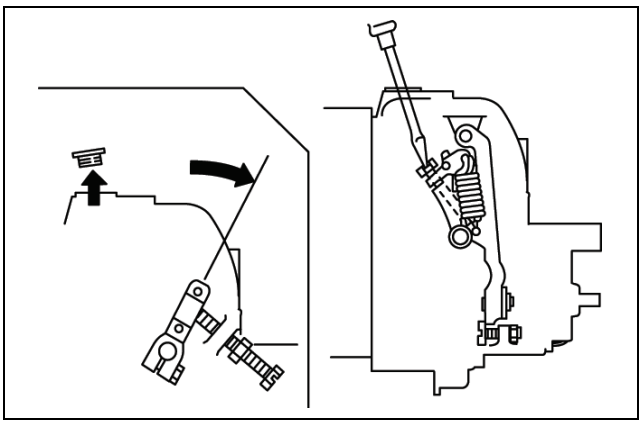


Figure 15 Adjusting speed regulation

5. Determining speed regulation (speed droop)

1) Speed regulation upon removing load

a Run the engine with the speed control lever set at the position for the rated load and speed.

b Under this condition, remove the load to bring the engine into no-load condition. Do not move the speed control lever.

c The engine speed will increase once and decrease and settle at a new steady state level as shown. Read the highest speed (N_2) occurring in this transition and the speed (N_3) after settling, and the time (t_1) from the moment of removing the load at the initial speed (N_1) to the settling at the new level (N_3).

2) Speed regulation upon applying load

With the engine running under no-load condition subsequent to the condition mentioned in (b), [1], above, and with the speed control lever held in the same position as above, apply the prescribed load instantaneously to the engine: the engine speed will decrease once and increase, as shown, and settle at a new steady state level. Read the lowest speed (N_5) occurring in this transition and the speed (N_6) after settling, and the time (t_2) from N4 to N_6.

3) Calculate the speed regulation

From the values obtained in [1] and [2], above, compute the speed regulation for each load change. A total of four percent values of speed regulation are to be determined by using the indicated formulas.

If the computer values are at variance with the prescribed values, “governor notch adjustment” should be made to eliminate the variance.

6. Setting no-load maximum speed (make governor notch adjustment)

1) This adjustment is to be made by turning the adjusting screw for the swivel lever to increase or decrease the preload of the governor spring.
2) To gain access to the adjusting screw, remove the plug at the top of the governor housing. Turn the speed control lever all the way to the low idle position: this will turn up the swivel lever, pointing the head of the adjusting screw toward the plug hole. Insert a flat-tip screwdriver through the hole to catch the screw head.
3) Tightening the adjusting screw will increase the preload of the governor spring to narrow the speed regulation; loosening it will

decrease the preload to widen the regulation. One notch corresponds to 1/4 turn of the adjusting screw and to 3 to 5 speed change of the engine speed.

4) Changing the setting of this adjusting screw changes the governor setting (for limiting the maximum speed). After making a governor notch adjustment, be sure to readjust the governor setting, as explained in (4), above.
5) Tightening the adjusting screw, mentioned above, will increase the maximum speed, and vice versa.

⚠ CAUTION

Never loosen the adjusting screw by more than 20 notches (5 turns) from the fully tightened position, or the control action of the governor will become hazardous.

7. Seal the set bolts.

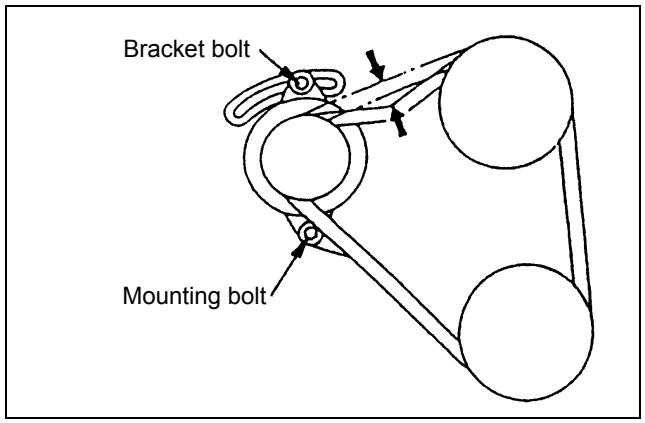


Figure 16 Checking V-belt

10.5 V-belt Inspection and Adjustment

Push the belt inward with thumb pressure exerted midway between the pulleys, as shown, to check the belt tension (deflection). If the tension is incorrect, loosen the adjusting bracket bolt and mounting bolt, and move the alternator in or out.

Unit: mm [in.]

Item	Assembly Standard
V-belt deflection	12 [0.5]

11 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:

11.1 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 15 seconds to permit lubricating oil to circulate through the engine. For this cranking, do not supply fuel to the engine, placing the stop lever in stop position.
3. Move the speed control lever slightly in the direction of increasing fuel injection, and turn the starter switch to START to start the engine. Do not move the control lever to the “full fuel injection” position.
4. After the engine starts, let it idle under no load by operating the speed control lever.

11.2 Inspection After Starting Up

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

1. Lubricating oil pressure should be 0.3 to 0.5 MPa (3 to 5 kgf/cm^2) [43 to 71 psi] at rated speed or 0.1 MPa (1 kgf/cm^2) [14.2 psi] at idling speed.
2. Coolant temperature should be 75 to 85°C [167 to 185°F].
3. Lube oil temperature should be 60°C to 95°C [140°F to 203°F]. (Varies according to engine specifications.)
4. Check for leakage of oil, coolant, fuel, especially oil leakage from oil pipe connections for turbocharger lubrication.
5. Knocking should die away as coolant temperature rises. No other defective noise should be heard.
6. Check for exhaust color and abnormal odors.

11.3 Bench Testing (Dynamometer) Conditions

Step	Speed (rpm)	Load (PS)	Time (min.)
1	1000	No-load	30
2	1500	25%	30
3	(According to engine specification)	25%	10
4		50%	10
5		75%	30
6		100%	20

11.4 Inspection and Adjustments After Bench Testing

1. Adjusting valve clearance
2. Adjusting injection timing
3. Re-tightening external bolts and nuts

12 PERFORMANCE TESTS

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

12.1 Engine Equipment Condition

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

12.2 Tests and Their Purposes

1. Operation load test

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

2. Continuous load test

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

3. No-load minimum idle speed test

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

12.3 Other Inspections

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

12.4 Adjustment Engine Output

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

1. Standard atmospheric conditions

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

2. Calculation of corrected power

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

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

   1) Atmospheric conditions for test

      Temperature (T): 283 K (10ºC) [50ºF] ≤ T ≤ 313 K (40ºC) [104ºF]

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

3. Calculation of correction factor (αc)

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

   fa: Atmospheric factor

   fm: Engine factor

   1) Calculation of atmospheric factor (fa)

   a Natural aspiration engine and engine with mechanically driven air charger

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

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

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

   c Turbocharged engine with air-to-liquid cooler

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

   2) Calculation of engine factor (fm)

   $$fm = 0.036\ qc - 1.14$$

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

   $$q = \frac{(z) \times (\text{Fuel flow rate g/s})}{(\text{Stroke volume } l) \times (\text{Engine idle speed rpm})}$$

   z = 120000 (4-cycle engine)

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

b Applicable range of engine factor (fm)

$37.2 \leq qc \leq 65$ mg/(ℓ-cycle)

- $qc \leq 37.2$ mg/(ℓ-cycle) : fm = 0.2 (Constant)
- 65 mg/(ℓ-cycle) $\leq qc$: fm = 1.2 (Constant)

3) Range of correction equation use

The range of correction factor (αc) use is as follows: $0.9 \leq \alpha c \leq 1.1$.

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

ENGINE AUXILIARIES REMOVAL AND INSTALLATION

13 PREPARATION

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

1. Shut off the fuel supply, and disconnect the starting system from the engine.
2. Loosen the drain plugs on the left-rear side of crankcase, and drain coolant.
3. Loosen the oil pan drain plug and drain engine oil.

⚠ WARNING

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

NOTE

Check the drained oil for contamination.

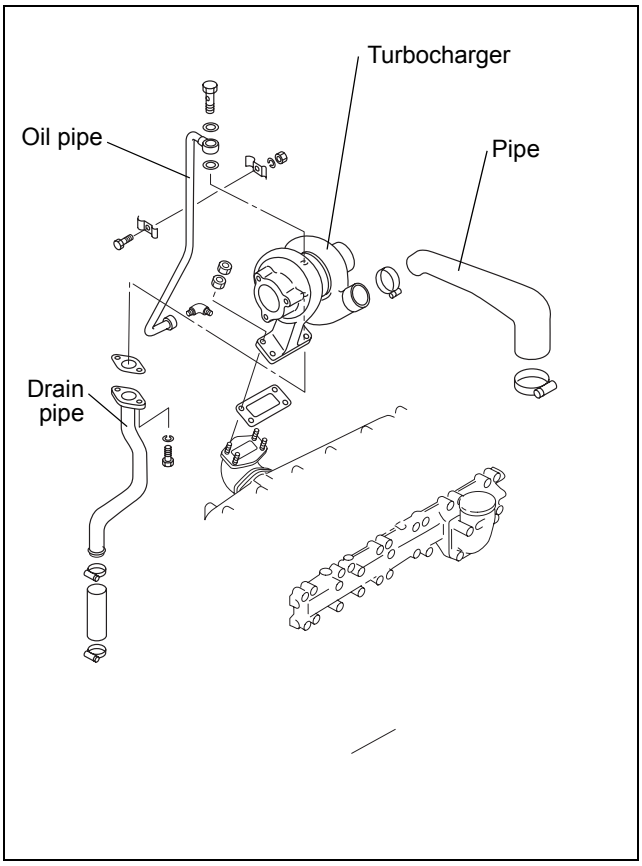


Figure 17 Removing turbocharger

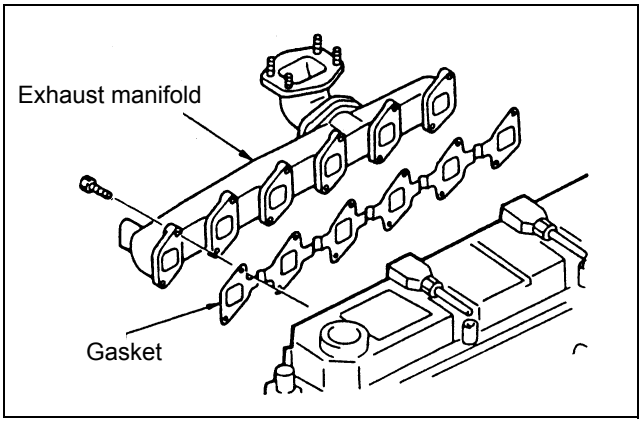


Figure 18 Removing exhaust manifold

14 ENGINE AUXILIARIES REMOVAL

1. Turbocharger (engines with turbocharger)

   1) Disconnect pipe from the turbocharger and inlet manifold.
   2) Disconnect oil pipe and drain pipe from the turbocharger.
   3) Remove turbocharger from the exhaust manifold.

2. Exhaust manifold

   Remove the bolts that hold exhaust manifold to the cylinder head. Remove the manifold and gasket from the head.

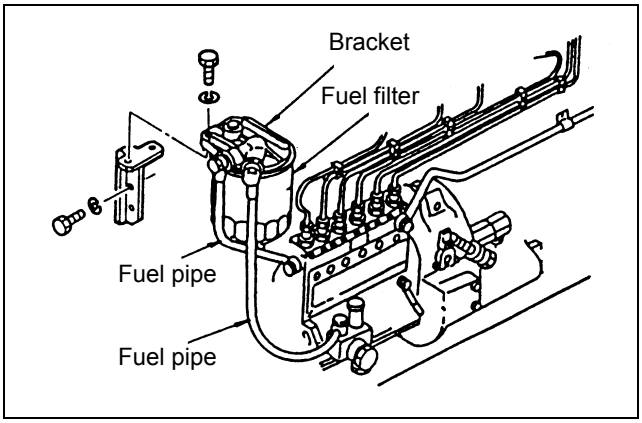


Figure 19 Removing fuel filter

3. Fuel filter

   1) Disconnect fuel pipes and from the fuel filter.
   2) Remove fuel filter complete with bracket from the inlet manifold.

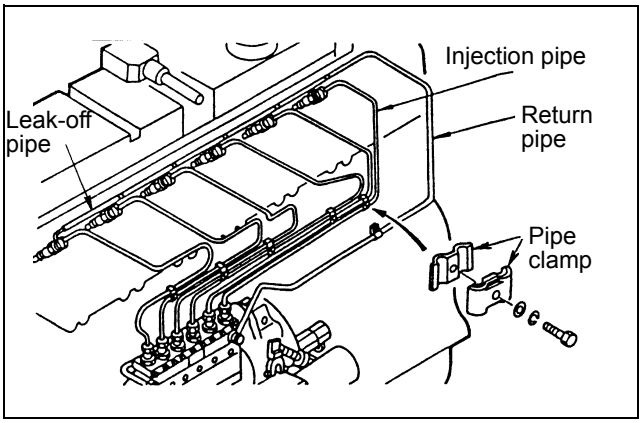


Figure 20 Removing fuel injection pipes

4. Fuel injection pipes

   1) Remove pipe clamps and disconnect injection pipes from the injection pump and nozzle holders.
   2) Disconnect leak-off pipe.
   3) Disconnect return pipe.

⚠ CAUTION

Be sure to put rubber caps over the openings of the injection pump and nozzle holders to prevent dust from getting inside the fuel system.

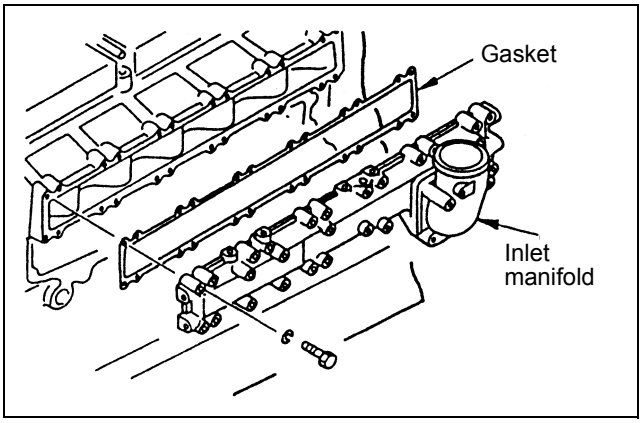


Figure 21 Removing inlet manifold

5. Inlet manifold

   Remove the bolts that hold inlet manifold to the cylinder head. Remove the manifold and gasket from the cylinder head.

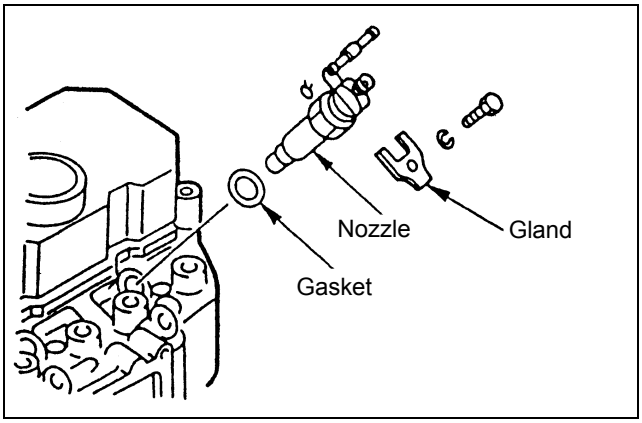


Figure 22 Removing fuel injection nozzles (direct injection type)

6. Fuel injection nozzles (direct injection type)

   Remove gland, then remove nozzle and gasket from the cylinder head.

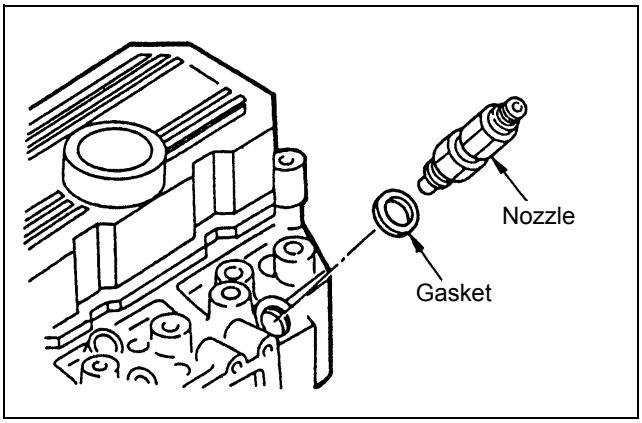


Figure 23 Removing fuel injection nozzles (swirl chamber type)

7. Fuel injection nozzles (swirl chamber type)

   Remove nozzle and gasket.

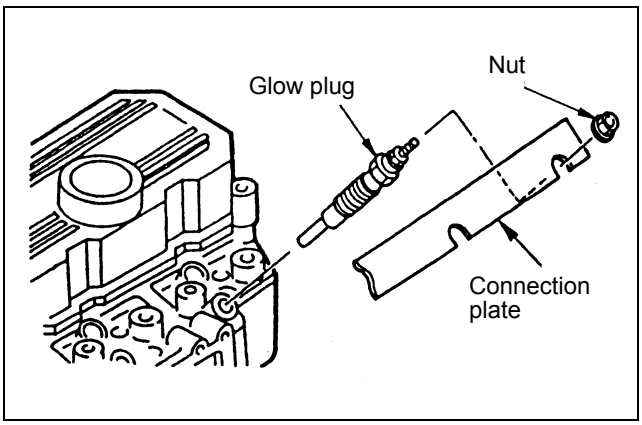


Figure 24 Removing glow plugs (direct injection type)

8. Glow plugs (direct injection type)

   Remove nuts, then remove connection plate and glow plug.

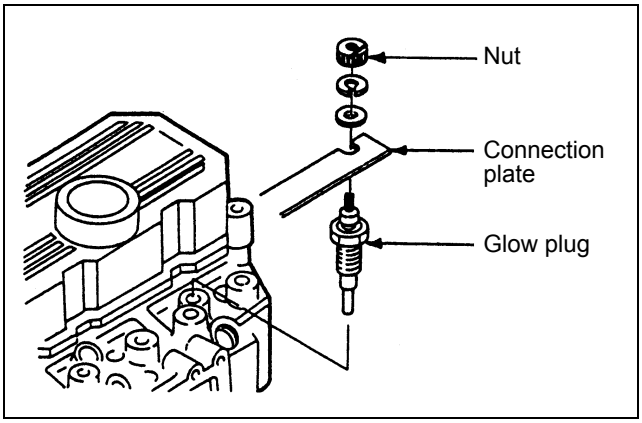


Figure 25 Removing glow plugs (swirl chamber type)

9. Glow plugs (swirl chamber type)

   Loosen nuts, then remove connection plate and glow plug.

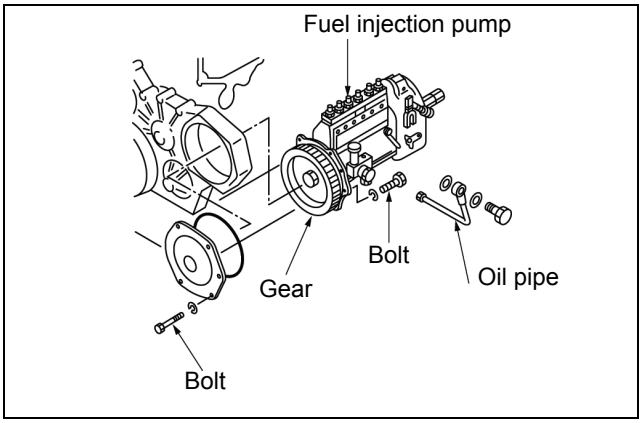


Figure 26 Removing fuel injection pump

10. Fuel injection pump

    1) Remove oil pipe.
    2) Remove bolts that hold the gear case cover.
    3) Remove bolts that hold the flange plate. Remove pump with gear and flange from the front plate. (Some engines are not equipped with pump bracket.)

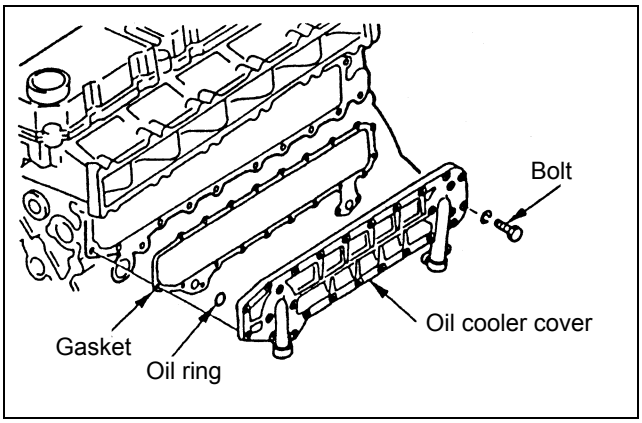


Figure 27 Removing oil cooler

11. Oil cooler (engines with oil cooler)

    Remove bolts that hold oil cooler cover to the crankcase. Remove the cooler, complete with the cover, from the crankcase. Remove gasket and O-ring.

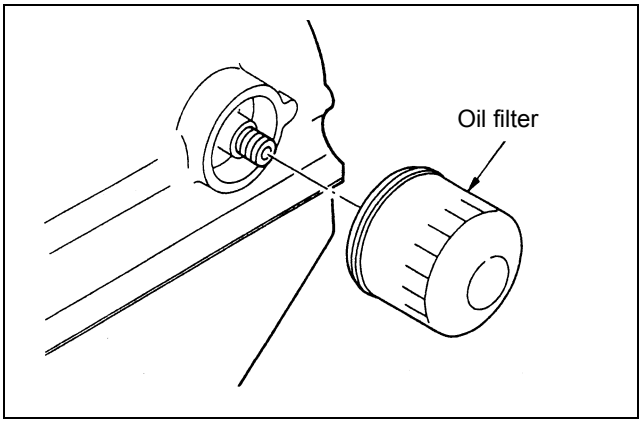


Figure 28 Removing oil filter

12. Oil filter

    Remove oil filter with a filter wrench.

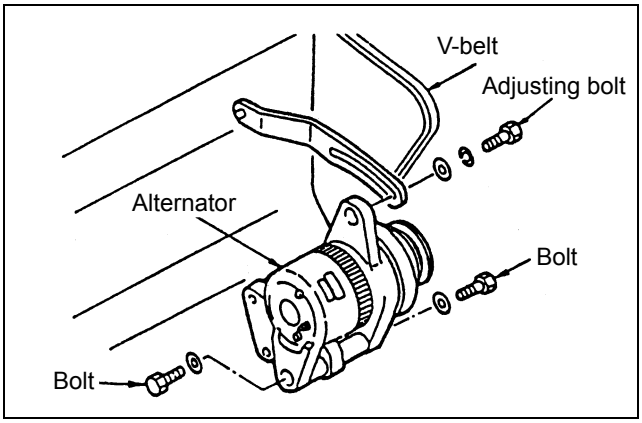


Figure 29 Removing alternator

13. Alternator

    1) Disconnect harness from alternator. Remove adjusting bolt.
    2) Remove bolts to remove the alternator.
    3) Remove V-belt.

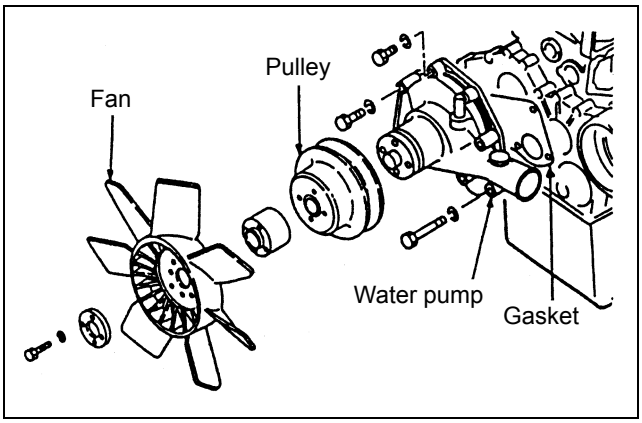


Figure 30 Removing water pump

14. Water pump

    1) Remove the bolts that hold fan and pulley and remove them.
    2) Remove the bolts that hold water pump and remove the pump and gaskets.

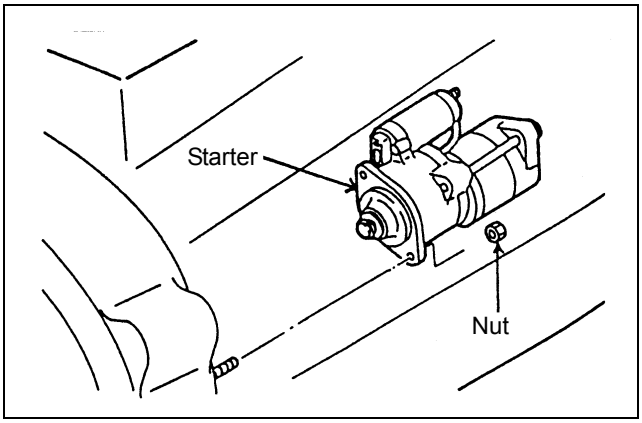


Figure 31 Removing starter

15. Starter

    Disconnect harness from starter. Remove nuts to remove the starter.

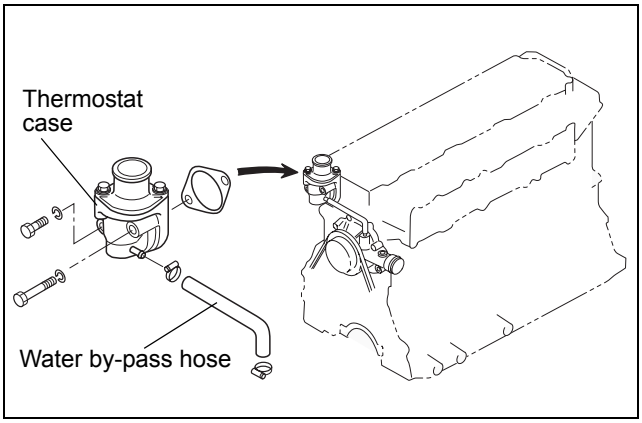


Figure 32 Removing thermostat

16. Thermostat

    1) Remove water by-pass hose.
    2) Remove the bolts that hold thermostat case to remove the termostat case.

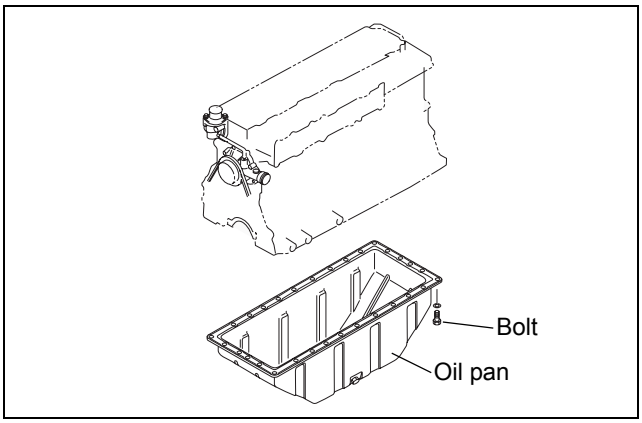


Figure 33 Removing oil pan

17. Oil pan

    Remove bolts to remove oil pan.

15 ENGINE AUXILIARIES INSTALLATION

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

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

ENGINE MAIN PARTS

16 CYLINDER HEADS AND VALVE MECHANISM

16.1 Disassembly

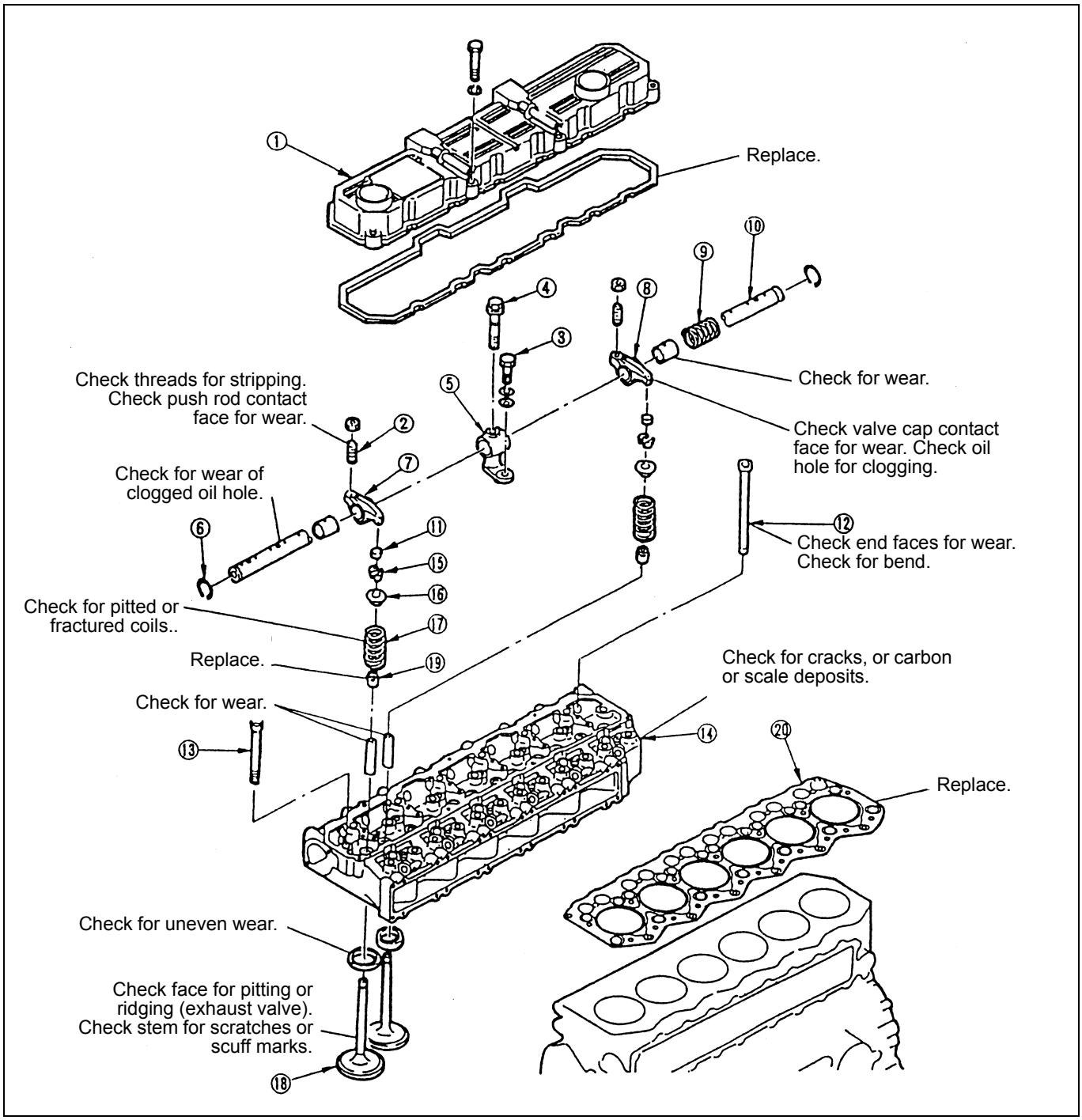


Figure 34 Disassembly sequence

1. Rocker cover
2. Adjusting screw
3. Bolt (short)
4. Bolt (long)
   Remove 5 through 10 as an assembly
5. Rocker shaft bracket

6. Snap ring
7. Inlet valve rocker arm
8. Exhaust valve rocker arm
9. Rocker shaft spring
10. Rocker shaft
11. Valve cap
12. Valve pushrod
13. Cylinder head bolt
    Remove 14 through 19 as an assembly
14. Cylinder head
15. Valve cotter
16. Valve retainer
17. Valve spring
18. Valve
19. Valve stem seal
20. Cylinder head gasket

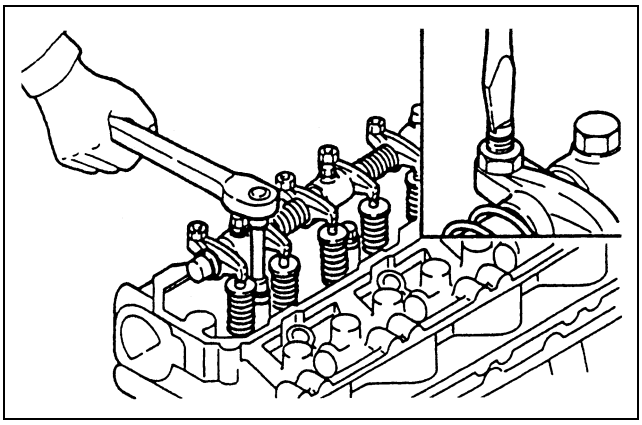


Figure 35 Removing rocker shaft assembly

1. Removing rocker shaft assembly

    1) Loosen the adjusting screw one turn.

    2) Loosen the bolts, long and short, that hold the rocker shaft bracket to the cylinder head. Be sure to loosen the short bolt first. Remove the rocker shaft assembly from the cylinder head.

⚠ CAUTION

If the long bolt is loosened first, the rocker shaft bracket might suffer damage.

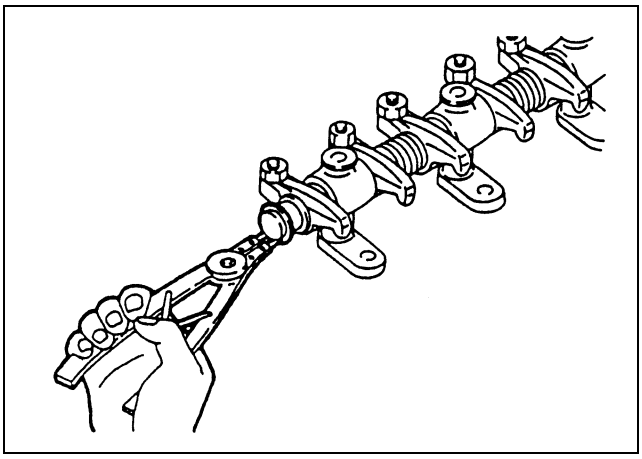


Figure 36 Disassembling rocker shaft assembly

2. Disassembling rocker shaft assembly

    Put a mark on the rocker arm and shaft so that the arm can be installed on the same shaft position from which it was removed.

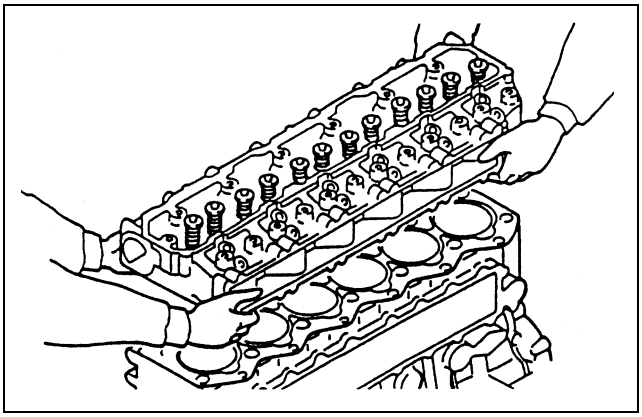


Figure 37 Removing cylinder head

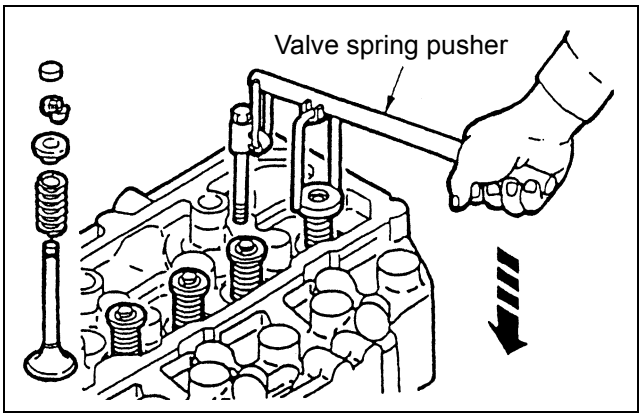


Figure 38 Removing valve and valve spring

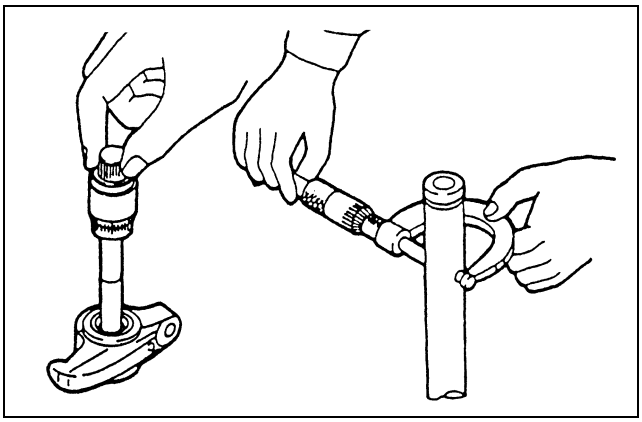


Figure 39 Measuring rocker arm bushing and rocker shaft

3. Removing cylinder head

   1) Remove the cylinder head bolts.

   2) Lift the head off the crankcase.

NOTE

a. When removing the gasket from the crankcase, be careful not to damage the gasket contact surface of the crankcase.
b. If any cylinder head parts are faulty, check the cylinder head bolts for torque with a torque wrench before removing them.

4. Removing valve and valve spring

   1) Use valve spring pusher (30691-04500) to compress the valve spring squarely, then remove the valve cotters.

   2) Remove the valves and valve springs.

NOTE

If the original valves are to be reused, mark them for their locations to ensure the original location and combinations of the valve, valve seat and valve guide.

16.2 Inspection

16.2.1 Rocker arms, rocker bushings and rocker shafts

1. Measuring rocker arm bushing and rocker shaft

   Measure the inside diameter of the rocker bushing and the diameter of the rocker shaft as shown in the illustration. Determine the clearance between the bushing and shaft on the basis of the measurements. If the clearance does not exceed the repair limit, replace the rocker arm. If it exceeds the repair limit, replace the shaft and rocker arm.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Repair Limit
Inside diameter of rocker bushings	19 [0.75]	19.010 to 19.030 [0.7484 to 0.7492]	
Diameter of rocker shaft		18.980 to 19.000 [0.7472 to 0.7480]	
Clearance between rocker bushing and shaft		0.010 to 0.050 [0.0004 to 0.0020]	0.070 [0.0028]

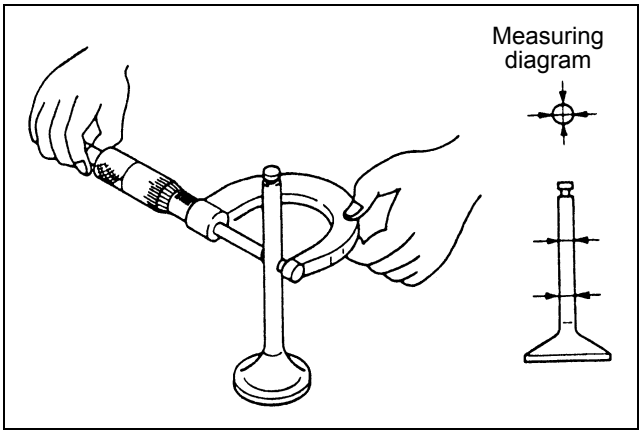


Figure 40 Measuring valve stem

16.2.2 Valves, valve guides and valve seats

1. Measuring valve stem

   Measure the diameter of the valve stem as shown in the illustration. If the stem is worn beyond the service limit or unevenly worn excessively, replace the valve.

Unit: mm [in.]

Item		Nominal Value	Assembly Standard	Service Limit
Diameter of valve stem	Inlet valve	8 [0.31]	7.940 to 7.955 [0.3126 to 0.3132]	7.900 [0.3110]
	Exhaust valve		7.920 to 7.940 [0.3118 to 0.3126]	7.850 [0.3091]

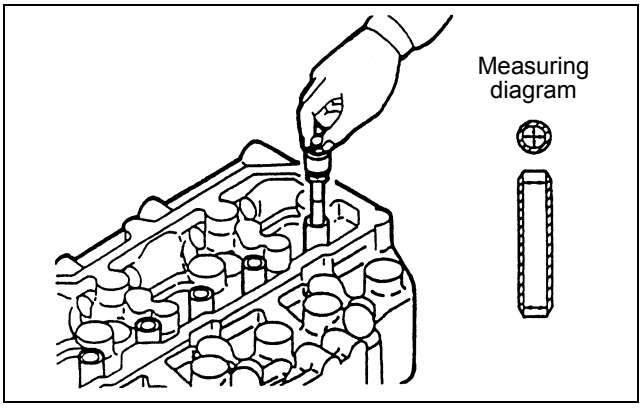


Figure 41 Measuring valve guide

2. Checking clearance between valve stem and valve guide

   The valve guide wears more rapidly at its both ends than at any other parts. Measure the inside diameter of the guide at its ends as shown in the illustration to determine the clearance between the guide and stem. If clearance exceeds the service limit, replace the valve or guide whichever is excessively worn.

Unit: mm [in.]

Item		Nominal Value	Assembly Standard	Repair Limit
Clearance between valve stem and guide	Inlet valve	—	0.065 to 0.095 [0.0026 to 0.0037]	0.150 [0.0059]
	Exhaust valve	—	0.080 to 0.115 [0.0032 to 0.0045]	0.200 [0.0079]
Height to top of valve guide		11.5 [0.45]	±0.1 [±0.004]	

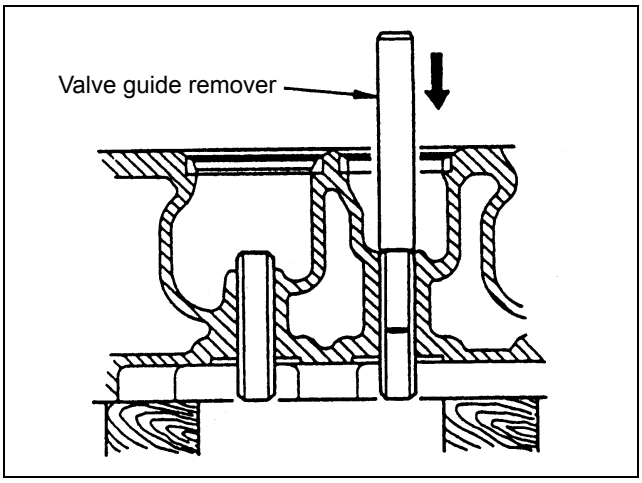


Figure 42 Removing valve guide

3. Replacing valve guide

1) Use the valve guide remover (32A91–00300), to remove the valve guide for replacement.

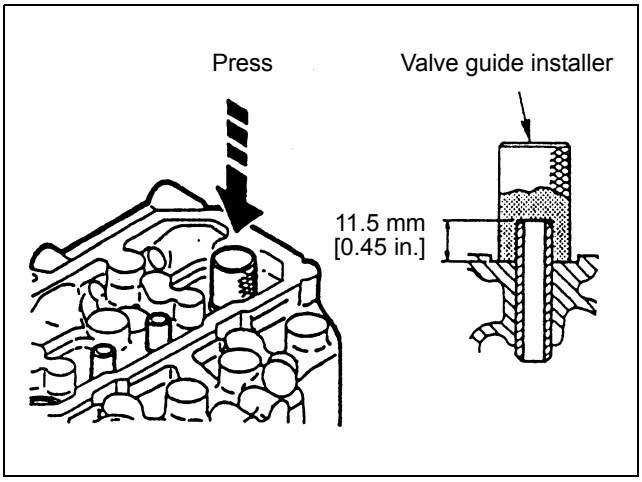


Figure 43 Installing valve guide

2) To install a replacement guide, use valve guide installer (32A91-00100).

