

FOREWORD

This is the Diesel Engine Maintenance manual of D1146, D1146T, D1146TI Diesel Engines produced by Daewoo Heavy Industries Co.

D1146, D1146T, D1146TI Diesel Engines (In-line, 6 cylinders, 4 stroke, direct injection type) have been so designed and manufactured to be used for the overland transport or industrial purpose. They meet all the requirements such as quiet operation, fuel economy, excellent durability at high speed running condition and so on, and accordingly are more economical and outstanding engines with high efficiency than any others.

For the contents for maintenance explained in detail by means of illustrations and graphs, we wish all the relevant person will consult with this manual in needs, securing it sufficiently.

All information, illustrations and specifications contained in this manual are based on the latest product information available at the time of publication approval. The right is reserved to make changes at any time without notice, and if you have any questions on its contents or maintenance, please feel free to contact with our service line.

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● WORLDWIDE NETWORK

1. General Information

1.1. Engine Characteristics

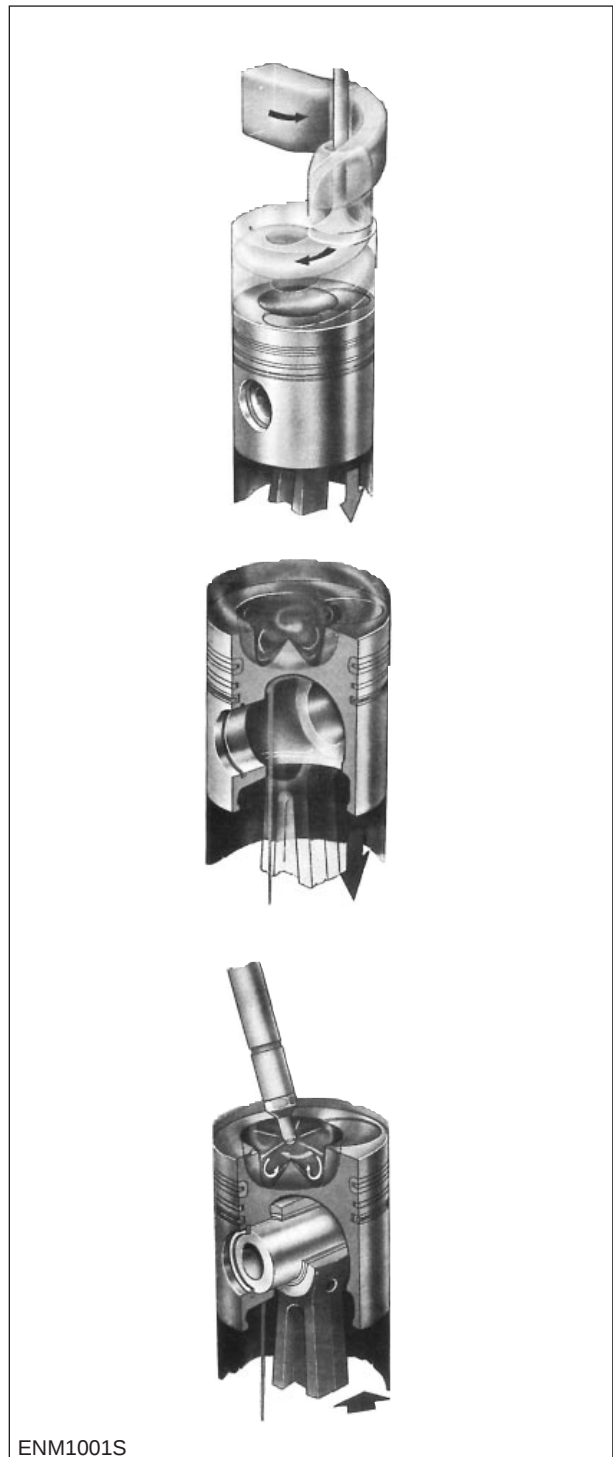
Toroidal combustion system developed by Daewoo Heavy Industries Co.

The main design features of this system are the combustion chamber arranged in the center of the piston and the swirling passage in the cylinder head.

Due to the swirling passage, the air entering the cylinder through the helical port designed specially during intake stroke is imparted a strong rotary motion in the combustion chamber and the complicated turbulence motion created by the swirl produced during compression stroke and strong squish flow makes the fuel be mixed more sufficiently with air.

During the power stroke, the fuel injected from a multi-orifice nozzle is mixed sufficiently with air for complete combustion, so that the improvement of performance is achieved.

Engine with the Toroidal combustion system are characterized by their quiet running, high flexibility and very low specific fuel and oil consumption.



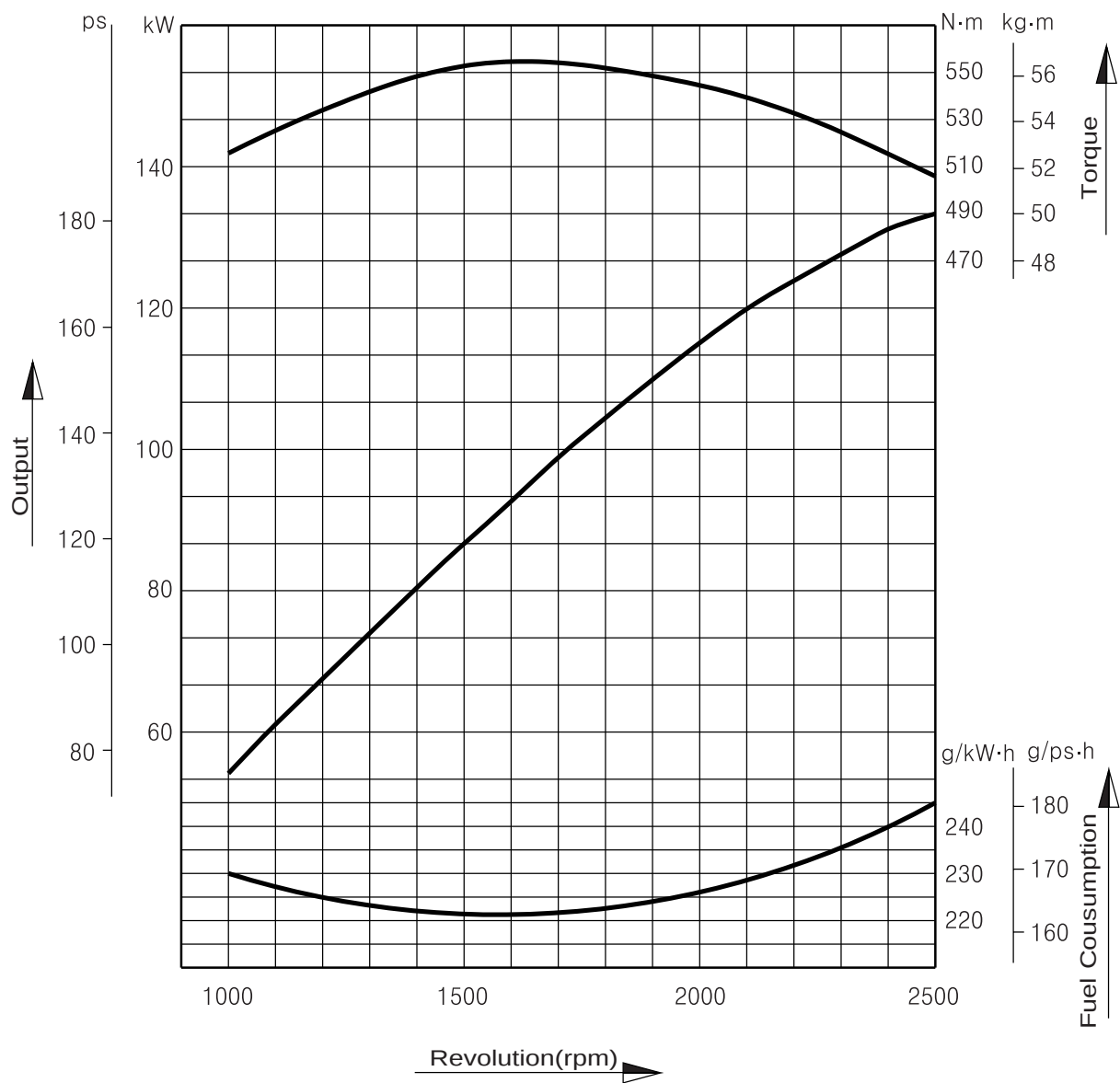
<Fig.1> Toroidal Combustion System

1.2. Main Data and Specifications

Engine Model		D1146	D1146T	D1146TI
Type		In-line, 6 Cylinders, 4 Stroke, Vertical Type	←	←
Intake Air Handling		Natural Aspirated	Turbo Charged	Turbo Charged & Inter Cooled
Combustion Chamber		Toroidal Combustion Chamber	←	←
Fuel Injection		Direct Injection Type	←	←
Bore B Stroke- No. of Cyl.		111mm × 139mm - 6	←	←
Total Displacement		8,071 cc	←	←
Compression Ratio		17.6 : 1	17.2 : 1	16.7 : 1
Maximum Output		182PS / 2,500 rpm	238PS / 2,300 rpm	205PS / 2,200 rpm
Maximum Torque		57.5 kg·m/1,600 rpm	80 kg·m/1,400 rpm	75 kg·m/1,400 rpm
Injection Timing		15° BTDC	11° BTDC	9° BTDC
Firing Order		1 - 5 - 3 - 6 - 2 - 4	←	←
Injection Pump Type		NP-PE 6AD95 B412 RS2	NP-PE 6P120/721RS3000	KP-PE 6AD100 B412 RS2
Governor Type		NP-EP/RFD200/1650AF9CHL	NP-EP/RFD200/1650PF9CZR	KP-EP/RLD250-1400A1FXL
Timer Type		NP-EP/SP700-1250 B4R	NP-EP/SP950-1150Z4R	KP-EP/SA700-1100B3DR
Injection Nozzle Type		DLLA150S312	DLLA150S1064	LUCAS DPN5227
Feed Pump Type		NP-FP/KE ADS	NP-FP/K-P	KP-FP/KE ADS
Valve open/ close	Intake Valve Open At	BTDC 16°	←	←
	Intake Valve Close At	ABDC 36°	←	←
	Exhaust Valve Open At	BBDC 46°	←	←
	Exhaust Valve Close At	ATDC 14°	←	←
Oil Pump		Gear Type	←	←
Oil Cooler		Water - Cooled	←	←
Fuel Filter		Double Element Type	←	Cartridge Type
Oil Capacity		15.5 ℓ (In Oil Pan)	←	←
Coolant Capacity		11 ℓ	←	←
Thermostat		Wax-Pallet	←	←
Alternator : V - I		24V-25A (For Industrial Use)	←	←
Starter : V - kW		24V-45kW	←	←