⚠ CAUTION

The installation depth for the valve guide is specified; be sure to use the valve guide installer to insure the correct depth.

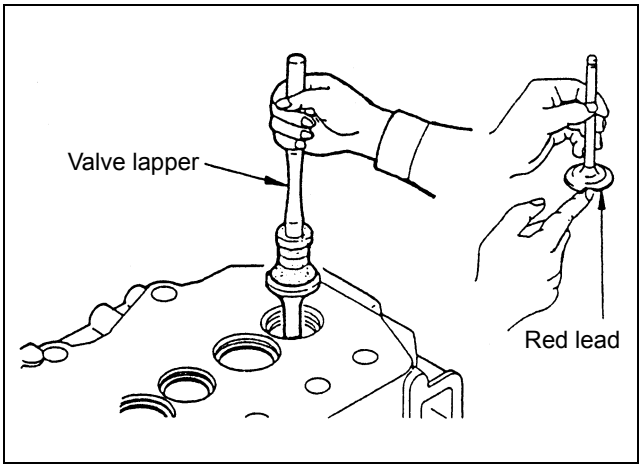


Figure 44 Inspecting valve face

4. Inspecting valve face

Coat the valve face lightly with red lead. Use the Valve lapper to inspect the valve contacts with its seat. If the contact is not uniform, or if the valve is defective or if the service limit is exceeded, repair or replace the valve and valve seat.

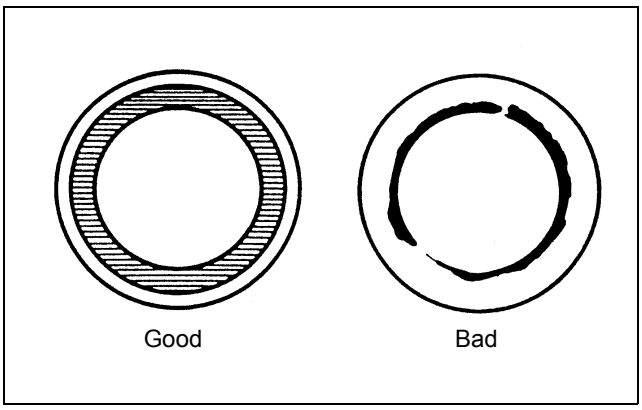


Figure 45 Valve contact pattern

NOTE

a. Inspect the valve face after the inspection or replacement of the valve guide.
b. Do not rotate the valve when checking its contact.
c. After refacing or replacing the valve or the valve seat, be sure to lap the valve in the seat. (See (8) Valve lapping.)

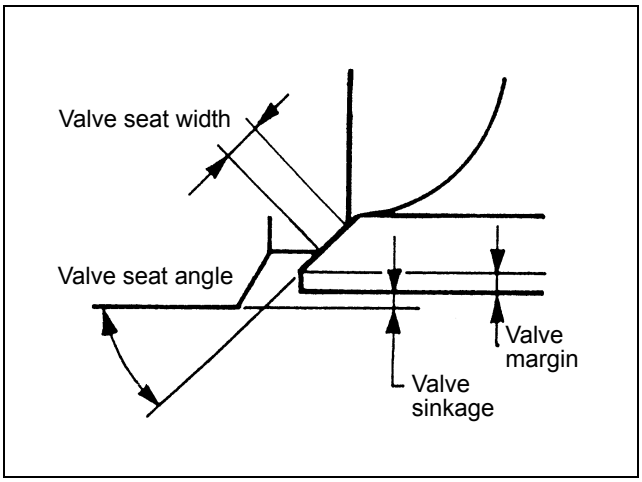


Figure 46

Unit: mm [in.]

Item			Assembly Standard	Repair Limit
Valve seat	Angle		30°	—
	Valve sinkage	Inlet valve	0.4 ± 0.1 [0.016 ± 0.004] (inlet)	1.0 [0.039]
		Exhaust valve	0.5 ± 0.1 [0.020 ± 0.004] (exhaust)	
	Width		1.4 ± 0.14 [0.055 ± 0.0055]	1.8 [0.071]
Valve margin			2.13 [0.0839]	Up to 1.83 [0.0720] by refacing

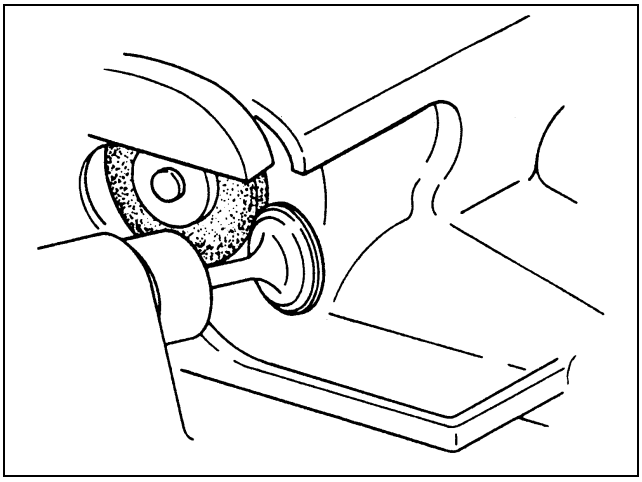


Figure 47 Refacing valve face

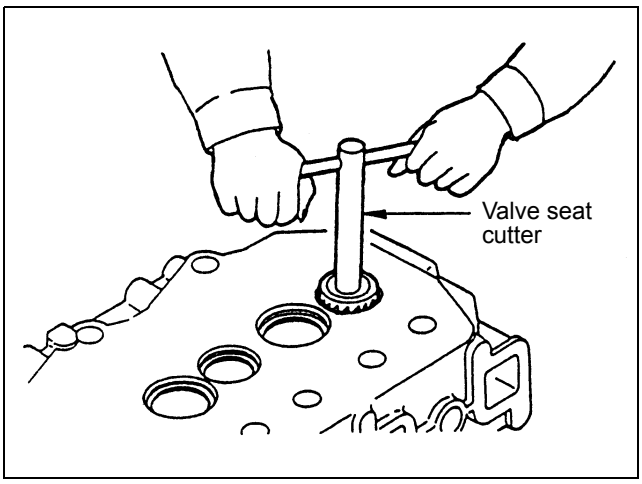


Figure 48 Refacing valve seat

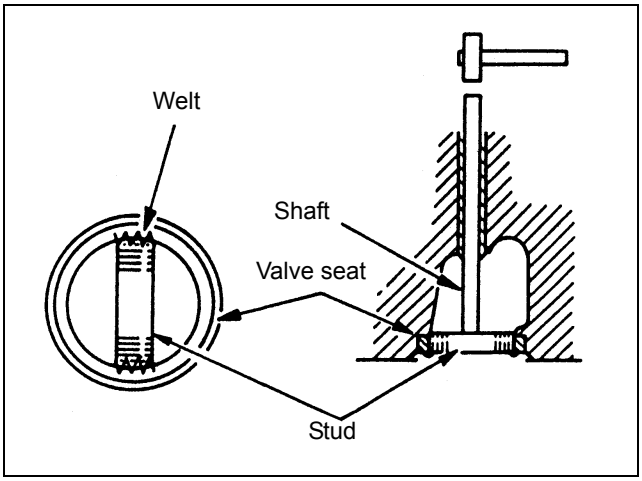


Figure 49 Removing valve seat

5. Refacing valve face

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

NOTE

a. Set a valve refacer to an angle of 30°
b. The valve has a stellate facing. This facing will be gone if the valve margin exceeds the service limit. If the margin seems to be less than the service limit when ground, replace the valve.

6. Refacing valve seat

   Use the Valve seat cutter or valve seat grinder to reface the valve seat. After refacing, grind the seat lightly using #400 grade sandpaper inserted between the cutter and valve seat.

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.

7. Replacing valve seat

   1) 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 from the cylinder head as shown.

NOTE

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

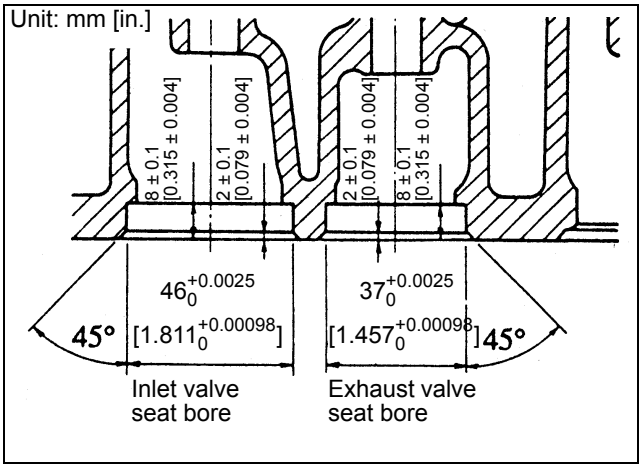


Figure 50 Valve seat dimensions

2) Before installing replacement valve seats in the cylinder head, measure the bores in the cylinder head for the valve seats.

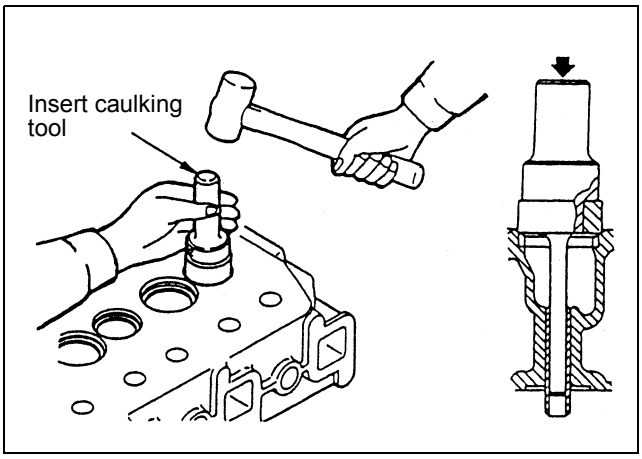


Figure 51 Installing valve seat

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

4) Using insert caulking tool, drive the seat into position.

Tools needed

Insert caulking tool (for inlet valve seat)	36791-00200
Insert caulking tool (for exhaust valve seat)	34491-03020

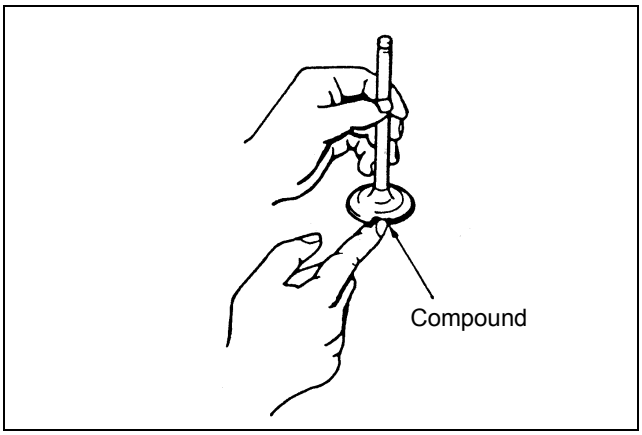


Figure 52 Coating valve with lapping compound

8. Lapping valve in valve seat

Be sure to lap the valve in the valve seat after the valve or the seat have been replaced.

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

NOTE

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

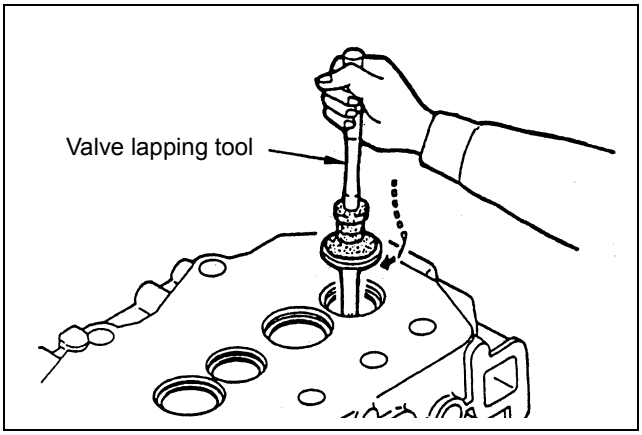


Figure 53 Lapping valve in valve set

2) Using lapping tool, hold the valve against the seat and rotate it only a part of a turn, then raise the valve off the seat, rotating it to a new position. Then press the valve against the seat for another part of a turn. Repeat this operation until the compound wears and loses it cutting particle.

3) Wash off the compound with diesel fuel.

4) Apply the valve face to the engine oil, and again lap the valve.

5) Check the valve face for contact.

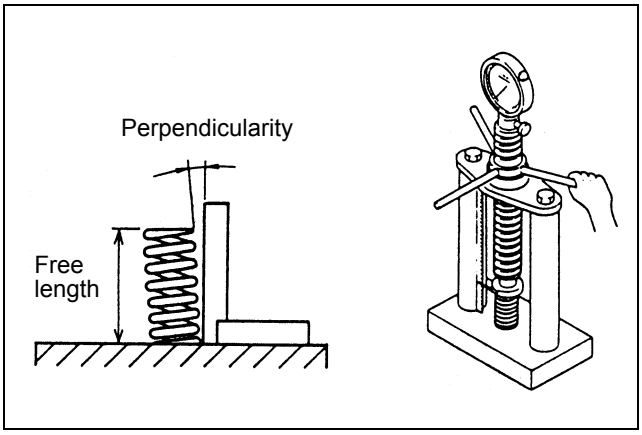


Figure 54 Measuring valve spring perpendicularity and free length

9. Measuring valve spring perpendicularity and free length

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

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Free length	48.85 [1.92]	47.60 [1.87]
Perpendicularity	1.5° or less	—
Set length	43 [1.69]	—
Set force N (kgf) [lbf]	176 to 196 (18-20) [40 to 44]	147 (15) [33]

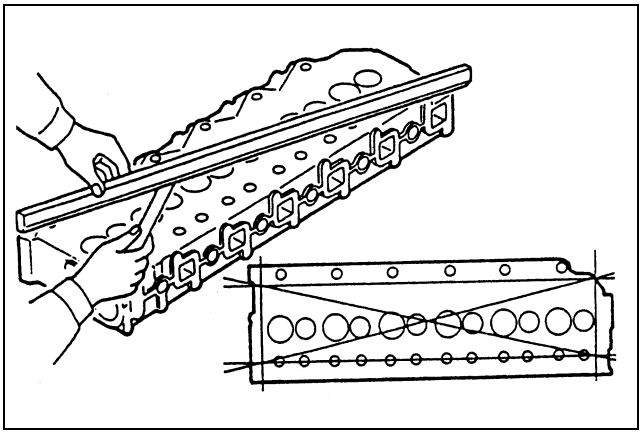


Figure 55 Measuring cylinder head warpage

10. Measuring cylinder head warpage

Using a heavy accurate straight edge and feeler gages, check the gasket contact surface for warpage in two positions lengthwise, two crosswise and two widthwise as shown in the illustration. If the warpage exceeds the repair limit, reface the head with a surface grinder.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Warpage of gasket contact surface	0.05 [0.0020] or less	0.20 [0.0079]

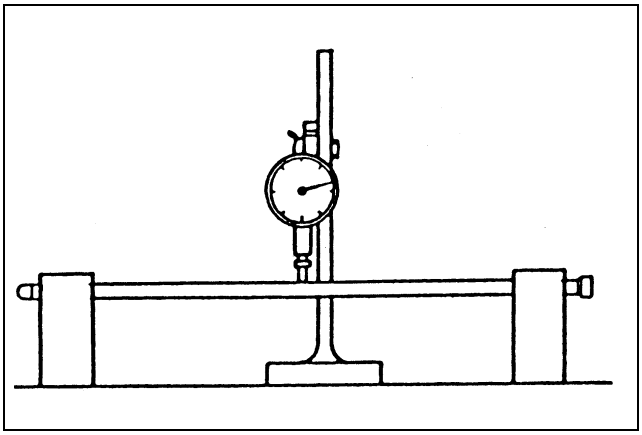


Figure 56 Measuring valve pushrod deflection

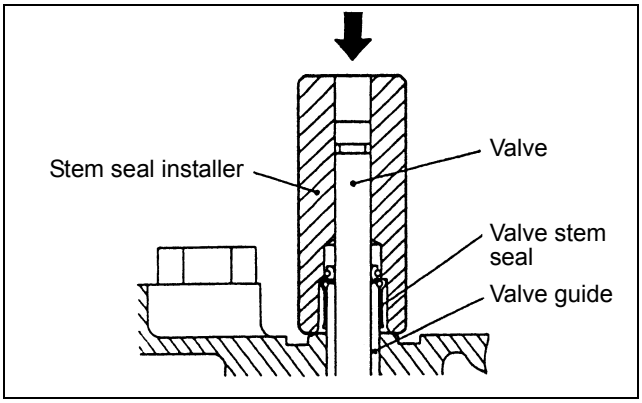


Figure 57 Installing valve stem seal

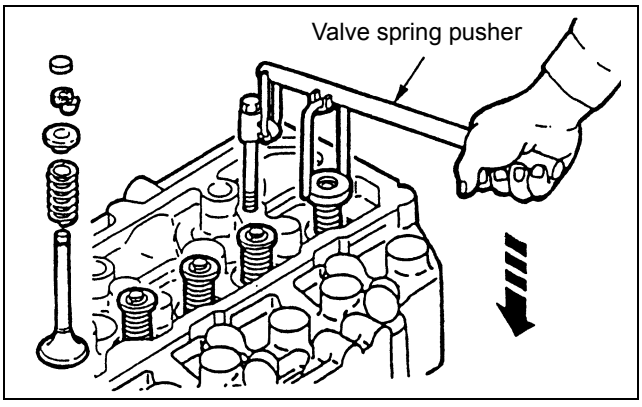


Figure 58 Installing valve and valve spring

11. Measuring valve pushrod deflection

    Measure the pushrod deflection with a V-block and a dial indicator as shown in the illustration. If the dial indicator reading exceeds the assembly standard, replace the pushrod.

Unit: mm [in.]

Item	Assembly Standard
Deflection (dial indicator reading) of valve pushrod	0.3 [0.012] or less

16.3 Reassembly

1. Installing valve stem seal

   After installing the valve in position, install the seal to the valve guide with stem seal installer (32A91–10200).

⚠ CAUTION

a. Do not put any oil or sealant on the face of the stem seal that comes in contact with the valve guide. When installing the seal, put engine oil on the seal contact surface of the stem to ensure initial lubrication of the stem seal lip.
b. Do not remove the valve after the seal has been installed in position to prevent damage to the seal lip.

2. Installing valve and valve spring

   1) Put the valve spring and retainer on the valve guide. Using valve spring pusher (30691–04500), compress the valve spring and install the valve cotters.

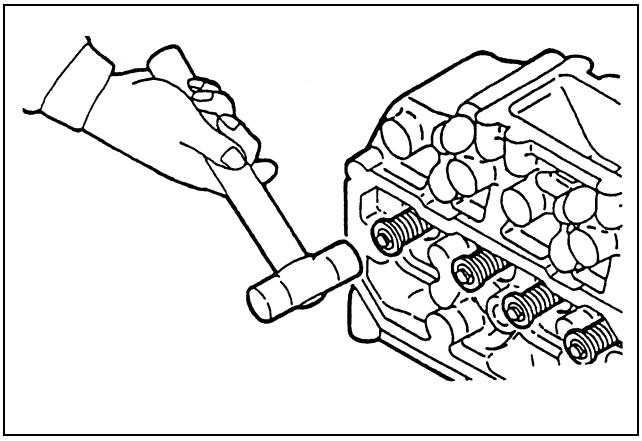


Figure 59 Installing valve cotters

2) Tap the valve stem top with a soft-faced hammer several times to make sure the valve spring and cotters are properly installed.

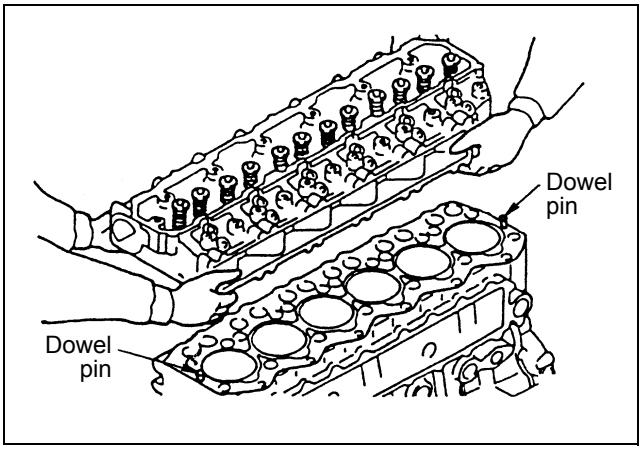


Figure 60 Installing cylinder head

3. Installing cylinder head

1) Put the gasket on the top of the crankcase, making sure the two dowel pins enter their holes in the gasket.
2) Put the cylinder head on the crankcase, making sure the two dowel pins enter their holes in the head. Tighten the head bolts.

⚠ CAUTION

Do not use any sealant. Make sure the gasket contact surface of the crankcase is free from any defects.

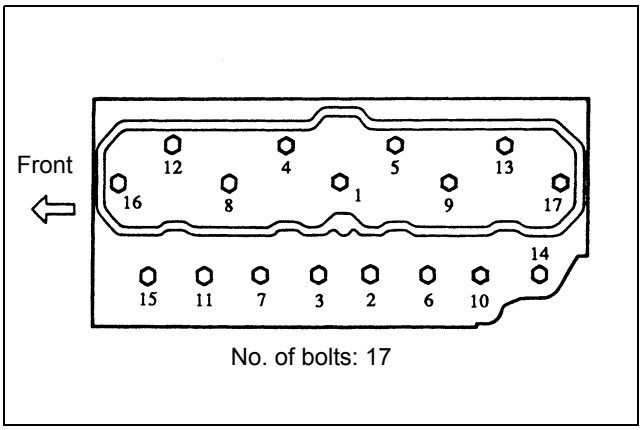


Figure 61 Cylinder head bolt tightening sequence (S4S)

3) Tighten the cylinder head bolts to the specified torque in the sequence shown in the illustration.

Tightening torque for cylinder head bolts	113 to 123 N·m (11.5 to 12.5 kgf·m) [83 to 90 lbf·ft]

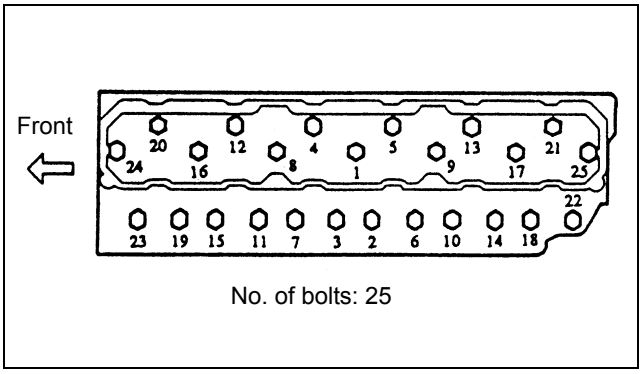


Figure 62 Cylinder head bolt tightening sequence (S6S)

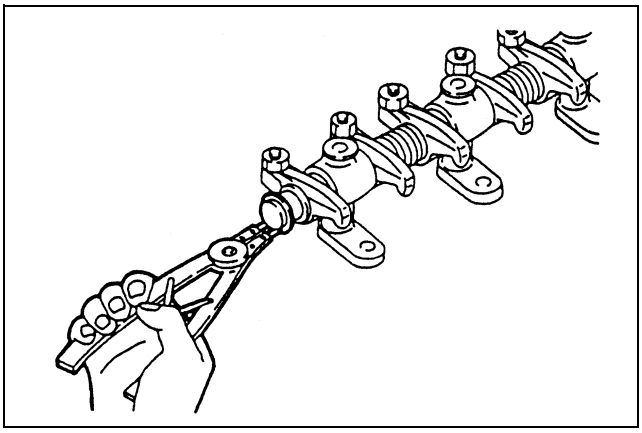


Figure 63 Reassembling rocker shafts

4. Reassembling rocker shafts

   After reassembling the rocker shafts, make sure the rocker arms move smoothly.

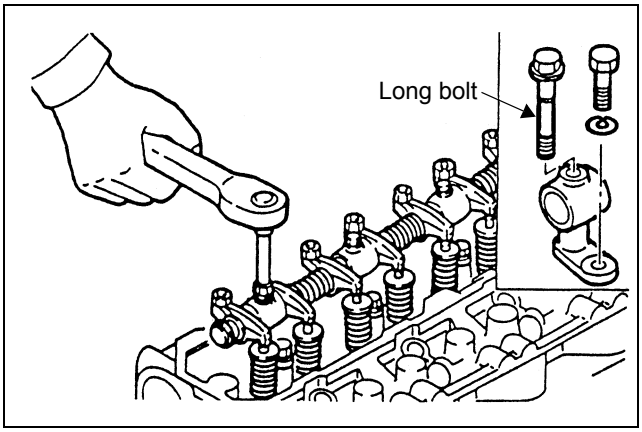


Figure 64 Installing rocker shaft assembly

5. Installing rocker shaft assembly

   1) Install the valve caps in position.

   2) Put the rocket shaft assembly on the cylinder head and tighten the bolts to the specified torque.

Tightening torque for rocker shaft bolts	10.0 to 20.0 N·m (1.0 to 2.0 kgf·m) [7.23 to 14.5 lbf·ft]

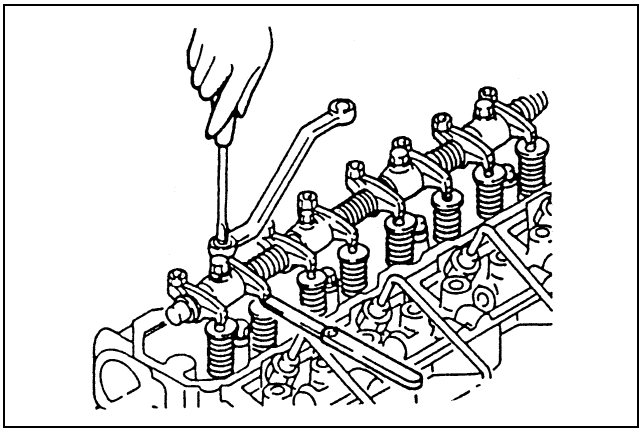


Figure 65 Adjusting valve clearance

6. Adjusting valve clearance

Refer to 1.1, Group 5.

17 FLYWHEEL

17.1 Disassembly

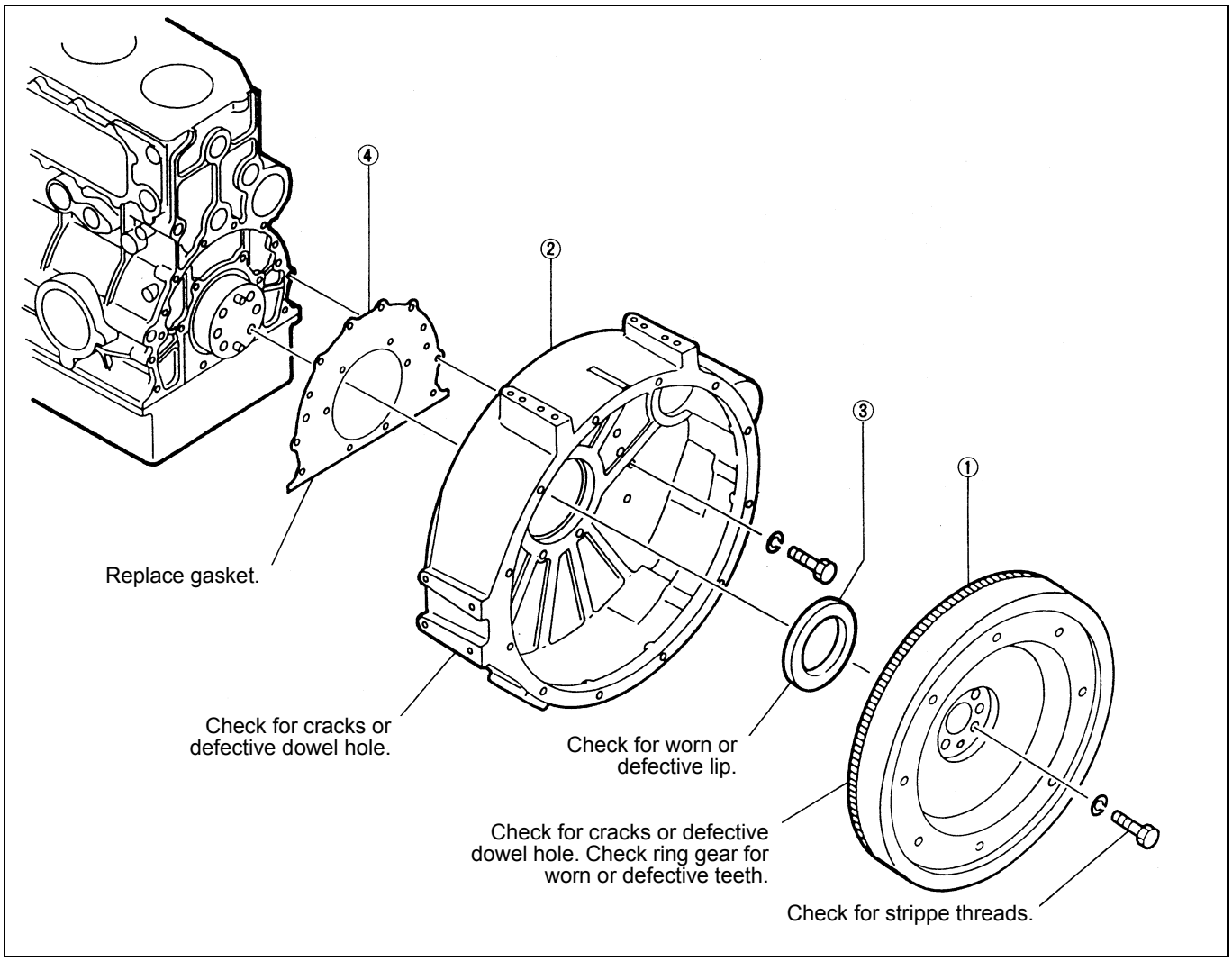


Figure 66 Disassembly sequence

1. Flywheel
   Remove 2 and 3 as an assembly.
2. Flywheel housing
3. Oil seal
4. Rear gasket

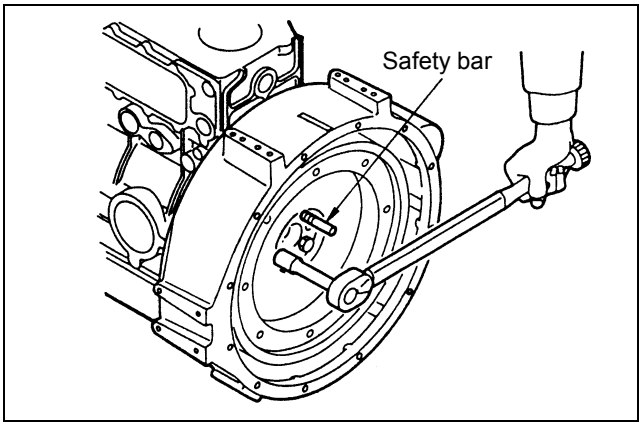


Figure 67 Removing flywheel

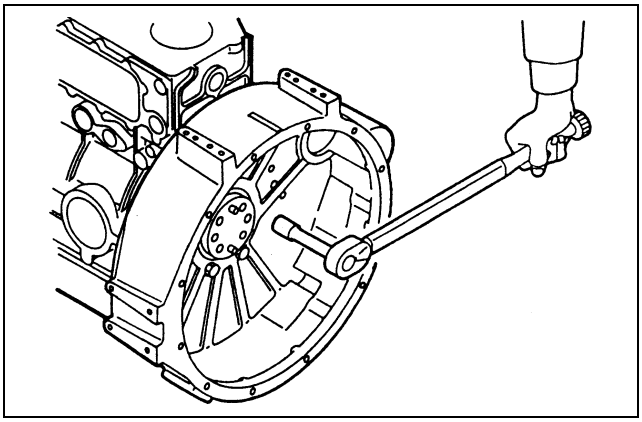


Figure 68 Removing flywheel housing

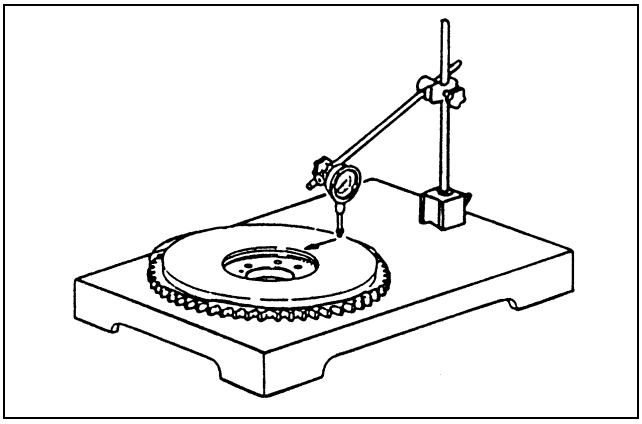


Figure 69 Measuring flywheel flatness

1. Removing flywheel

   1) Remove one of the bolts that hold the flywheel to the crankshaft.
   2) Run safety bar (M12 × 1.25) in the hole from which the bolt was removed in Step (a). Remove the remaining flywheel bolts.
   3) Remove the flywheel from the crankshaft by pulling it straight.

⚠ CAUTION

When removing the flywheel, wear heavy gloves to avoid injury.

2. Removing flywheel housing

   Remove the bolts that hold the flywheel housing to the crankcase. Remove the housing.

⚠ CAUTION

Do not cause damage to the oil seal.

17.2 Inspection

17.2.1 Flywheel and ring gear

1. Flatness (difference between lower and higher measurements) of flywheel

   Put the flywheel on the surface plate. Set a dial indicator at one side of the friction surface and move it over to the opposite side of that surface as shown in the illustration. If the surface flatness is over the repair limit, regrind it.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Flatness of flywheel friction surface	0.15 [0.0059] of less	0.50 [0.020]

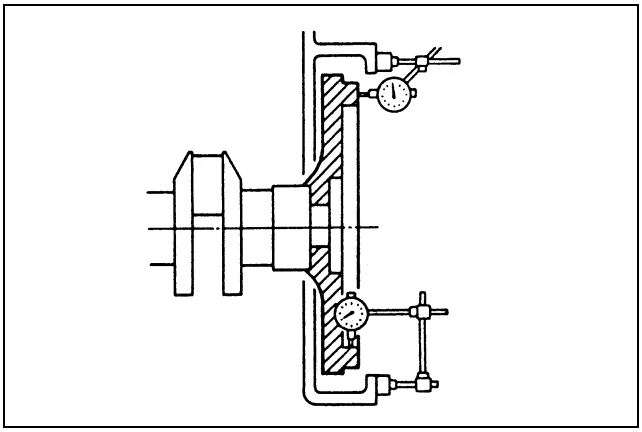


Figure 70 Measuring flywheel runouts

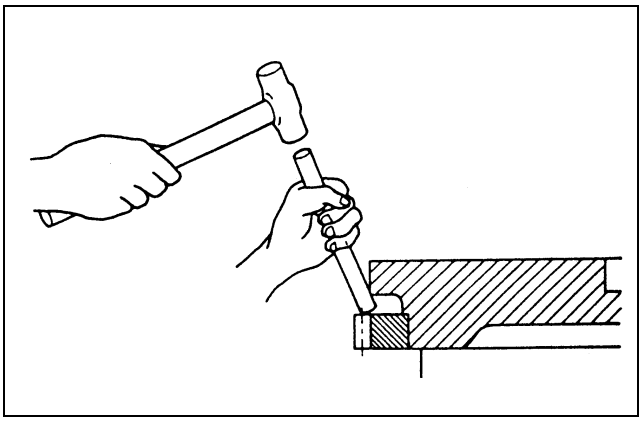


Figure 71 Removing ring gear

2. Face runout and circular runout (radial eccentricity) of flywheel

   Set a dial indicator at the friction (vertical) surface and turn the flywheel one full revolution to check the face runout. Set a dial indicator at the horizontal surface of the pilot bearing bore and turn the flywheel one full revolution to check the circular runout. Excessive runout of the flywheel in either position will probably be caused by dirt in the mounting face or improper tightening of the bolts.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Face and bore runouts of flywheel	0.15 [0.0059] of less	0.50 [0.020]

3. Ring gear replacement

   Check the ring gear teeth and, if they are defective, replace the gear as outlined below.

(Removal)

1) Heat the ring gear evenly with an burner.
2) Hit the ring gear all the way around with a bar and a hammer to remove it.

(Installation)

Heat a replacement ring gear up to 100°C [212°F] with a heater, and install the gear to the flywheel placing the unchamfered side of the teeth to the flywheel.

NOTE

Do not heat the ring gear excessively.

17.3 Reassembly

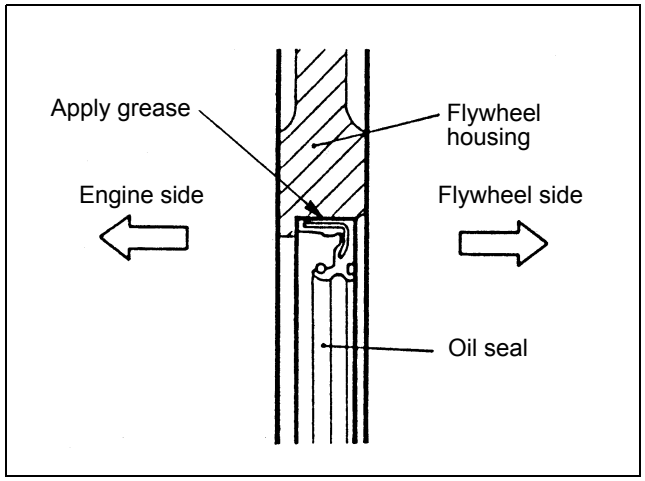


Figure 72 Installing oil seal

1. Installing oil seal (According to engine specification)

   Apply a thin coat of grease to the oil seal and install the oil seal to the flywheel housing with an installer.

NOTE

If the oil seal contact surface of the crankshaft is excessively worn, use an oil seal with sleeve.

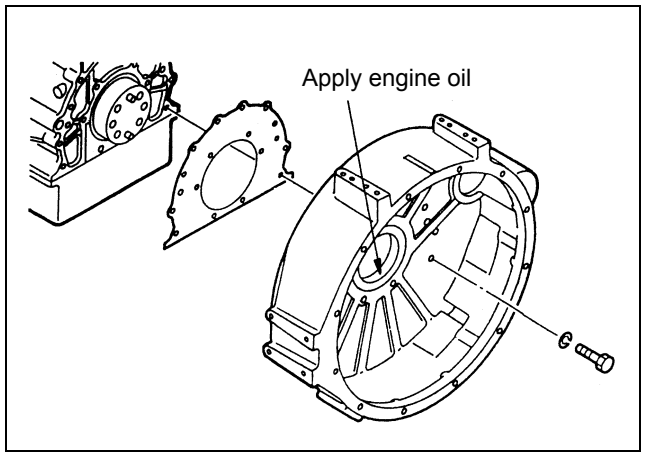


Figure 73 Installing flywheel housing

2. Installing flywheel housing

   1) Put the new rear gasket in position.
   2) Apply engine oil to the oil seal lip.
   3) Install the flywheel housing, making sure the dowels enter their holes, and tighten the bolts.

NOTE

Install the starter to the housing to facilitate installation work.

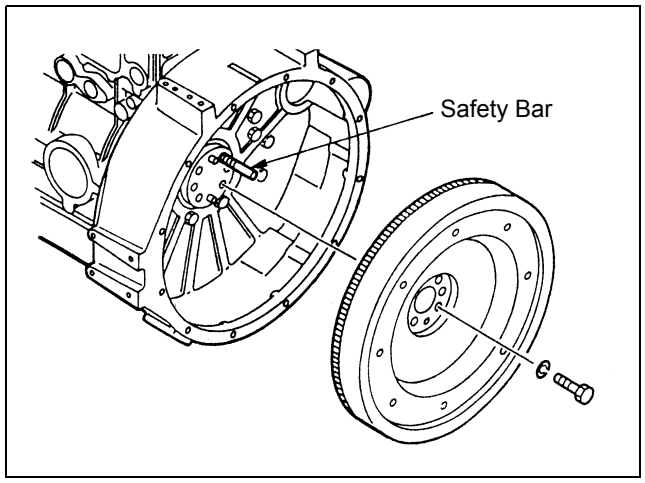


Figure 74 Installing flywheel

3. Installing flywheel

   1) Install safety bar (M12 × 1.25) in the rear end of the crankshaft.
   2) Install the flywheel to the crankshaft, making sure the safety bar enters the hole in the flywheel.
   3) Tighten the bolts (five) finger tight only.
   4) Remove the safety bar and install the last one bolt.
   5) Have someone hold the crankshaft pulley nut with a wrench.
   6) Tighten the bolts that hold the flywheel to the specified torque.

Tightening torque for flyweel bolts	78.5 to 88.3 N·m (8.0 to 9.0 kgf·m) [57.9 to 65.1 lbf·ft]

⚠ CAUTION

During installation, signal to each other to avoid personal injury.