1.3. Engine Performance Curve

1.3.1. D1146

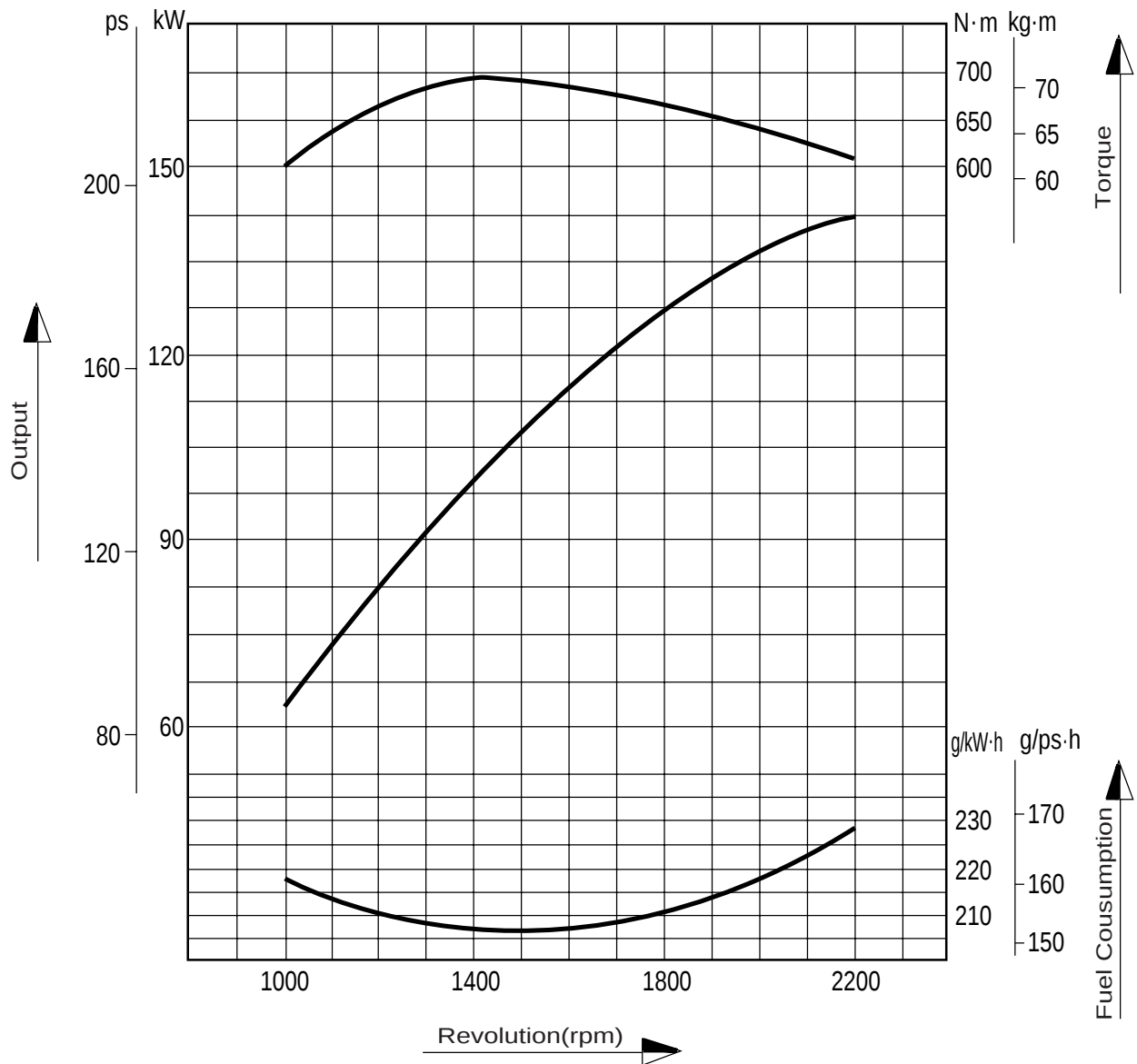


Performance Creteria	KS-R0071
Output(Max.)	182ps/2,500rpm
Torque(Max.)	57.5kg·m/1,600rpm
Fuel Cousumption Ratio(Min.)	163g/ps·h

ENM1002I

<Fig.2>

1.3.2. D1146T

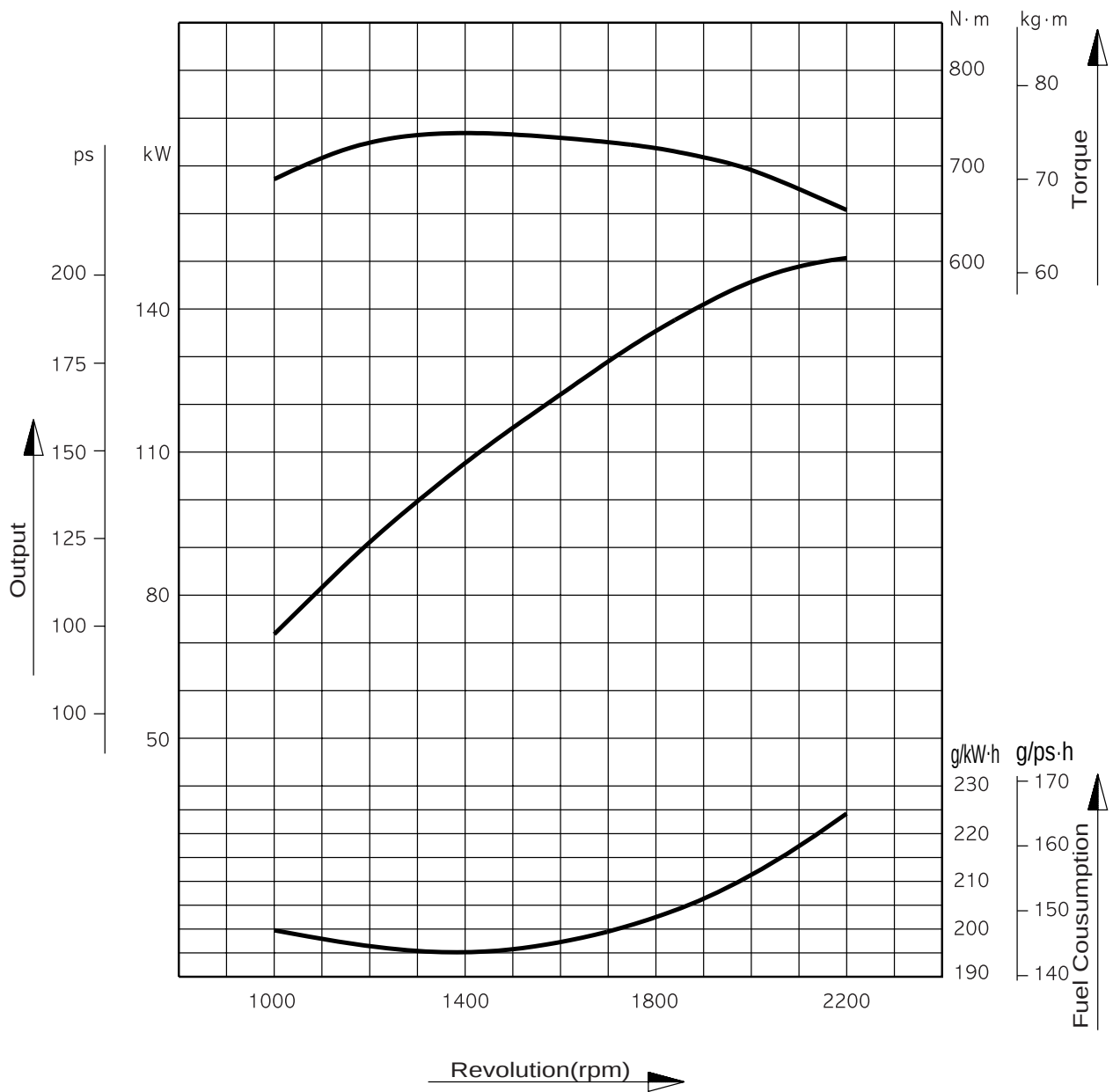


Performance Criteria	KS-R1004
Output(Max.)	190ps/2,200rpm
Torque(Max.)	71kg ·m/1,400rpm
Fuel Consumption Ratio(Min.)	152g/ps ·h

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<Fig.3>

1.3.3. D1146TI



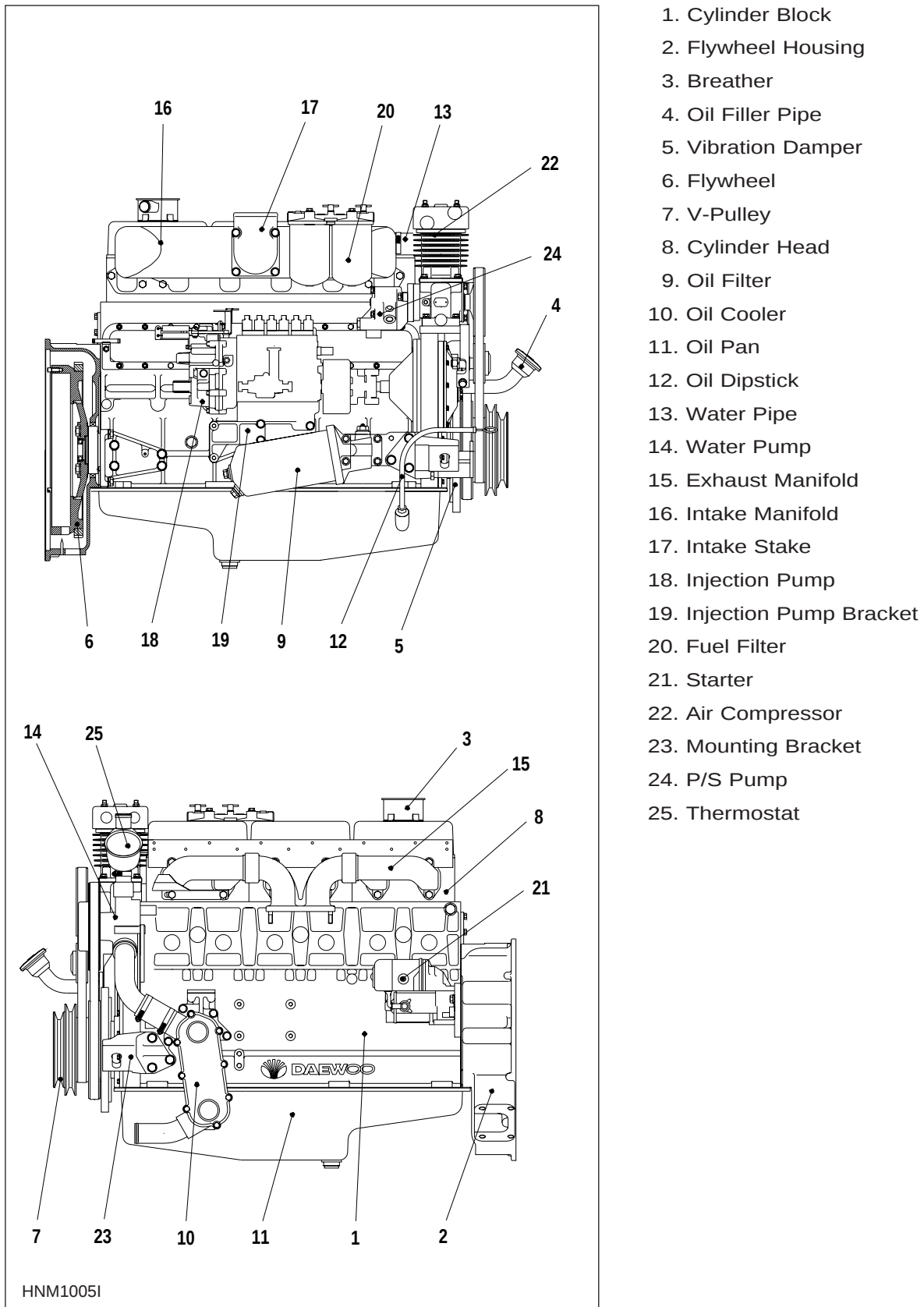
Performance Criteria	KS-R0071
Output(Max.)	205ps/2,200rpm
Torque(Max.)	75kg ·m/1,400rpm
Fuel Consumption Ratio(Min.)	143g/ps ·h

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<Fig.4>

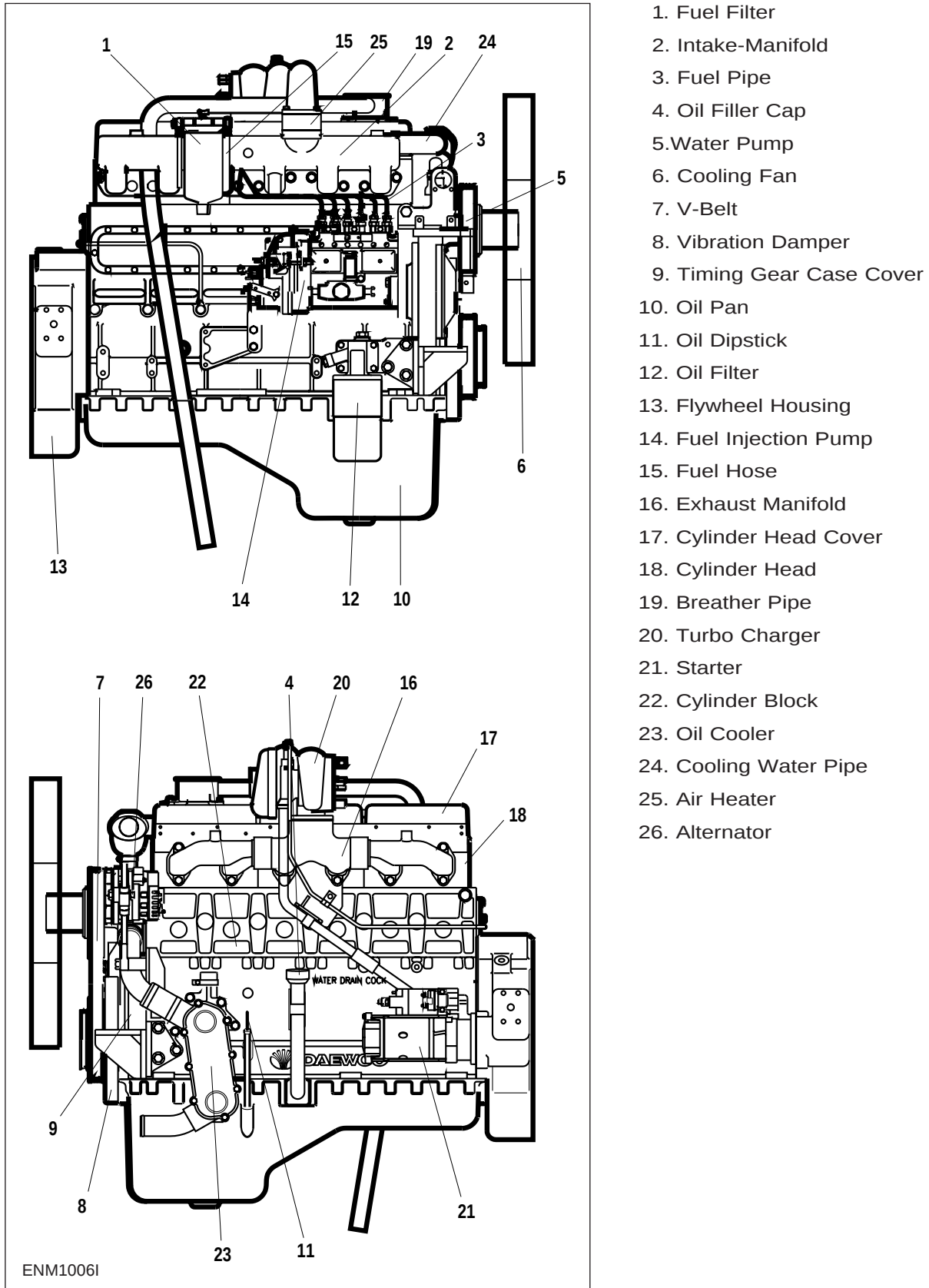
1.4. Exterior View of Engine

1.4.1. D1146



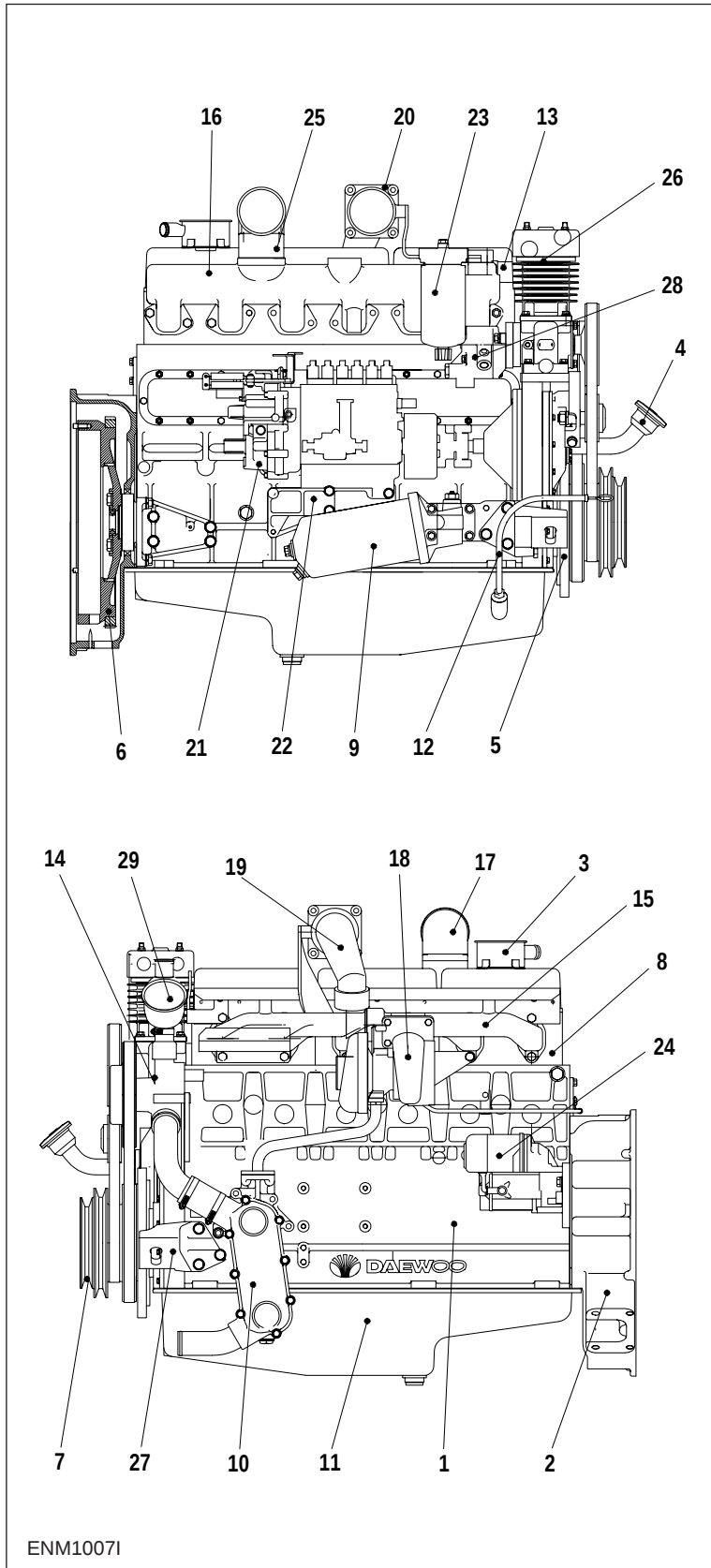
<Fig.5>

1.4.2. D1146T



<Fig.6>

1.4.3. D1146TI(Inter Cooler Separate Type)



1. Cylinder Block
2. Flywheel Housing
3. Breather
4. Oil Filler Pipe
5. Vibration Damper
6. Flywheel
7. V-Pulley
8. Cylinder Head
9. Oil Filter
10. Oil Cooler
11. Oil Pan
12. Oil Dipstick
13. Water Pipe
14. Water Pump
15. Exhaust Manifold
16. Intake Manifold
17. Intake Stake
18. Turbocharger
19. Air Pipe (T/C-A/P)
20. Air Pipe (A/P-I/C)
21. Injection Pump
22. Injection Pump Bracket
23. Fuel Filter
24. Starter
25. Air Heater
26. Air Compressor
27. Mounting Bracket
28. P/S Pump
29. Thermostat

<Fig.7>

2. Major Maintenance

2.1. Preventive Maintenance

2.1.1. Coolant

- 1) Check the coolant level of the radiator by removing the radiator filler cap, and add coolant if necessary.
- 2) Check the pressure valve opening pressure using a radiator cap tester. Replace the radiator filler cap assembly if the measured value does not reach the specified limit (0.5 kg/cm²).
- 3) When injecting antifreeze solution, first drain out the old coolant from the cylinder block and radiator, and then clean them with cleaning solution.
- 4) Be sure to mix soft water with antifreeze solution .
- 5) A proportion of antifreeze is represented as the ratio of antifreeze in volume, and antifreeze must be added according to each ambient temperature as described below:

Cooling Water(%)	Antifreeze Solution(%)	Freezing Point(°C)
85	15	-10 or above
80	20	-10
73	27	-15
67	33	-20
60	40	-25
56	44	-30
50	50	-40

- ※ If you add antifreeze in excess of 50% in volume, the engine may be overheated. Avoid this.
- ※ As the individual freezing points corresponding to the above proportions of antifreeze are subject to change slightly according to the kind of antifreeze, you must follow the specifications provided by the antifreeze manufacturer.

- 6) As the ratio of antifreeze in the mixture decreases each time new coolant is added to make up for the loss in old coolant resulting from engine operation, check the mix ratio with every replenishment of coolant, and top up as necessary.
- 7) To prevent corrosion or air bubbles in the coolant path, be sure to add a specific additive, i.e. corrosion inhibitor, to the coolant.
 - Type : INHIBITOR (DCA4, DCA65L …)
 - Mix ratio : 1.5ℓ of inhibitor to 50ℓ of coolant
(Namely, add corrosion inhibitor amounting to 3% of water capacity.)
- 8) Add antifreeze of at least 5% in volume to prevent possible engine corrosion in hot weather.

2.1.2. Fan Belt

- 1) Use a fan belt of specified dimensions, and replace if damaged, frayed, or deteriorated.
- 2) Check the fan belt for belt tension. If belt tension is lower than the specified limit, adjust the tension by relocating the alternator and idle pulley. (Specified deflection: 10~15mm when pressed down with thumb)

2.1.3. Engine Oil

- 1) Check oil level using the oil dip stick and replenish if necessary.
- 2) Check the oil level with the vehicle stationary on a level ground, engine cooled. The oil level must be between MAX and MIN lines on the stick.
- 3) Engine oil should be changed at the specified intervals. Oil in the oil filter also should be changed simultaneously.

• Engine Oil Change Interval : At Least 2 Times / Year

First Oil Change	500 ~ 1,000km (50 hours)
High speed, long distance running vehicle	every 15,000 km
Inner city, short distance running vehicle	every 10,000 km
Heavy duty vehicle	every 8,000 km (250 hours)

• Suggested Engines Oils

SAE NO.	API NO
15W40	CD grade or above

2.1.4. Oil Filter

- 1) Check for oil pressure and oil leaks, and repair or replace the oil filter if necessary.
- 2) Change the oil filter element simultaneously at every replacement of engine oil.

2.1.5. Fuel Filter (Cartridge Type)

- 1) Drain water in cartridge with loosen the cock under filter from time to time.
- 2) The fuel filter should be replaced at every 20,000km

2.1.6. Fuel Filter (Element Type)

- 1) The secondary stage fuel filter (fine filter) should be replaced at the same time when replacing Engine oil because that filter cannot be cleaned.
- 2) The primary stage fuel filter (felt element) should be cleaned up using diesel oil and compressed air at every 5,000km.
- 3) Be sure to replace the felt element after its 3rd cleaning.

2.1.7. Air Cleaner

- 1) Replace any deformed or broken element or cracked air cleaner.
- 2) Clean or replace the element at regular intervals.

2.1.8. Valve Clearance

- 1) Turn the crank shaft so that the piston in No. 1 cylinder reaches the TDC on compression stroke, then adjust the valve clearance.
- 2) After releasing the lock nut for the rocker arm adjusting screw, insert a feeler gauge of specified thickness into the clearance between the rocker arm and valve stem, and adjust the clearance with the adjusting screw. Fully tighten the lock nut when a correct adjustment is obtained.
- 3) Carry out the same adjusting operation according to the firing order(1-5-3-6-2-4)
(Valve clearance(with engine cooled): 0.30mm for both intake and exhaust)

2.1.9. Cylinder Compression Pressure

- 1) Stop the engine after warming it up, then remove the nozzle holder assembly.
- 2) Install a special tool(gauge adapter) in nozzle holder hole and mount the compression gauge in position of the nozzle holder.

Standard	28 kg/cm ² Over
Limit	24 kg/cm ² or less
Difference between each cylinder	±10% or less

- 3) Cut off fuel circulation, rotate the starter, then measure compression pressure in each cylinder.

※ Testing conditions: Coolant temperature, 20°C Engine rpm, 200 rpm (10 turns)

2.1.10. Injection Nozzle

- 1) Assemble a nozzle to a nozzle tester.
- 2) Check injection pressure, and adjust the nozzle using the adjusting shim if the pressure does not meet the specified limit.
- 3) Check nozzle spray patterns and replace if damaged.