18 DAMPER, TIMING GEARS AND CAMSHAFT

18.1 Disassembly

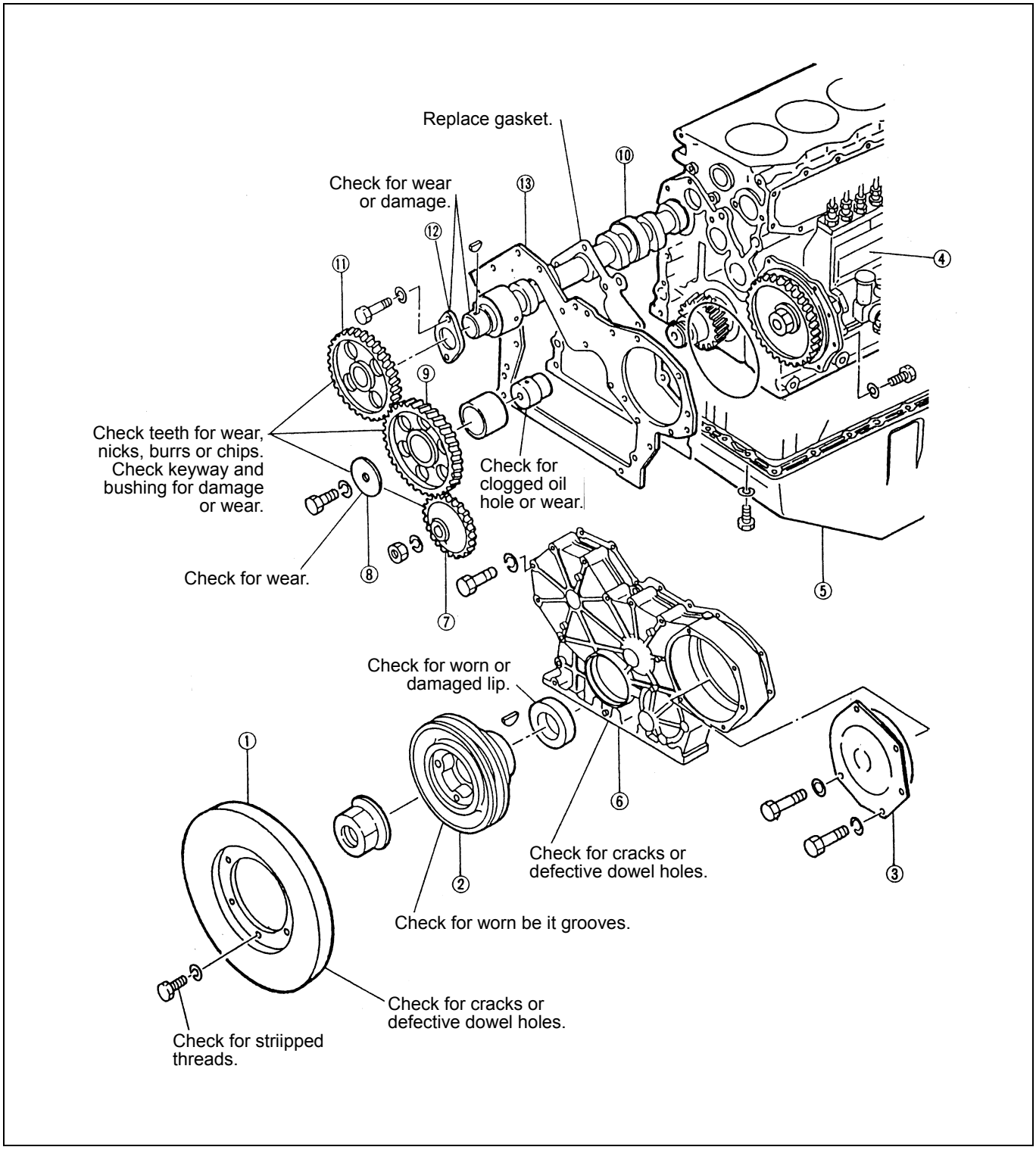


Figure 75 Disassembly sequence

1. Damper (S6S)
2. Crankshaft pulley
3. Cover
4. Fuel injection pump
5. Oil pan
6. Timing gear case
7. Oil pump gear
8. Thrust plate
9. Idler gear
   Remove 10 through 12 as an assembly
10. Camshaft
11. Camshaft gear
12. Thrust plate
13. Front plate

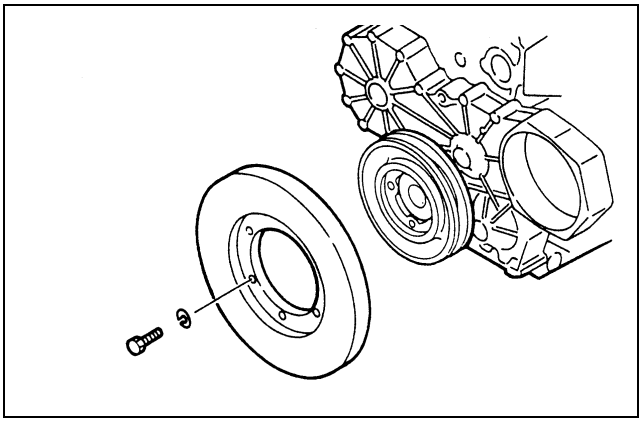


Figure 76 Removing damper

1. Removing damper (S6S/DT)

   1) Install two safety bars (M12 x 1.25) in the rear end of the crankshaft to hold the crankshaft.
   2) Remove the damper.

⚠ WARNING

Be to install the safety bars securely.

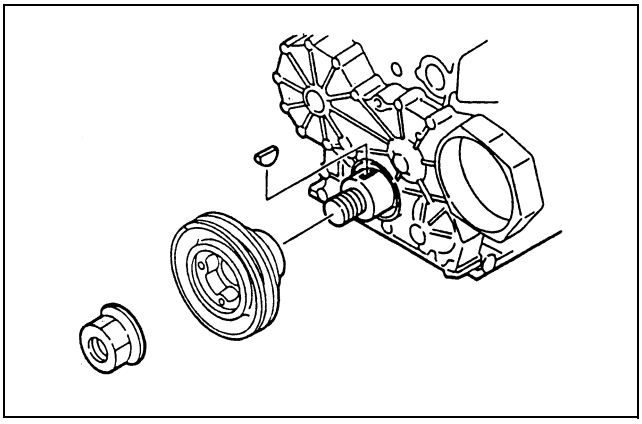


Figure 77 Removing crankshaft pulley

2. Removing crankshaft pulley

   Remove the pulley from the crankshaft as shown.

3. Removing oil pan

   Remove the bolts and remove the oil pan.

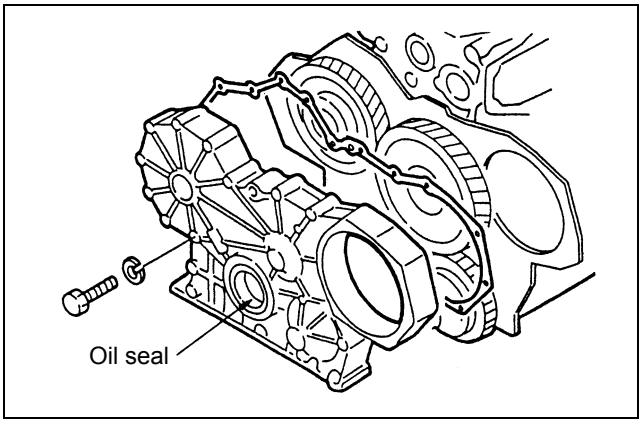


Figure 78 Removing timing gear case assembly

4. Removing timing gear case assembly

   Remove the timing gear case assembly as shown.

⚠ CAUTION

Do not cause damage to the oil seal.

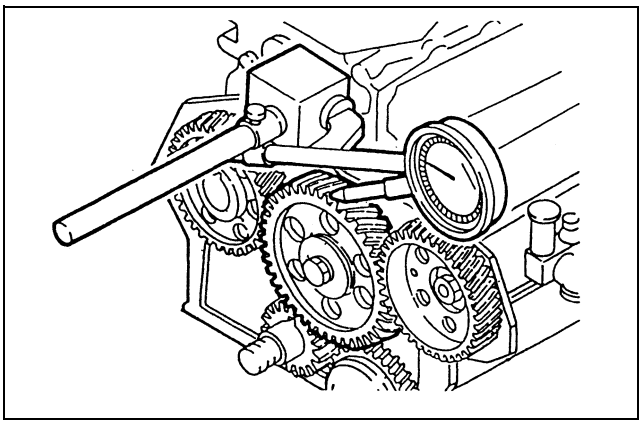


Figure 79 Measuring backlash and end play

5. Measuring backlash and end play

   Make a record of the backlash and end play measurements to be referred to for reassembly. (Refer to 3.2)

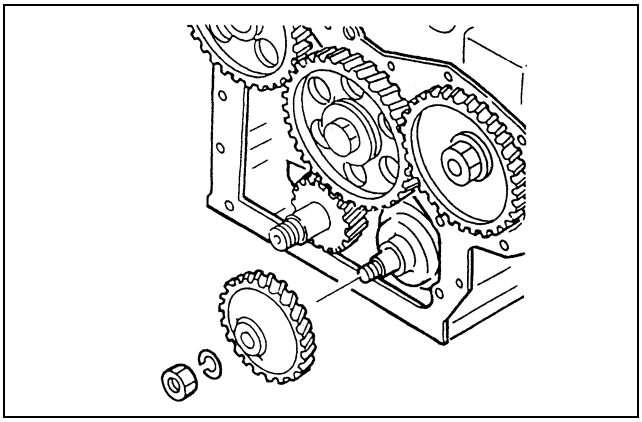


Figure 80 Removing oil pump gear

6. Removing oil pump gear

   Loosen the nut and remove the gear.

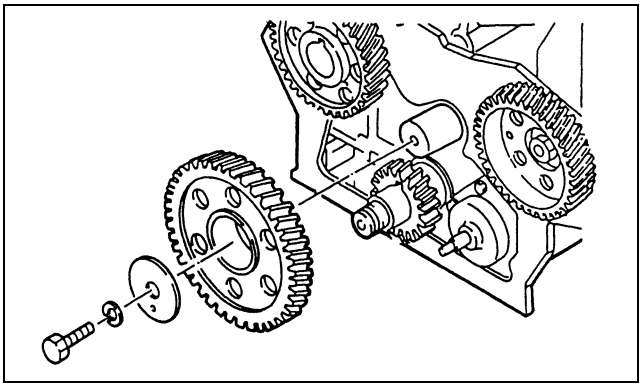


Figure 81 Removing idler gear

7. Removing idler gear

   Remove the thrust plate and remove the gear as shown.

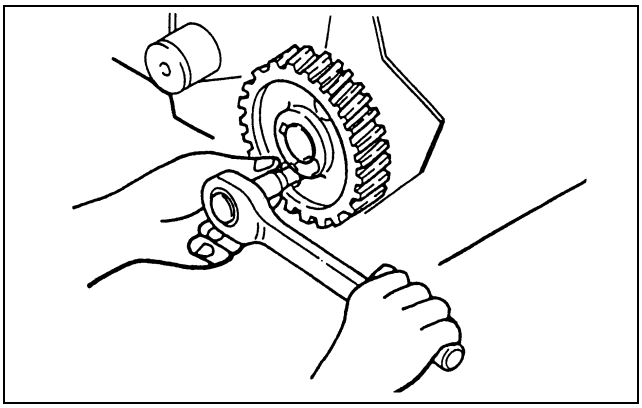


Figure 82 Removing camshaft

8. Removing camshaft

   1) Turn the crankcase upside down.
   2) Position the camshaft gear so that its lightening holes come to top and bottom. Remove the bolts that hold the thrust plate. Remove the camshaft from the crankcase.

⚠ CAUTION

Do not cause damage to the lobe faces of the camshaft and the bushings.

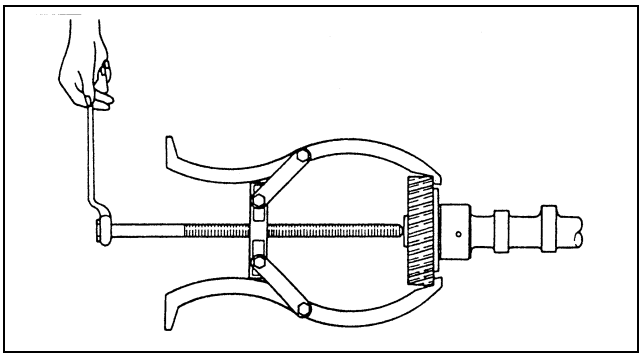


Figure 83 Removing camshaft gear

9. Removing camshaft gear

   Remove the gear from the camshaft with a puller. Now the thrust plate can be removed.

NOTE

Do not remove the camshaft gear and thrust plate unless they are damaged to the extent of requiring replacement.

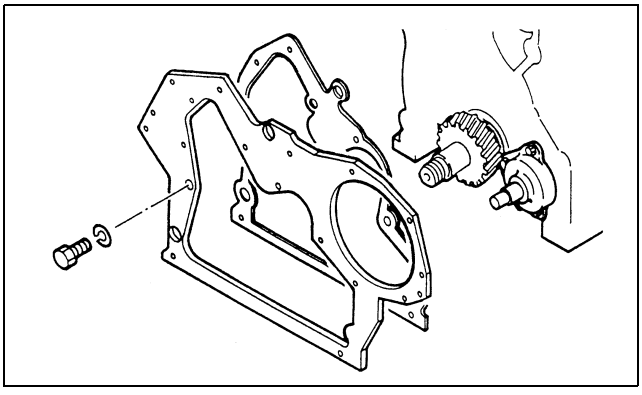


Figure 84 Removing front plate

10. Removing front plate

    Remove the bolts that hold the front plate to the crankcase. Remove the front plate.

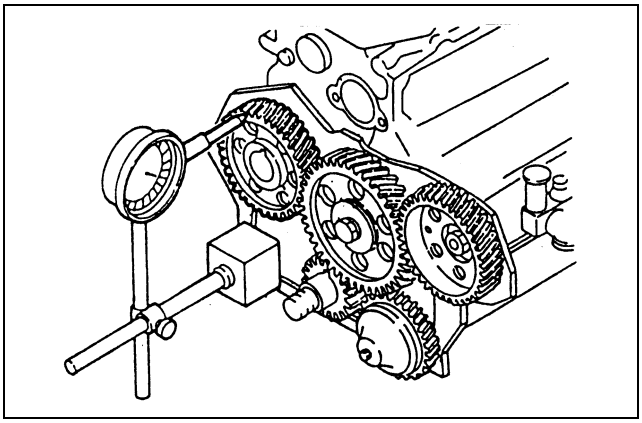


Figure 85 Measuring camshaft end play

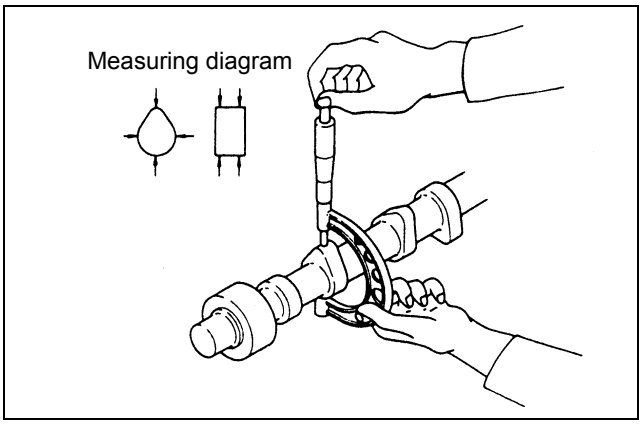
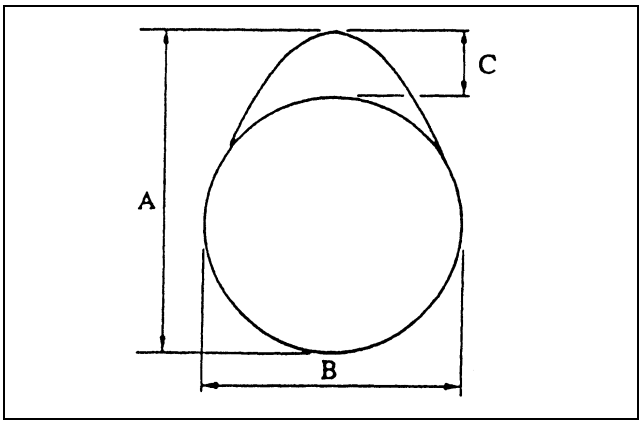


Figure 86 Measuring cam lift



18.2 Inspection

18.2.1 Camshaft and camshaft bushings

1. Measuring camshaft end play

   Measure the camshaft end play as shown in the illustration. If the end play exceeds the service limit, replace the thrust plate.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
End play of camshaft	0.10 to 0.25 [0.0039 to 0.0098]	0.30 [0.118]

2. Measuring cam lift

   To find the cam lift, use the procedure that follows:

   1) Measure lobe height (A).
   2) Measure base circle (B).
   3) Subtract base circle (B) from the lobe height (A). The difference is lobe lift (C).

   If the cam lift is less than the service limit, replace the camshaft.

Unit: mm [in.]

Item			Nominal Value	Assembly Standard	Service Limit
Cam lift C	Inlet valve	DI	A= $46.918^{+0.01}_{-0.3}$ [$1.8472^{+0.004}_{-0.012}$]	6.62 [0.2631]	6.182 [0.2434]
		SC	A= $46.916^{+0.01}_{-0.3}$ [$1.8471^{+0.004}_{-0.012}$]	6.684 [0.2632]	6.184 [0.2435]
	Exhaust valve	DI	A= $46.878^{+0.01}_{-0.3}$ [$1.8456^{+0.004}_{-0.012}$]	6.722 [0.2647]	6.222 [0.2450]
		SC	A= $46.880^{+0.01}_{-0.3}$ [$1.8457^{+0.004}_{-0.012}$]	6.720 [0.2646]	6.220 [0.2450]

DI: Direct injection
SC: Swirl chamber

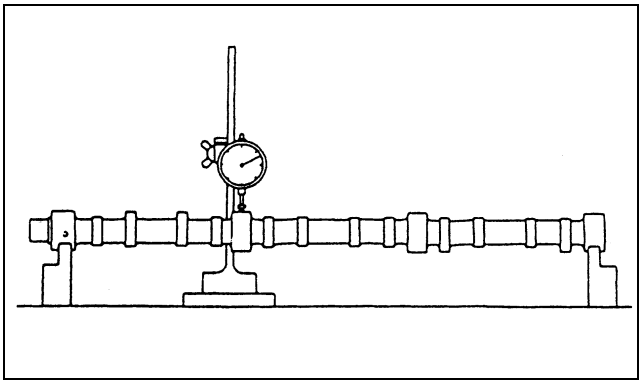


Figure 87 Measuring camshaft deflection

3. Measuring camshaft deflection

Support the camshaft on its front and rear journals in V-blocks. With the dial indicator set at 0.00 mm [0.0000 in.] at the center journal, turn the camshaft full one revolution and read the indicator, as shown in the illustration. 1/2 of the reading on the indicator is the deflection of the camshaft. If deflection exceeds the repair limit, straighten the camshaft by cold working, or replace it.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Camshaft deflection	0.02 [0.0008] or less	0.20 [0.0020]

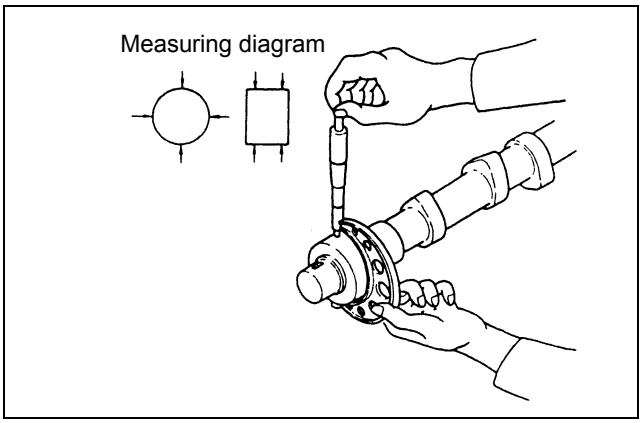


Figure 88 Measuring camshaft journals

4. Clearance between camshaft journals and bushings

Measure the diameter of the camshaft journals and the inside diameter of the bushings in the crankcase to check the clearance between the journal and bushing. If the clearance exceeds the service limit, replace the bushings.

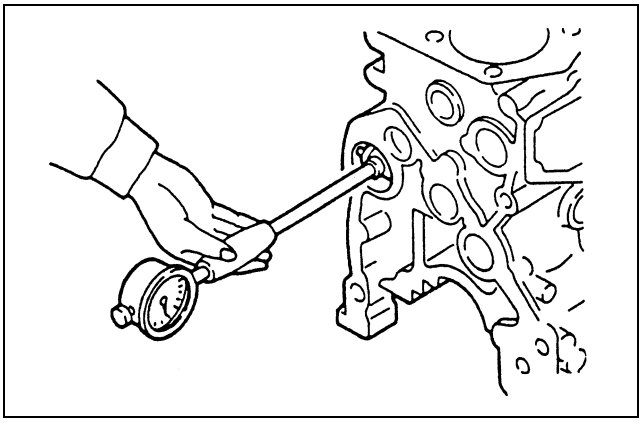


Figure 89 Measuring camshaft bushings

Unit: mm [in.]

Item		Nominal Value	Assembly Standard	Service Limit
Diameters of camshaft journals	No. 1, 2 (S4S) No. 1, 2, 3 (S6S)	54 [2.13]	53.94 to 53.96 [2.1236 to 2.1244]	53.90 [2.1220]
	No. 3 (S4S) No. 4 (S6S)	53 [2.09]	52.94 to 52.96 [2.0842 to 2.0850]	52.90 [2.0827]
Clearance between camshaft journals and bore	Front and middle		0.070 to 0.118 [0.0028 to 0.0047] (without bushings)	0.15 [0.0059] (Repair limit)
	Rear		0.070 to 0.110 [0.0028 to 0.0043] (without bushings)	
			0.040 to 0.119 [0.0016 to 0.0047] (with bushing)	

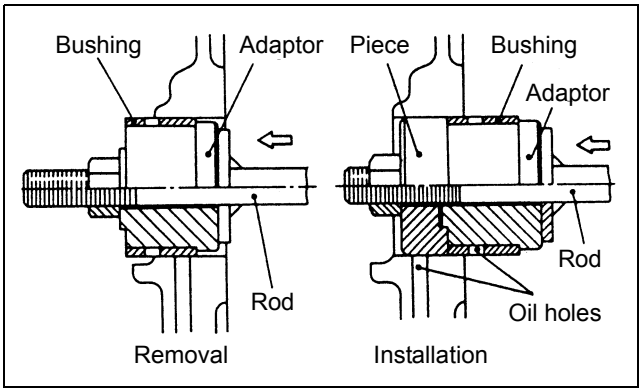


Figure 90 Replacing camshaft bushings

5. Replacing camshaft bushings

   1) If the clearance between the camshaft journal and bore in the crankcase exceeds the service limit, refinish the bore to 57H6 ($^{+0.019}_{0}$) 3.125 Ra. and install bushings.
   2) To replace or install bushings, use camshaft bushings installer set (30691–00010).
   3) Install bushings with their oil holes aligned with the holes leading to the oil gallery.

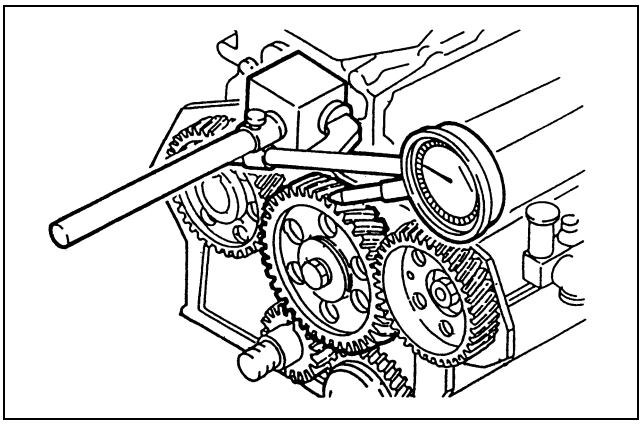


Figure 91 Measuring timing gear backlash

18.2.2 Timing gears

Backlash

Put a dial indicator on the gear along its pitch circle as shown. Hold it tightly in place. Move one of the mating gears back and forth to check the backlash. If the backlash exceeds the service limit, replace the worn gears.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Backlash	0.03 to 0.18 [0.0012 to 0.0071]	0.25 [0.0098]

NOTE

Install the injection pump drive gear to the front plate in the state of being installed on the injection pump.

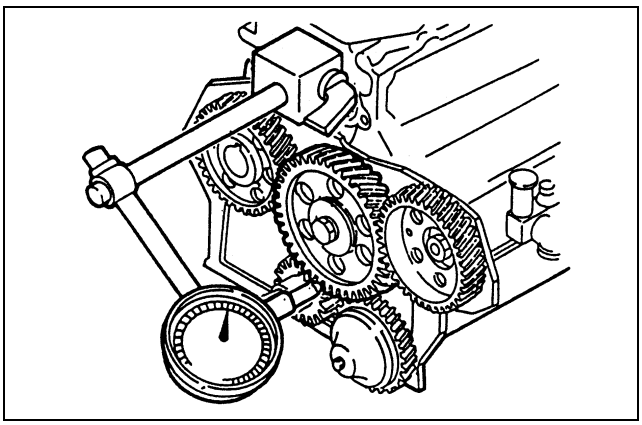


Figure 92 Measuring idler gear end play

18.2.3 Idler gear, bushing and shaft

1. Measuring idler gear end play

   Measure the idler gear end play with feeler gages or a dial indicator as shown in the illustration. If the end play exceeds the service limit, replace the thrust plate.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
End play of idler gear	0.05 to 0.20 [0.0020 to 0.0079]	0.35 [0.0138]

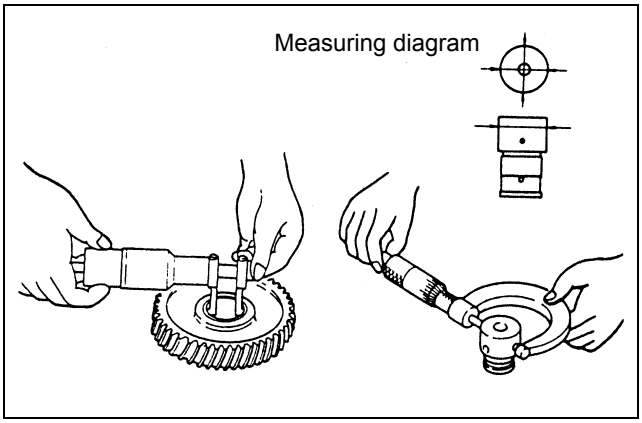


Figure 93 Measuring clearance between idler gear bushing and shaft

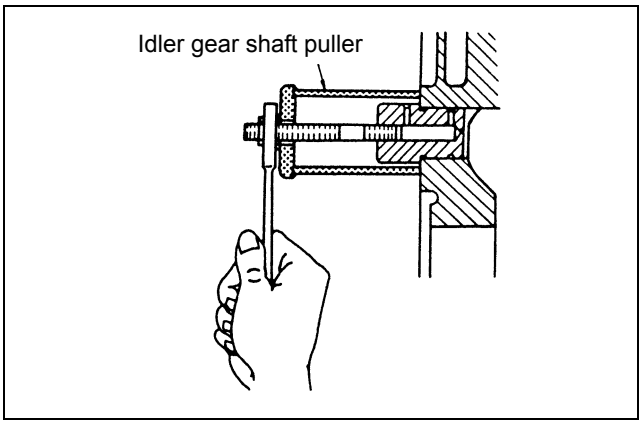


Figure 94 Removing idler gear shaft

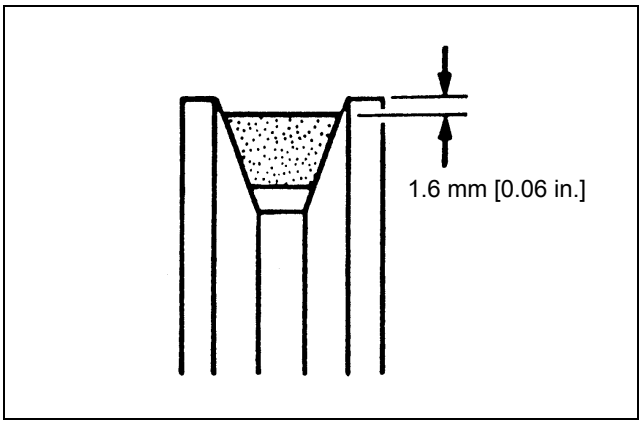


Figure 95 Inspecting V-belt groove

2. Measuring clearance between idler gear bushing and shaft

   Measure the inside diameter of the bushing and the diameter of the shaft to determine the clearance between the two. If the clearance exceeds the service limit, replace the idler gear or shaft.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Clearance between idler gear bushing and shaft	0.009 to 0.050 [0.0004 to 0.0020]	0.100 [0.0039]

3. Removing idler gear shaft

   To remove the idler gear shaft for replacement, use idler shaft puller (MH061077).

18.2.4 Crankshaft pulley

Check the V-belt groove for wear. Wrap a new belt around the pulley, pressing it in the groove as far as it goes, and see if the top surface of the belt is above the top of the pulley.

If the top surface of the new belt is uniformly above the top of the pulley all the way around, it is not necessary to replace the pulley.

If the top surface of the new belt sinks into the groove more than 1.6 mm [0.06 in.], replace the pulley.

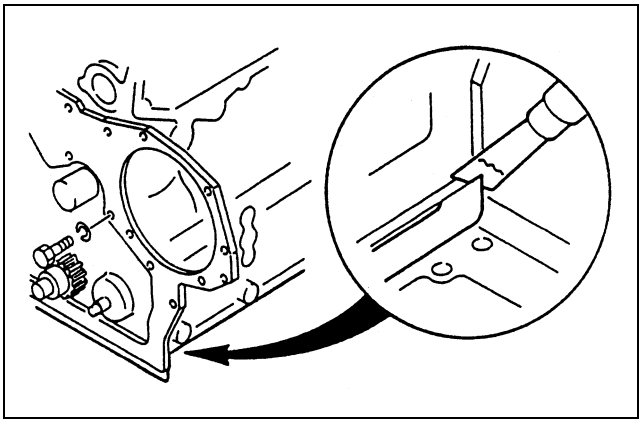


Figure 96 Installing front plate

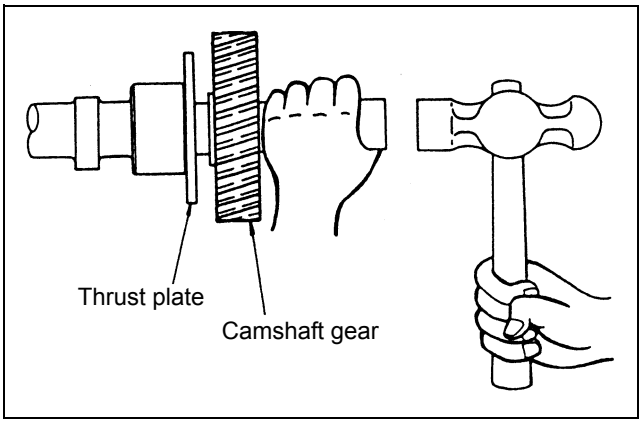


Figure 97 Installing camshaft gear and thrust plate

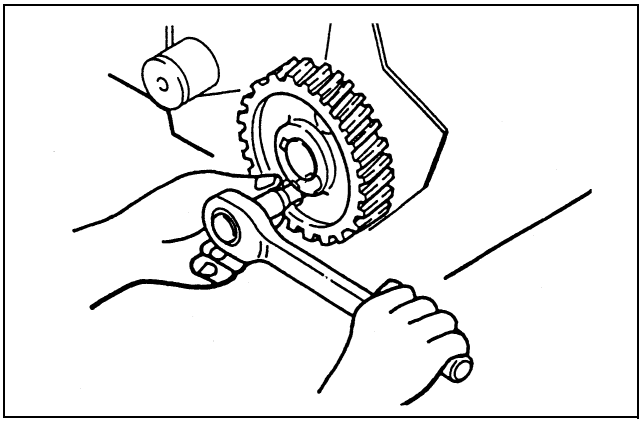


Figure 98 Installing camshaft

18.3 Reassembly

1. Installing front plate

   1) Put the gasket on the crankcase, making sure the dowels enter the holes in the gasket.
   2) Tighten the bolts that hold the front plate to the crankcase to the specified torque.

Tightening torque for front plate bolts	10.0 to 13.0 N·m (1.0 to 1.3 kgf·m) [7.23 to 9.40 lbf·ft]

   3) Cut off the excess of the gasket with a cutter.

2. Installing camshaft gear and thrust plate

   1) Heat the camshaft gear for installation.
   2) Have the thrust plate installed in advance.

3. Installing camshaft

   1) Apply engine oil to the lobes and journals of the camshaft.
   2) Carefully put the camshaft in the bore in the crankcase.
   3) Tighten the bolts that hold the thrust plate to the specified torque.

Tightening torque for front plate bolts	10.0 to 13.0 N·m (1.0 to 1.3 kgf·m) [7.23 to 9.40 lbf·ft]

⚠ CAUTION

Do not cause damage to the lobes and bushings.

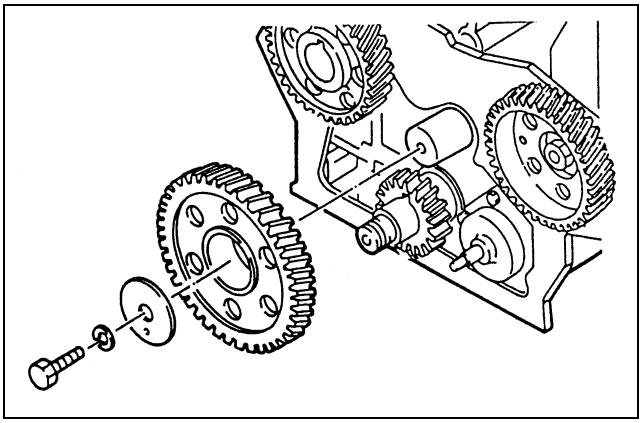


Figure 99 Installing camshaft

4. Installing idler gear

1) Install the idler gear by aligning its matching mark with those on the crankshaft gear, injection pump gear and camshaft gear and install the thrust plate.
2) Tighten the thrust plate mounting bolts to the specified torque.

Tightening torque for thrust plate bolts	29.0 to 39.0 N·m (3.0 to 4.0 kgf·m) [21.7 to 28.9 lbf·ft]

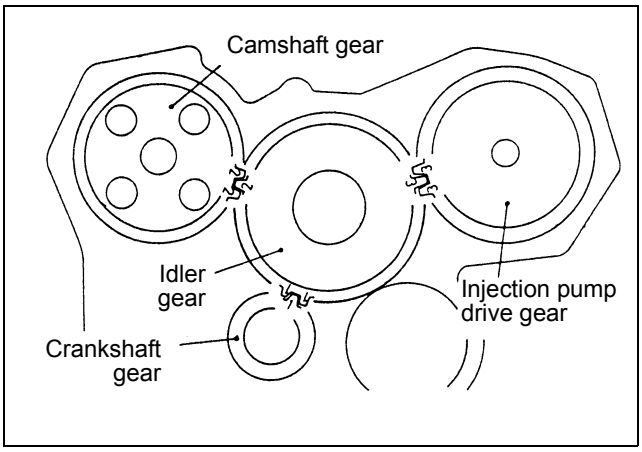


Figure 100 Marks on timing gear

3) The marks on the gears will be aligned as shown when the No.1 piston is at top dead center of compression stroke.

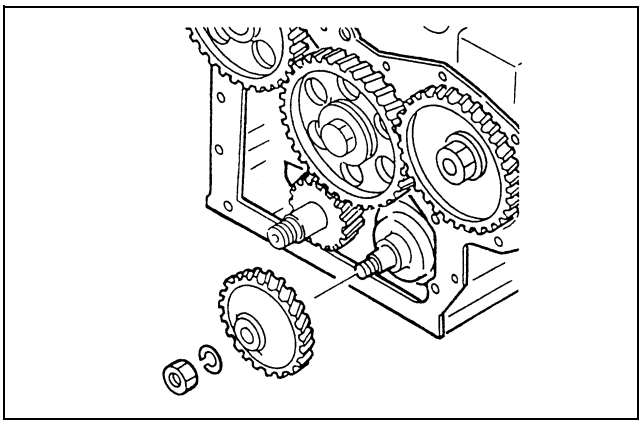


Figure 101 Installing oil pump gear

5. Installing oil pump gear

1) Install the gear to the oil pump shaft.
2) Tighten the jam nut to the specified torque.

Tightening torque for jam nut	28.0 to 38.0 N·m (2.9 to 3.9 kgf·m) [21.0 to 28.2 lbf·ft]

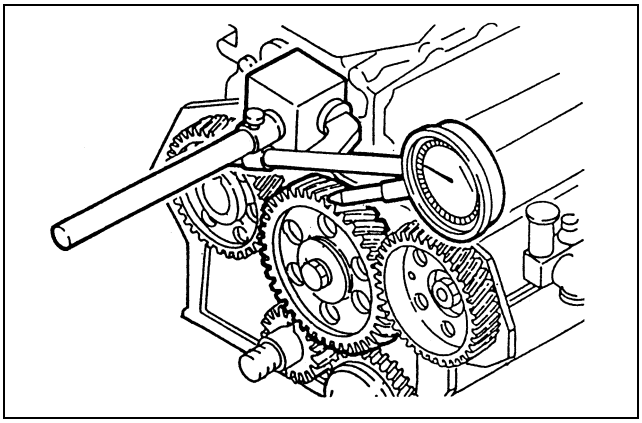


Figure 102 Inspecting backlash and end play

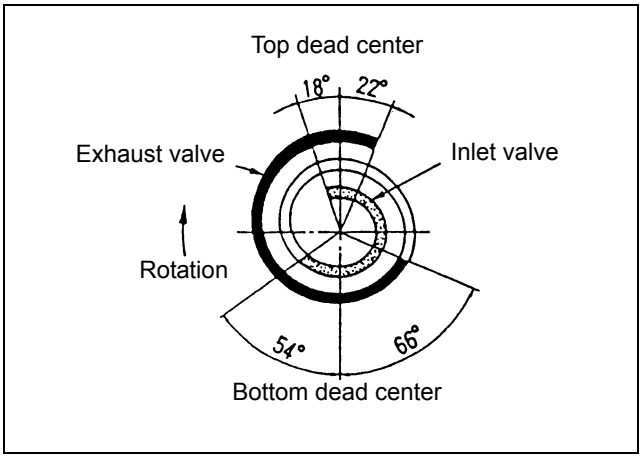


Figure 103 Valve timing diagram (direct injection type)

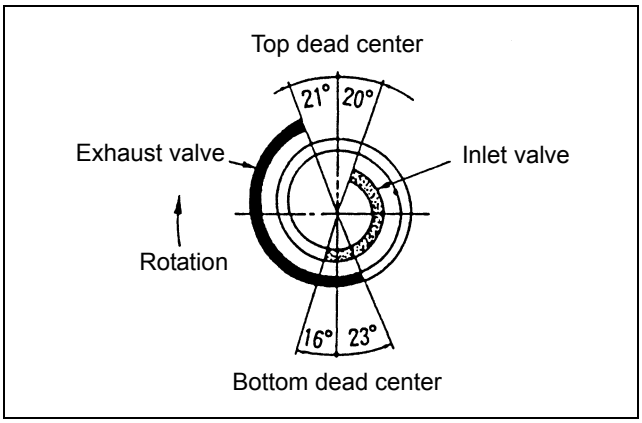


Figure 104 Valve timing diagram with 3 mm [0.12 in.] clearance added (direct injection type)

6. Inspecting and adjusting after reassembly

Timing gear backlash and end play

After installing the timing gears, check the backlash and end play and, if necessary, adjust them. (Refer to 3.2.)

7. Inspecting valve timing

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

1) Using a 3 mm [0.12 in.] thick smooth steel plate, add 3 mm [0.12 in.] clearance to the inlet and exhaust valves of the No.1 cylinder.
2) Put a 0.05 mm [0.0020 in.] feeler gage between the top of the valve cap and the rocker.
3) Slowly turn the crankshaft to find a position where the feeler gage is firmly gripped (the valve starts opening) and a position where the gage is just ungripped (the valve starts closing).
4) Check to make sure these positions agree with the angular positions shown in the valve timing diagram with 3 mm [0.12 in.] clearance added to the valves.

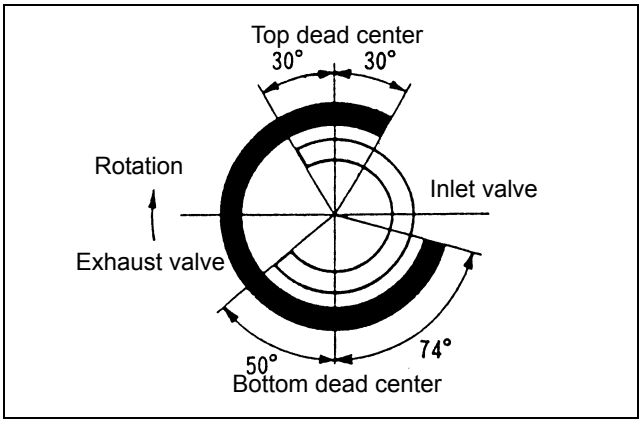


Figure 105 Valve timing diagram (swirl chamber type)

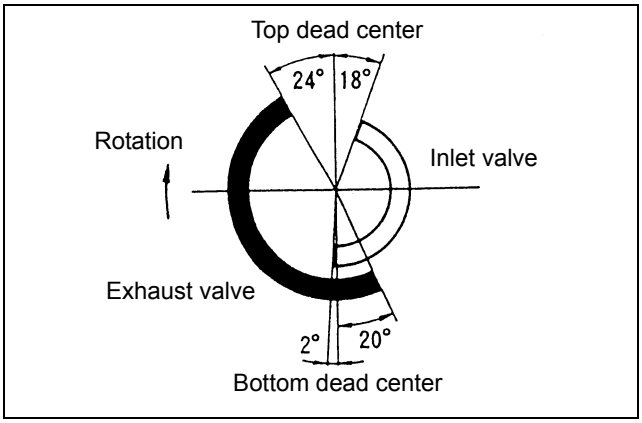


Figure 106 Valve timing diagram with 3 mm [0.12 in.] clearance added (swirl chamber type)

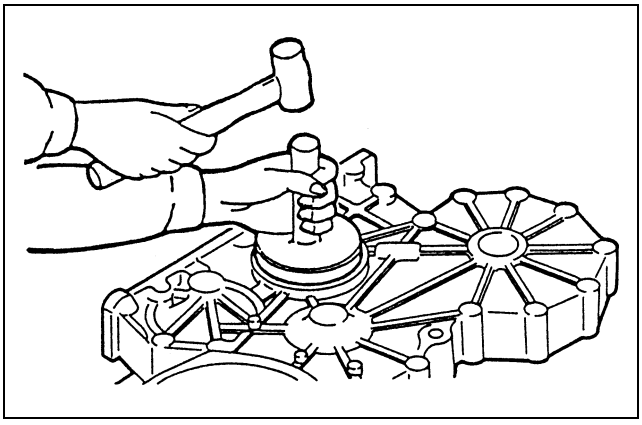


Figure 107 Installing oil seal

8. Installing oil seal (if necessary)

   Apply a small amount of grease to the oil seal and install it to the timing gear case with an installer.

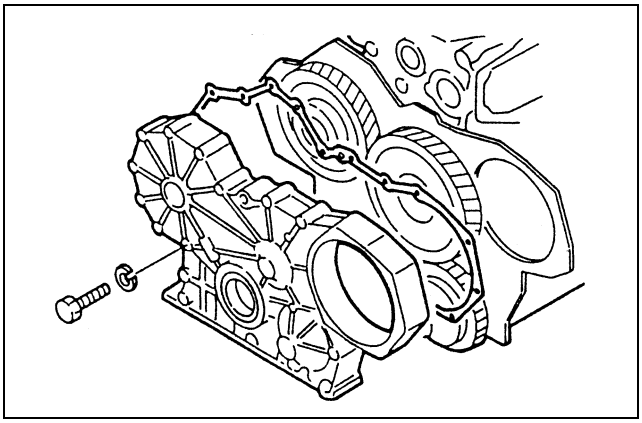


Figure 108 Installing timing gear case

9. Installing timing gear case

   1) Put the gasket on the front plate, making sure the dowels enter their holes in the gasket.
   2) Apply oil to the lip of the oil seal.
   3) Tighten the bolts that hold the timing gear case to the specified torque.

Tightening torque for timing gear case bolts	10.0 to 13.0 N·m (1.0 to 1.3 kgf·m) [7.23 to 9.40 lbf·ft]

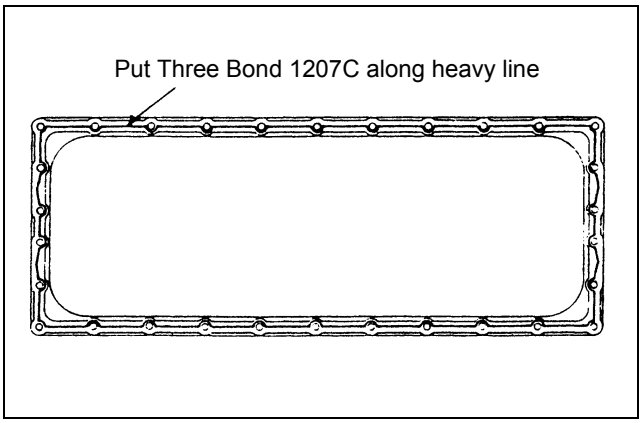


Figure 109 Oil pan flange to be coated with Three Bond 1207C

10. Installing oil pan

   1) Clean the mounting surfaces of the crankcase, timing gear case and oil pan.
   2) Squeeze out a 4 mm [0.2 in.] thickness of Three Bond 1207C (32A91–05100) from the tube and put it on the oil pan flange.
   3) Install the oil pan to the crankcase within 5 minutes after putting Three Bond 1207C.
   4) Tighten the bolts to the specified torque.