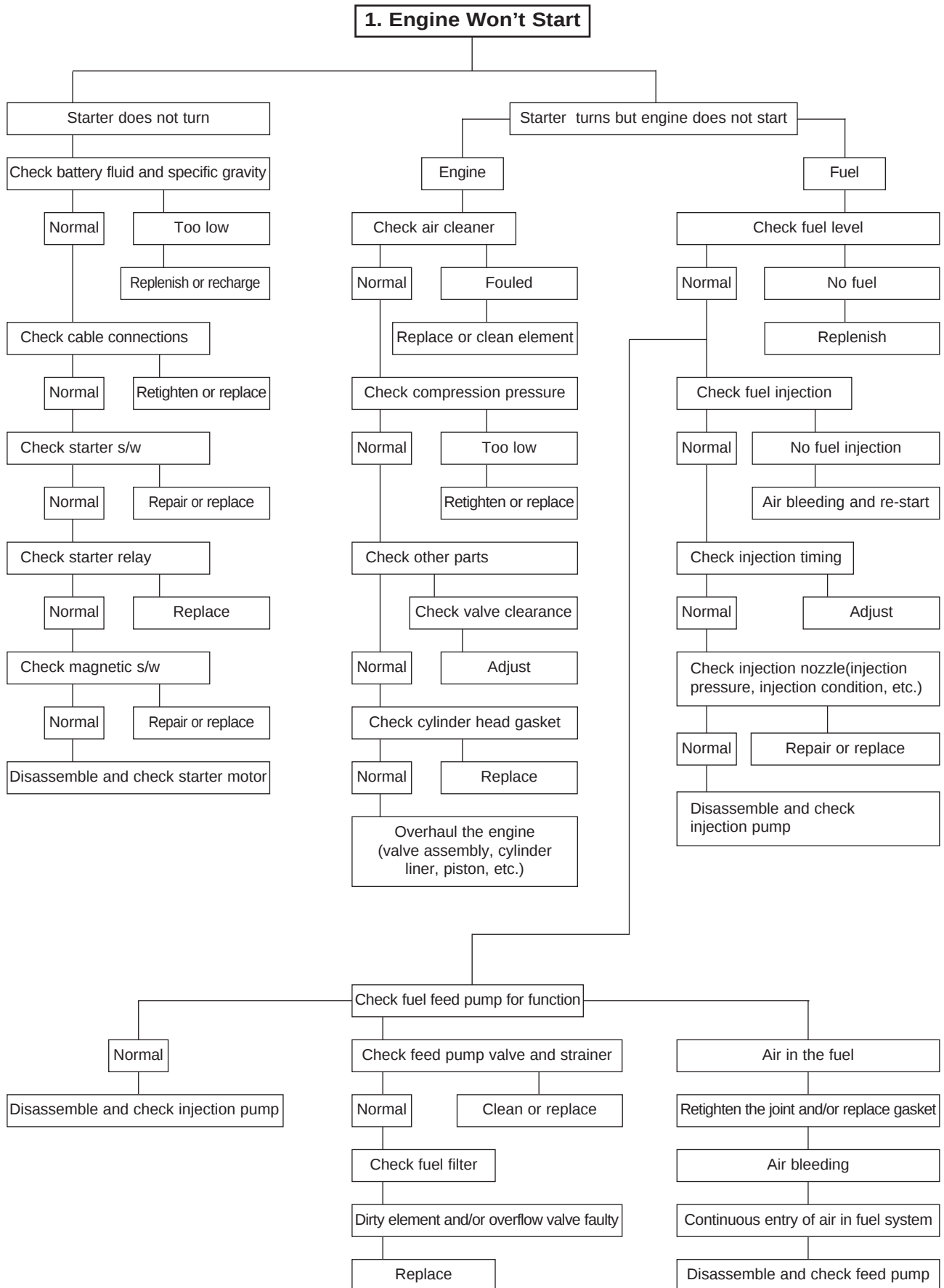
2.1.11. Fuel Injection Pump

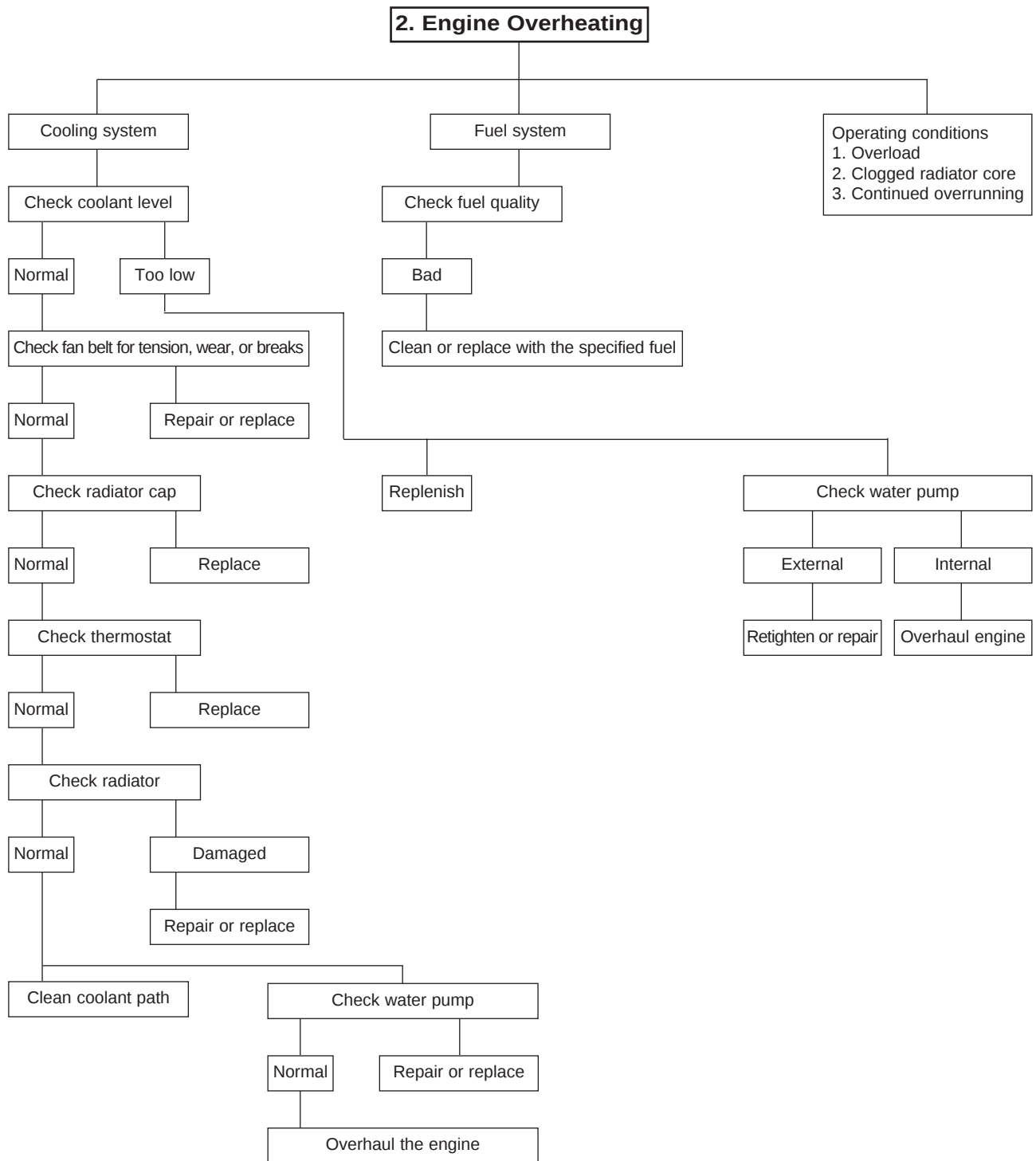
- 1) Check the fuel injection pump housing for cracks or breaks, and replace if damaged.
- 2) Check and see if the lead seal for idling control and speed control levers have not been removed.

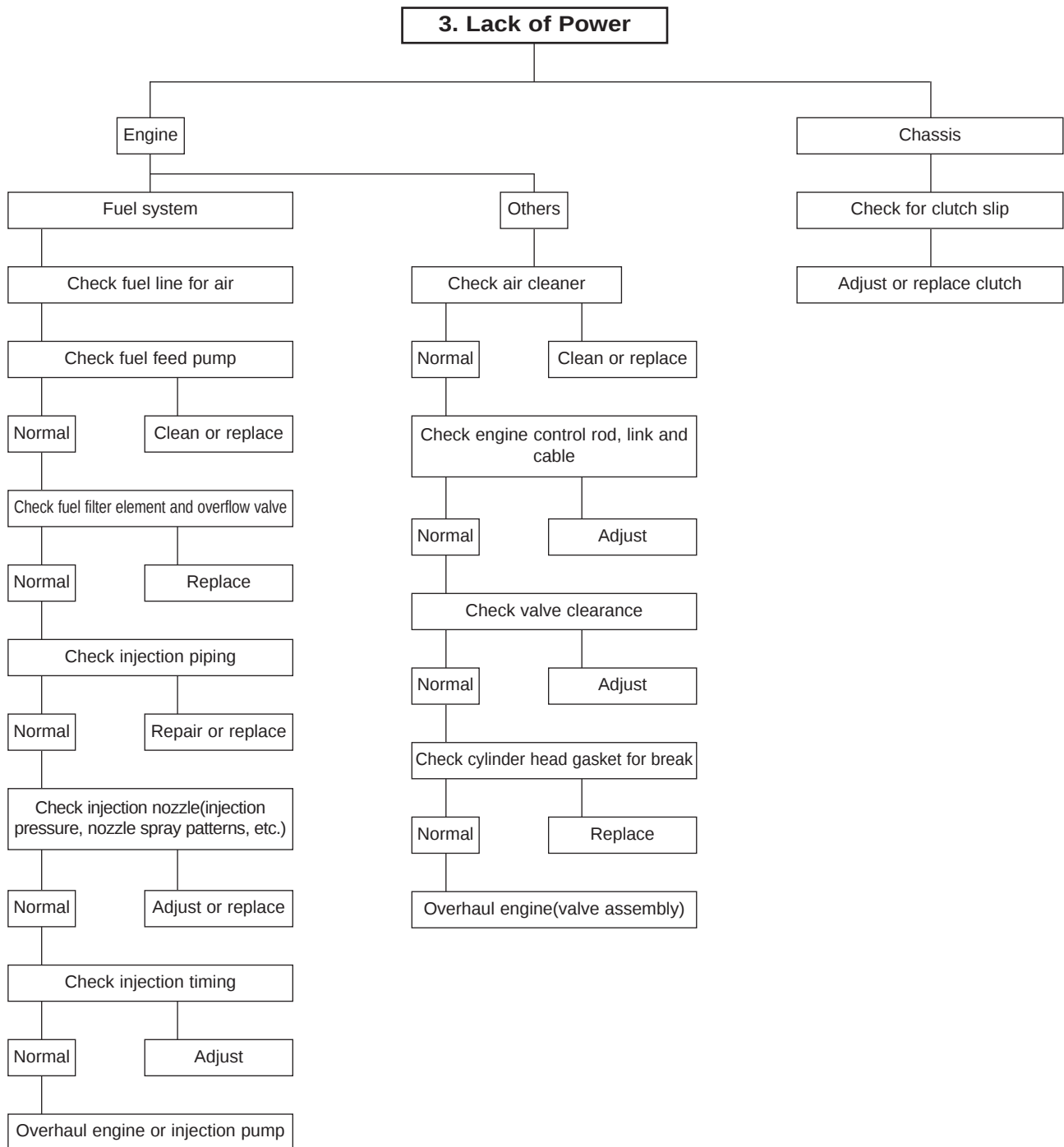
2.1.12. Battery

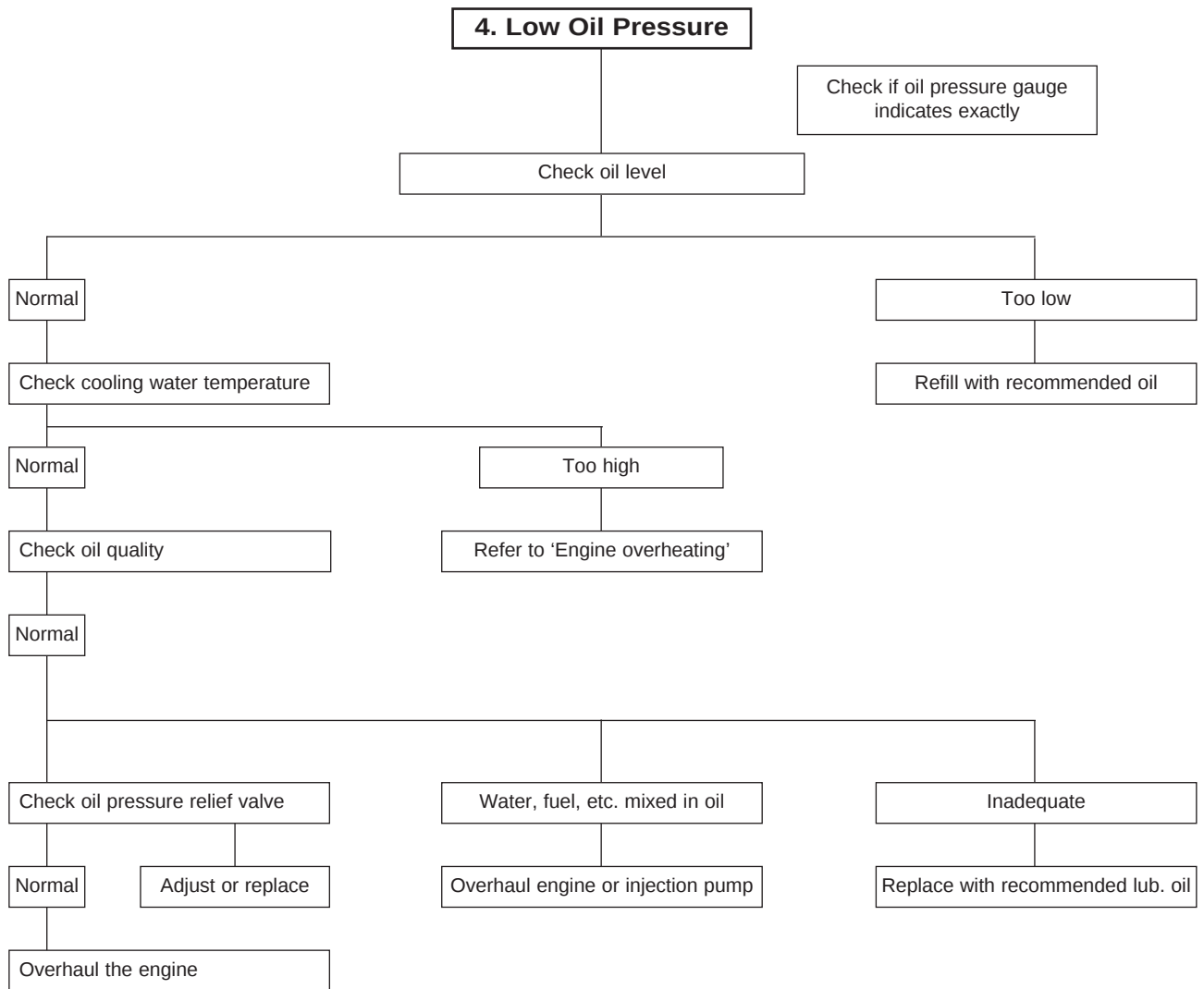
- 1) Check the battery for damage or leaking of battery fluid(electrolyte) from cracks on the battery. Replace the battery if damaged.
- 2) Check battery fluid level and add distilled water if necessary.
- 3) Measure the specific gravity of the electrolyte in the battery. Recharge the battery if the hydrometer readings are lower than the specified limit(1.12~1.28)