Tightening torque for oil pan bolts	10.0 to 13.0 N·m (1.0 to 1.3 kgf·m) [7.23 to 9.40 lbf·ft]

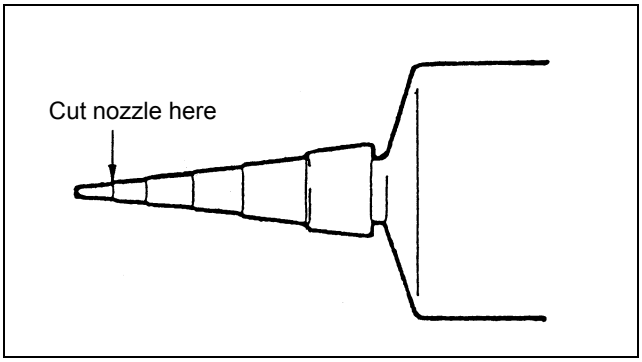


Figure 110 Nozzle for Three Bond 1207C tube

NOTE

To squeeze out a 4 mm [0.2 in.] thickness of Three Bond, cut the first node of the nozzle.

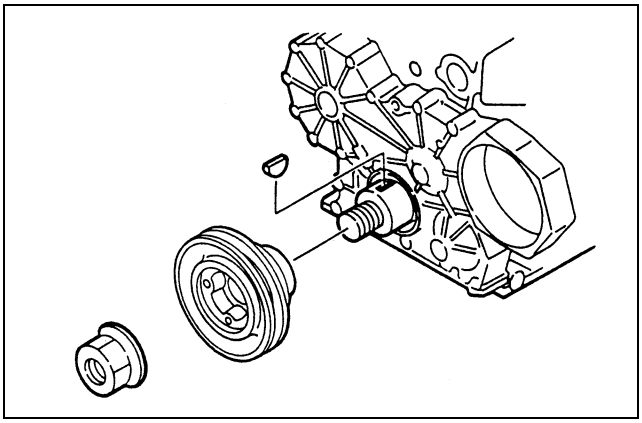


Figure 111 Installing crankshaft pulley

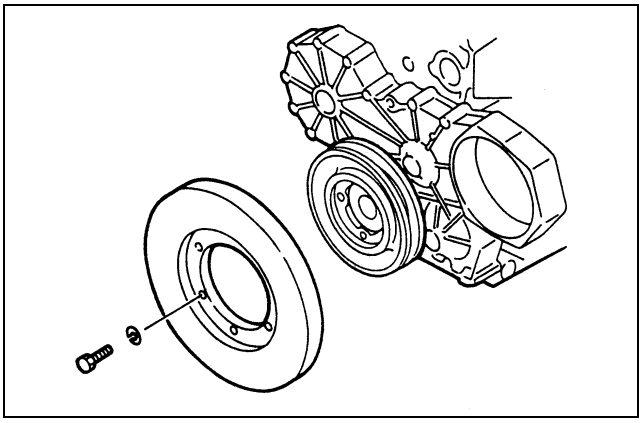


Figure 112 Installing damper

11. Installing crankshaft pulley

    Install two safety bars (M12 x 1.25) to the rear end of the crankshaft. Put a bar between the safety bars to hold the crankshaft. Under this condition, install the crankshaft pulley and tighten the nut to the specified torque.

Tightening torque for crankshaft pulley nut	480 to 500 N·m (49 to 51 kgf·m) [354 to 369 lbf·ft]

⚠ WARNING

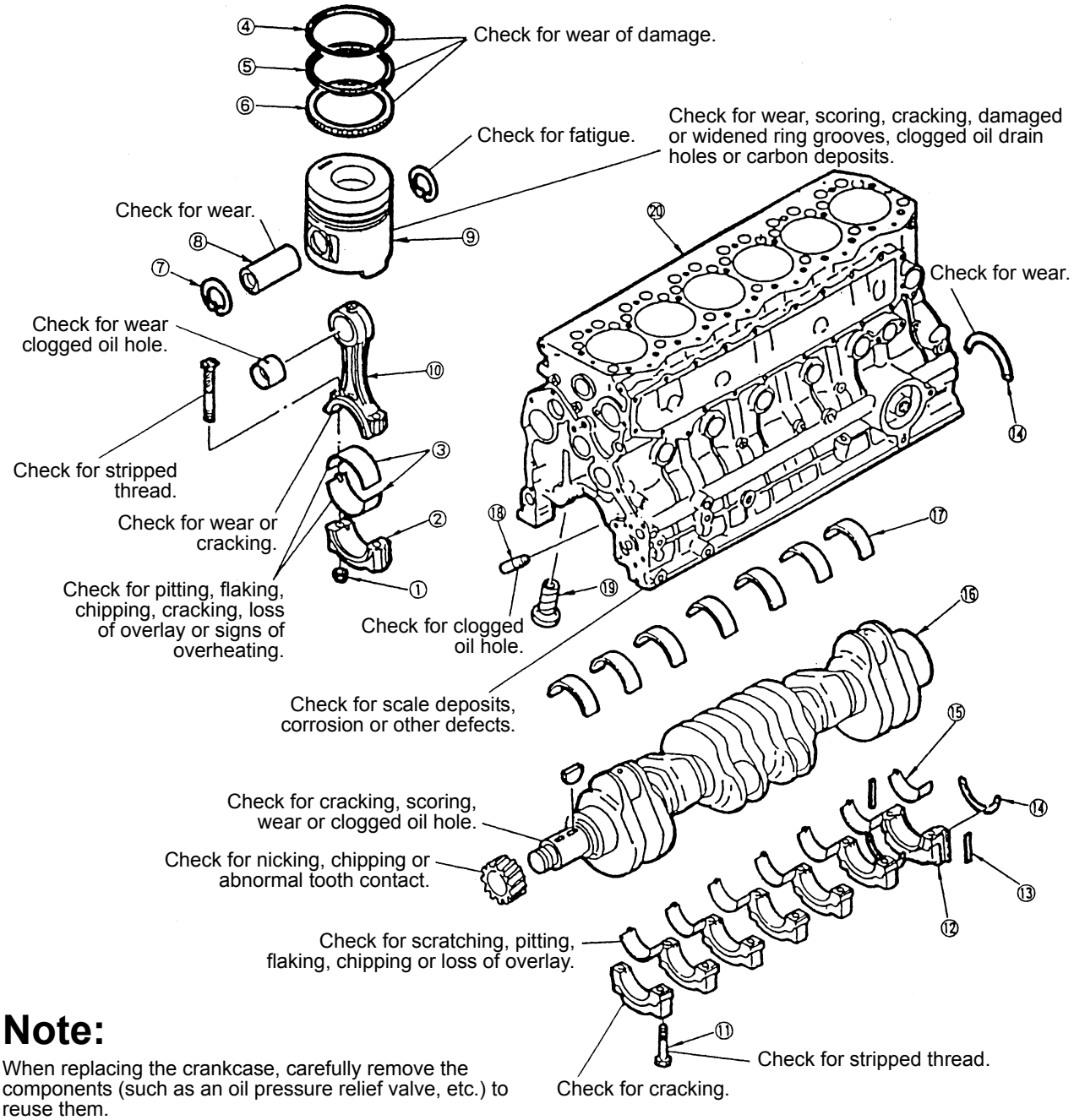
Be on standby to act when the safety bar comes off inadvertently.

12. Installing damper (S6S/–DT)

    Hold the crankshaft with safety bars and install the damper.

19 PISTONS, CONNECTING RODS, CRANKSHAFT, CRANKCASE AND TAPPETS

19.1 Disassembly



Note:

When replacing the crankcase, carefully remove the components (such as an oil pressure relief valve, etc.) to reuse them.

Figure 113 Disassembly sequence

1. Nut
2. Connecting rod cap
3. Connecting rod bearing
   Remove 4 through 10 as an assembly.
4. Top compression ring
5. Second compression ring
6. Oil ring
7. Snap ring
8. Piston pin
9. Piston
10. Connecting rod
11. Bearing cap bolt
12. Main bearing cap
13. Side seal
14. Thrust plate
15. Main bearing (lower half)
16. Crankshaft
17. Main bearing (upper half)
18. Check valve (direct injection with turbocharger)
19. Tappet
20. Crankcase

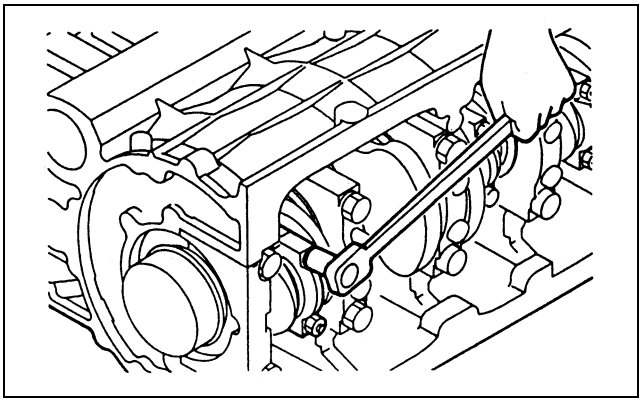


Figure 114 Removing connecting rod cap

1. Removing connecting rod cap

   1) Remove the nuts that hold the cap to the connecting rod. Tap the bolts squarely and evenly with a hammer and, after the cap comes off the reamer bolts, remove the cap.
   2) Mark the bearings for cylinder number and location.

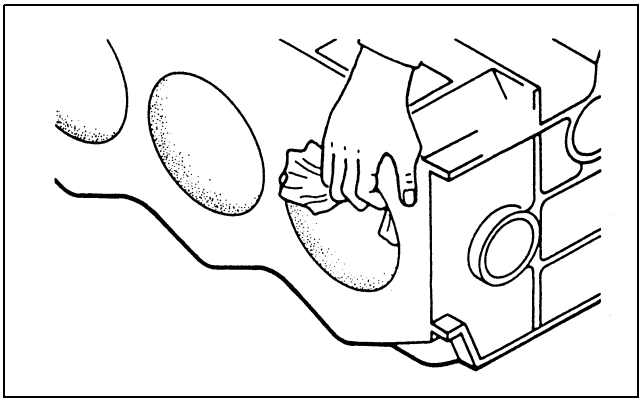


Figure 115 Removing carbon from cylinders

2. Preparation before removing pistons

   1) Lay the crankcase on its side.
   2) 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 upward.

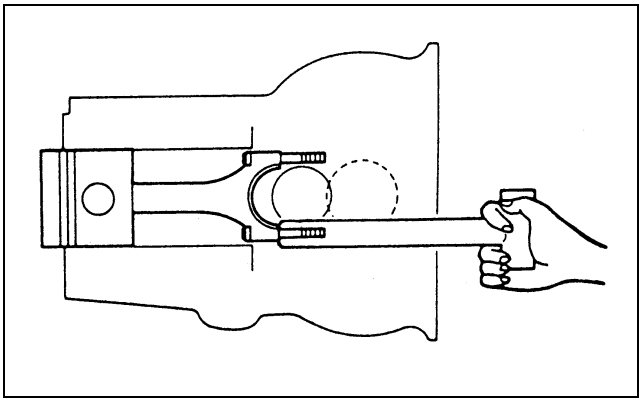


Figure 116 Removing piston

3. Removing piston

   1) Turn the crankshaft to bring the piston (from which the connecting rod cap has been removed) to top dead center.
   2) Put the handle of a hammer on the big-end of the connecting rod and push the piston assembly off the cylinder.

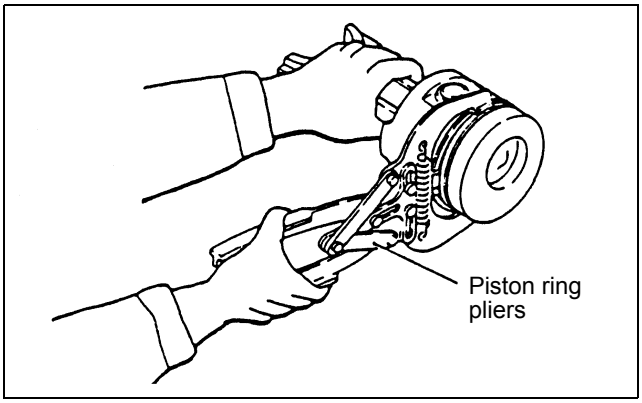


Figure 117 Removing piston rings

4. Removing piston rings

   Use piston ring pliers (31391–12900) to remove the piston rings.

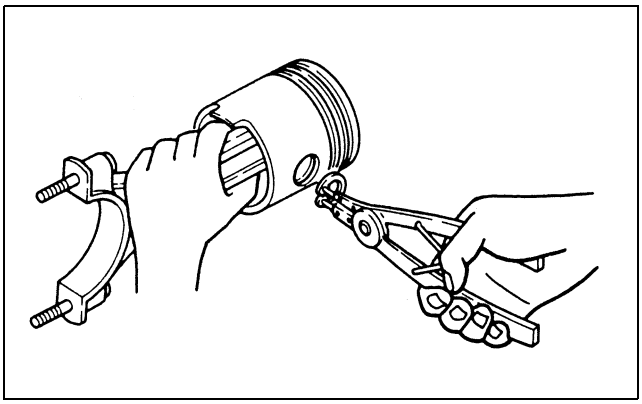


Figure 118 Removing piston pin

5. Removing piston pin

   Using snap ring pliers, remove the snap rings from the piston.

   Remove the piston pin to separate the piston from the connecting rod.

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

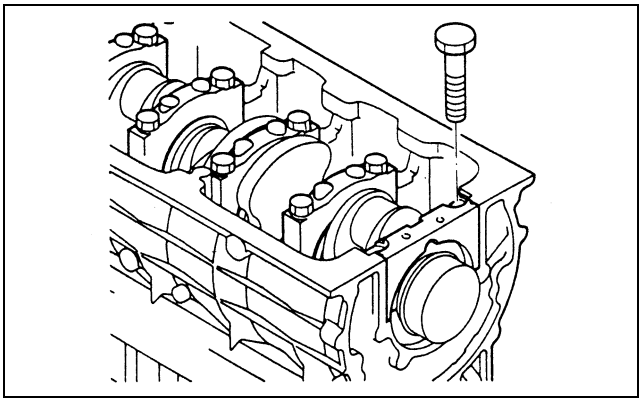


Figure 119 Removing main bearing caps

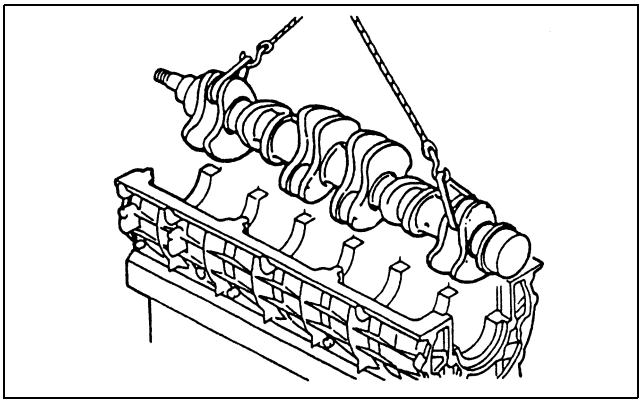


Figure 120 Removing crankshaft

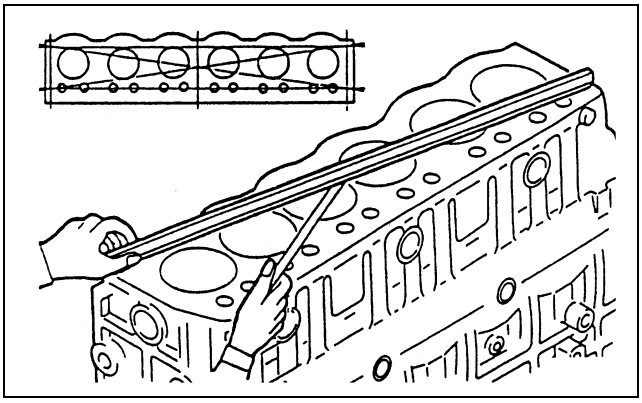


Figure 121 Checking crankcase flatness

6. Removing main bearing caps

   Remove the bolts that hold the cap to the crankcase. Remove the cap with lower main bearing. To remove the rearmost bearing cap, use a puller as shown in the illustration.

NOTE

When removing the caps, do not cause damage to the bearings. After removing the caps and bearings, mark each combination of the cap and bearing for its location so that it can be restored to the original position at reassembly.

7. Removing crankshaft

   Fasten a hoist to the crankshaft. Remove the crankshaft by lifting it in horizontal position.

8. Removing tappets

   Remove the tappets.

NOTE

Put a mark on each tappet so that it can be installed in the same position.

19.2 Inspection

19.2.1 Crankcase

1. Gasket contact surface

   Measure flatness of the gasket contact (top) surface with a heavy accurate straight edge and feeler gages, in three positions lengthwise, two crosswise and two widthwise, as shown in the illustration. If flatness exceeds the repair limit, grind the crankcase.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Flatness of gasket contact surface	0.05 [0.0020] or less	0.20 [0.0079]

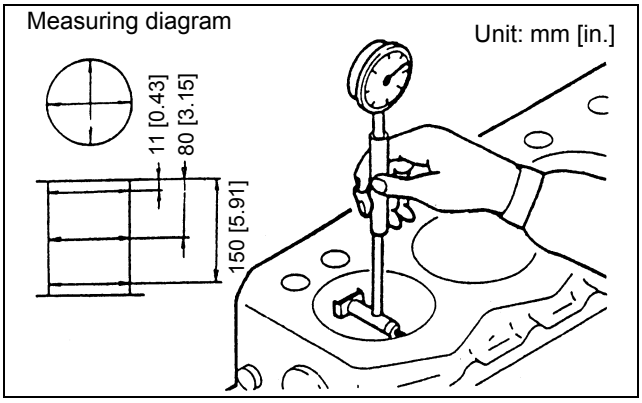


Figure 122 Measuring cylinder

2. Inside diameter of cylinders

1) Measure the inside diameter of the cylinder at the top (ridged portion), middle and bottom, each in two directions parallel and transverse to the crankshaft, as shown in the illustration.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit	Service Limit
Inside diameter of cylinder	94.000 to 94.035 [3.7008 to 3.7022]	94.200 [3.7087]	94.700 [3.7283]
Circularity	0.01 [0.004] or less		
Taper	0.015 [0.0006] or less		

2) If the cylinder has reached the repair limit, with the wear far less than the service limit, bore it to 0.25 mm [0.0098 in.] or 0.5 mm [0.0197 in.] oversize.
3) Hone the cylinder within an accuracy of 0.035 mm [0.00138 in.], and use the piston and piston rings of the same oversize.
4) If any cylinder is unevenly worn, determine the oversize on the basis of the maximum wear noted to ensure perfect roundness in the oversized bore.

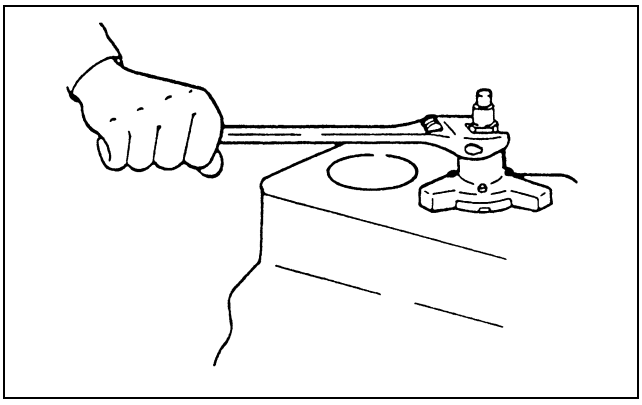


Figure 123 Ridge-reaming cylinder

NOTE

a. Refinish all cylinders to the same oversize.
b. If the cylinder is found in good condition, with the wear far less than the repair limit, replace the piston ring and ream off “ridge” at the top of the cylinder. Hone the bore if necessary.

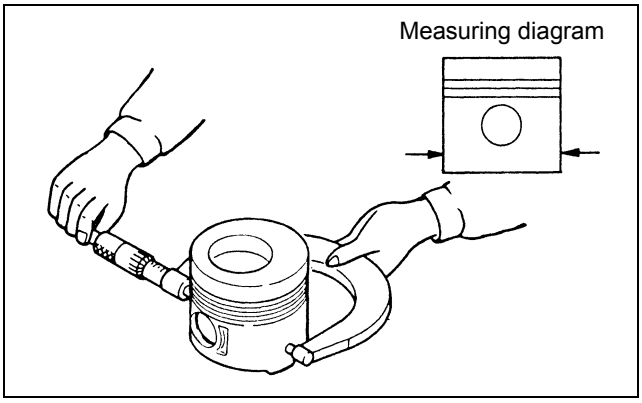


Figure 124 Measuring piston diameter

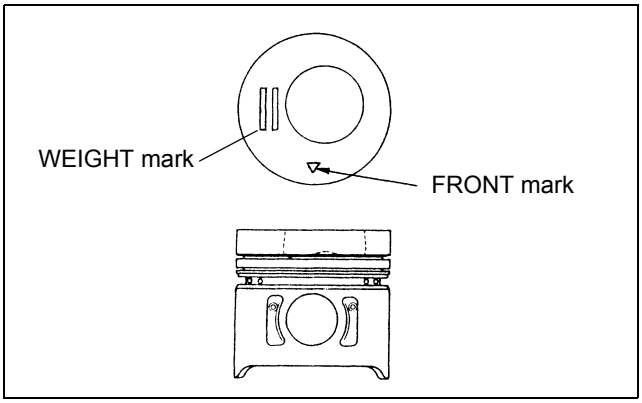


Figure 125 FRONT mark and WEIGHT mark on piston (direct injection type)

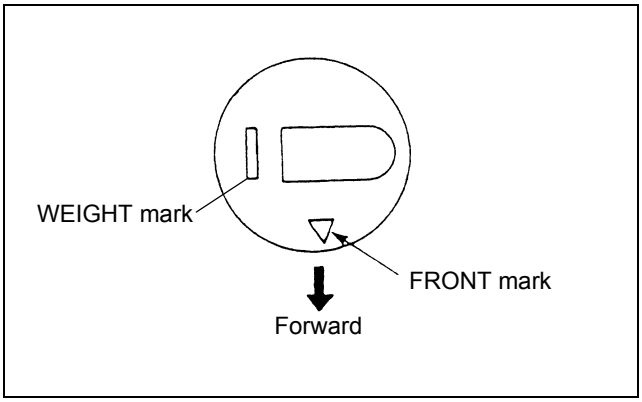


Figure 126 FRONT mark and WEIGHT mark on piston (swirl chamber type)

19.2.2 Pistons and piston rings

1. Measuring piston diameter

   1) Measure the diameter of the piston at skirt in the direction transverse to the piston pin with a micrometer, as shown in the illustration. If the piston is worn beyond the service limit, replace it.

Unit: mm [in.]

Item		Assembly Standard	Service Limit
Outside diameters of pistons	Standard	93.955 to 93.985 [3.6990 to 3.7002]	93.770 [3.6917]
	0.25 [0.0098] oversize	94.205 to 94.235 [3.7089 to 3.7100]	94.020 [3.7016]
	0.50 [0.0197] oversize	94.455 to 94.485 [3.7187 to 3.7199]	94.270 [3.7114]
Piston weight difference per engine		5 g [0.18 oz] or less	WS

   2) When installing the piston, make sure the weight difference of the piston per engine is in the assembly standard.

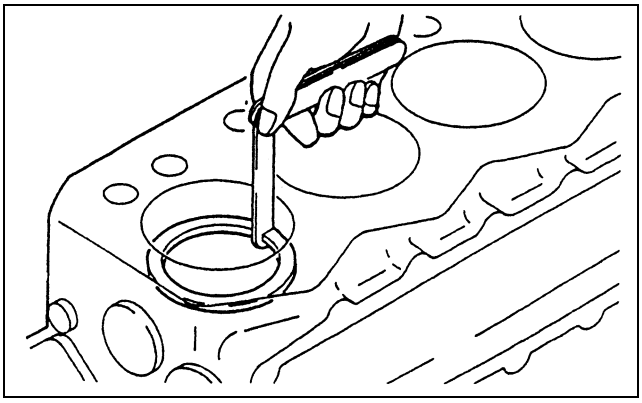


Figure 127 Measuring cut clearance between ends of piston ring

2. Measuring cut clearance between ends of piston ring

   Put the piston ring in the gage or a new cylinder sleeve and measure the cut clearance with feeler gages as shown in the illustration. If the clearance exceeds the service limit, replace all piston rings.

   Inside diameter of gage: $94_{0}^{+0.035}$ [$3.70_{0}^{+0.001\ 38}$]

NOTE

Use the piston to put the ring in the gage or the cylinder sleeve squarely.

Unit: mm [in.]

Item		Assembly Standard	Service Limit
Cut clearance	No. 1 and No. 2 rings	0.30 to 0.50 [0.0118 to 0.0197]	150 [0.0591]
	Oil ring		

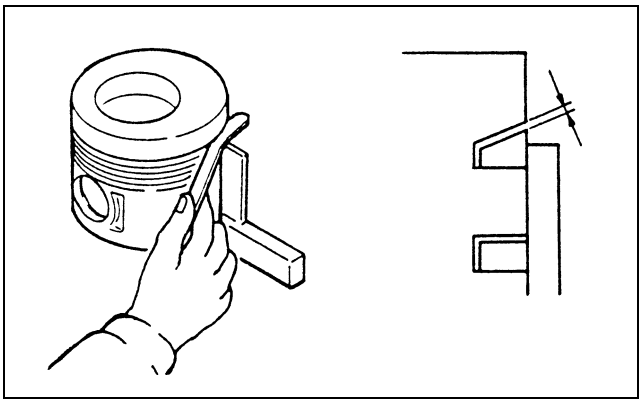


Figure 128 Measuring clearance between groove and piston ring

3. Measuring clearance between groove and piston ring

   Put a new piston ring in the groove. Measure the clearance between the groove and piston ring with a straight edge and feeler gages as shown in the illustration. If the clearance exceeds the service limit, replace the piston.

Unit: mm [in.]

Item		Assembly Standard	Service Limit
Clearance between groove and piston ring	No. 1 rings	0.07 to 0.11 [0.0028 to 0.0043]	0.200 [0.0079]
	No. 2 rings	0.045 to 0.085 [0.0018 to 0.0034]	0.150 [0.0059]
	Oil ring	0.025 to 0.065 [0.0010 to 0.0026]	0.150 [0.0059]

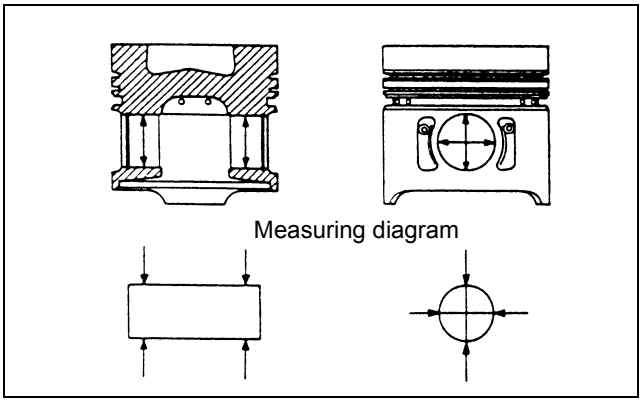


Figure 129 Measuring clearance between piston pin and bore

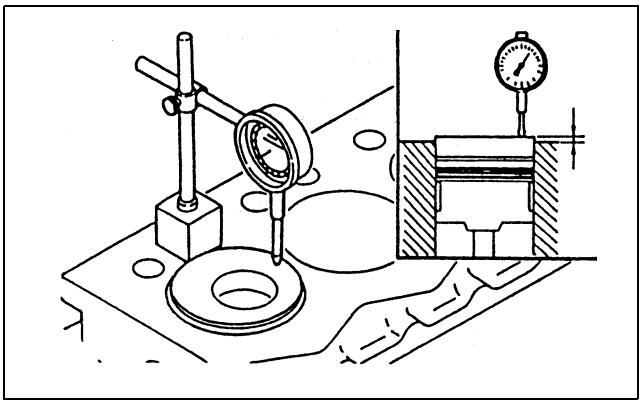


Figure 130 Measuring piston protrusion

4. Measuring clearance between piston pin and bore

   Measure the inside diameter of the piston pin bore and the diameter of the pin as shown in the illustration to check the clearance between the piston and pin. If the clearance exceeds the service limit, replace the pin or piston whichever is excessively worn.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Diameter of piston ring	30 [1.18]	29.994 to 30.000 [1.1809 to 1.1811]	
Clearance between piston pin and bore		0.000 to 0.016 [0.0000 to 0.0006]	0.050 [0.0020]

5. Measuring piston protrusion

   If the piston protrusion is not correct, check the various parts for clearance. Measure the piston protrusion as outlined below.

   1) Measure the top dead center of the pistons with a dial gage.
   2) Install the dial indicator on the top of the crankcase. Set the indicator to read 0.0 mm [0.000 in.].
   3) Measure the piston protrusion at least three locations on the top of the piston and average the three measurements to check the protrusion. Subtract the projection from the compressed thickness of the cylinder head gasket to check the clearance between the piston top and the cylinder head.

Unit: mm [in.]

Item		Assembly Standard
Piston protrusion	Direct injection	0.05 to 0.45 [0.0020 to 0.0177]
	Swirl chamber	–0.25 to 0.15 [–0.0098 to 0.0059]
Compressed thickness of cylinder head gasket		1.2 ± 0.05 [0.05 ± 0.002]

⚠ CAUTION

Incorrect piston protrusion affects engine performance and causes valve interference with the piston.

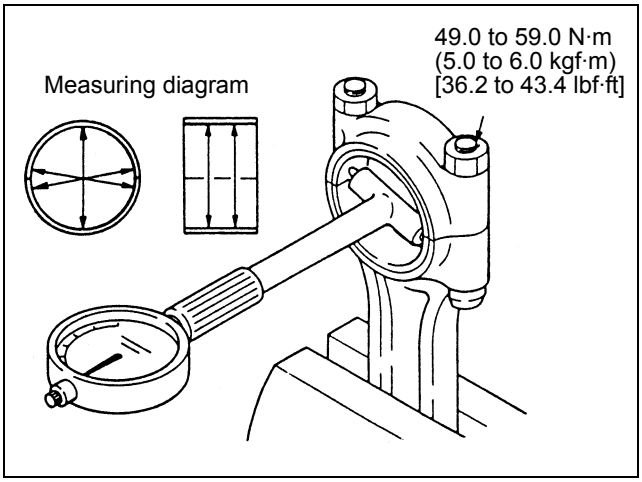


Figure 131 Measuring connecting rod bearing

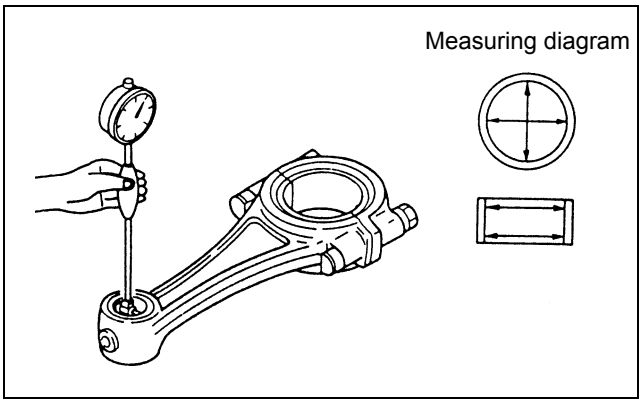


Figure 132 Measuring connecting rod bushing

19.2.3 Connecting rods, connection rod bearings and piston pin bushings

1. Clearance between connecting rod bearing and crankpin

   Measure the diameter of the crankpin and the inside diameter of the connecting rod bearing as shown in the illustration to check the clearance between the two. If the clearance exceeds the service limit, replace the bearing. If the crankpin is badly or unevenly worn, grind the crankpin and use an undersize bearing.

   0.25 mm [0.0098 in.], 0.50 mm [0.0197 in.] and 0.75 mm [0.0295 in.] undersize connecting rod bearings are available for service.

NOTE

To measure the inside diameter of the connecting rod bearing, install the upper and lower halves in the connecting rod and tighten the cap bolts to the specified torque.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Diameter of crankpin	58 [2.28]	57.955 to 57.970 [2.2817 to 2.2823]	57.800 [2.2756] (Repair Limit)
Clearance between connecting rod bearing and crankpin		0.030 to 0.090 [0.0012 to 0.0035]	0.200 [0.0079]

2. Clearance between connecting rod bushing and piston pin

   Measure the inside diameter of the connecting rod bushing and the diameter of the piston pin as shown in the illustration to check the clearance between the two. If the clearance exceeds the service limit, replace the pin or bushing whichever is badly worn.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Inside diameter of connecting rod bush	30 [1.18]	30.020 to 30.045 [1.1819 to 1.1829]	
Clearance between pin and bushing		0.020 to 0.051 [0.0008 to 0.0020]	0.080 [0.0032]

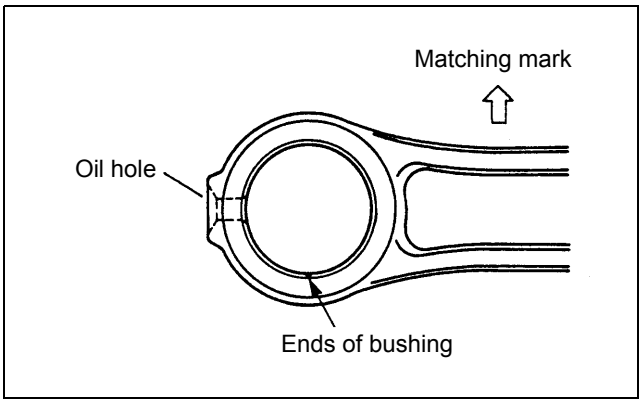


Figure 133 Installing connecting rod bushing

3. Installing connecting rod bushing

   1) Use connecting rod bushing puller (MH061236) to install the connecting rod bushing.
   2) When installing a new bushing, align the oil holes in the bushing and connecting rod. Position the ends of the bushing as shown in the illustration.
   3) After installing the bushing, put the piston pin in position and make sure the pin rotates freely.

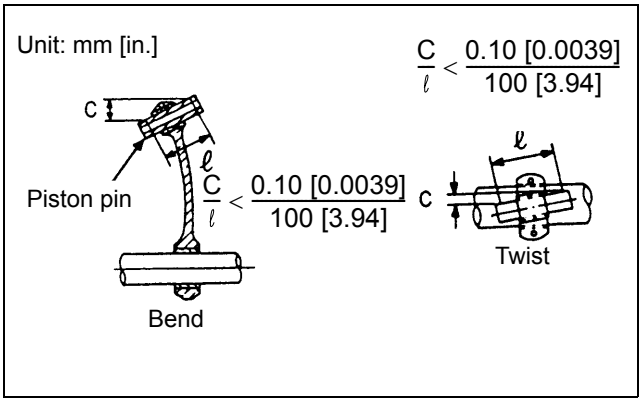


Figure 134 Measuring connecting rod bend and twist

4. Inspecting connecting rods for bend and twist

   1) Measure C and ℓ. If the measurement at C is more than 0.10 mm [0.0039 in.] per 100 mm [3.94 in.] of ℓ, straighten the rod with a press.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Bent or twisting of connecting rod	0.10/100 [0.0039/3.94] or less	0.15 [0.0059]

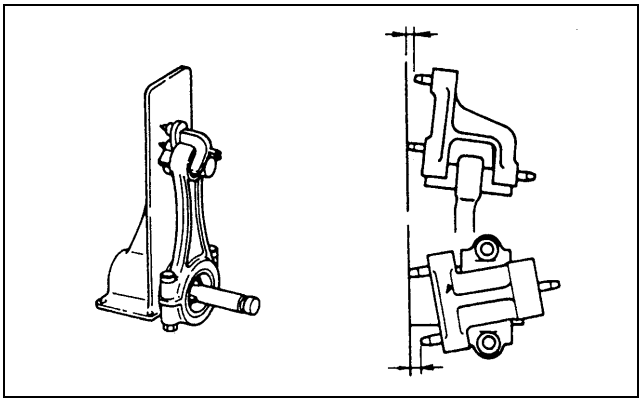


Figure 135 Checking connecting rod on a connecting rod aligner

   2) A connecting rod aligner is generally used for checking the connecting rod bend and twist.

NOTE

To check for bending, install the bearing cap to the connecting rod and tighten the cap nuts to the 49.0 to 59.0 N·m (5.0 to 6.0 kgf·m) [36.2 to 43.4 lbf·ft].

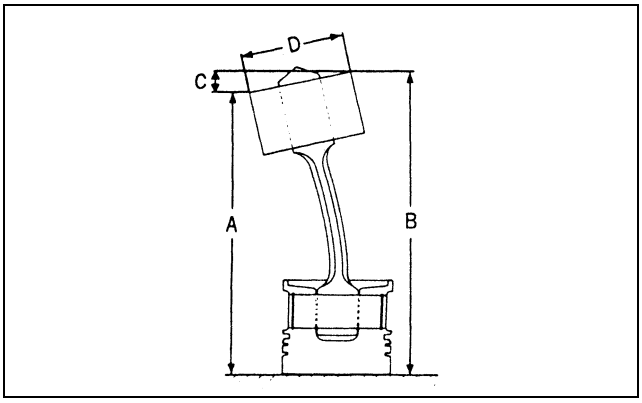


Figure 136 Measuring connecting rod

3) To check the rod complete with the piston, put the piston on the surface plate, put a round bar identical with the crankpin in diameter in the big end bore and measure the heights A and B of the bar with a dial indicator.

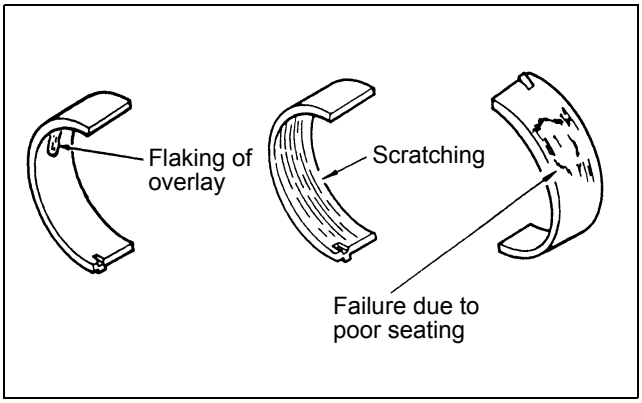


Figure 137 Checking connecting rod bearings

5. Inspecting connecting rod bearings

Check each bearing for flaking of overlay, scratching, burning, pitting or other defects. Replace defective bearings if any.

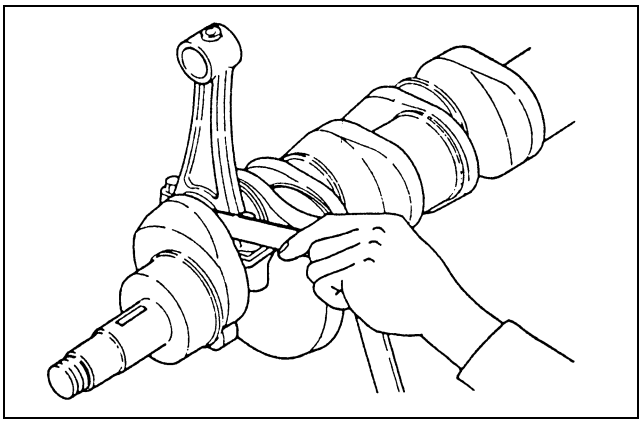


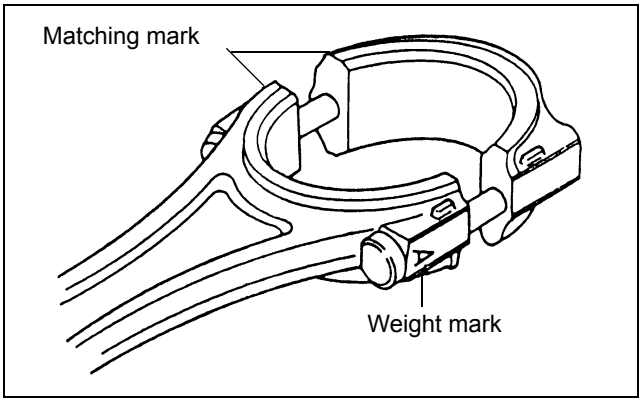
Figure 138 Measuring connecting rod end play

6. Measuring connecting rod end play

Install the connecting rod to the mating crankpin by tightening the cap nuts to the specified torque. Measure the end play (clearance between the rod and crank arm) with feeler gages as shown in the illustration. If the end play exceeds the service limit, replace the connecting rod.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
End play of connecting rod	0.15 to 0.35 [0.0059 to 0.0138]	0.50 [0.020]



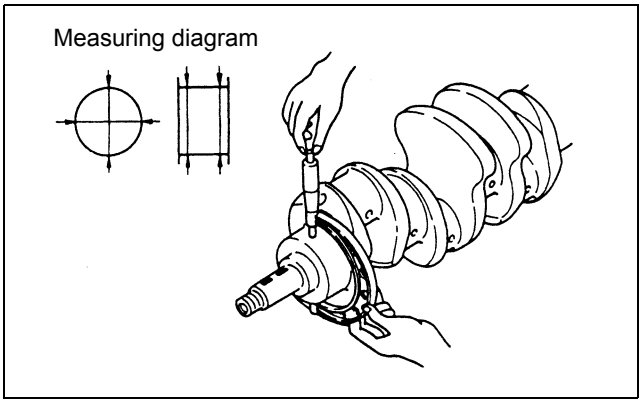


Figure 139 Measuring journals

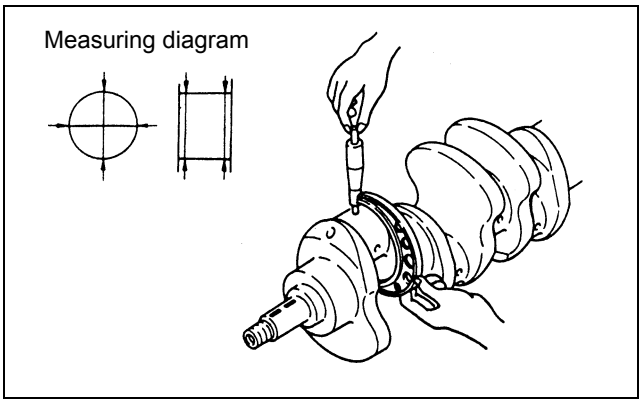


Figure 140 Measuring crankpins

7. Weight difference between connecting rod assemblies

   When installing the connecting rod, make sure the weight difference of the connecting rod per engine is in the assembly standard.

Unit: mm [in.]

Item	Assembly Standard
Connecting rod weight difference per engine	10 g. [0.35 oz.] or less

19.2.4 Crankshaft

1. Measuring journal diameter

   Measure the journal with a micrometer as shown in the illustration to check wear, circularity, taper and clearance between the bearing and journal. If any measurement exceeds the repair limit, grind the crankshaft to an undersize. If it exceeds the service limit, replace the crankshaft.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Repair Limit	Service Limit
Journal diameter	78 [3.07]	77.955 to 77.970 [3.0691 to 3.0697]	77.850 [3.0650]	77.100 [3.0354]
Circularity		0.01 [0.0004] or less	0.03 [0.0012]	
Taper				

2. Measuring crankpin diameter

   Measure the crankpin with a micrometer as shown in the illustration to check wear, circularity, taper and clearance between the bearing and crankpin. If any measurement exceeds the repair limit, grind the crankshaft to an undersize, or replace the crankshaft.