2.2. Diagnostics and Troubleshooting for the Engine





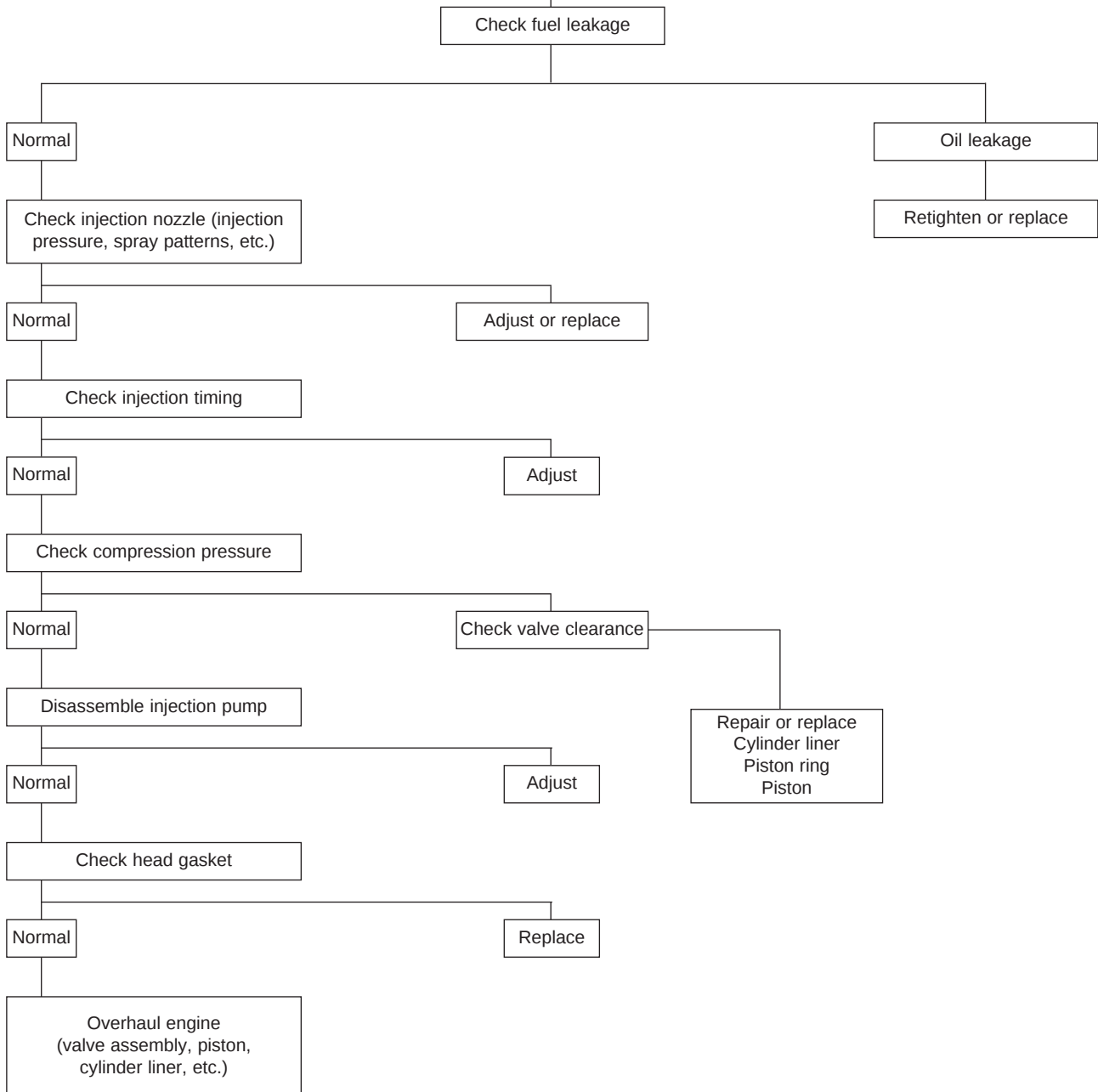




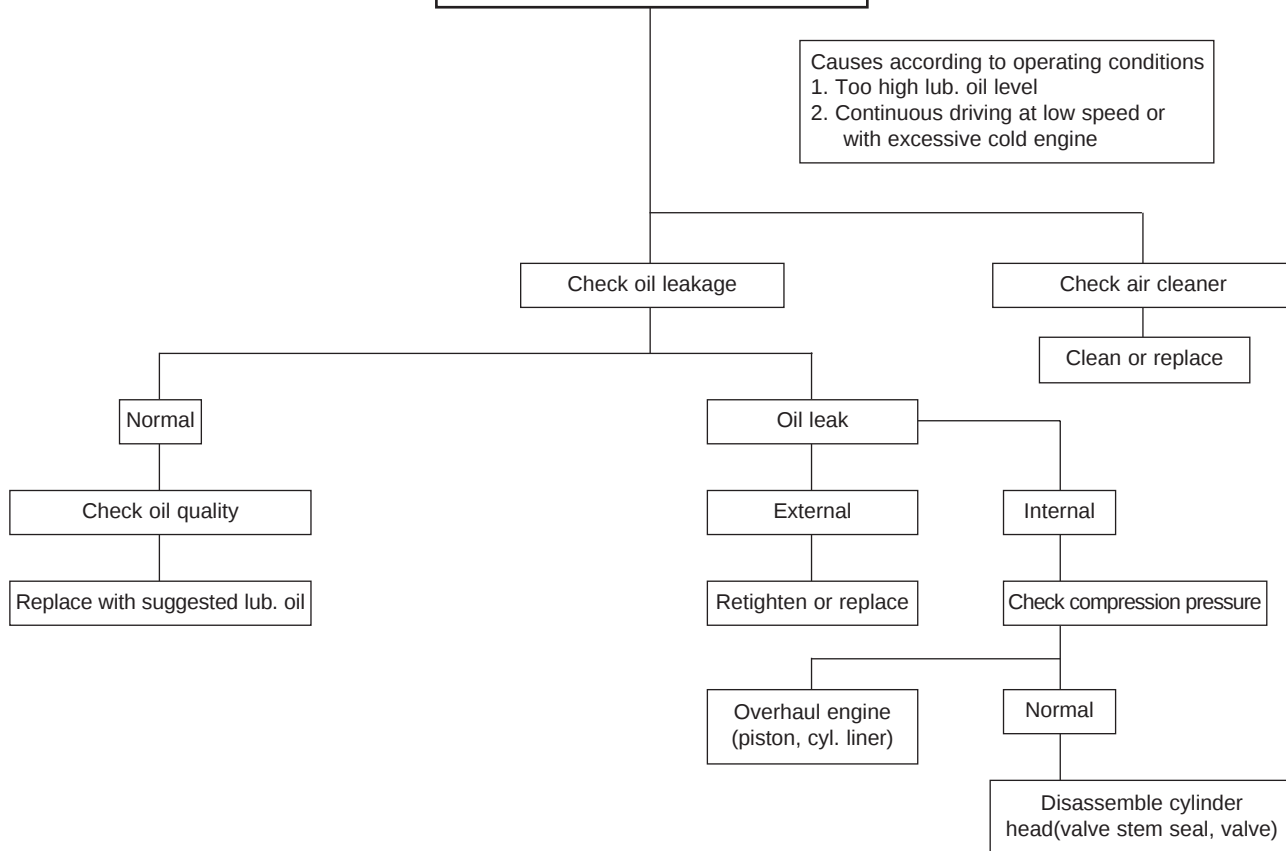
5. High Fuel Consumption

Causes according to operating conditions

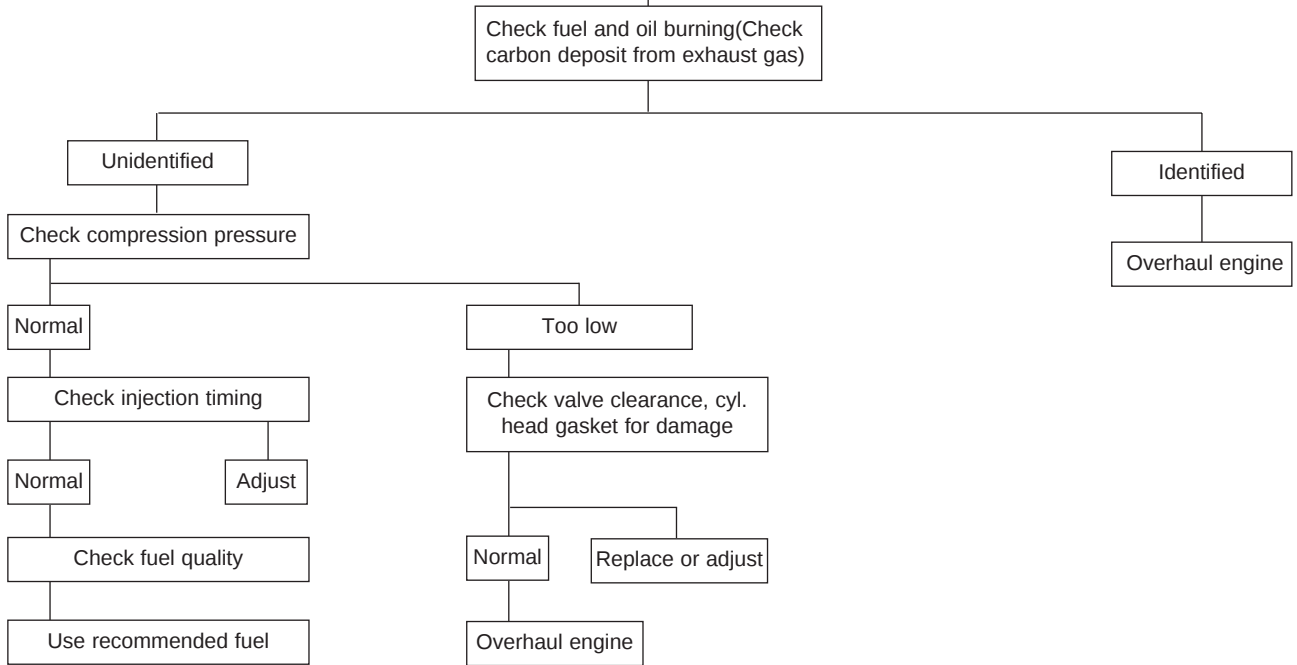
1. Overload
2. Frequent use of low gear shift at high speed
3. Frequent use of high gear shift at low speed
4. Clutch slip
5. Too low tire inflation pressure



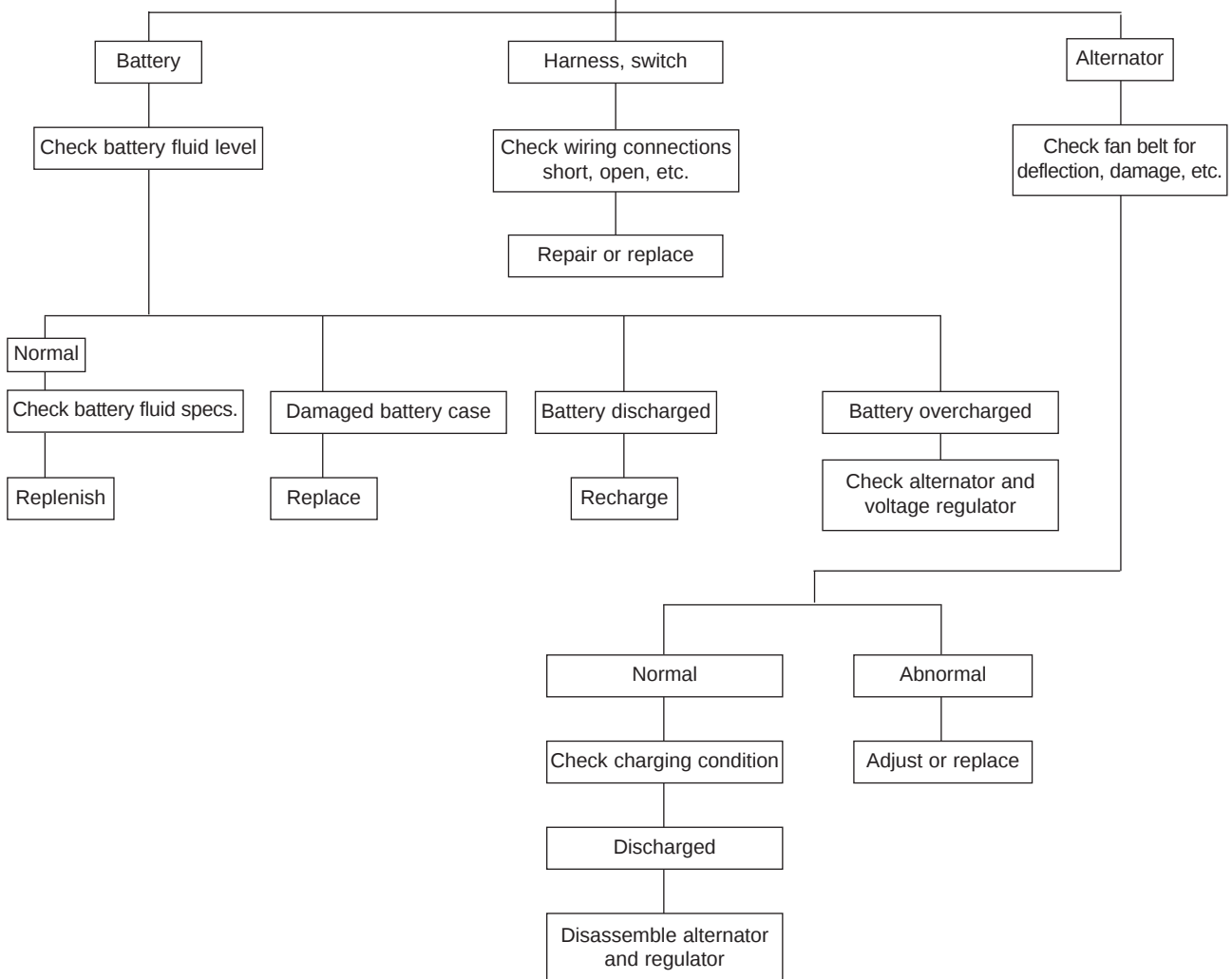
6. Excessive Oil Consumption



7. Engine Knocks(Excessive)



8. Dead or weak battery



Complaint	Cause	Correction
1) Difficulty in engine starting (1) Trouble in starter (2) Trouble in fuel system (3) Lack of compression pressure	(See <page 103>) (See <Section 4.3 Fuel system>) ① Valves holding open, skewed valve stem ② Valve springs damaged ③ Leaky cylinder head gasket ④ Worn pistons, piston ring, or liner	Check valve and valve seat, then repair or replace Replace valve springs Replace gasket Replace
2) Rough engine idling	① Wrong injection timing ② Air in injection pump	Adjust Air bleeding
3) Lack of engine power (1) Engine continues to lack power	① Valve clearance incorrect ② Valve poorly seated ③ Leaky cylinder head gasket ④ Piston rings worn, sticking, or damaged ⑤ Injection timing incorrect ⑥ Volume of fuel delivery insufficient ⑦ Nozzle injection pressure incorrect or nozzles seized ⑧ Feed pump faulty ⑨ Restrictions in fuel pipes ⑩ Volume of intake air insufficient	Adjust Repair Replace gasket Replace piston rings Adjust Adjust injection pump Adjust or replace nozzles Repair or replace Repair Clean or replace air cleaner
(2) Engine lacks power on acceleration	① Compression pressure insufficient ② Injection timing incorrect ③ Volume of fuel delivery insufficient ④ Injection pump timer faulty ⑤ Nozzle injection pressure or spray angle incorrect ⑥ Feed pump faulty ⑦ Volume of intake air insufficient	Overhaul engine Adjust Adjust injection pump Repair or replace Repair or replace Repair or replace Clean or replace air cleaner
4) Engine overheating	① Lack of engine oil or poor oil ② Lack of coolant ③ Fan belts slipping, worn or damaged ④ Water pump faulty ⑤ Thermostat inoperative ⑥ Valve clearance incorrect ⑦ Back pressure in exhaust line	Replenish or replace Replenish or replace Adjust or replace Repair or replace Replace Adjust Clean or replace

Complaint	Cause	Correction
5) Engine noises	It is important to correctly locate the causes of noise since generally noises may originate from various engine components such as rotating parts, sliding parts, etc.	
(1) Crankshaft	① Oil clearance excessive due to worn bearings or crankshaft ② Crankshaft worn out-of-round ③ Restrictions in oil ports and resultant lack of oil supply ④ Bearings seized up	Replace bearings and grind crankshaft Grind or replace crankshaft Clean oil path Replace bearings and grind crankshaft
(2) Conn. rod and conn. rod bearings	① Conn. rod bearings worn out-of-round ② Crank pin worn out-of-round ③ Conn. rod skewed ④ Bearings seized up ⑤ Restrictions in oil ports and resultant lack of oil supply	Replace bearings Grind crankshaft Repair or replace Replace bearings and grind crankshaft Clean oil path
(3) Pistons, piston pins, and piston rings	① Piston clearance excessive due to worn piston and piston rings ② Piston or piston pin worn ③ Piston seized up ④ Piston poorly seated ⑤ Piston rings damaged	Replace pistons and piston rings Replace pistons and piston rings Replace pistons Replace pistons Replace piston rings
(4) Others	① Crankshaft and/or thrust bearing worn ② Camshaft end play excessive ③ Idle gear end play excessive ④ Timing gear backlash excessive ⑤ Valve clearance excessive ⑥ Tappets and cams worn	Replace thrust bearings Replace thrust plate Replace thrust washers Adjust or replace Adjust valve clearance Replace tappets and camshaft
6) Excessive fuel consumption	① Injection timing incorrect ② Volume of fuel injection excessive ③ Tire under-inflated ④ Gear selection inadequate(frequent use of low gears)	Adjust Adjust injection pump Adjust Select gears correctly according to load

Complaint	Cause	Correction
7) High oil consumption		
(1) Oil leaking into combustion chamber	① Clearance between cylinder liner and piston excessive ② Piston rings and ring grooves worn excessively ③ Piston rings broken, worn, or sticking ④ Piston rings gaps set incorrectly ⑤ Piston skirt portion broken, worn excessively ⑥ Oil return holes in oil control ring restricted ⑦ Oil ring seated incorrectly ⑧ Breather piping restricted	Replace Replace pistons and piston rings Replace piston rings Correct Replace pistons Replace piston rings Replace piston rings Clean or replace
(2) Oil leaking past cylinder head	① Valve stems and valve guide loose excessively ② Valve stem seals worn ③ Leaky cylinder head gasket	Replace as complete set Replace seals Replace gasket
(3) Oil leaks	① Applicable parts loosened ② Applicable packings worn ③ Oil seals worn	Replace or repair gasket Replace packings Replace oil seals

3. Disassembly and Reassembly of Major Components

3.1. Disassembly

3.1.1. General Precautions

- 1) Prior to disassembly, provide parts shelf for storage of various tools and disassembled parts.
- 2) Perform disassembly and reassembly works with clean bare hands and keep clean your surroundings.
- 3) After disassembly, prevent disassembled parts from being interchanged or colliding with each other.
- 4) Keep the disassembled parts in the disassembled sequence.

3.1.2. Oil Dipstick

- 1) Take out the oil Dipstick from the guide tube.

3.1.3. Cooling Water

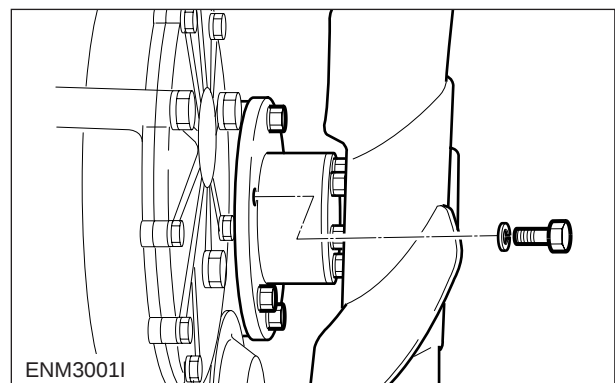
- 1) Remove the drain plug in the cylinder block and drain out the cooling water into a prepared container.

3.1.4. Engine Oil

- 1) Remove the drain cock in the oil pan and drain out the engine oil into a prepared container.
- 2) Also, drain the oil filter by removing the drain plug.

3.1.5. Cooling Fan

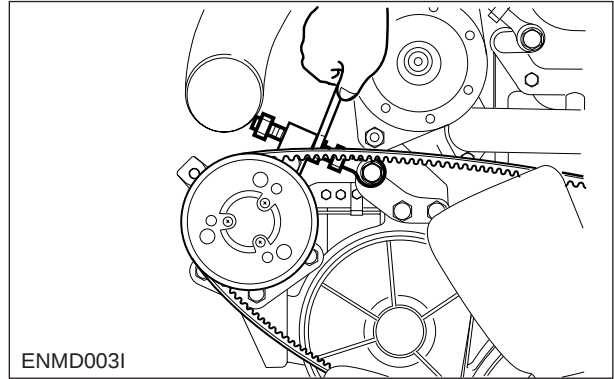
- 1) Remove the flange fixing bolts, then take off the flange and cooling fan.



<Fig.1> Cooling Fan Disassembling

3.1.6. V-Belt

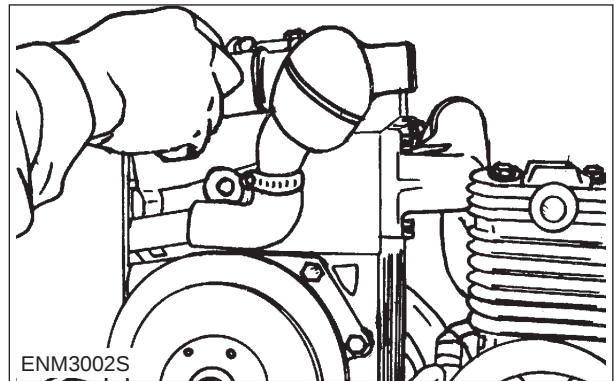
- 1) Loosen the tension adjusting bolts of the alternator and the idle pulley, and take off the V-belts.



<Fig.2> V-Belt Removal

3.1.7. Thermostat

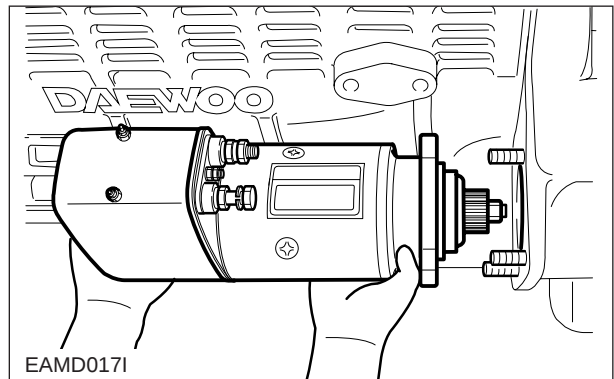
- 1) Loosen the rubber hose connected to the cooling. Water pipe, and remove the thermostat.
- 2) Remove the rubber hose of the by-pass line.



<Fig.3> Thermostat Disassembling

3.1.8. Starter

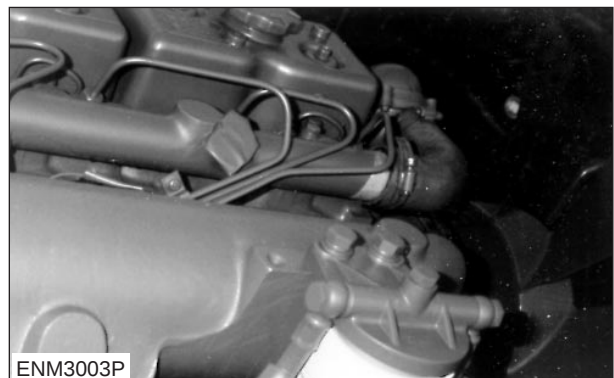
- 1) Unscrew the starter fixing nuts and remove the starter as taking care not to damage it.



<Fig.4> Starter Disassembling

3.1.9. Fuel Filter

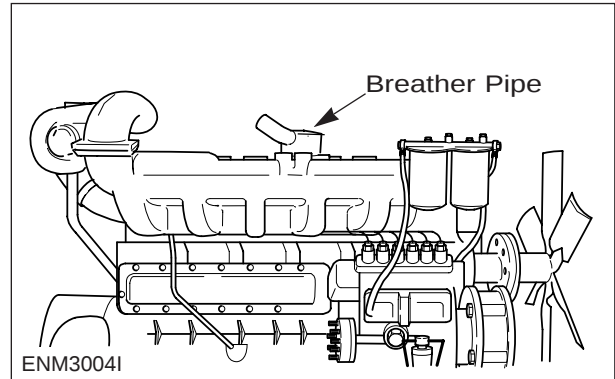
- 1) Unscrew the hollow screw, then remove the fuel inlet and outlet hoses.
- 2) Unscrew the filter fixing bolts and remove the fuel filter.
(if the fuel filter is of cartridge type, disassemble the cartridge element only)



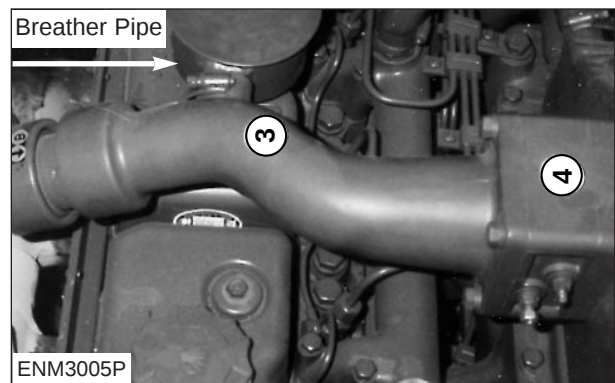
<Fig.5> Fuel Filter (Cartridge Type)

3.1.10. Breather Pipe

- 1) Unscrew the hose clamp with a screw driver and remove the breather pipe.
(There are two types of breather pipes according to their mounting locations. that is, on the oil cooler and on the cylinder head cover)



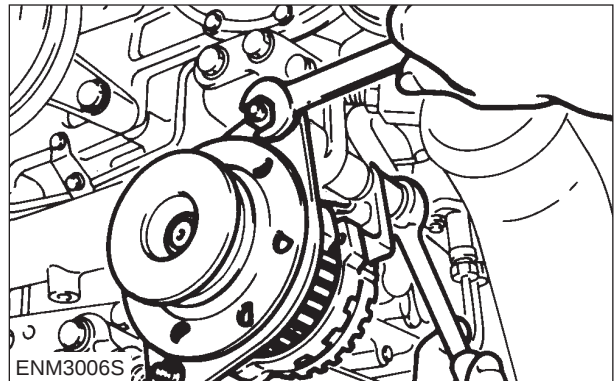
<Fig. 6> Breather Pipe (On The Cylinder Head Cover)



<Fig. 7> Breather Pipe (Top View)

3.1.11. Alternator

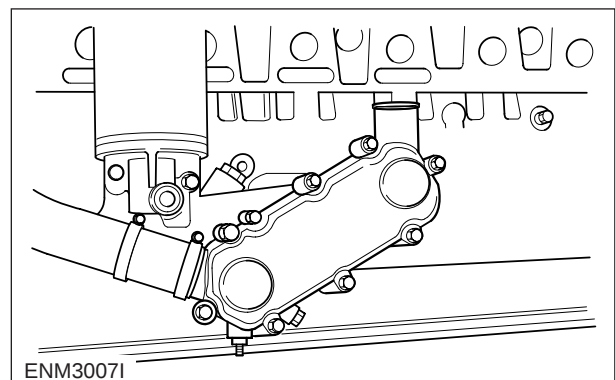
- 1) Remove the alternator fixing bolts and take off the alternator.



<Fig. 8> Alternator Disassembling

3.1.12. Oil Cooler

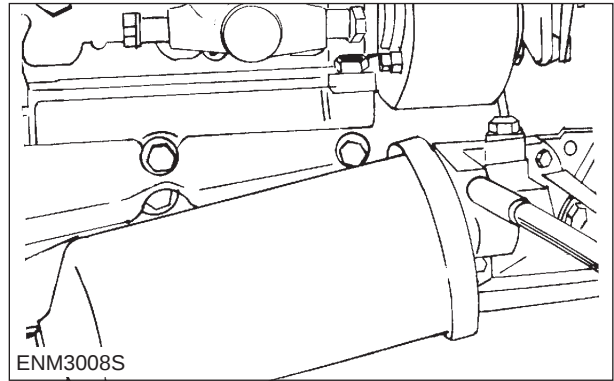
- 1) Loosen the rubber hose clamps of both sides of the oil cooler.
- 2) Unscrew the nuts and take off the oil cooler.



<Fig.9> Oil Cooler

3.1.13. Oil Filter

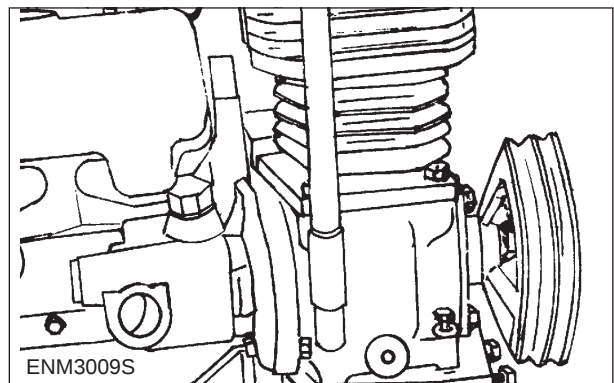
- 1) Remove the oil drain cock from the oil filter and drain out the Engine oil into a container.
- 2) Unscrew the oil filter fixing bolt and take off the oil filter.



<Fig.10> Oil Filter Disassembling

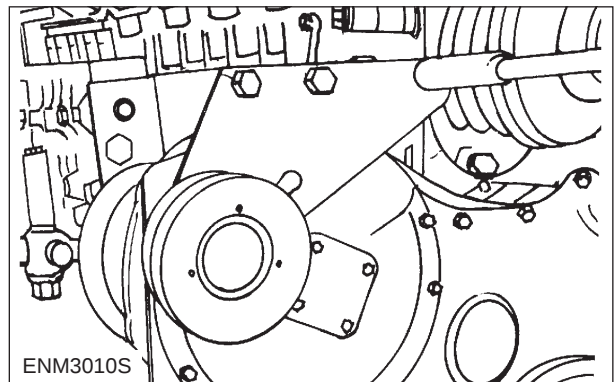
3.1.14. Air Compressor and Idle Pulley

- 1) Remove the oil pipe between cylinder block and air compressor.
- 2) Unscrew the air compressor fixing bolts and take off the air compressor.



<Fig.11> Air Compressor Disassembling

- 3) Unscrew the idle pulley fixing bolts and take off the idle pulley.

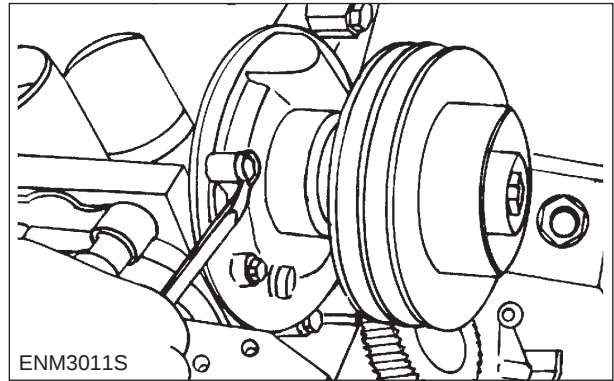


<Fig.12> Idle Pulley Disassembling

- 4) Unscrew the air compressor fixing bolts and remove the bracket.
- 5) Unscrew the power steering pump fixing bolts and remove the power steering pump.

3.1.15. Water Pump

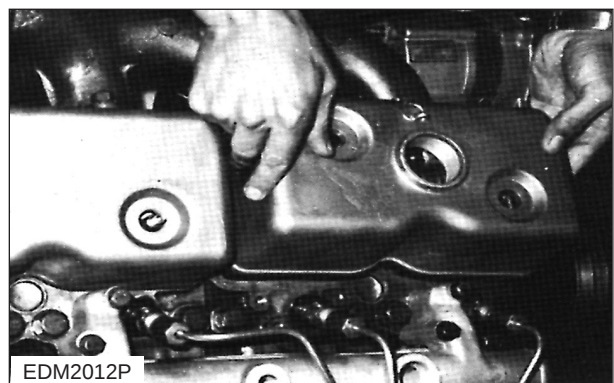
- 1) Remove the cooling fan fixing bolt and take off the fan and flange.
- 2) Unclamp the rubber hose connected to the oil cooler.
- 3) Unscrew the V-belt fixing nuts.
- 4) Unscrew the water pump fixing bolt from the cylinder block and take off the water pump.