Unit: mm [in.]

Item	Nominal Value	Assembly Standard	Service Limit
Crankpin diameter	58 [2.28]	57.955 to 59.970 [2.2817 to 2.2823]	57.800 [2.2756]
Circularity		0.01 [0.0004] or less	0.03 [0.0012]
Taper			

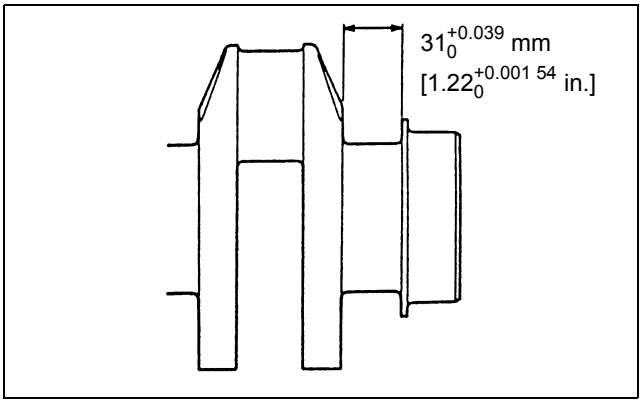


Figure 141 Measuring crankshaft end play

3. Grinding crankshaft

When grinding the crankpins and journals, be sure to produce the same fillet radius as the original one. They should have a hardness of 620 or more in terms of Vickers Hardness Number. If necessary, re-harden the crankpins and journals, and inspect them for cracks by conducting a magnalux (magnetic particle) test.

Crankshaft grinding dimensions

Unit: mm [in.]

	Undersize	Grinding dimension
Journal	0.25 [0.0098]	77.705 to 77.720 [3.0593 to 3.0598]
	0.50 [0.0197]	77.455 to 77.470 [3.0494 to 3.0500]
	0.75 [0.0295]	77.205 to 77.220 [3.0396 to 3.0402]
Crankpin	0.25 [0.0098]	57.705 to 57.720 [2.2719 to 2.2724]
	0.50 [0.0197]	57.455 to 57.470 [2.2620 to 2.2626]
	0.75 [0.0295]	57.205 to 57.220 [2.2522 to 2.2528]

4. Measuring crankshaft end play

1) With the thrust plates installed in the front and rear journals and all bearing caps tightened to the specified torque, measure the end play (the difference in width between the journal and thrust plate). If the end play exceeds the repair limit, replace the thrust plate.
2) If the end play still exceeds the repair limit even after the new thrust plates have been installed, replace the thrust plates with the oversize ones. 0.15 mm [0.005 9 in.], 0.30 mm [0.011 8 in.] and 0.45 mm [0.017 7 in.] oversize thrust plates are available for service. Generally the rear journal is likely to wear more rapidly than the front journal. This means that replacement of the rear thrust bearings will generally be sufficient.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Crankshaft end play	0.100 to 0.264 [0.0039 to 0.0104]	0.300 [0.0118]

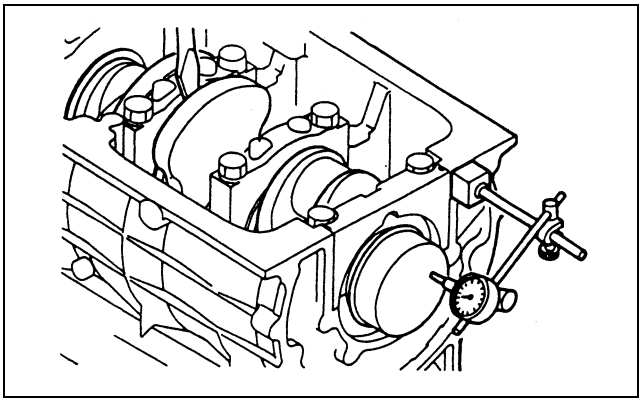


Figure 142 Measuring crankshaft end play

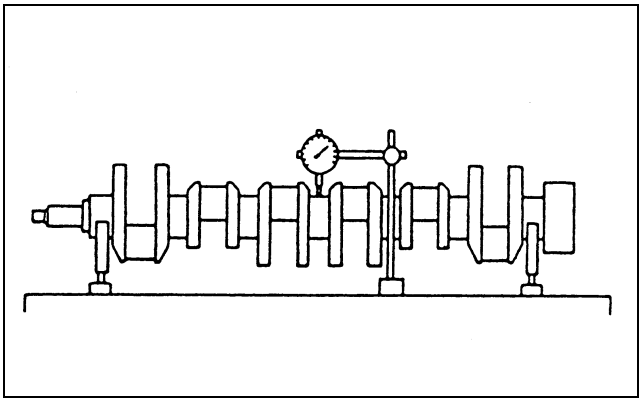


Figure 143 Measuring crankshaft deflection

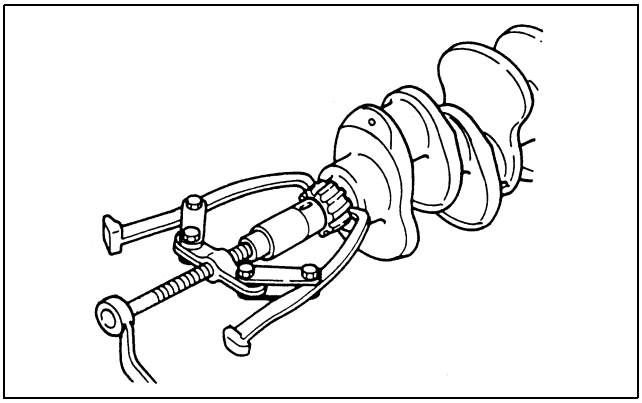


Figure 144 Replacing crankshaft gear

Crankshaft grinding dimensions for oversize thrust plates

Unit: mm [in.]

Oversize	Oversize for front or rear	Oversize for front and rear	Tolerance
0.15 [0.005 9]	31.15 [1.2264]	31.30 [1.2323]	+0.039 0 +0.00154 0
0.30 [0.011 8]	31.30 [1.2323]	31.45 [0.2382]	
0.45 [0.017 7]	31.45 [1.2382]	31.60 [1.2441]	

5. Measuring crankshaft deflection

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

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Crankshaft deflection	0.02 [0.0008] or less	0.05 [0.002]

6. Replacing crankshaft gear

   1) Use gear puller to remove the gear from the crankshaft.

⚠ CAUTION

Do not remove the gear by tapping with a hammer.

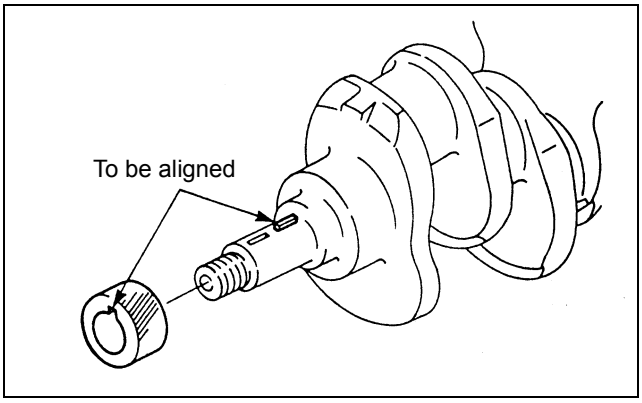


Figure 145 Installing crankshaft gear

2) Heat a replacement gear up to 100°C [212°F] with a gear heater. Put the gear on the crankshaft with its keyway aligned with the key and tap the end face of the gear with a hammer.

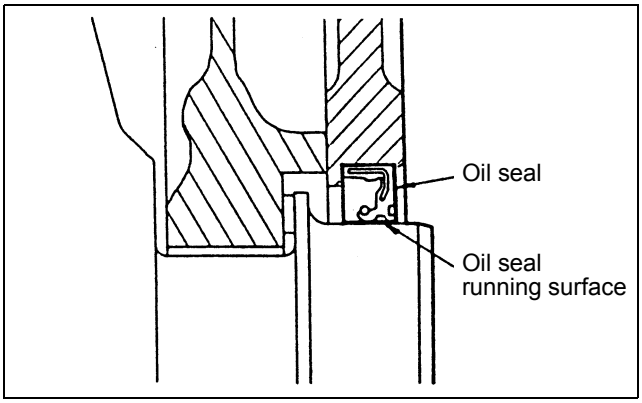


Figure 146 Checking oil seal running surface

7. Checking oil seal running surface

Check the oil seal running surface of the crankshaft for wear. If the crankshaft is badly worn, replace the oil seal complete with oil seal sleeve.

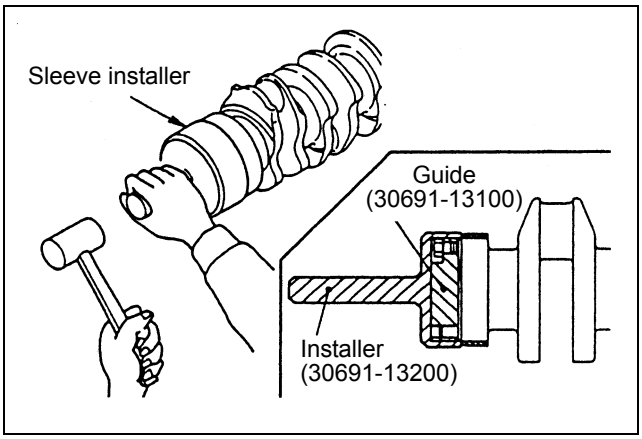


Figure 147 Installing oil seal sleeve

1) Installing oil seal sleeve
Apply oil to the inside of an oil seal sleeve and, using oil seal sleeve installer set (30691-13010), install the sleeve in position, as shown in the illustration.

⚠ CAUTION

Be careful not to cause damage to the sleeve when installing it.

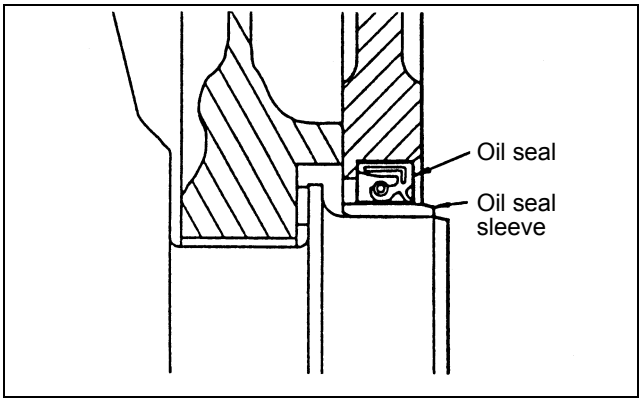


Figure 148 Checking oil seal running surface

The oil seal sleeve will be worn in the course of time. In such a case, replace both the oil seal and sleeve.

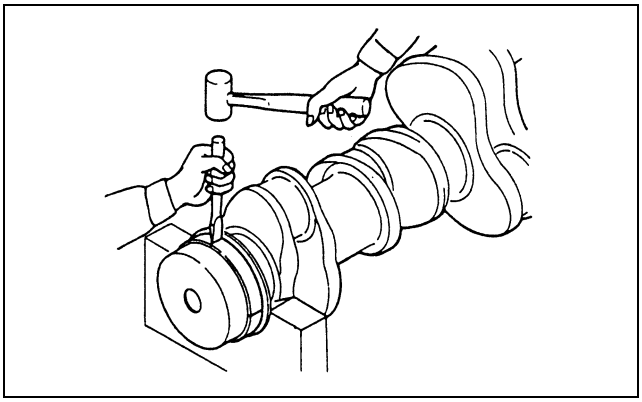


Figure 149 Removing oil seal sleeve

2) Removing oil seal sleeve
Hold a flat chisel at right angles to the sleeve and cut the sleeve at three places to loosen it, as shown in the illustration. If it is impossible to remove the sleeve in this method, hold the chisel in the axial direction and lightly tap the sleeve to loosen it.

⚠ CAUTION

Be careful not to cause damage to the crankshaft when removing the sleeve.

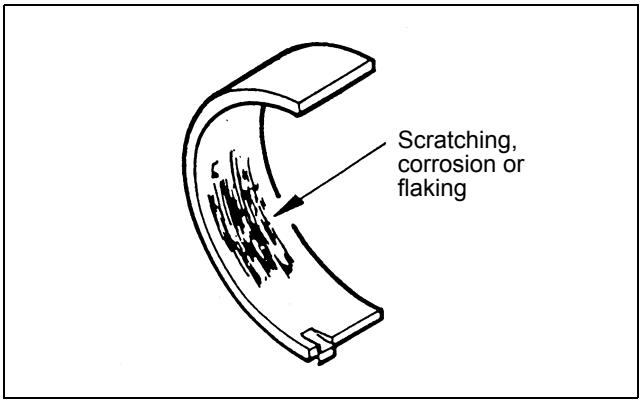


Figure 150 Inspecting main bearing surface

19.2.5 Main bearings

1. Inspecting the main bearing surface

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

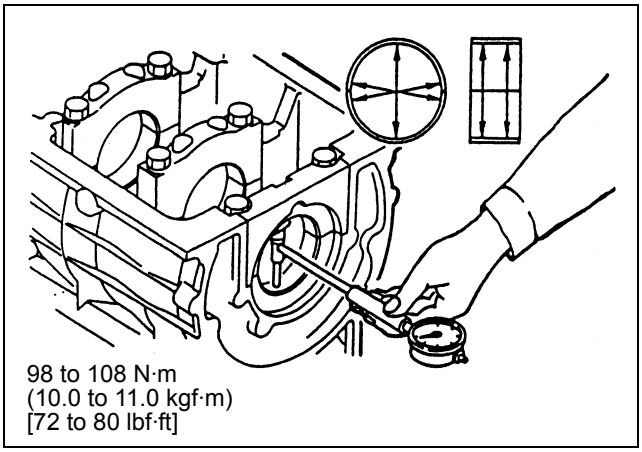


Figure 151 Measuring main bearing

2. Clearance between bearing and journal

Install the bearings to the crankcase and bearing cap. Tighten the cap to the specified torque. Measure the inside diameter of the bearing in two positions lengthwise and three crosswise as shown in the illustration to take an average. Check the clearance between the bearing and journal on the basis of this measurement.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Clearance between bearing and journal	0.050 to 0.110 [0.0020 to 0.0043]	0.200 [0.0079]

3. Replacement

If the clearance between the bearing and journal exceeds the repair limit, replace the bearings, or grind the crankshaft and use undersize bearings. If the crankshaft is ground, it is necessary to check the bearing contact.

19.2.6 Tappets

1. Inspecting cam contact face of tappet

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

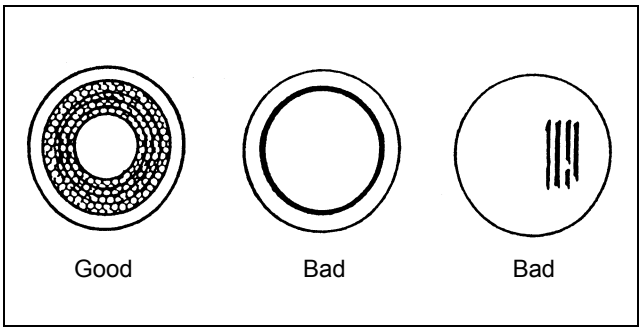


Figure 152 Cam contact face of tappet

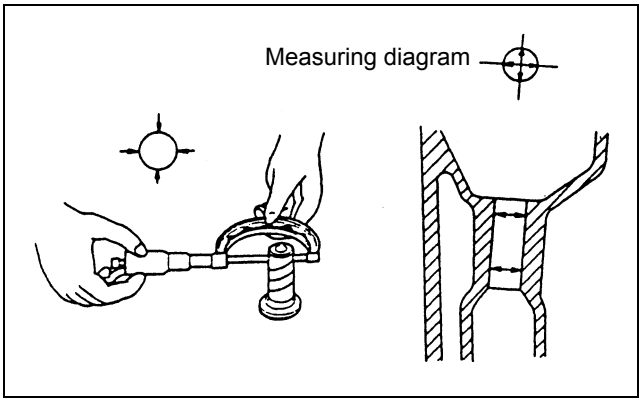


Figure 153 Measuring clearance between tappet and tappet bore

2. Measuring clearance between tappet and tappet bore

Measure the diameter of the tappet and the inside diameter of the bore for the tappet, as shown in the illustration, to check the clearance between the two. If the clearance exceeds the repair limit, replace the tappet.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit	Service Limit
Inside diameter of tappet bore	14.000 to 14.018 [0.5512 to 0.5519]		14.100 [0.5551]
Clearance between tappet and tappet bore	0.016 to 0.052 [0.0006 to 0.0021]	0.08 [0.0031]	

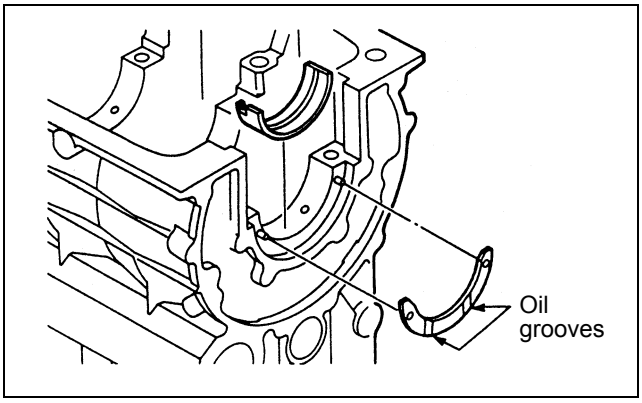


Figure 154 Installing main bearings

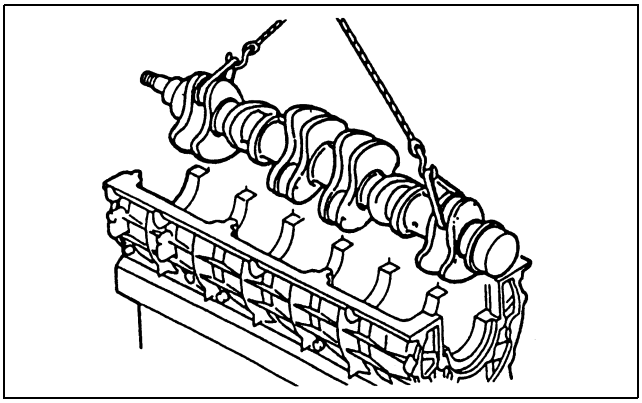


Figure 155 Installing crankshaft

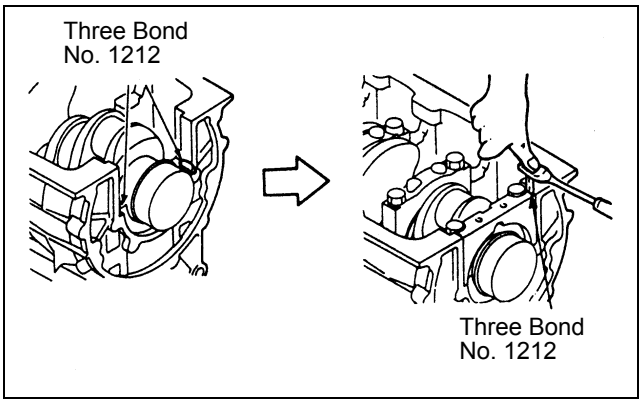


Figure 156 Installing main bearing caps

19.3 Reassembly

1. Installing main bearings

    1) Install each upper shell of the main bearing to the crankcase so that the bearing lug fit into the notch in the crankcase. The oil hole in the bearing and crankcase will be aligned when the bearing is so installed.
    2) Apply a small amount of engine oil to the bearings.
    3) Install the thrust plate to the rear face of the crankcase with oil grooves toward the outside as shown in the illustration.

2. Installing crankshaft

    1) Wash the crankshaft with cleaning solvent, and dry it by air blow.
    2) Hold the crankshaft in a horizontal position by using a hoist, and carefully put it in the crankcase.
    3) Lightly coat the journals with engine oil.

3. Installing main bearing caps

    1) Apply engine oil to the bearings and install the bearings to the caps.
    2) Apply Three Bond 1212 to the corners of the rear bearing cap and install the cap to the crankcase so that the rear face of the cap is even with the rear face of the crankcase.

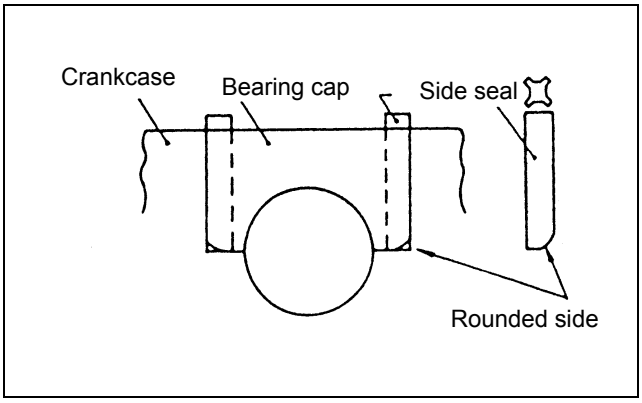


Figure 157 Installing side seals

3) Apply soapy water to the side seals and put the seals in the groove in each bearing cap with rounded side toward outside. Push them into position with the blade of a screwdriver or the like, taking care not to bend or twist them.
4) Apply Three Bond 1212 to and around the side seals.

NOTE

Install the main bearing caps in number sequence.

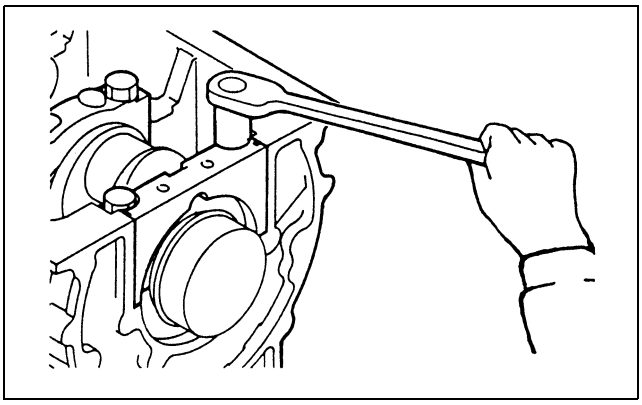


Figure 158 Installing main bearing cap bolts

4. Installing main bearing cap bolts

Apply engine oil to the bolts and tighten them to the specified torque.

Tightening torque for main bearing cap bolts	98 to 108 N·m (10.0 to 11.0 kgf·m) [72 to 80 lbf·ft]

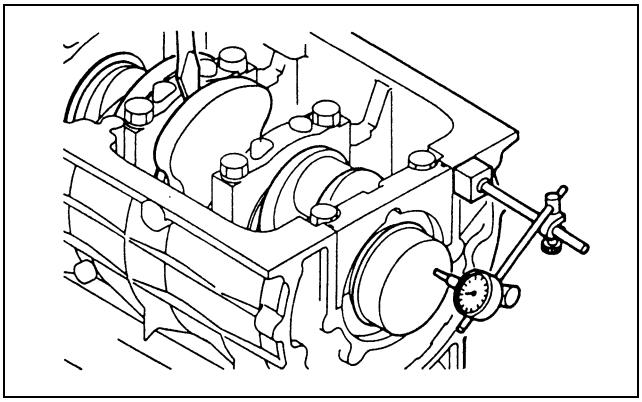


Figure 159 Measuring crankshaft end play

5. Measuring crankshaft end play

After installing the bearing caps, check the end play of the crankshaft. (Refer to 4.2.)

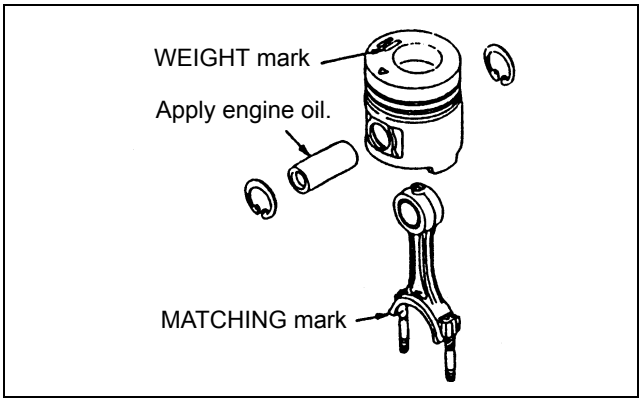


Figure 160 Assembling piston and connecting rod (direct injection type)

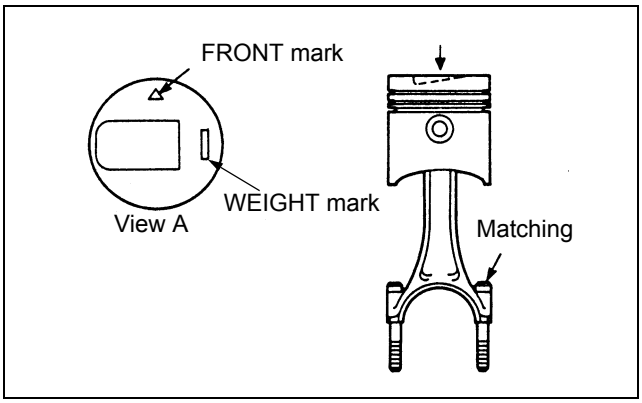


Figure 161 Assembling piston and connecting rod (swirl chamber type)

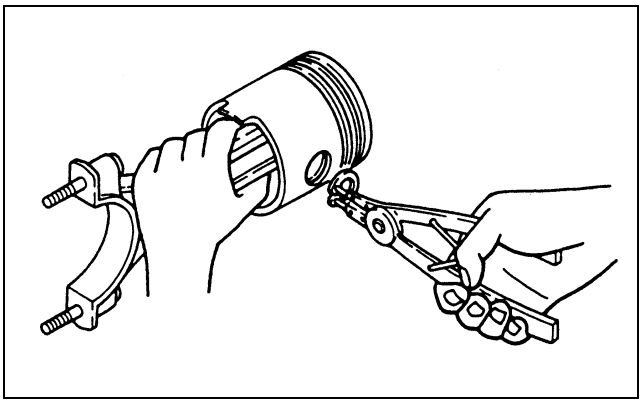


Figure 162 Installing snap rings

6. Assembling piston and connecting rod

   1) Assemble the piston and the connecting rod with the WEIGHT mark of the piston and the MATCHING mark of the rod on the same side.
   2) Apply engine oil to the piston pin and insert the pin into position.

   3) Install each snap ring in the snap ring groove of the piston with snap ring pliers. Make sure the snap ring fits in the groove properly.

NOTE

Install the snap ring with the ends toward the bottom of the piston.

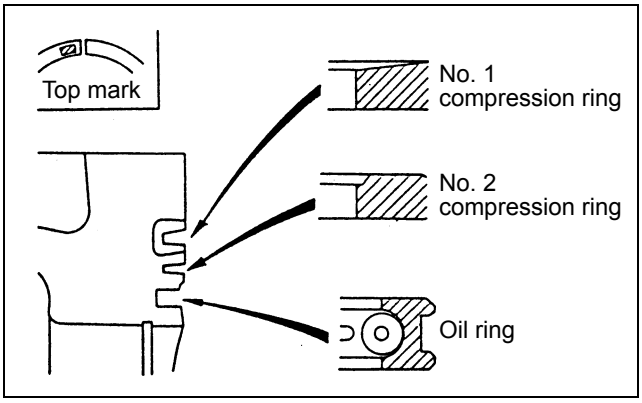


Figure 163 Installing piston rings

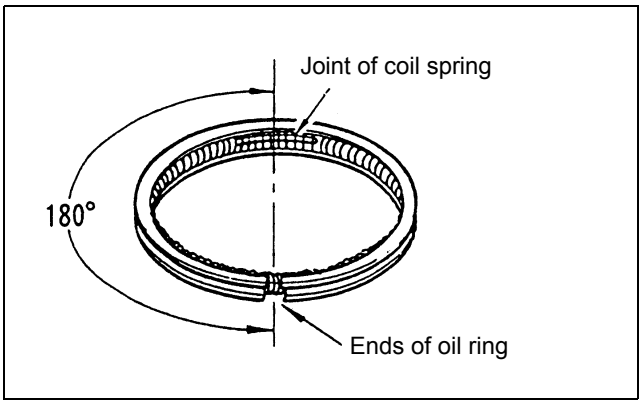


Figure 164 Ends of oil ring and coil spring

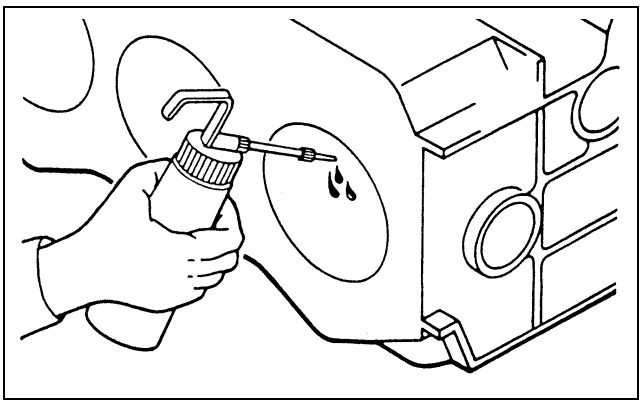


Figure 165 Preparation before for piston installation

7. Installing piston rings

   1) Put the compression rings and oil ring in the ring grooves of the piston with piston ring pliers (31391–12900).

NOTE

Install the compression rings on the piston with “R” or “T” mark toward the top of the piston.

   2) Install the oil ring with the joint of the coil spring 180° apart from those of the ring gap.

8. Preparation before installing pistons

   1) Lay the crankcase on its side
   2) Clean the cylinder bores with a clean rag and apply engine oil to the bore surfaces.
   3) Put the connecting rod cap bolts in the big end of the connecting rod so that the flats of their heads fit to the rod properly.

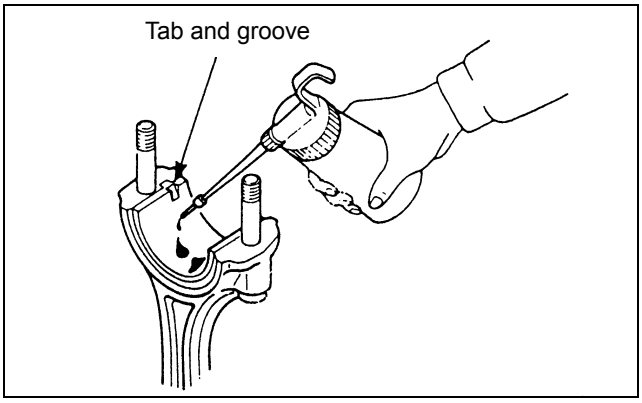


Figure 166 Connecting rod and bearing

4) Install the upper half of the connecting rod bearing to the big end of the connecting rod, making sure the locating lug fits into the notch in the rod. Apply engine oil to the bearing.

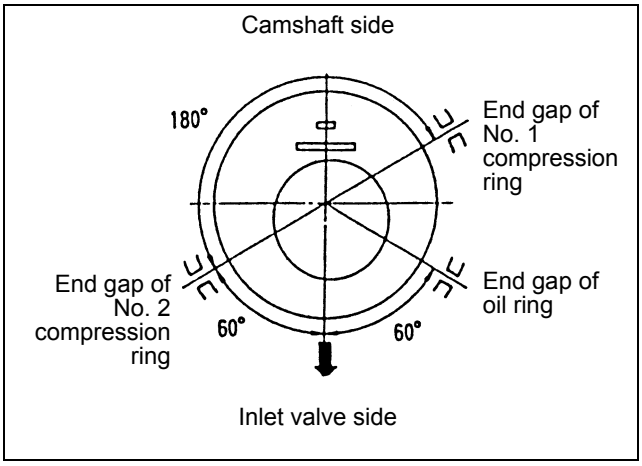


Figure 167 Configuration of piston ring ends (direct injection type)

9. Inserting pistons

1) Apply engine oil to the piston rings. Install the rings on the piston with the ring ends positioned as shown in the illustration.

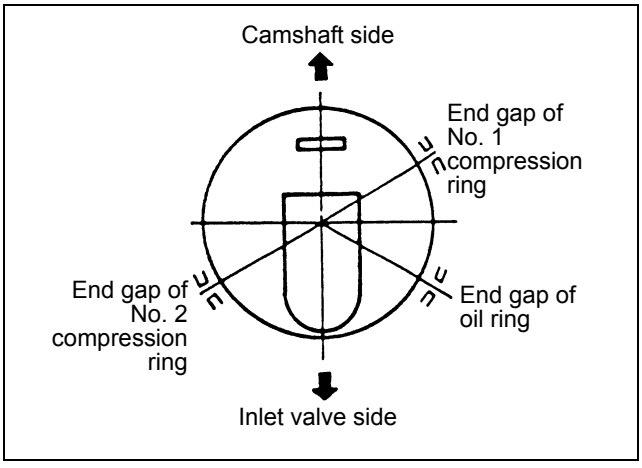


Figure 168 Configuration of piston ring ends (direct injection type)

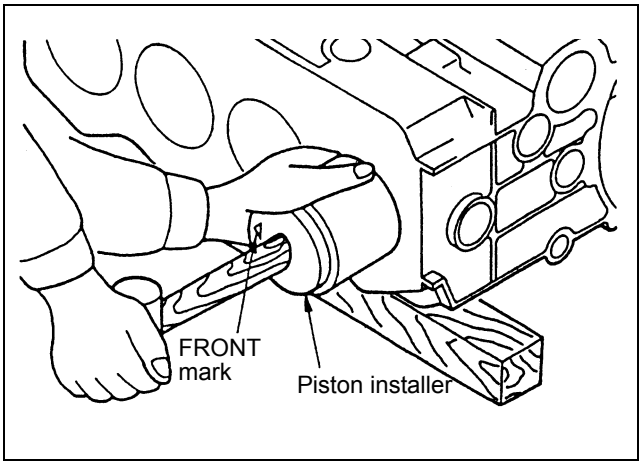


Figure 169 Installing piston and connecting rod assembly

2) Turn the crankshaft to bring a crankpin to install the piston and connecting rod assembly top dead center. Using piston installer (34491–00200), put the assembly in the cylinder, with FRONT mark () on the piston toward the front of the engine.
3) After resting the big-end of the connecting rod on the crankpin, turn the crankshaft 180° while pushing the piston head to bring the big- end to a position where the cap can be installed easily.

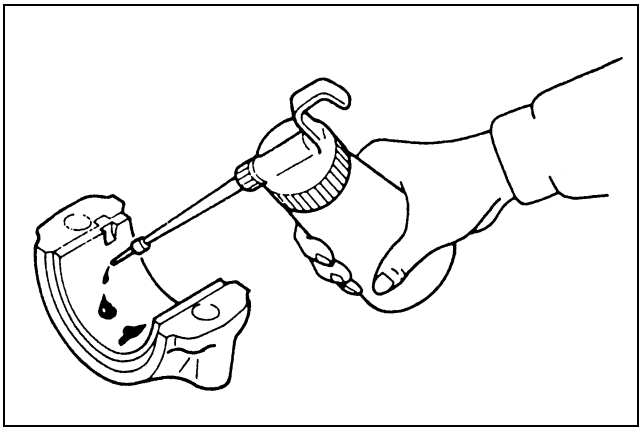


Figure 170 Installing connecting rod cap

10. Installing connecting rod cap

1) Install the lower half of the connecting rod bearing to the cap, making sure the locating lug fits into the notch in the cap. Apply engine oil to the bearing.
2) Install the cap to the rod and tighten the cap nuts to the specified torque.

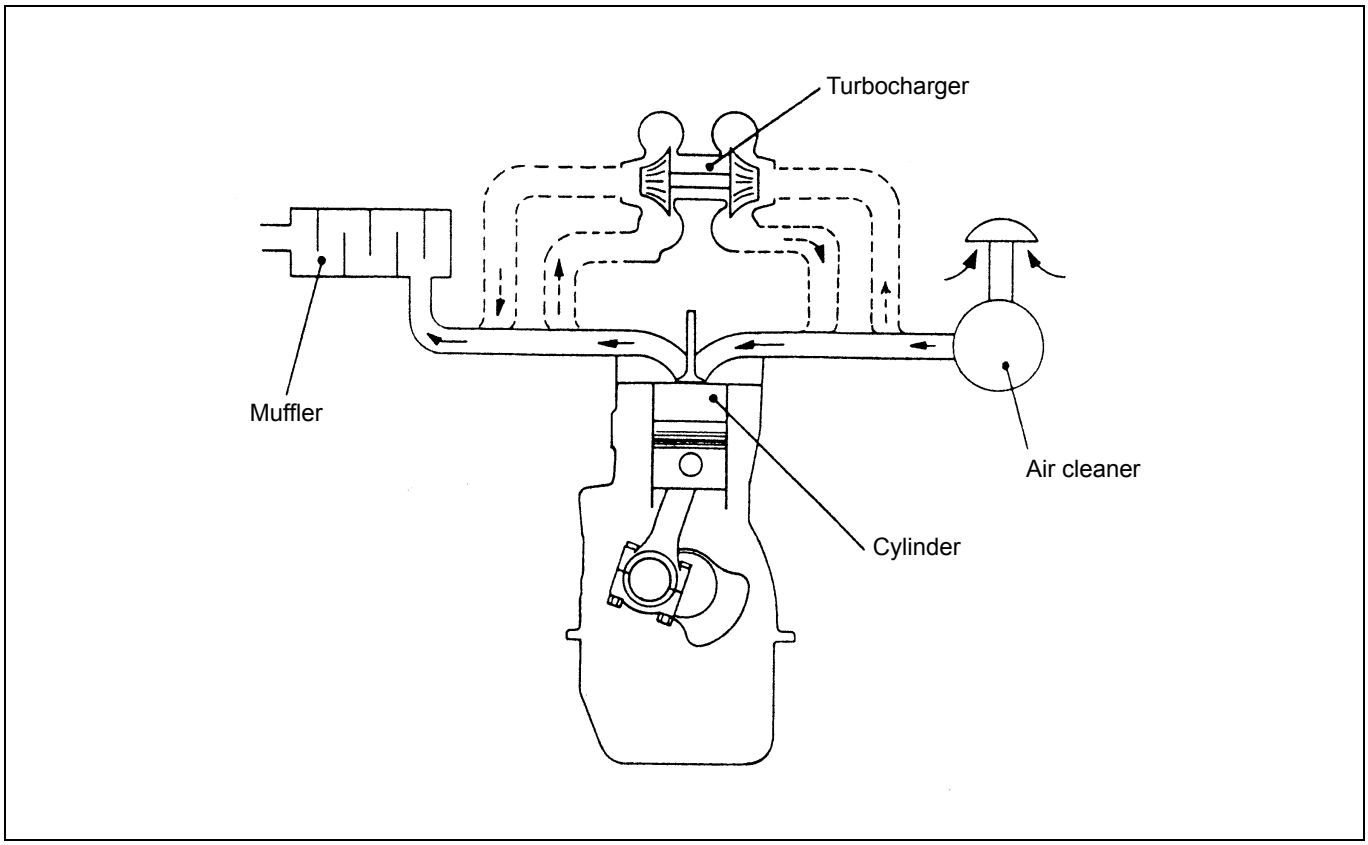
Tightening torque for front cap nuts	49.0 to 59.0 N·m (5.0 to 6.0 kgf·m) [36.2 to 43.4 lbf·ft]

⚠ CAUTION

Make sure the matching mark on the cap is on the same side as the mark on the connecting rod.

INLET AND EXHAUST SYSTEM

20 DESCRIPTION



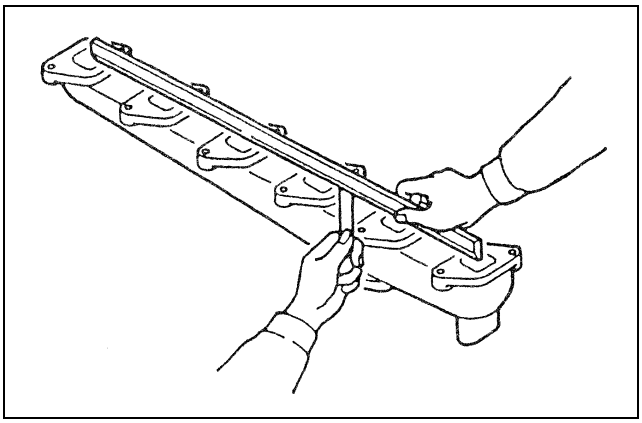


Figure 171 Checking exhaust manifold flange for warpage

21 EXHAUST MANIFOLD

21.1 Inspection

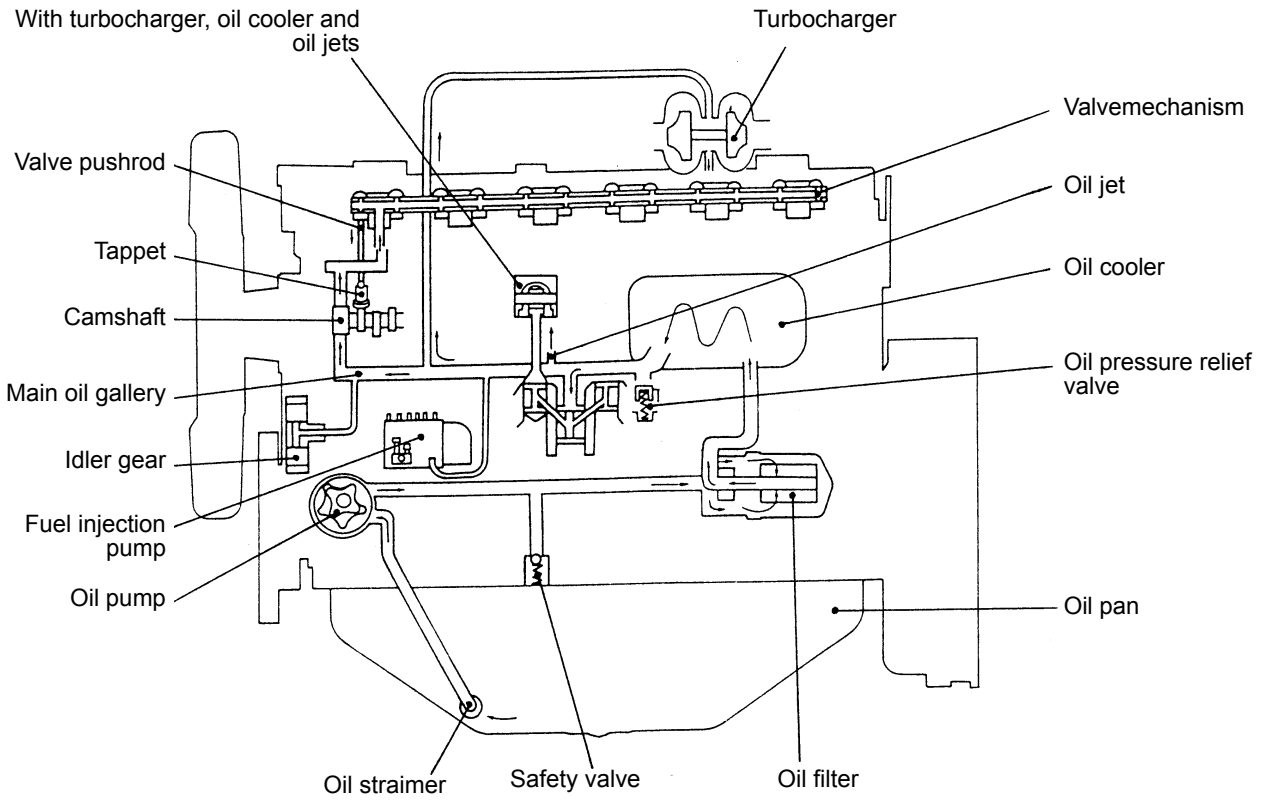
1. Check the flanges for cracking.
2. Check the flanges for warpage as shown in the illustration. If the warpage exceeds the assembly standard, repair the flanges.

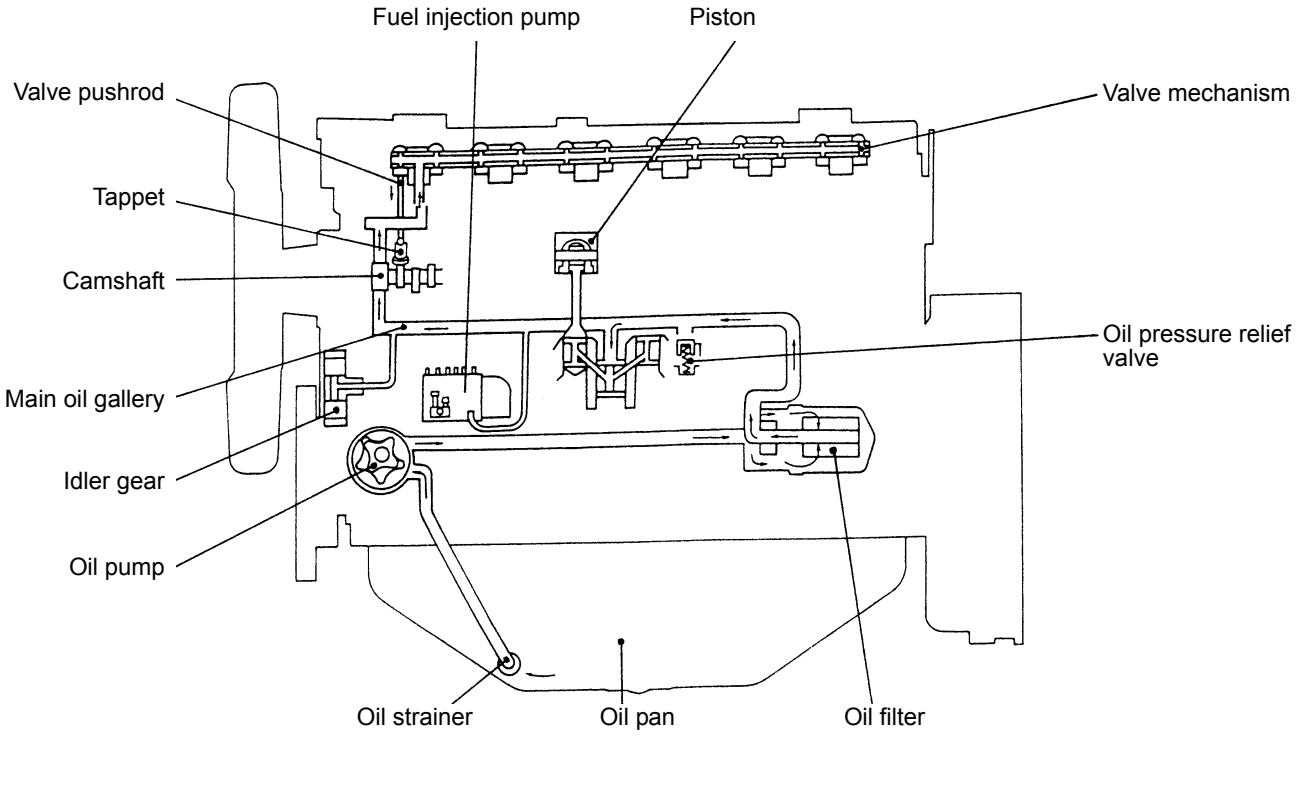
Unit: mm [in.]

Item	Assembly Standard
Warpage of exhaust manifold flange	0.2 [0.008], maximum

LUBRICATION SYSTEM

22 DESCRIPTION





23 OIL PUMP

23.1 Disassembly

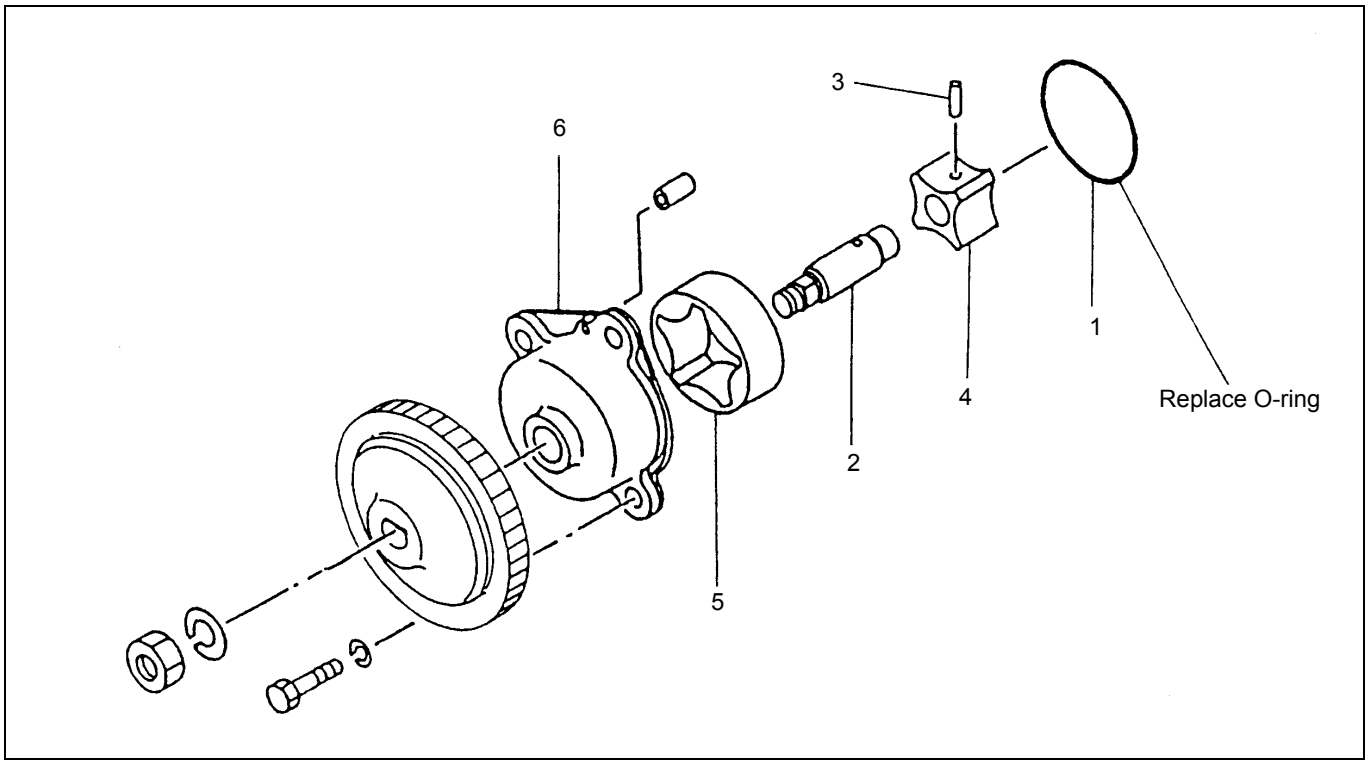


Figure 172 Disassembly sequence

1. O-ring
2. Main shaft
3. Pin
4. Inner rotor
5. Outer rotor
6. Pump case

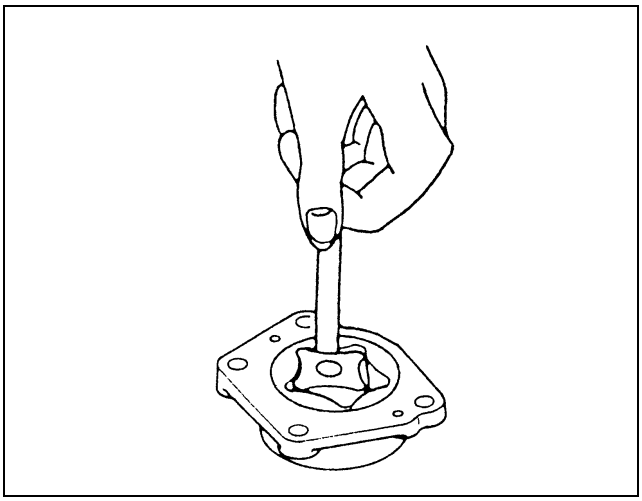


Figure 173 Checking clearance between outer rotor and inner rotor

23.2 Inspection

1. Checking clearance between outer rotor and inner rotor

   Check the clearance with a feeler gage, as shown in the illustration. If the clearance exceeds the service limit, replace the pump assembly.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Clearance between outer rotor and inner rotor	0.13 to 0.15 [0.0051 to 0.0059]	0.20 [0.0079]

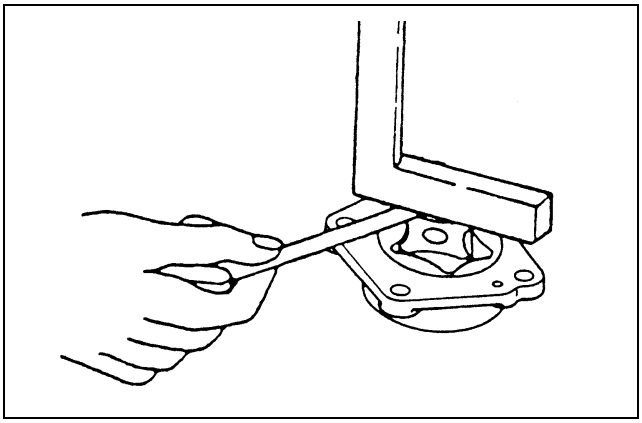


Figure 174 Checking clearance between rotors and cover

2. Checking clearance between rotors and cover

   Check the clearance with feeler gages and straight edge, as shown in the illustration. If the clearance exceeds the service limit, replace the pump assembly.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Clearance between rotors and cover	0.04 to 0.09 [0.0016 to 0.0035]	0.15 [0.0059]

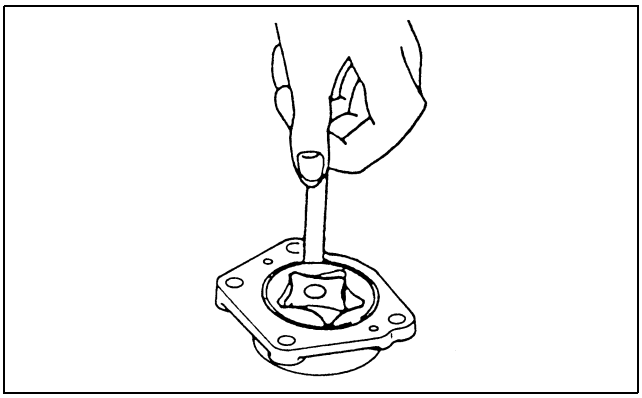


Figure 175 Checking clearance between outer rotor and case

3. Checking clearance between outer rotor and case

   Check the clearance with feeler gages, as shown in the illustration. If the clearance exceeds the service limit, replace the pump assembly.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Clearance between outer rotor and case	0.20 to 0.30 [0.0079 to 0.0118]	0.500 [0.0197]

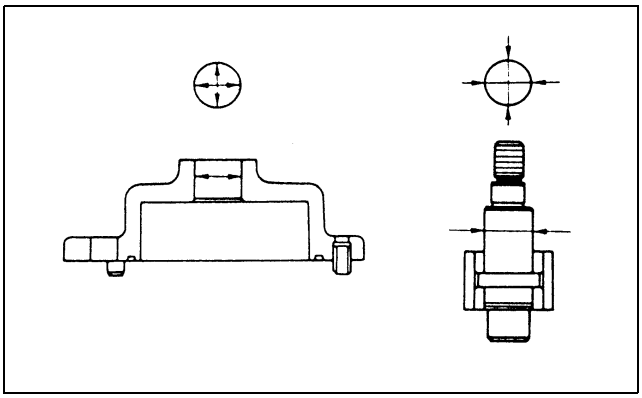


Figure 176 Checking clearance between main shaft and pump case

4. Checking clearance between main shaft and pump case

   Measure the diameter of the shaft and the inside diameter of the bore in the case for the shaft to find the clearance between the two. If the clearance exceeds the service limit, replace the pump case or the pump assembly.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Diameter of main shaft (case side)	15.985 to 16.000 [0.6293 to 0.6299]	
Clearance between main shaft and case	0.032 to 0.074 [0.0013 to 0.0029]	0.15 [0.0059]

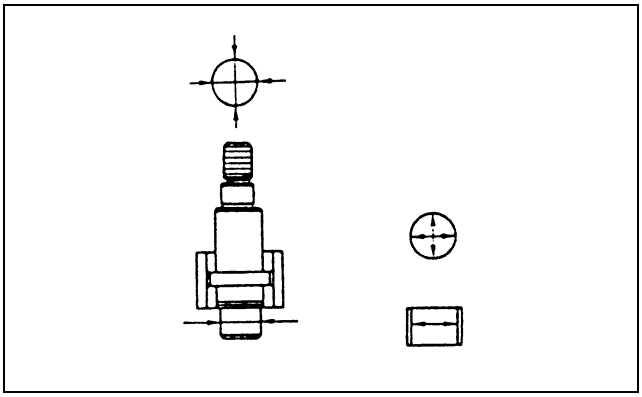


Figure 177 Checking clearance between main shaft and bushing

5. Checking cearance between main shaft and bushing

   Measure the diameter of the shaft and the inside diameter of the oil pump bushing in the crankcase to find the clearance between the two. If the clearance exceeds the service limit, replace the bushing or the pump assembly.

6. Installing oil pump bushing

   To install the oil pump bushing, use oil pump bushing installer (32A91–00400).

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Diameter of main shaft (bushing side)	13.957 to 13.975 [0.5495 to 0.5502]	
Clearance between main shaft and case	0.025 to 0.111 [0.0010 to 0.0044]	0.200 [0.0079]

NOTE

Install the oil pump bushing in the crankcase so that it is even with the front face of the crankcase.

23.3 Reassembly

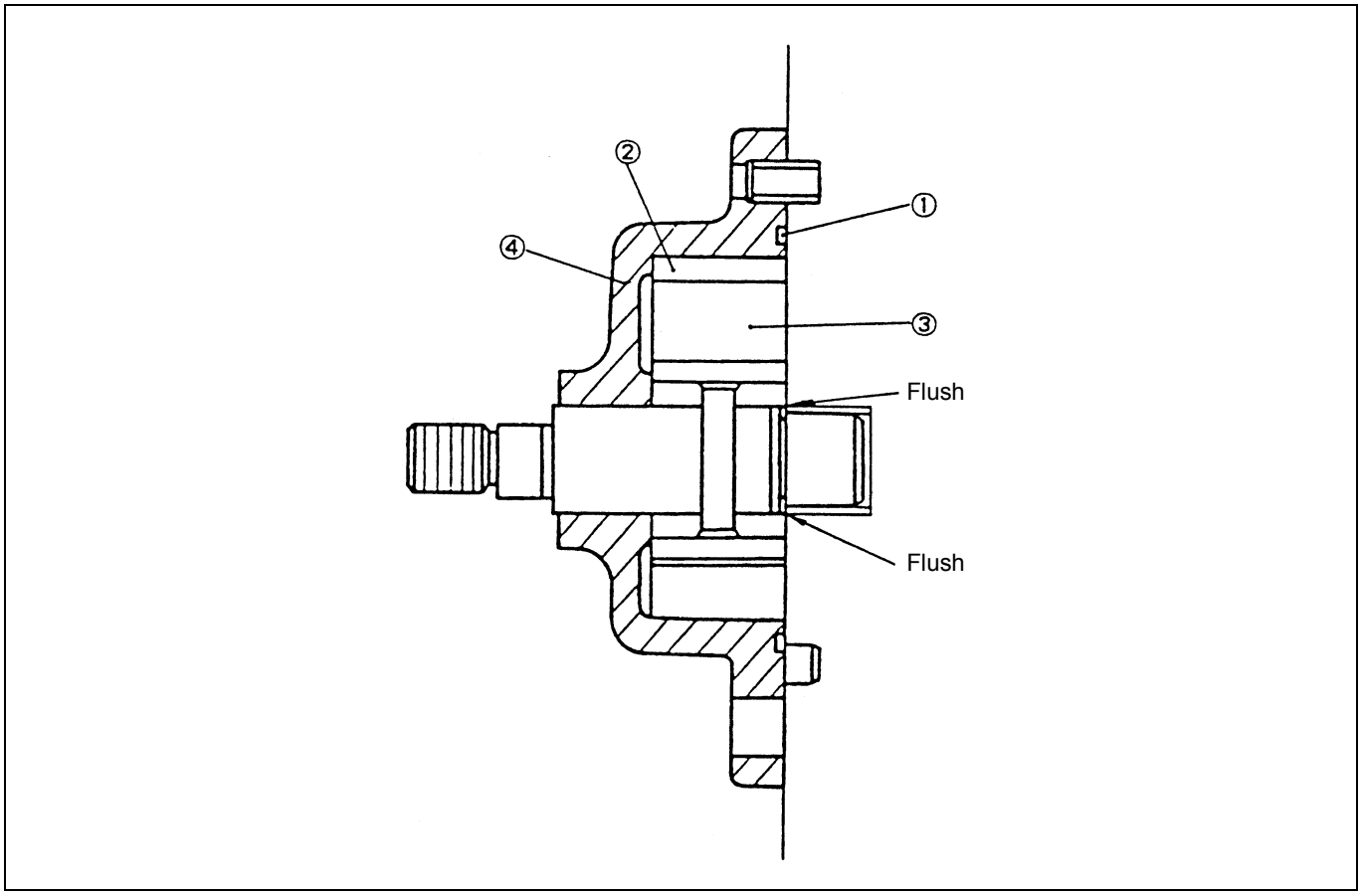


Figure 178 Reassembly sequence

4 → 3 → 2 → 1

24 OIL FILTER

24.1 Disassembly and Inspection

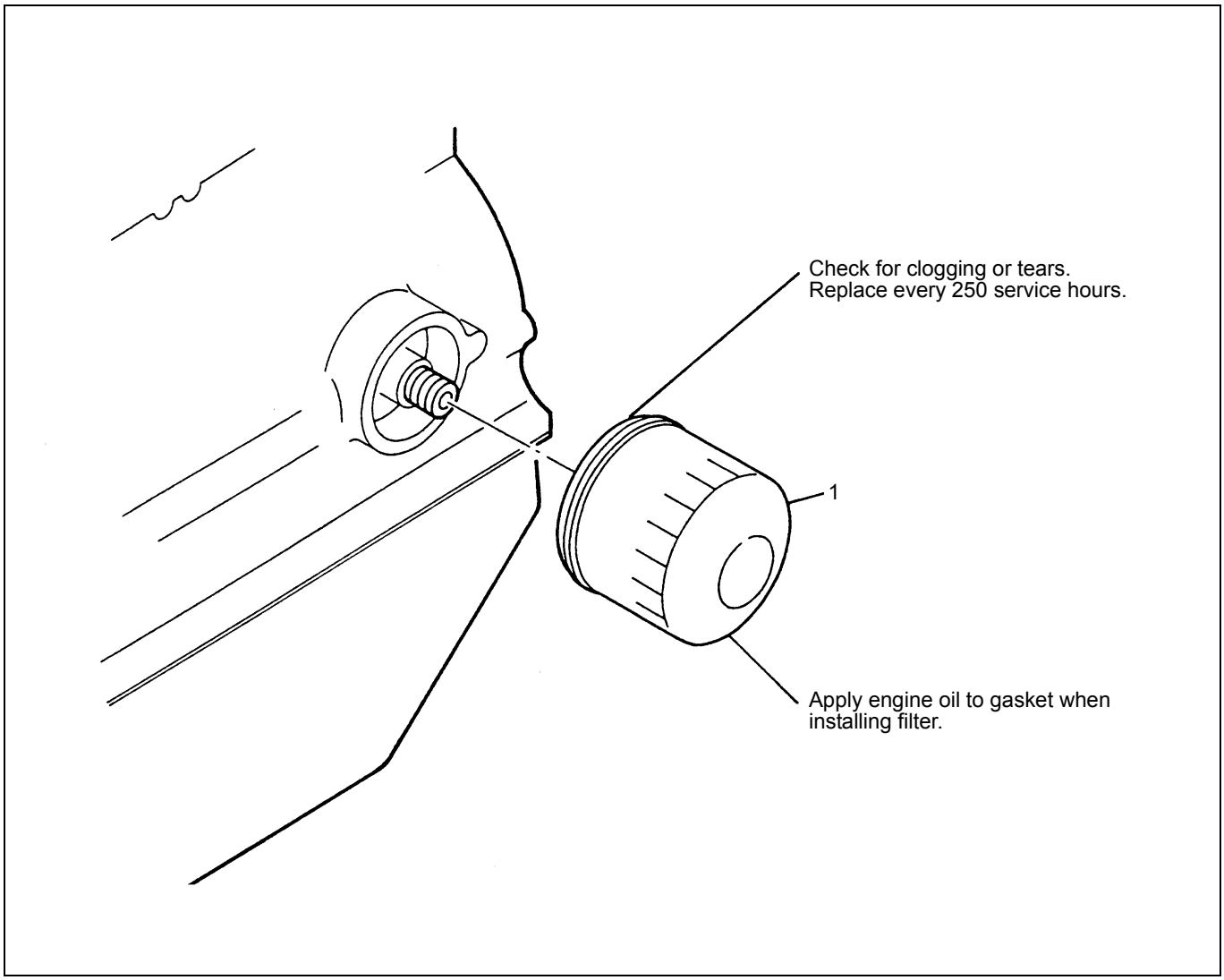


Figure 179 Disassembly sequence

1. Filter element

25 OIL COOLER (ENGINE WITH OIL COOLER)

25.1 Disassembly and Inspection

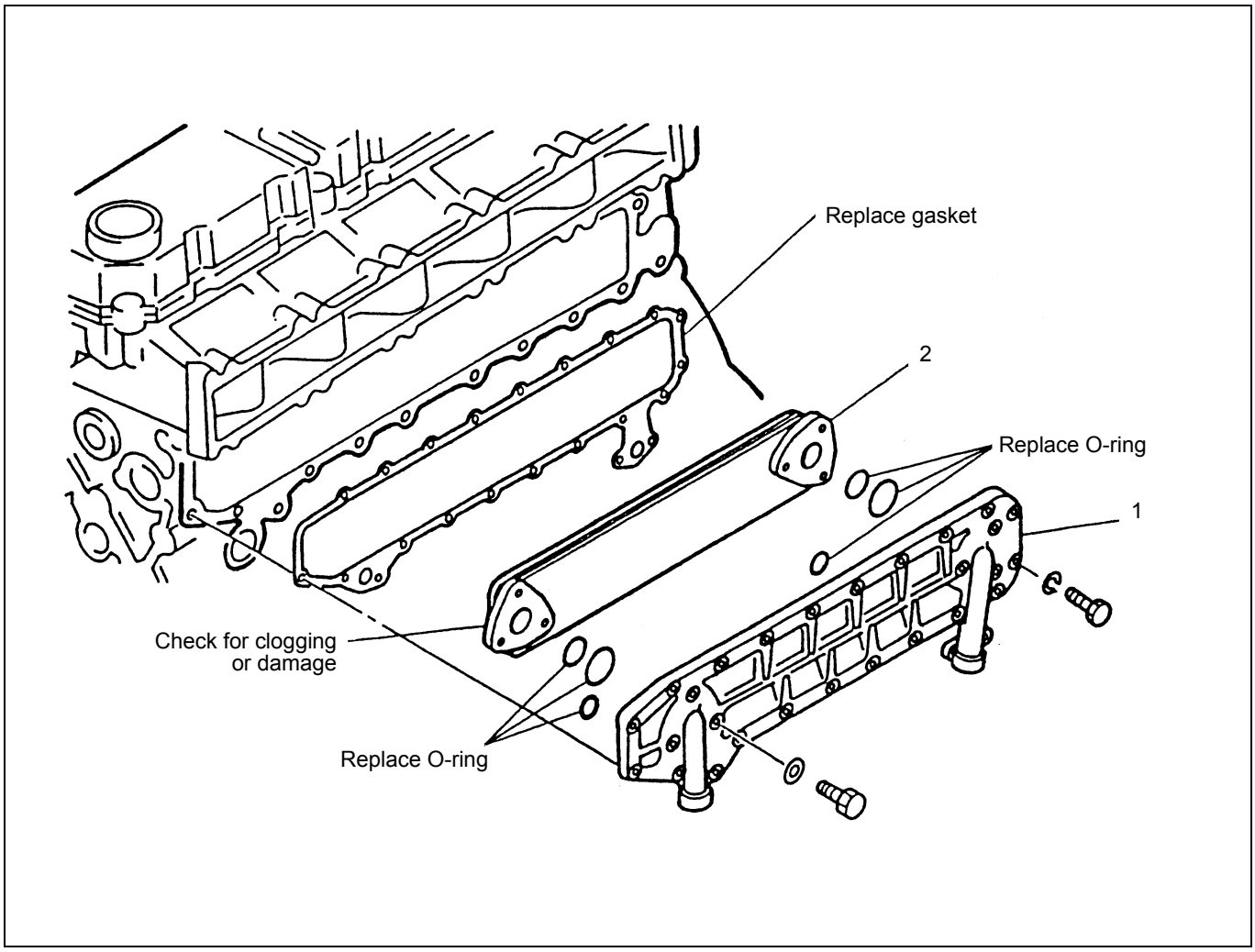


Figure 180 Disassembly sequence

1. Cover
2. Element

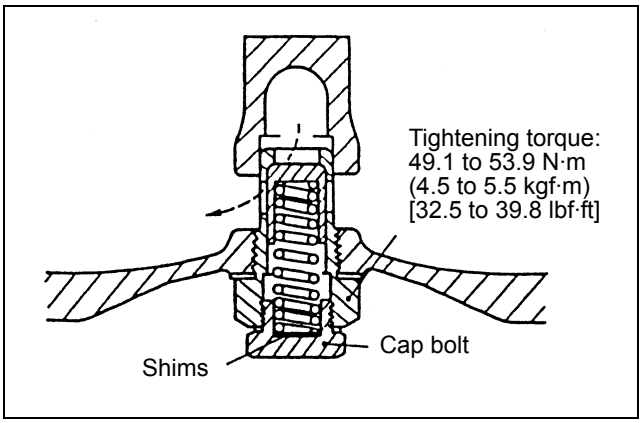


Figure 181 Checking pressure relief valve

26 OIL PRESSURE RELIEF VALVE

26.1 Inspection

1. Check the valve and valve seat for contact. Check the spring the damage.
2. Measure the opening pressure. If the opening pressure is not correct, make a shim adjustment.

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

Item	Assembly Standard
Opening pressure	0.35 ± 0.05 (3.5 ± 0.5) [50 ± 7]

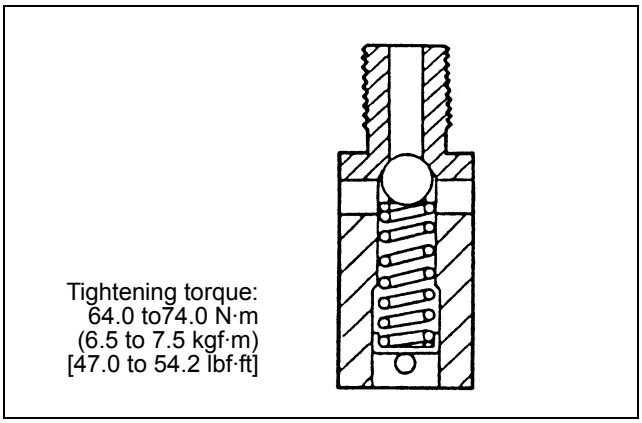


Figure 182 Checking pressure safety valve

27 SAFETY VALVE (ENGINE WITH OIL COOLER)

27.1 Inspection

Check the valve and valve seat for contact.
Check the spring for damage.

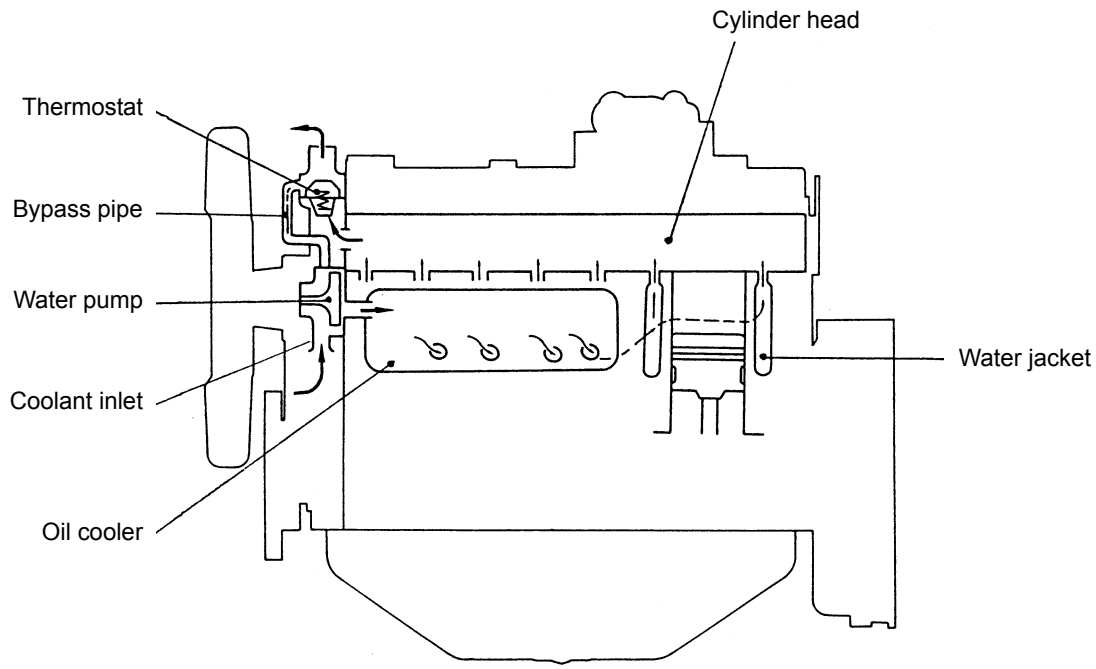
Unit: MPa (kgf/cm^2) [psi]

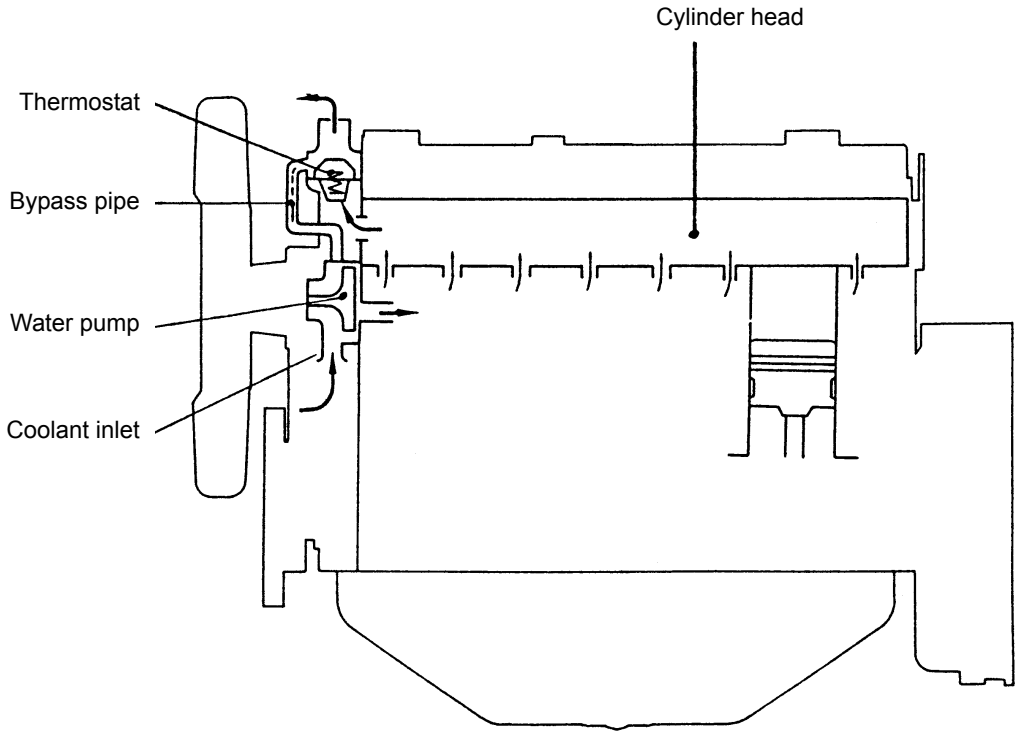
Item	Assembly Standard
Opening pressure	1.1 (11) [156]

COOLING SYSTEM

28 DESCRIPTION

With oil cooler





29 WATER PUMP (ACCORDING TO ENGINE SPECIFICATION)

29.1 Inspection

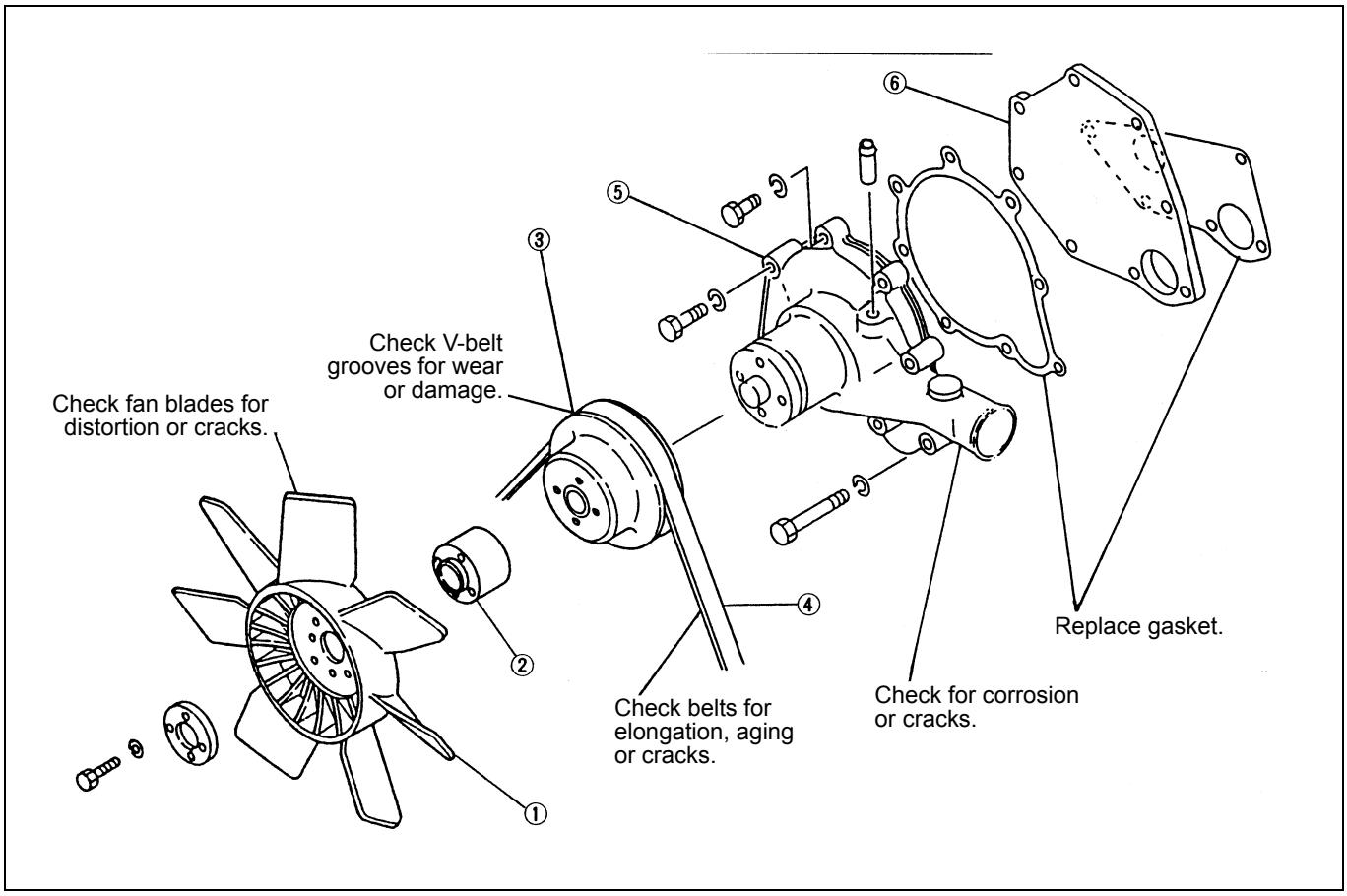


Figure 183 Disassembly sequence

1. Fan
2. Spacer
3. Pulley
4. V-belt
5. Water pump assembly
6. Cover

Visually check the water pump for coolant leaks, rough rotation, cracks or other defects and replace it as an assembly if any of these defects is found.

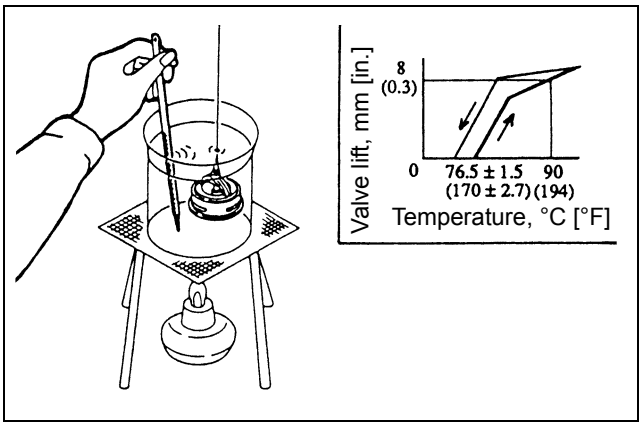


Figure 184 Testing thermostat

30 THERMOSTAT

30.1 Inspection

1. Remove the thermostat from the engine.
2. Hang the thermostat in the jar of water, as shown in the illustration. Thermostat must be below the surface of the water and it must be away from the sides of the jar.
3. Heat the water uniformly in the jar and measure a temperature at which the valve starts opening and a temperature at which the valve lift is more than 8 mm [0.3 in.]. If the valve does not start opening at the correct temperature, or if it does not open to correct lift, replace the thermostat.

Item	Assembly Standard
Temperature at which valve starts opening	76.5 ± 1.5°C [170 ± 2.7°F]
Temperature at which valve lift is more than 8 mm [0.3 in.]	90°C [194°F]

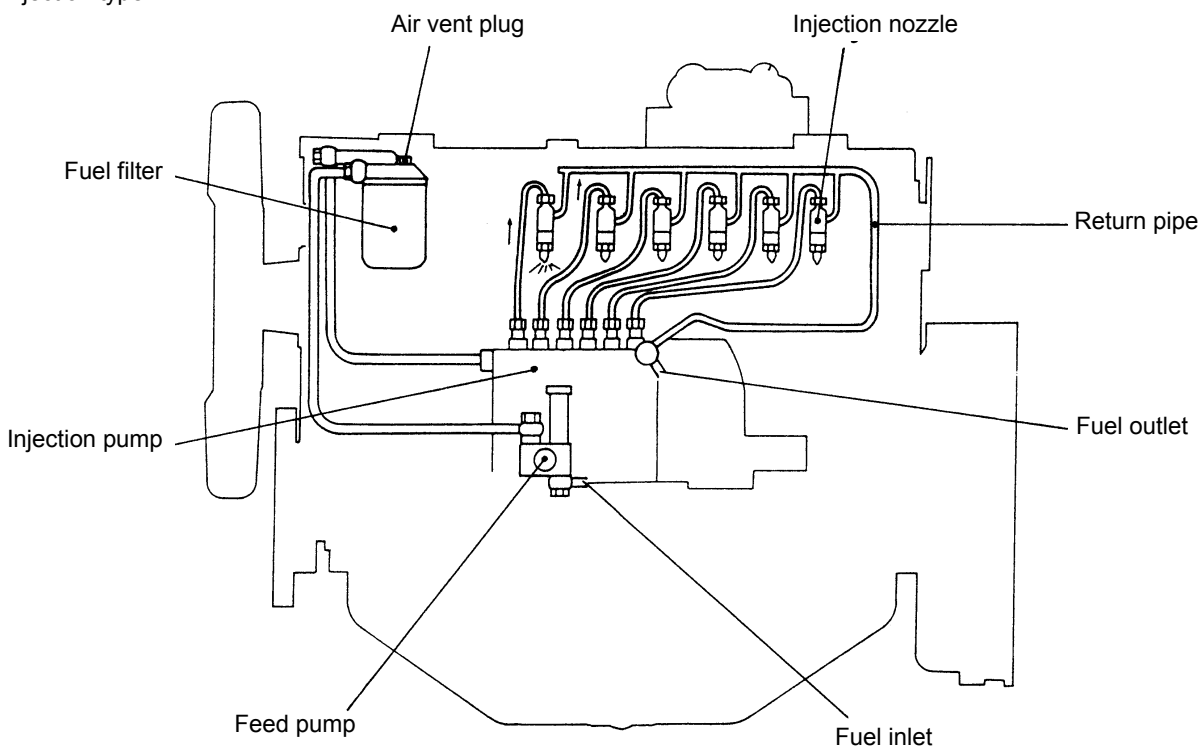
⚠ CAUTION

a. Stir the water in the jar with a stick to maintain its temperature uniform during test.
b. Install the thermostat with its air vent hole up.

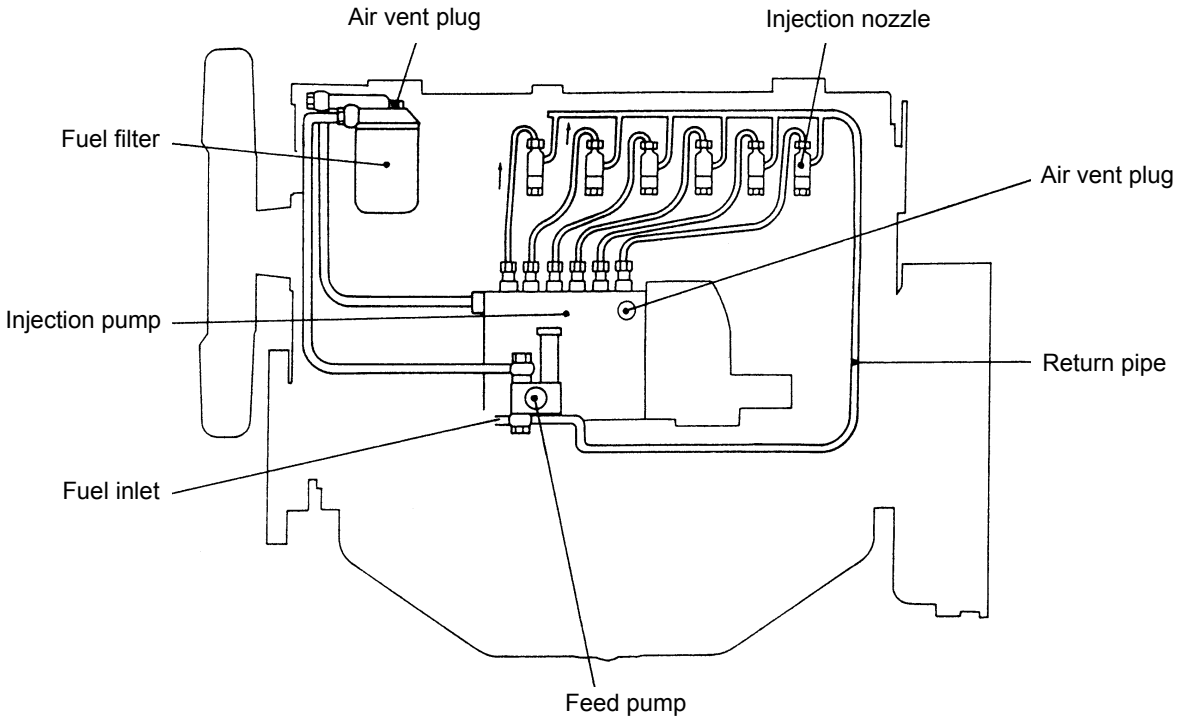
FUEL SYSTEM

31 DESCRIPTION

Direct injection type



Swirl chamber type



32 FUEL FILTER (PAPER-ELEMENT CARTRIDGE TYPE)

32.1 Disassembly and Inspection

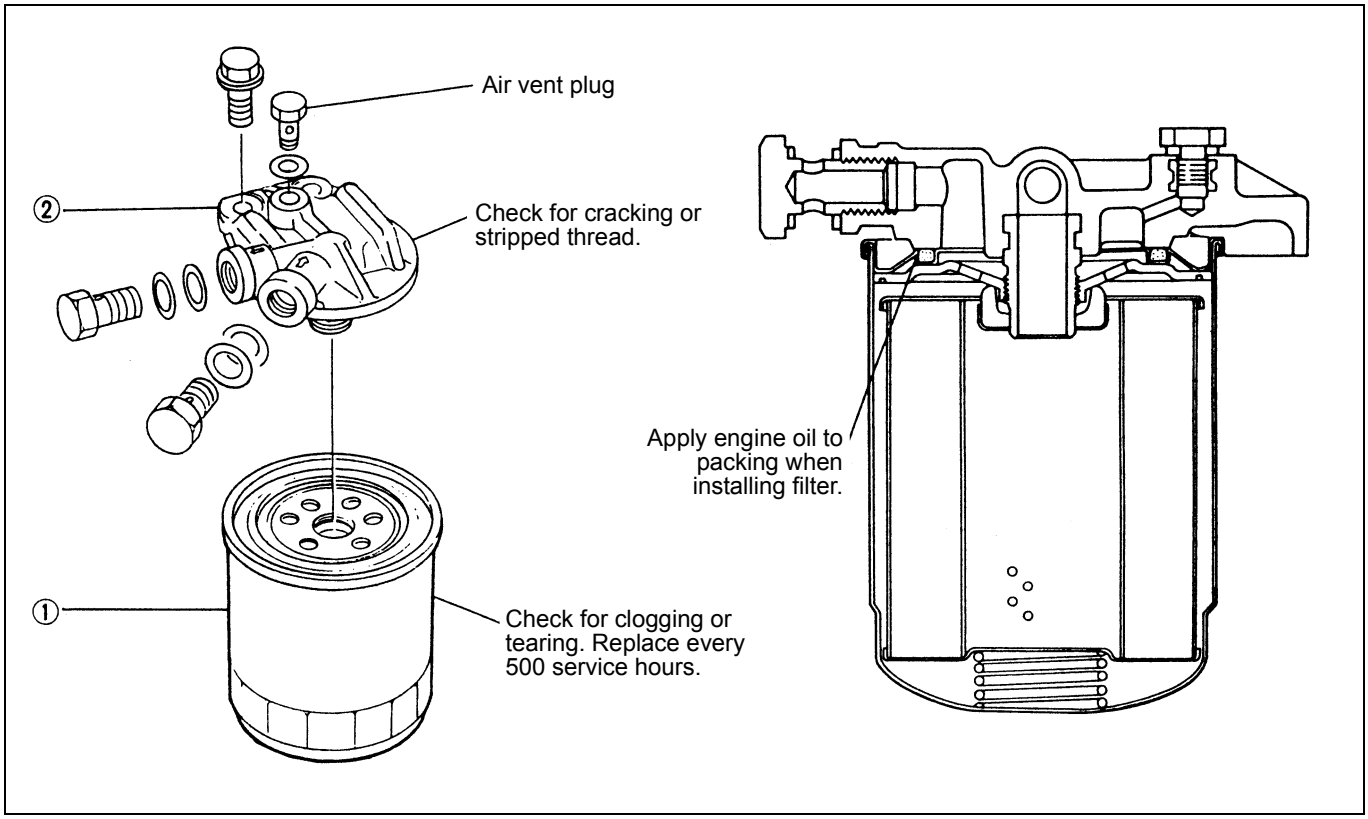


Figure 185 Disassembly sequence

1. Element assembly
2. Bracket

33 INJECTION NOZZLES (ACCORDING TO ENGINE SPECIFICATION)

33.1 Disassembly

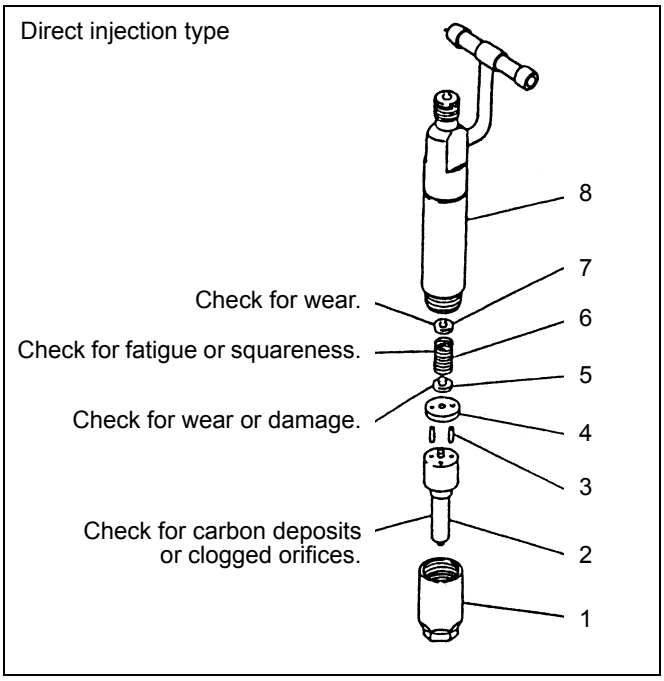


Figure 186 Disassembly sequence

1. Retaining nut
2. Nozzle tip
3. Straight pin
4. Tip packing
5. Pressure pin
6. Pressure spring
7. Shims
8. Nozzle body

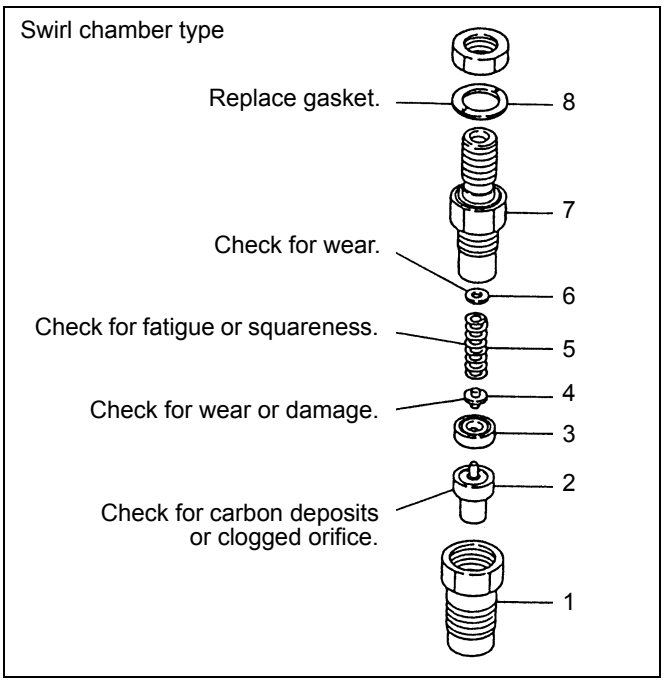


Figure 187 Disassembly sequence

1. Retaining nut
2. Nozzle tip assembly
3. Piece
4. Pin
5. Spring
6. Washer
7. Body
8. Gasket

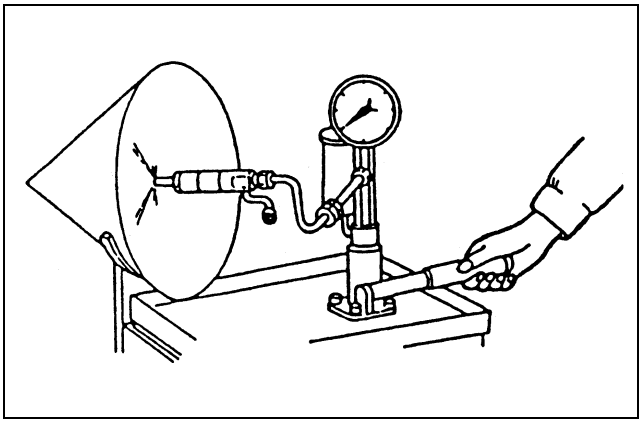


Figure 188 Testing fuel injection nozzle

33.2 Inspection

1. Injection pressure (valve opening pressure)

   1) Install the injection nozzle on the tester. Slowly operate the tester handle full strokes to bleed (remove) air from the pipe and nozzle.

   2) Make a slow increase in pressure by operating the tester handle at a speed of more than one stroke per second while observing the pressure gage.

   3) The pressure gage reading will slowly increase and, when the nozzle starts discharging fuel, it will go down fast. Take the gage reading right then as the injection pressure.

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

Item		Nominal Value	Assembly Standard
Injection pressure	DI	17.65 (180) [2561]	18.14 to 19.12 (185 to 195) [2632 to 2774]
	SC	11.77 (120) [1707]	11.77 to 12.75 (120 to 130) [1707 to 1849]

DI: Direct injection
SC: Swirl chamber

NOTE

The injection pressure varies according to the model and type of the engine. Confirm the injection pressure for each engine.

⚠ DANGER

When testing the injection nozzle, keep its tip pointed away from the operator. Fuel from the orifices in the tip of the nozzle is under high pressure and can cause injury to the operator.

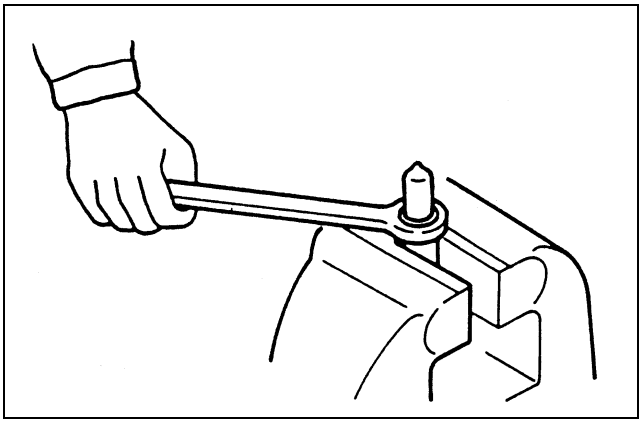


Figure 189 Removing nozzle tip

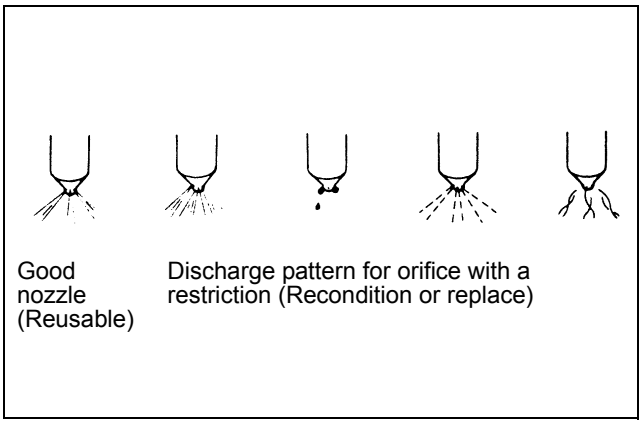


Figure 190 Direct injection type

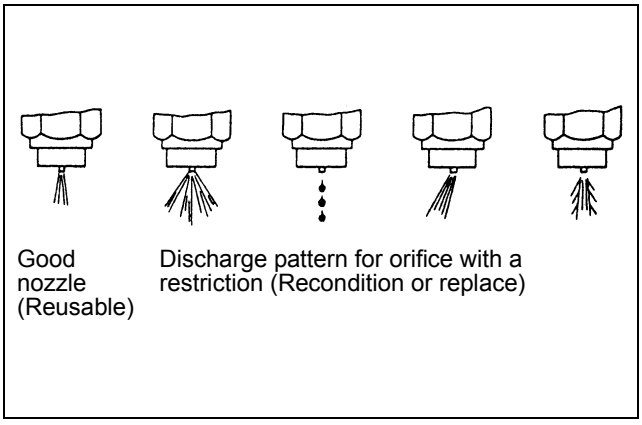


Figure 191 Swirl chamber type

4) To adjust the injection pressure, increase or decrease the amount of shims fitted to the nozzle holder.

NOTE

0.1 mm [0.004 in.] thickness of shims will change the injection pressure approximately 1 MPa (10 kgf/cm^2) [142 psi]. The shims are available in 34 different thicknesses from 1.0 mm [0.039 in.] to 1.225 mm [0.0482 in.] in increments of 0.05 mm [0.002 in.] for the direct injection engines. They are available in 43 different thicknesses from 0.9 mm [0.035 in.] to 1.95 mm [0.0768 in.] in increments of 0.025 [0.00098 in.] for the swirl chamber type engines.

2. Spray pattern

1) Operate the handle of the tester at a speed of one stroke per second and look at the orifice discharge pattern (shape of discharge) when fluid begins to flow through the injection nozzle. The discharge must occur from all four orifices a t the same time and must be approximately 155° in angle (direct injection type), or must be straight (swirl chamber type). It must be finely and uniformly atomized. Any change is an indication of a bad nozzle.

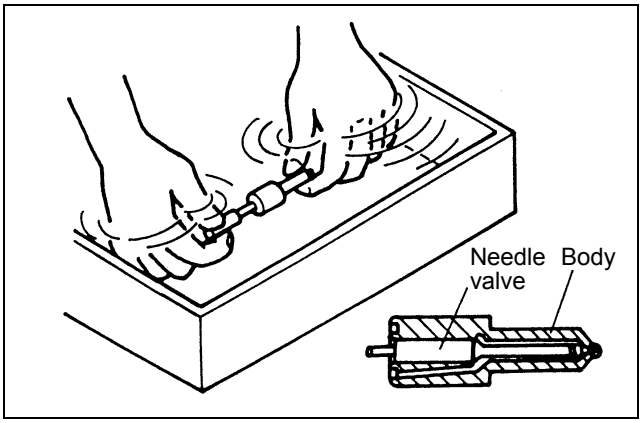


Figure 192 Washing nozzle type (direct injection type)

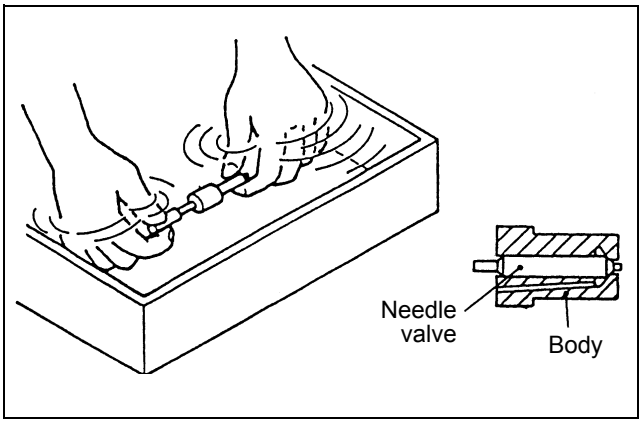


Figure 193 Washing nozzle tip (swirl chamber type)

2) If the nozzle is bad, remove the tip from the nozzle and wash needle valve and body in clean washing solution.

3) If the nozzle is still bad after the tip has been washed, replace the tip.

NOTE

When installing the new tip, remove synthetic resin film from the tip and slide the needle valve in the body in clean diesel fuel to wash off inhibitor completely.

33.3 Reassembly

8 → 7 → 6 → 5 → 4 → 3 → 2 → 1

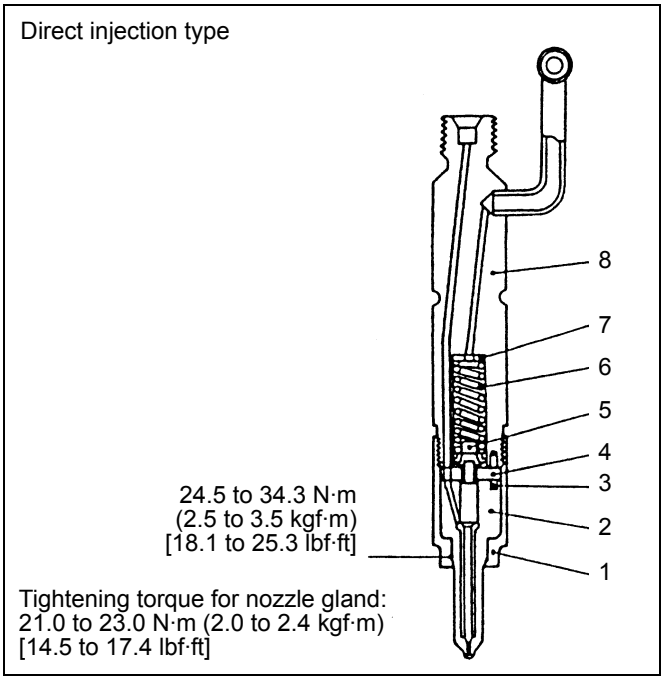


Figure 194 Reassembly sequence

7 → 6 → 5 → 4 → 3 → 2 → 1

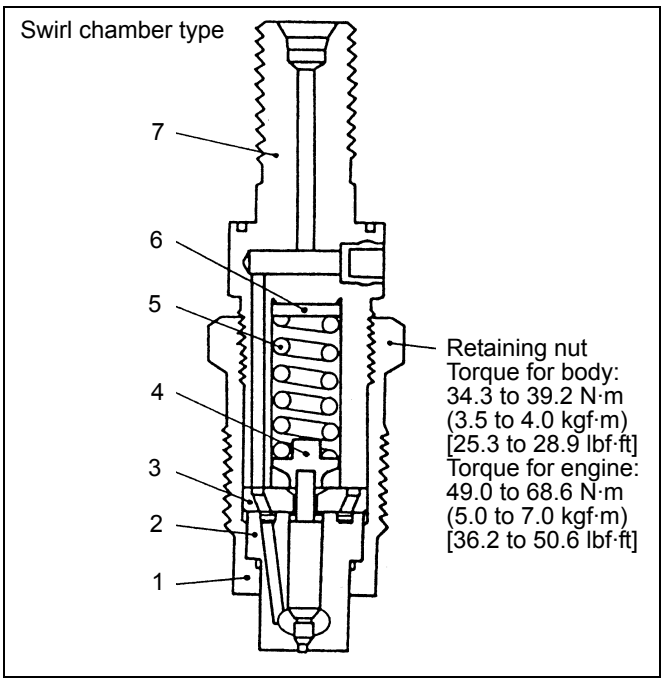


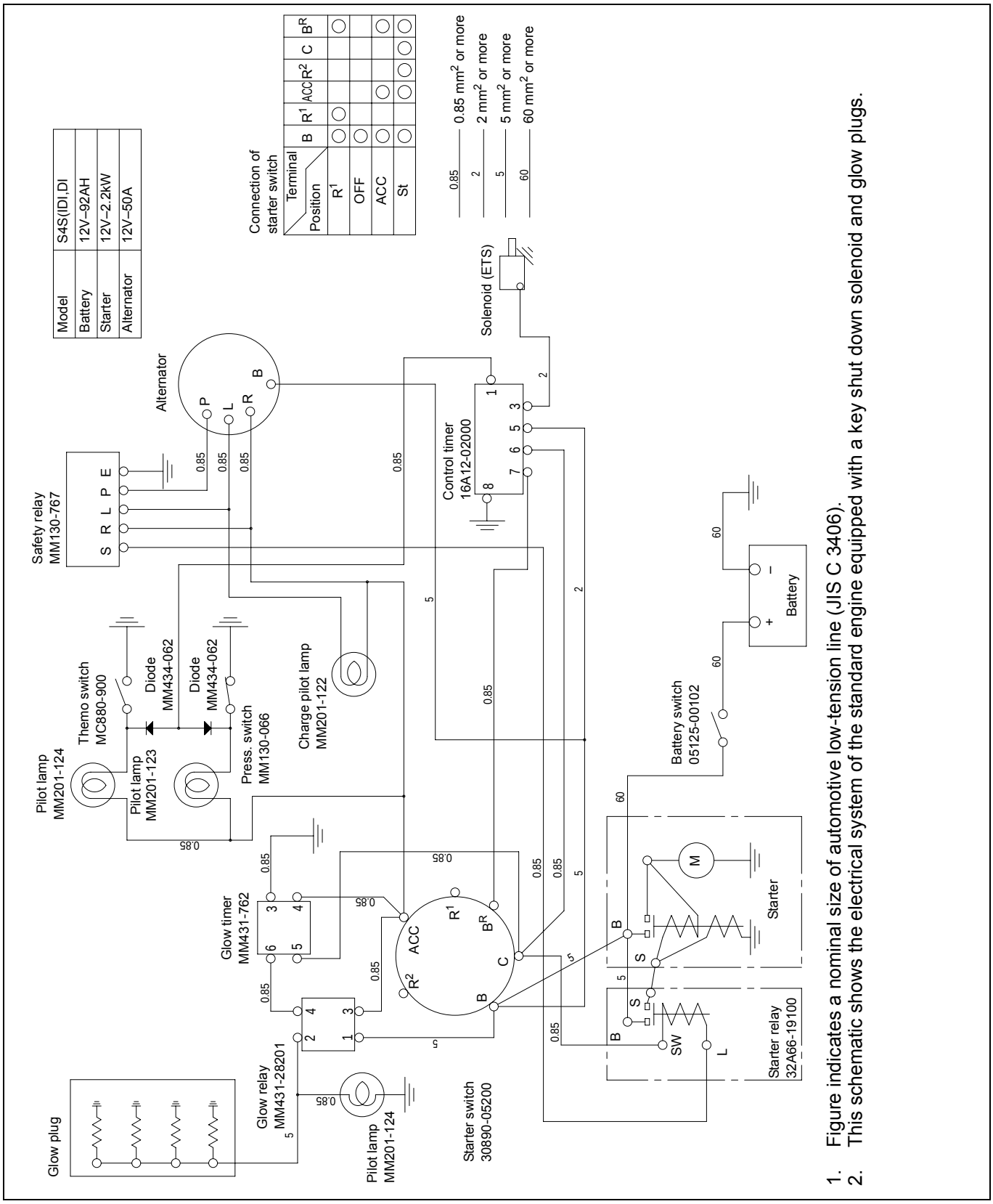
Figure 195 Reassembly sequence

ELECTRICAL SYSTEM

34 GENERAL

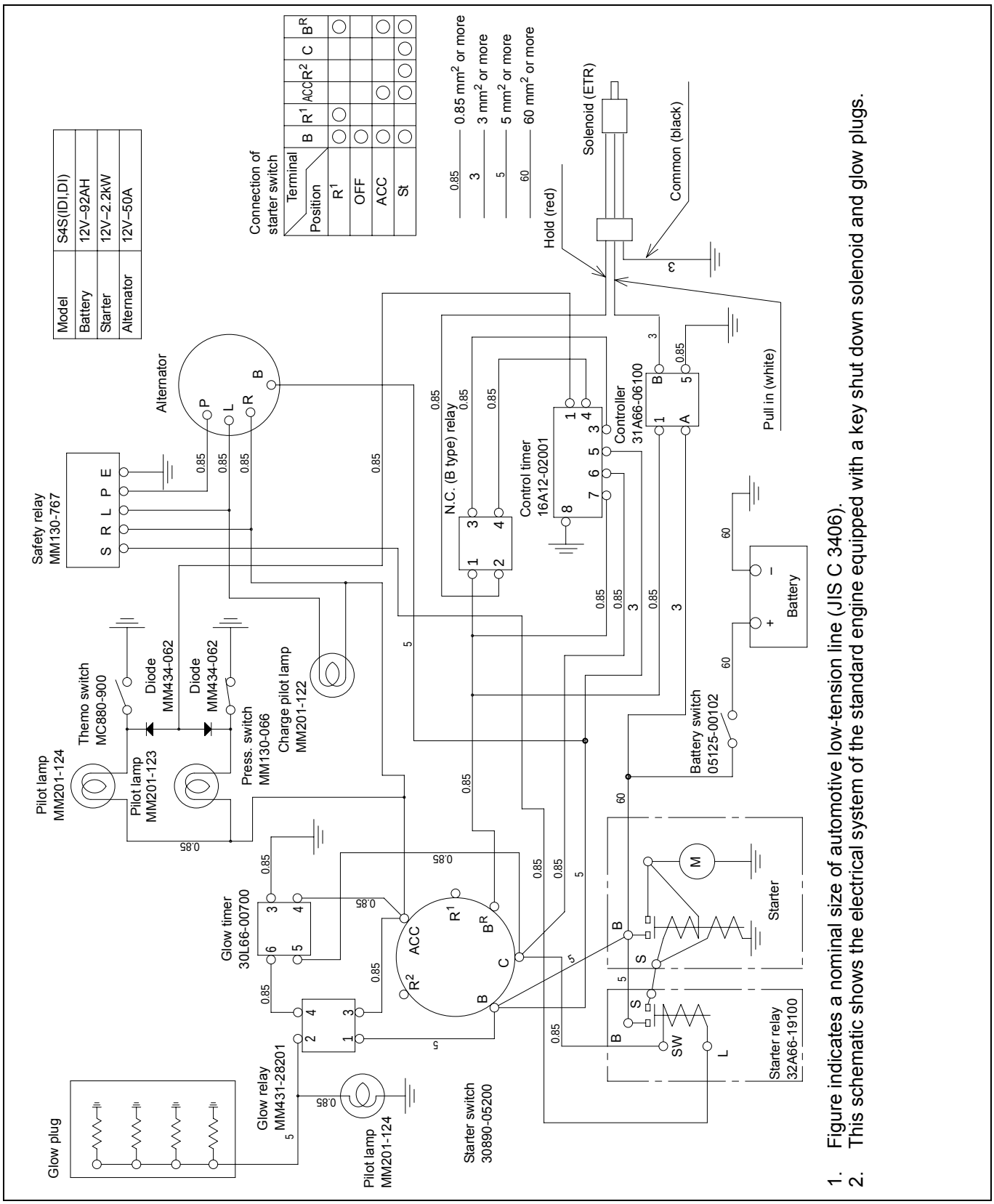
< S4S ETS type stop solenoid >

34.1 Wiring diagrams



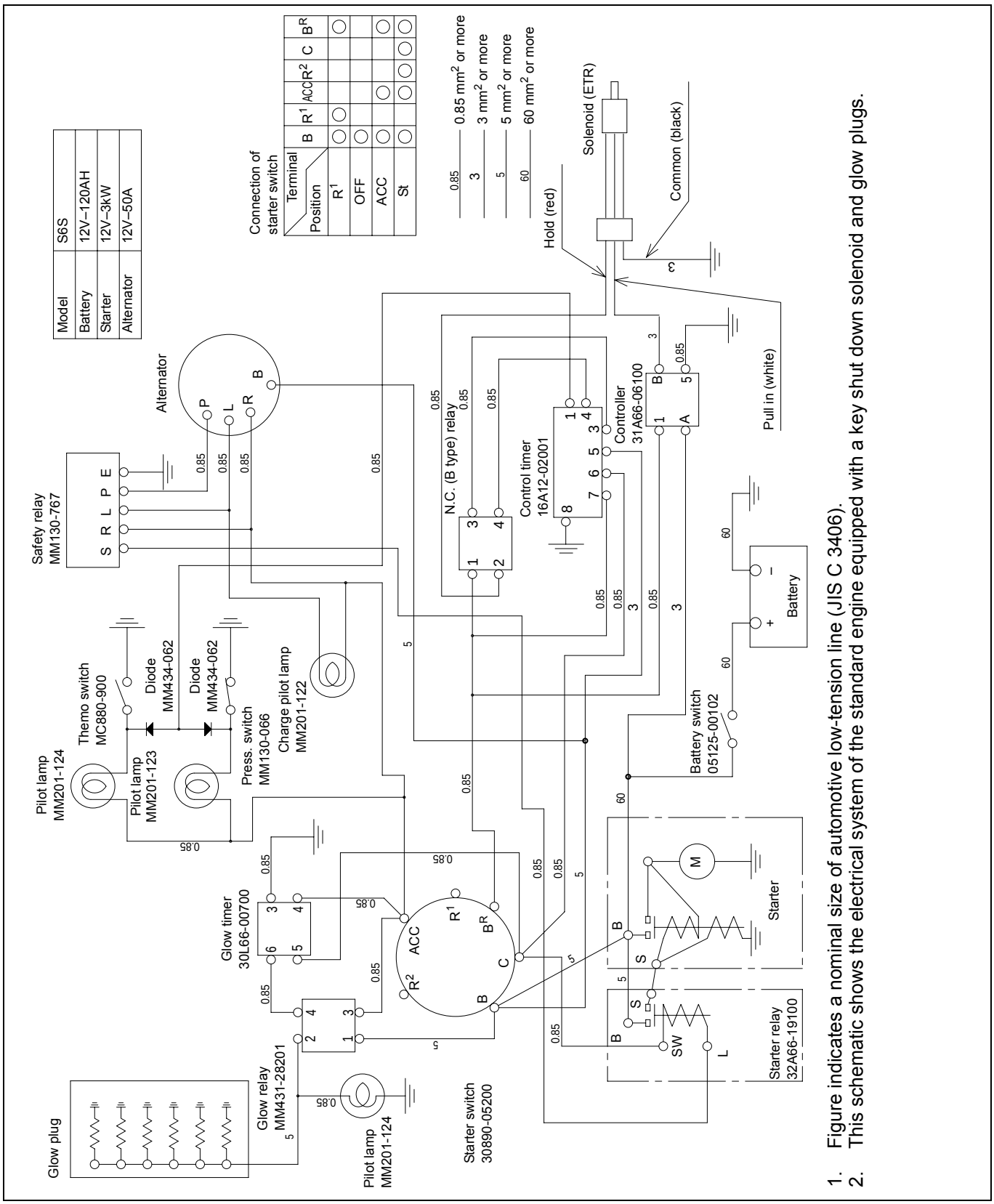
1. Figure indicates a nominal size of automotive low-tension line (JIS C 3406).
2. This schematic shows the electrical system of the standard engine equipped with a key shut down solenoid and glow plugs.

< S4S ETR type stop solenoid >



1. Figure indicates a nominal size of automotive low-tension line (JIS C 3406).
2. This schematic shows the electrical system of the standard engine equipped with a key shut down solenoid and glow plugs.

< S6S ETR type stop solenoid >



1. Figure indicates a nominal size of automotive low-tension line (JIS C 3406).
2. This schematic shows the electrical system of the standard engine equipped with a key shut down solenoid and glow plugs.

35 STARTER

35.1 Disassembly

[12 V - 2.2 kW, 12 V - 3 kW]

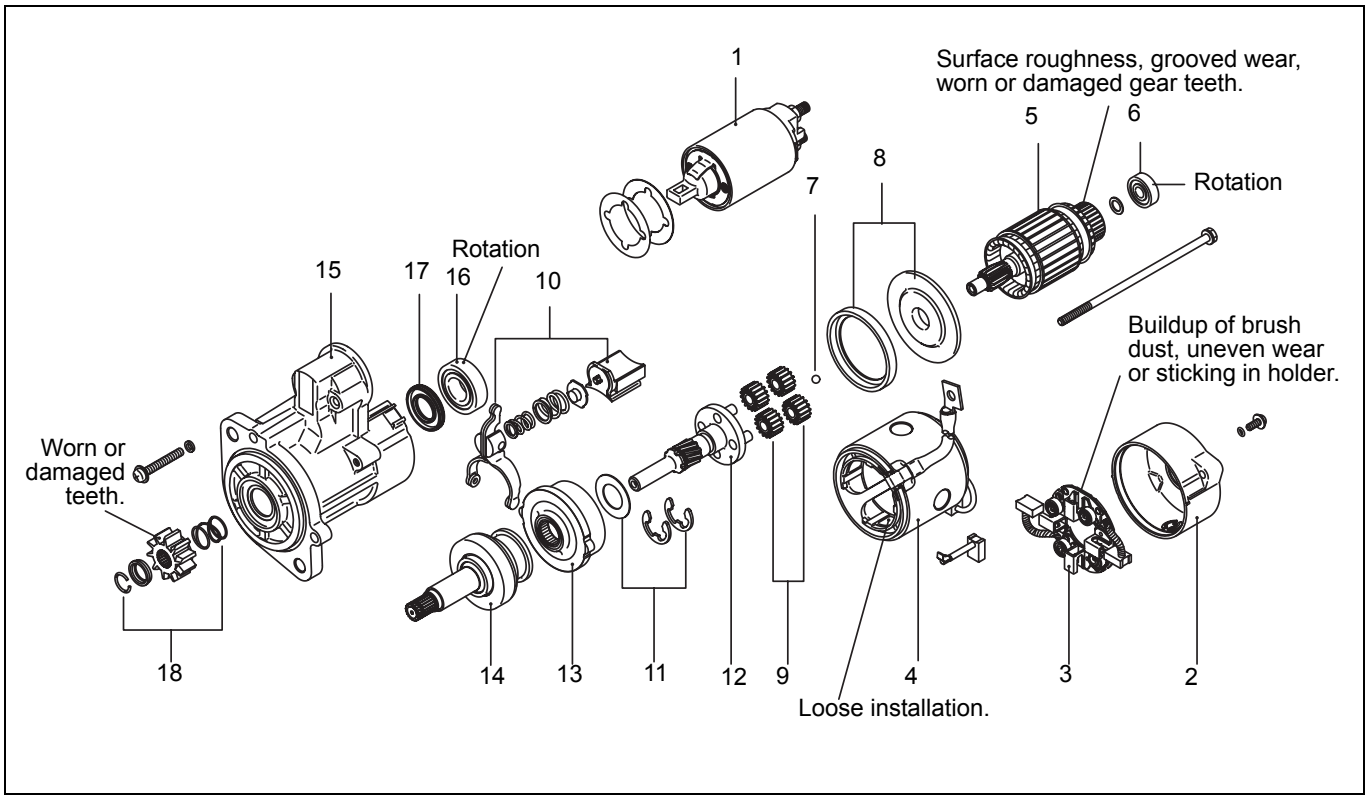


Figure 196 Disassembly sequence

1. Switch assembly
2. Rear bracket
3. Brush holder assembly
4. Yoke assembly
5. Armature
6. Bearing
7. Ball
8. Packing set
9. Gear
10. Lever assembly
11. Washer set
12. Gear shaft
13. Install gear
14. Overrunning clutch
15. Front bracket
16. Bearing
17. Oil seal
18. Pinion set

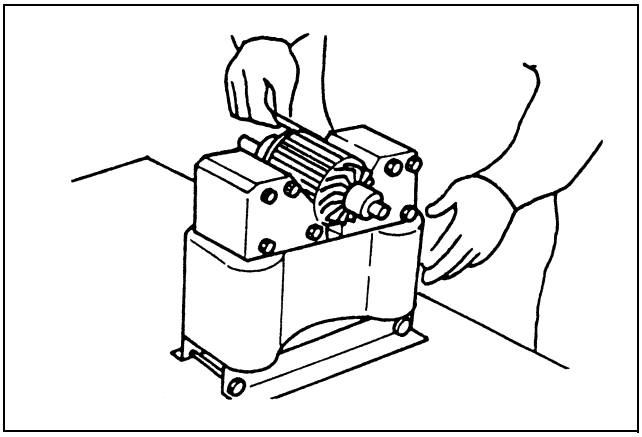


Figure 197 Testing for short circuit

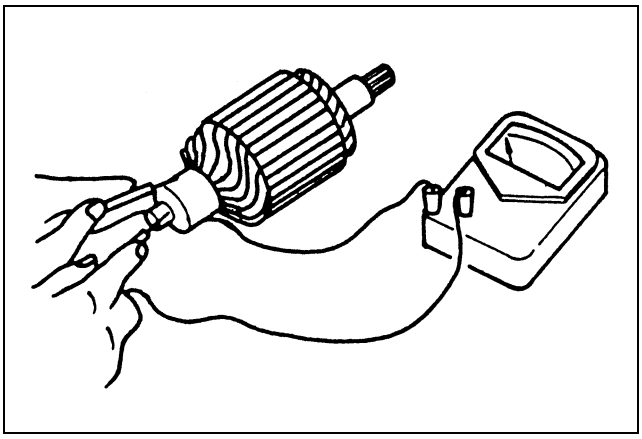


Figure 198 Testing for grounded circuit

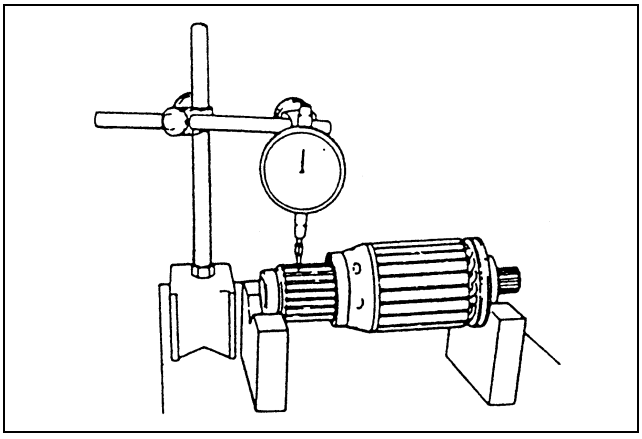


Figure 199 Measuring commutator runout

35.2 Inspection

1. Armature

   1) Testing for short circuit

      Place the armature on a growler, and slowly revolve it with a hacksaw blade held above the armature core. The hacksaw blade vibrates against the core when it is above a slot containing a shorted winding. Replace the armature if shorted.

   2) Testing for grounded circuit

      If there is any continuity between the commutator and shaft (or core), the armature is grounded and should be replaced.

   3) Measuring commutator runout

      a. Support the armature in V-blocks and measure the runout of the commutator with a dial indicator. If the runout is near the service limit, recondition the commutator, making sure the commutator diameter does not exceed the service limit. If the commutator surface is rough smoothen it with a sandpaper of #300 to #500.

Unit: mm [in.]

Item	Assembly Standard	Service Limit
Runout of commutator	0.03 [0.004]	0.1 [0.0012]

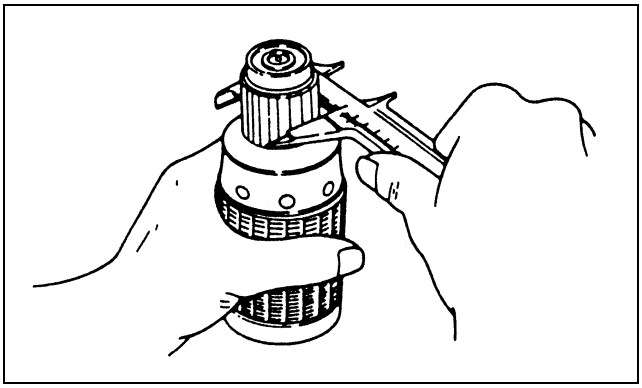


Figure 200 Measuring commutator diameter

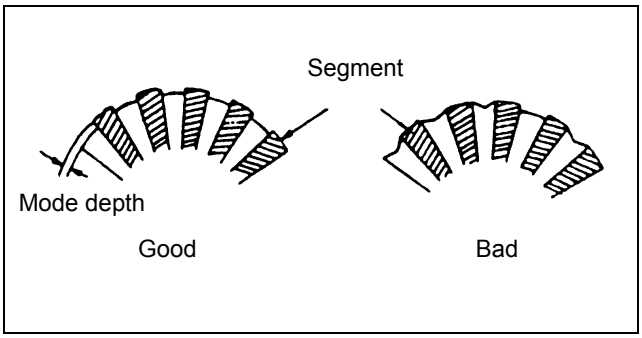


Figure 201 Measuring commutator mold depth

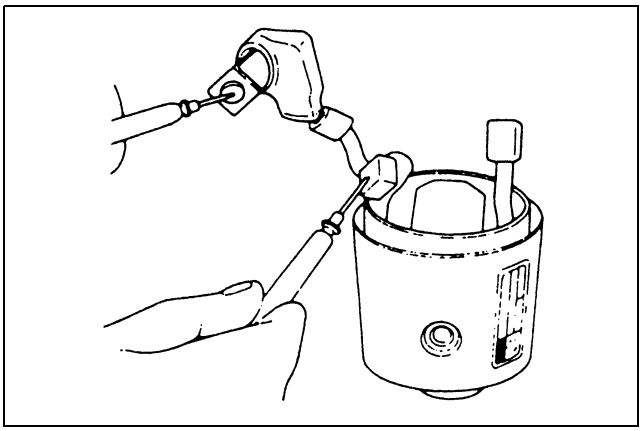


Figure 202 Testing for open circuit

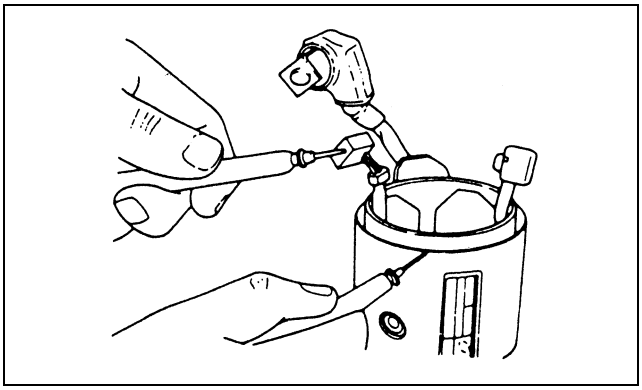


Figure 203 Testing for grounded circuit

b. Measure the diameter of commutator. If it is smaller than the service limit, replace the armature.

Unit: mm [in.]

Item		Nominal value	Service Limit
Diameter of commutator	12 V - 2.2 kW	32 [1.24]	31.4 [1.26]
	12 V - 3 kW	38.7 [1.52]	38.1 [1.50]

c. Measure the depth of each mild between segments with a depth gage. If the depth is less than the repair limit, recondition the mild.

Unit: mm [in.]

Item	Assembly Standard	Repair Limit
Dept of commutator mild	0.4 to 0.6 [0.016 to 0.024]	0.20 [0.008] or less

2. Field coil

1) Testing for open circuit

If there is no continuity between the lead wire and positive (+) brush, the field coil is open and the yoke assembly should be replaced.

2) Testing for grounded circuit

If there is any continuity between the yoke and positive (+) brush, check the insulation and repair or replace the yoke assembly.

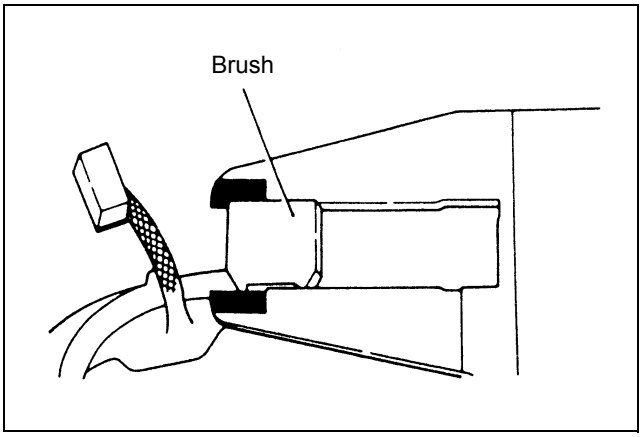


Figure 204 Measuring brush length

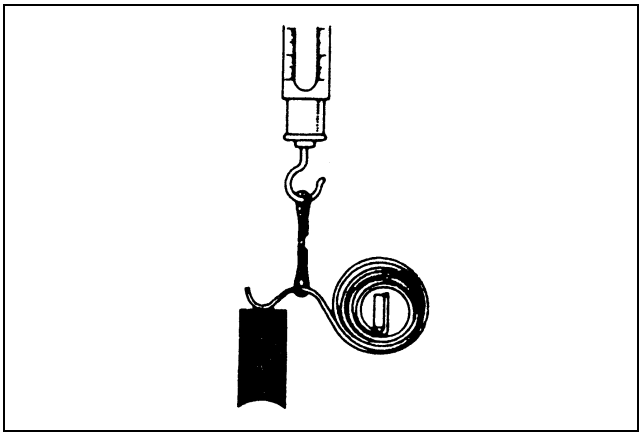


Figure 205 Measuring brush spring force

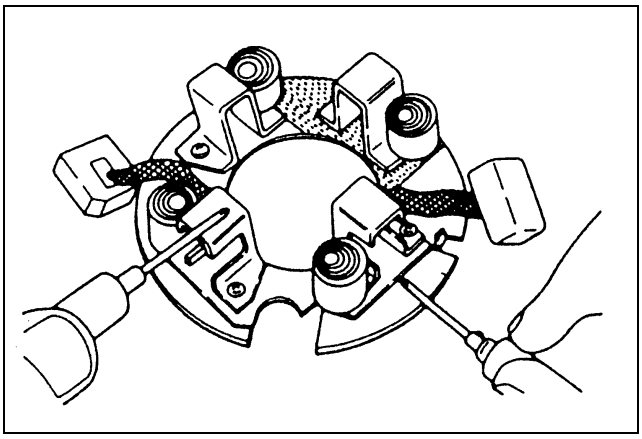


Figure 206 Testing brush holders for insulation

3. Brushes and holders

1) Wear and brushes

Measure the brush length and, if it is less than the service limit, replace the brushes. If the brushes are unevenly worn or rough, recondition them with a sandpaper of #300 to #500.

Unit: mm [in.]

Item		Nominal value	Service Limit
Length of brush	12 V - 2.2 kW	18 [0.71]	11 [0.4]
	12 V - 3 kW	17 [0.67]	

2) Measuring brush spring force

Test the spring force using a new brush. In the test, read the load at the instant the spring moves off the brush. If the force is less than the service limit, replace the spring.

Unit: mm [in.]

Item		Assembly Standard	Service Limit
Force of brush spring	12 V - 2.2 kW	30.4 to 38.2 (3.1 to 3.9) [6.8 to 8.6]	19.6 (2.0) [4.4]
		33.3 to 45.1 (3.4 to 4.6) [7.5 to 10.1]	17.7 (1.8) [4.0]

3) Testing brush holders for insulation

If there is any continuity between the positive (+) brush holder and negative (-) holder plate, replace the brush holder assembly.

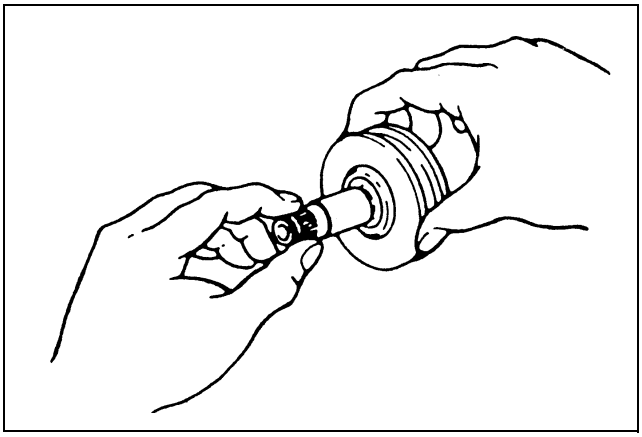


Figure 207 Checking pinion shaft

4. Overrunning clutch

   Make sure that the pinion shaft turns freely when turned in the direction of driving (clockwise) and it is locked when turned in the opposite direction. If not, replace the overrunning clutch.

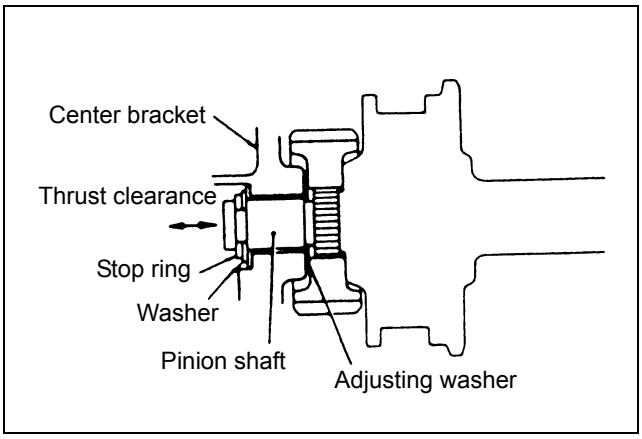


Figure 208 Adjusting pinion shaft thrust clearance

5. Pinion shaft thrust clearance

   The pinion shaft thrust clearance is the play exhibited by the pinion shaft when it is moved in the thrust direction.

   Measure the thrust clearance in the following manner. If it is incorrect, select a proper adjusting washer and adjust the clearance with the washer.

   1) With pinion off starter:

      Install the gear on the pinion shaft, insert the shaft into the center bracket, and lock the shaft with the washer and ring. Under this condition, move the shaft in the axial direction, and measure the thrust clearance.

   2) With pinion on starter:

      Install the pinion shaft and gear between the front and center brackets, and temporarily tighten the bolt. Under this condition, move the shaft in the axial direction, and measure the thrust clearance.

Unit: mm [in.]

Item	Assembly Standard
Thrust clearance of pinion shaft	0.5 [0.020] or less [Below 0 not permissible]

35.3 Reassembly

[12 V - 2.2 kW, 12 V - 3 kW]

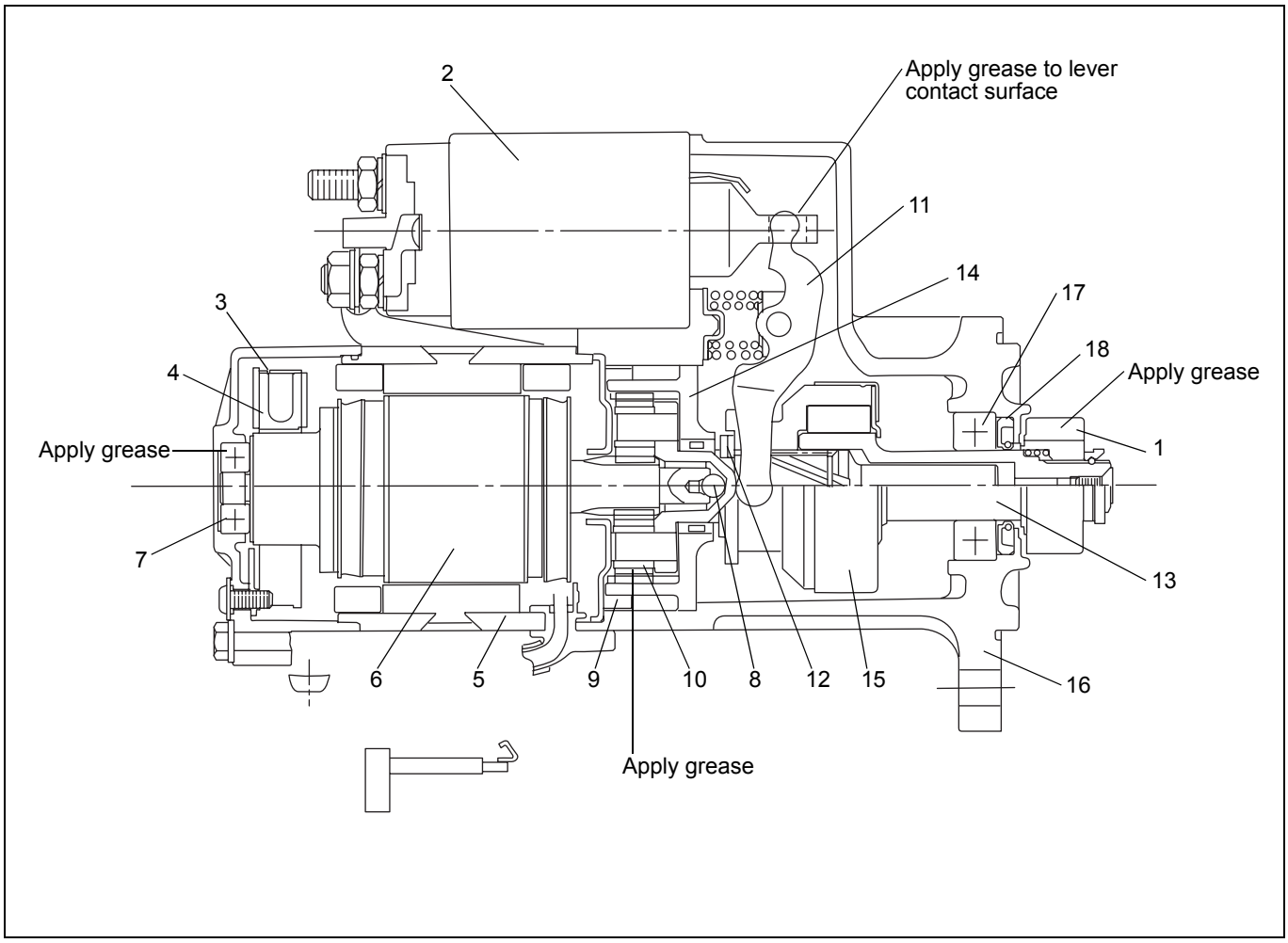


Figure 209 Reassembly sequence

18 → 17 → 16 → 12 → 13 → 14 → 15 → 1 → 10 → 11 → 9 → 8 → 5 → 6 → 7 → 4 → 3 → 2

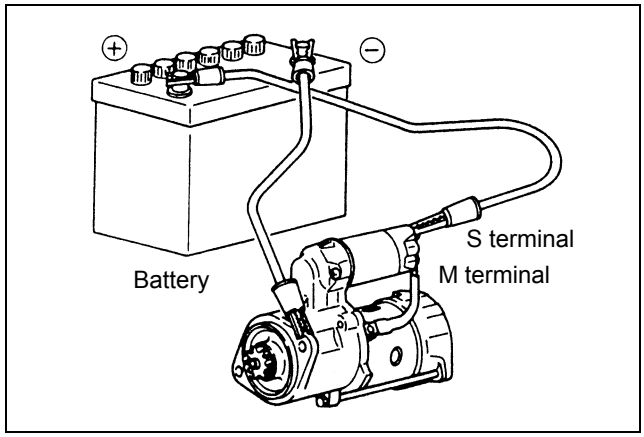


Figure 210 Starter test hookup

35.4 Inspection and Testing After Assembly

1. Pinion clearance adjusment

   1) If the assembled starter is wired as shown, the pinion will shift and turn slowly. Remove the connector from the M terminal to stop the pinion.

   2) Under this condition, lightly push in the pinion toward the armature, and measure the movement (clearance) of the pinion.

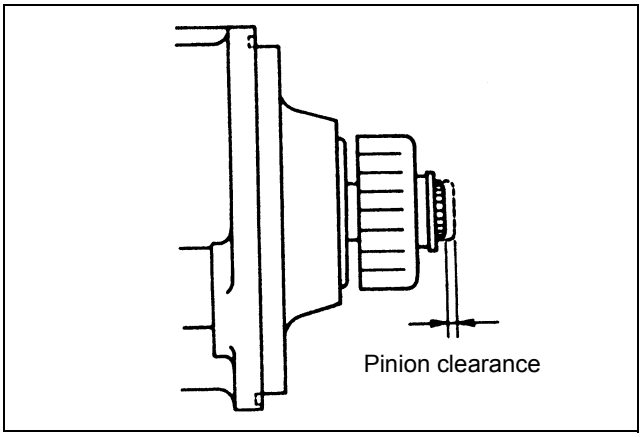


Figure 211 Measuring pinion clearance

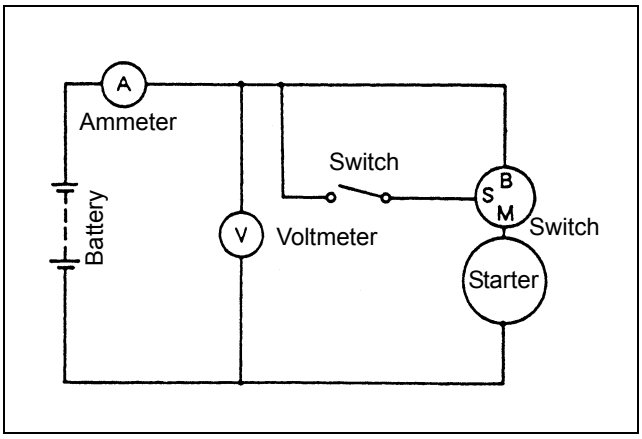


Figure 212 No-load test hookup

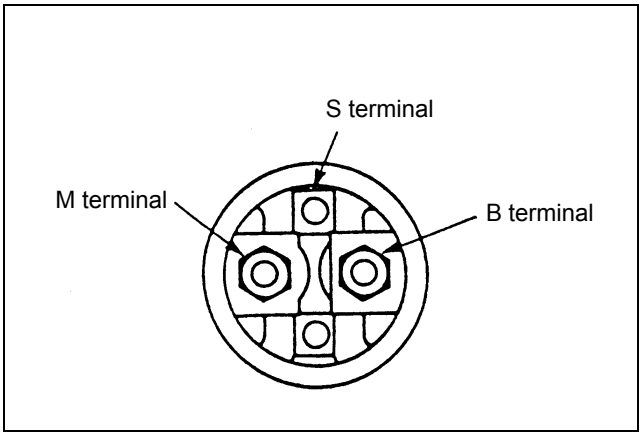


Figure 213 Magnetic switch terminals

3) To adjust the clearance, increase or decrease the number of packings fitted to the magnetic switch. Increasing the number of packings decreases the pinion clearance.

Unit: mm [in.]

Item	Assembly Standard
Pinion clearance	0.5 to 2.0 [0.020 to 0.079]

NOTE

Do not test the starter continuously for more than 20 seconds to prevent the switch coil from overheating.

2. No-load test

After adjusting the pinion clearance, connect the starter as shown, and test it for no-load characteristics.

⚠ CAUTION

Use wires as thick as possible and tighten each terminal securely.

Starter		Voltage, V	Current, A	Speed, rpm
No-load characteristic	12 V - 2.2 kW	11	130 or less	3800 or more
	12 V - 3 kW	11	180 or less	3800 or more

3. Magnetic switch

1) Testing coil for open circuits

If there is no continuity between S and M terminals and between S terminal and ground, replace the switch.

2) Checking contactors for fusion

If there is any continuity between B and M terminals, replace the switch.

3) Checking contactors for poor contact action

Check the voltage drop across the contactors. If voltage drop is excessive, the contactors are defective.

36 ALTERNATOR

36.1 Disassembly

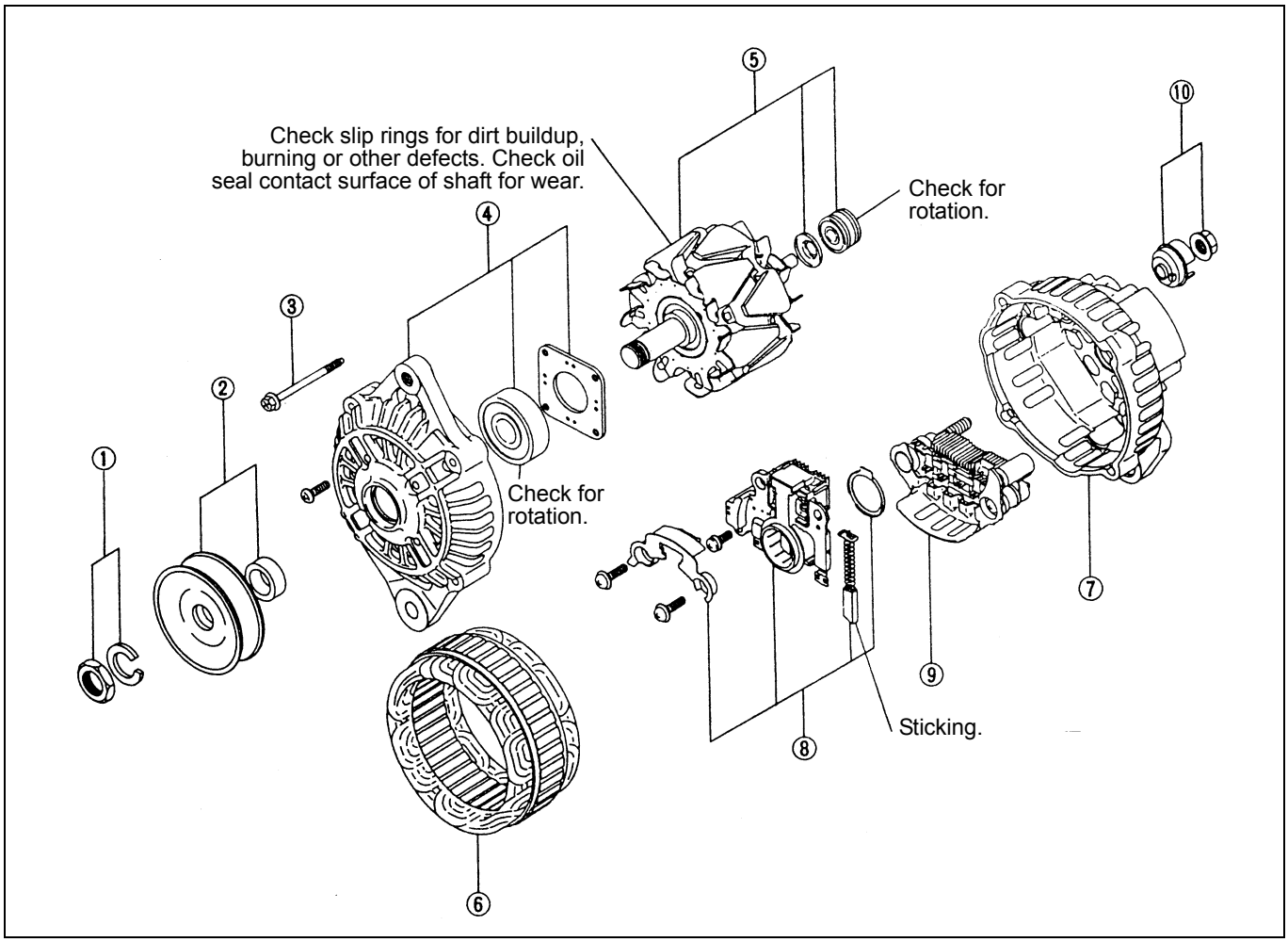


Figure 214 Disassembly sequence

1. Nut, washer
2. Pulley, spacer
3. Screw
4. Front bracket assembly
5. Rotor assembly
6. Stator
7. Rear bracket
8. Regulator assembly
9. Rectifier assembly
10. Nut set

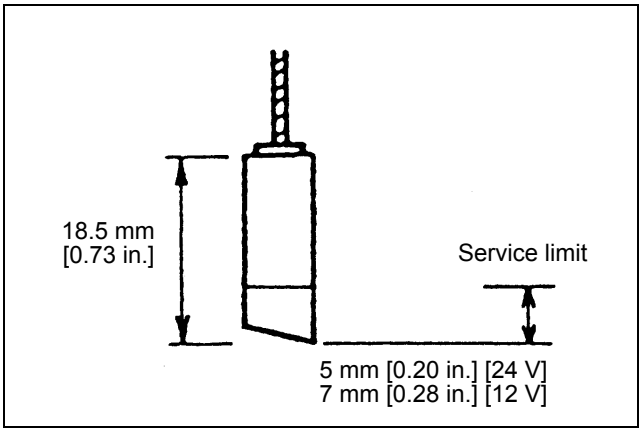


Figure 215 Checking brush

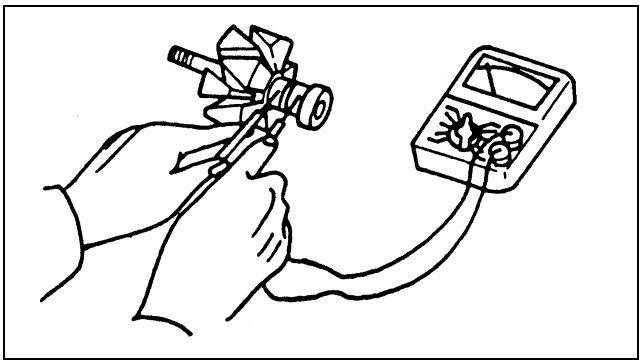


Figure 216 Testing field coil

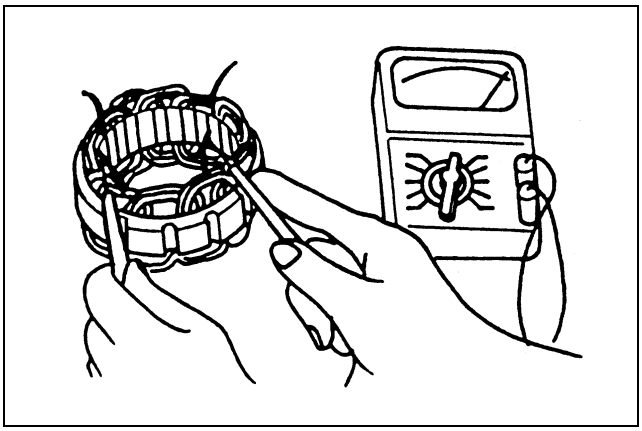


Figure 217 Testing stator coil

36.2 Inspection

1. Brushes

   Replace the brushes if they are worn down to the service limit line.

Unit: mm [in.]

Item		Assembly Standard	Service Limit
Brush length	12 V - 50 A	18.5 [0.73]	7 [0.28]
	24 V - 25 A	18.5 [0.73]	5 [0.20]

2. Field coil

   Measure the resistance between the slip rings. If the resistance is out of assembly standard, replace the rotor.

Unit: mm [in.]

Item		Assembly Standard
Resistance in slip rings (20°C [68°F])	12 V - 50 A	2.4Ω
	24 V - 25 A	12.4Ω

3. Stator coil

   Check for continuity between the lead wires. If no continuity is noted, the coil is open-circuited. Also check for continuity between the lead wire and coil. If a continuity is noted, the coil is grounded.

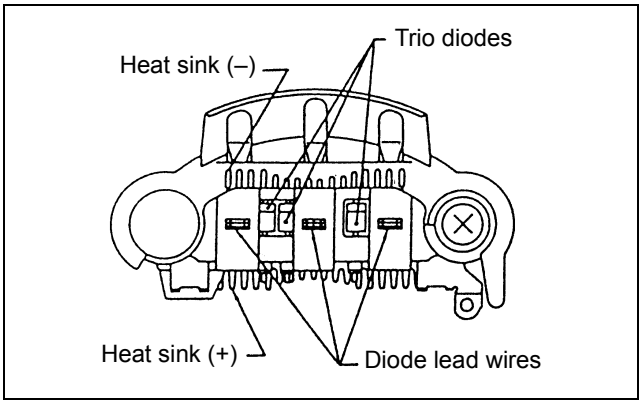


Figure 218 Testing rectifier

4. Rectifier

   Test the resistance between each diode lead wire and heat sink. To test, connect the positive (+) lead wire of the tester to the diode and then the negative (–) lead wire of the tester to the diode. If the resistance is infinite in both cases, the diode is open-circuited. If it is nearly zero in both cases, the diode is short-circuited. If the diode is open- or short-circuited, replace the rectifier.

36.3 Reassembly

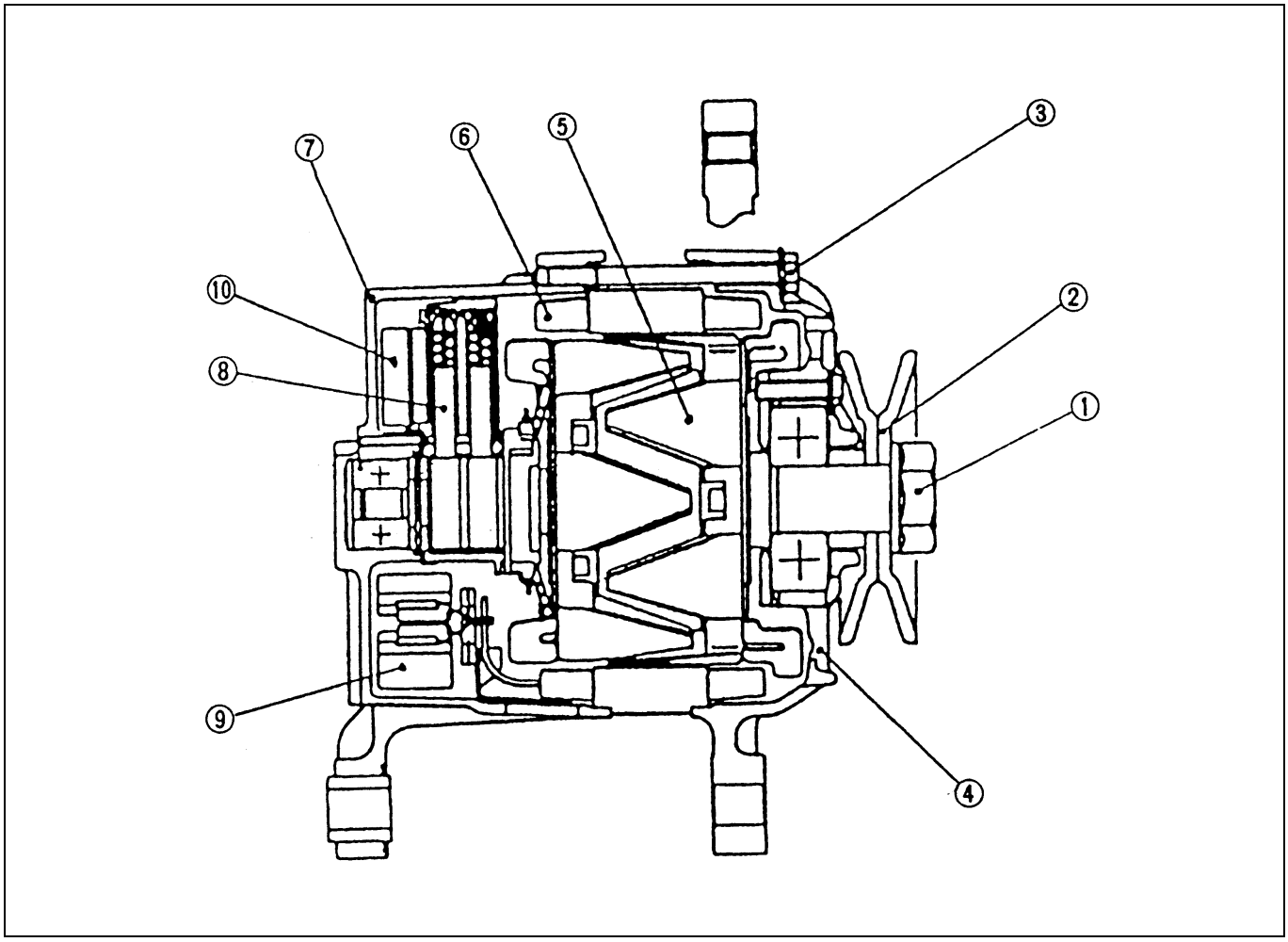


Figure 219 Reassembly sequence

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

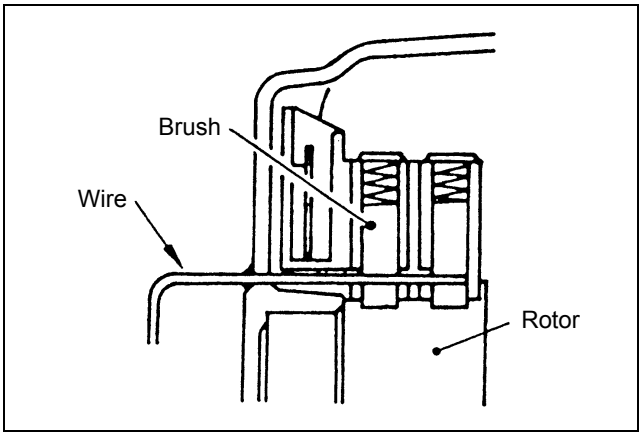


Figure 220 Holding brushes for installing rotor

Holding brushes for installing rotor

Push the brushes into the holder assembly, and hold them by inserting a 2 mm [0.08 in.] diameter wire into the holes in the brushes. Then install the rotor. Remove the wire after installing the rotor.

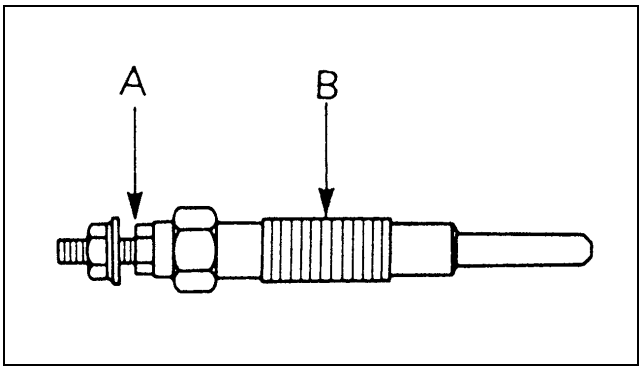


Figure 221 Inspection glow plug

37 GLOW PLUGS

37.1 Inspection

If the glow plug glows red when the positive (+) wire is connected to the portion A with the portion B grounded, the plug can be used.

Rated voltage – current, V – A	12 V	11 – 5.5 (DI) (30 sec. rating)
		10.5 – 9.7 (SC) (30 sec. rating)

DI: Direct injection
SC: Swirl chamber

38 ETR type stop solenoid

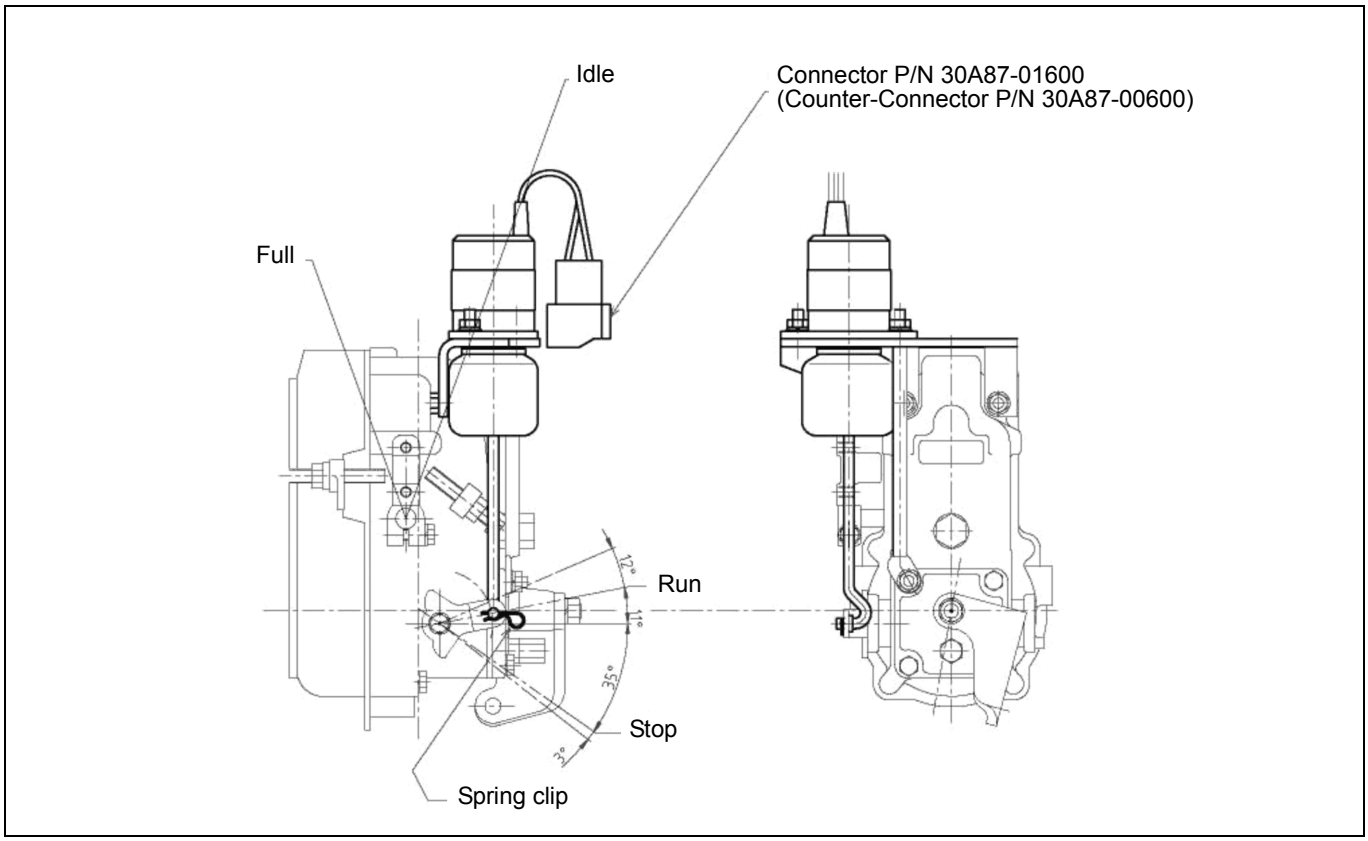


Figure 222

38.1 General

The energize-to-run (ETR) solenoid controlled engine shutdown system operates as follows:

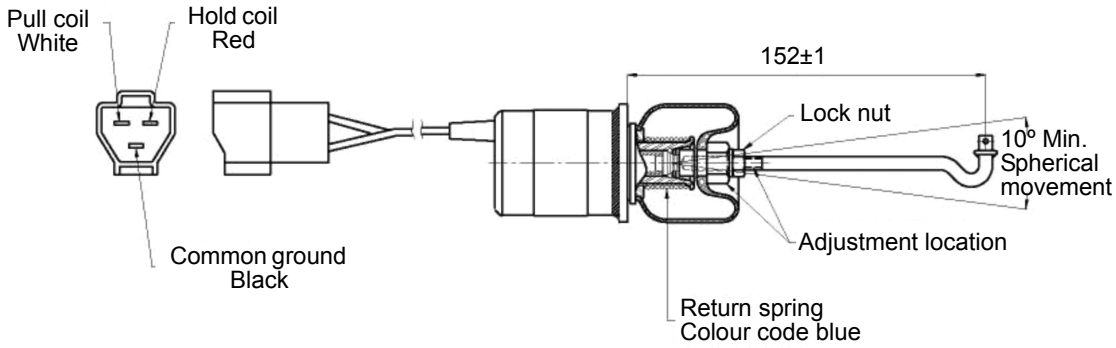
When the starter switch is turned to the "ON" position, the hold coil and the pull coil are energized simultaneously, pulling the stop lever to the "RUN" position. However, the pull coils is energized only for about 1 second (maximum 3 seconds) by a special controller.

The hold coil of the solenoid remains energized in both the "ON" and "START" position of the starter switch, keeping the stop lever in the "RUN" position. When the current to the hold coil is interrupted, the hold coil is no longer energized causing that the stop lever immediately will be pushed to the no-injection position by the internal return spring force of the solenoid. The engine then stops.

This system is a safety device designed to stop the engine whenever the wiring is open or when the starter switch is turned "OFF".

NOTE

If the electrical system includes a control timer to stop the engine, the starter switch should be turned in the "OFF" position for at least 10 seconds before making another start attempt in order to reset the control timer automatically.



Note: Plunger shown in energized position

Figure 223

38.2 Solenoid specification

		current		resistance (+/-10%) at 20 ºC	
connection	wire color	rated 12V	rated 24V	rated 12V	rated 24V
hold coil	red	55 A	29 A	11.15 Ω	41.35 Ω
pull coil	white	1.1 A	0.6 A	0.217 Ω	0.817 Ω
common ground	black				

Notice that the housing is ungrounded.

Replace the complete solenoid if not within the above mentioned specification.

⚠ CAUTION

To avoid damage to the stop solenoid, do not energize the pull coil for more than 10 seconds. Allow the solenoid to cool down before energizing again.

38.3 Inspection

1. Check the spring: the coil ends should be squared and ground.
2. Check the connecting rod spherical movement freely.
3. Check the rubber boot for any cracks or leaks.

Replace the complete solenoid assy if any failure at 1, 2 or 3.

4. The plunger and hub should be free of any wear, dirt or grease: clean if necessary. Install a tie rap to install the rubber boot.
5. Check the spring clip to secure well.

38.4 Connecting rod adjustment

1. Check the connecting rod length and adjust to 152 +/- 1 mm if necessary (see Figure 223 on page 164).
2. Install the connecting rod from inside out to the stop lever and lock it by the spring clip (see Figure 222 on page 163).
3. Start and stop the engine to check proper operation of the shutdown system.

⚠ WARNING

Wrong adjustment will cause that the engine can not run or can not be stopped. It is also possible that the engine can not reach its maximum output.

WORKSHOP TIPS

39 BASIC RECOMMENDED ASSEMBLY PROCEDURES

Proper installation of parts is important to the reliable operation of an engine. This section outlines basic recommended procedures, some of which require special tools, devices or work methods. Improper parts installation can result in parts or engine damages.

39.1 Oil Seals

When installing an oil seal (metal-encased type), observe the following points:

39.1.1 Driving an oil seal into housing

1. Before installing the oil seal, make sure the lip is not damaged and apply a thin coat of grease to the press-fitted surface of the outer case of the seal.
2. When installing the oil seal, position the lip in the correct direction.
3. Using a special tool (oil seal installer) to guide the lip, install the oil seal squarely in the housing. Do not tap the oil seal with a hammer.

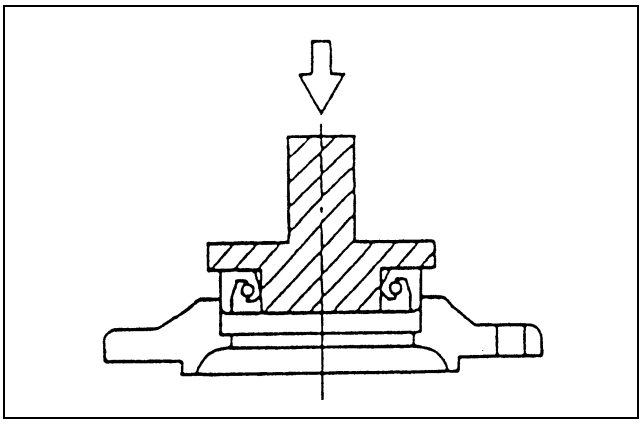


Figure 224 Oil seal installer

39.1.2 Driving oil seal onto shaft

1. Apply a thin coat of grease to the lip of the oil seal.
2. When installing the oil seal on a shaft having splines, threads or keyway, use a special tool (oil seal guide) in order not to cause damage to the lip of the oil seal.

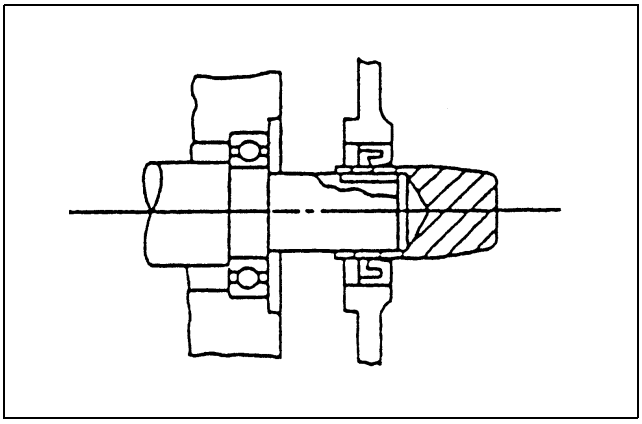


Figure 225 Oil seal guide

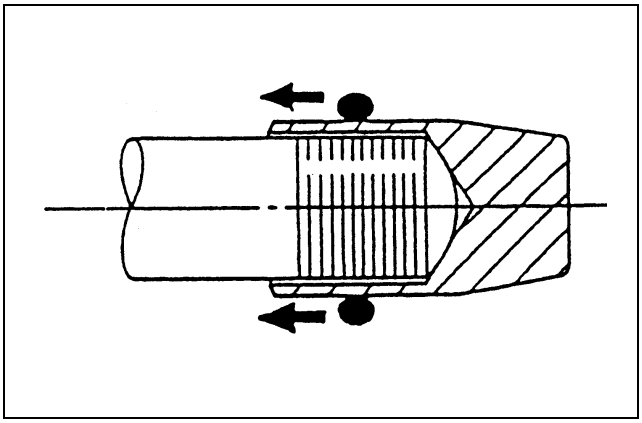


Figure 226 O-ring guide

39.2 O-rings

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

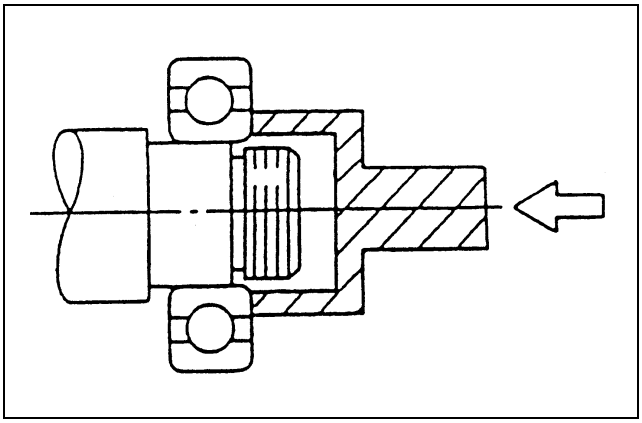


Figure 227 Bearing driver

39.3 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.

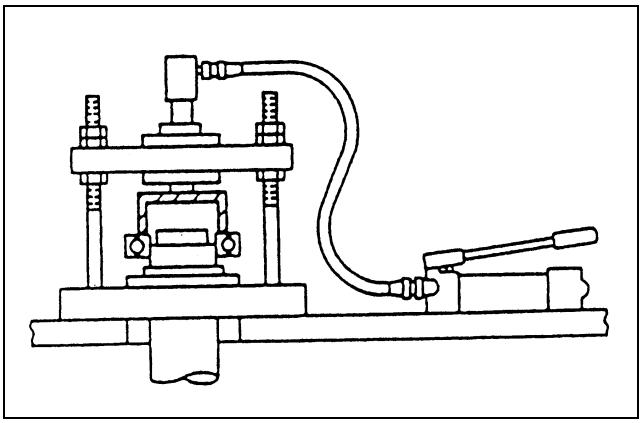


Figure 228 Bearing installation with a press

2. Whenever possible, use a press to minimize shock to the bearing and to assure proper installation.

39.4 Split Pins and Spring Pins

Generally, split pins are to be replaced once disturbed. Instert 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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