<Fig.13> Water Pump Disassembling

3.1.16. Cylinder Head Cover

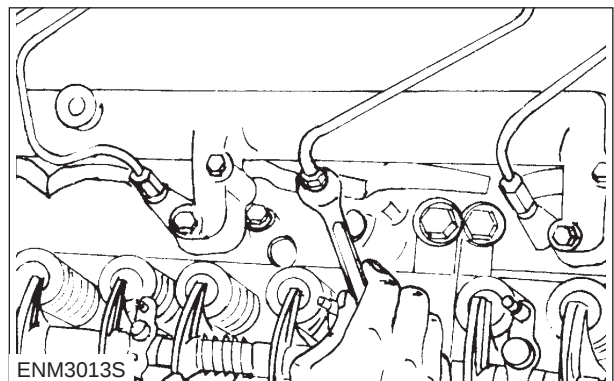
- 1) Unscrew the cylinder head cover fixing bolts and take off the cylinder head cover.



<Fig. 14> Cylinder Head Cover Removing

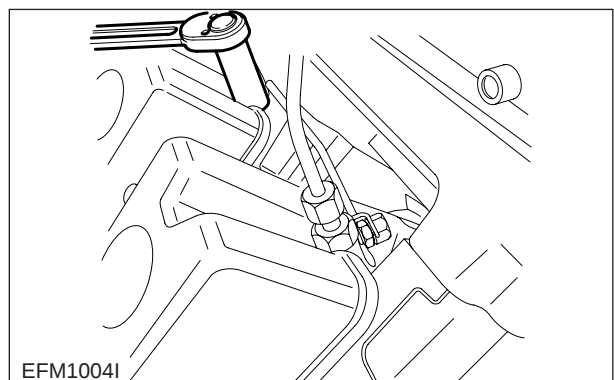
3.1.17. Injection Nozzle

- 1) Unscrew the injection pipe between the injection pump and injection nozzle and take off the pipe.



<Fig. 15> Injection Pipe Removal

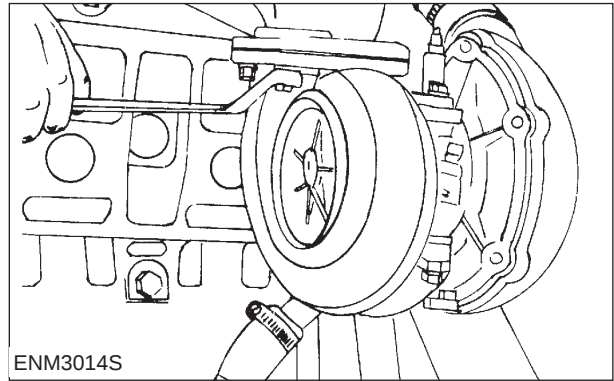
- 2) Install a special jig on the nozzle holder, and then pull out the nozzle as striking the hammer of the jig backwardly.
(Take care not to damage the nozzle at disassembly)
- 3) Take out the seal ring from the nozzle hole of the cylinder head and discard it.



<Fig.16> Injection Nozzle Removal

3.1.18. Turbo Charger <For D1146T and D1146TI>

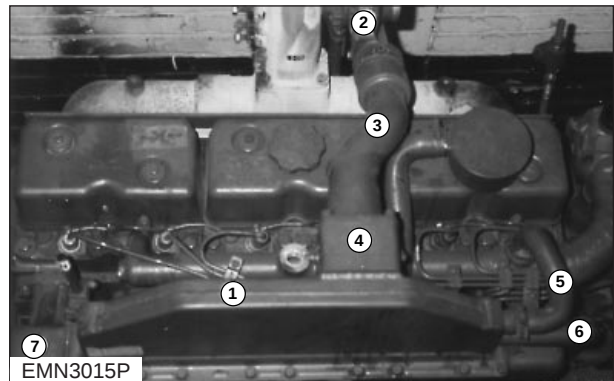
- 1) Remove the oil feed pipe and the oil return pipe between the turbo charger and the cylinder block.
- 2) Unclamp the rubber hose connected to the intake manifold.
- 3) Unscrew the turbo charger fixing bolts and take off the turbo charger from the exhaust manifold.



<Fig.17> Turbo Charger

3.1.19. Inter Cooler <For D1146TI Only>

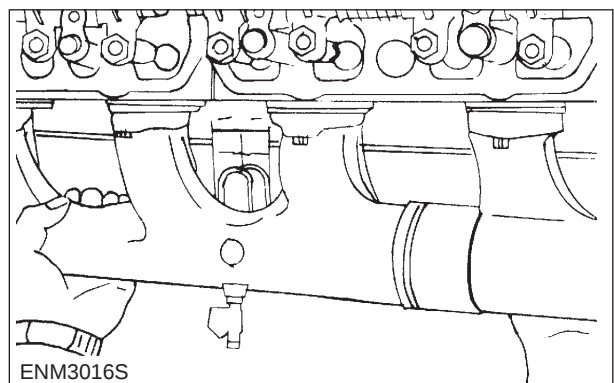
- 1) Unscrew the air heater fixing bolt, then loosen the air heater (4) from the air pipe (3) which is connected to the turbo charger (2) on the other side.
- 2) Unclamp the water outlet pipe (5) and water inlet pipe (6)
- 3) Unscrew the bolt tightened to both the intake manifold(7) and inter cooler(1).



<Fig.18> Inter Cooler

3.1.20. Exhaust Manifold

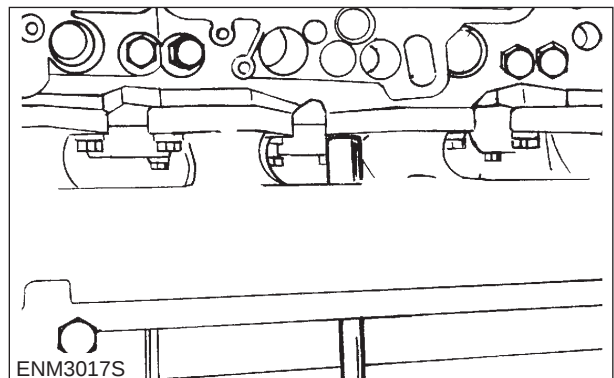
- 1) Unscrew the exhaust manifold fixing bolts and remove the exhaust manifold from the cylinder head.
- 2) Remove the exhaust manifold gasket and discard it.



<Fig.19> Exhaust Manifold Disassembling

3.1.21. Intake Manifold

- 1) Unscrew the intake manifold fixing bolts and remove the intake manifold from the cylinder head.
- 2) Remove the intake manifold gasket and discard it.



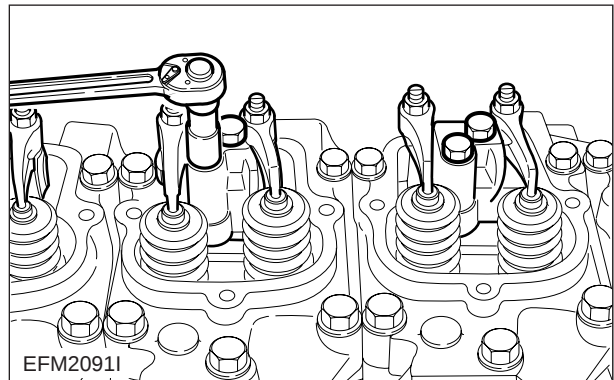
<Fig.20> Intake Manifold

3.1.22. Cooling Water Pipe

- 1) Unscrew the cooling water pipe fixing bolts and remove the cooling water pipe from the cylinder head.
- 2) Remove the cooling water pipe gasket and finish the surface with a scraper.
(Be sure that pieces of the gasket do not come into the water passage)

3.1.23. Rocker Arm Shaft Assembly

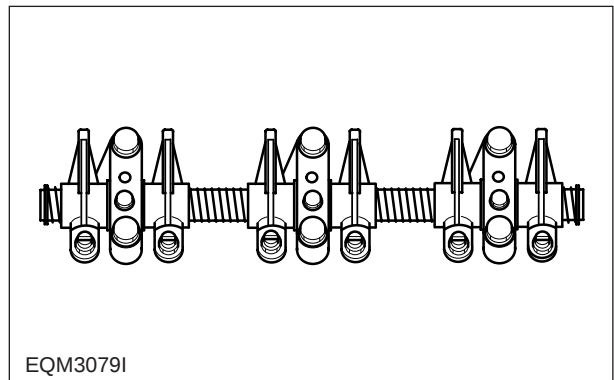
- 1) Remove the rocker arm bracket fixing bolts in reverse sequence of assembling sequence and take out the rocker arm shaft assembly.
- 2) Take out the push rod upwards.



<Fig.21> Rocker Arm Disassembling

3) Optional Disassembly

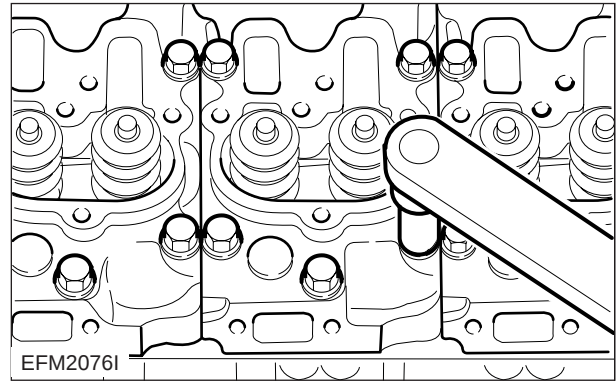
- (1) Remove the snap rings from the both ends of rocker arm shaft by means of a piler.
- (2) Remove the washer, rocker arm, bracket and spring from the rocker arm shaft in sequence.
- (3) Press out the rocker arm bush.
(When reassembling the bush, cool the bush in dry ice and press the bush while aligning the bush with the oil hole of the rocker arm)



<Fig.22> Rocker Arm Disassembled

3.1.24. Cylinder Head Assembly

- 1) Remove the cylinder head bolts by loosening them in sequence in two steps.
 - (1) 1st step : Loosen all the bolts evenly by 1 ~ 2 threads.
 - (2) 2nd step : Loosen all the bolts completely.

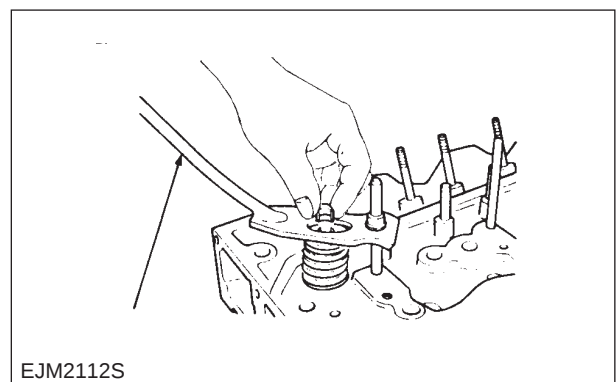
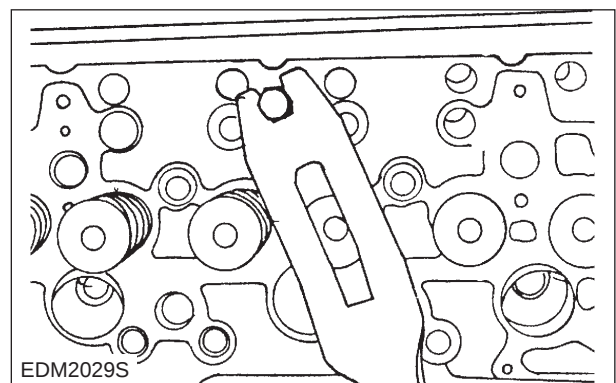


<Fig. 23> Cylinder Head Bolt Removal

- 2) Keep the removed bolts in place to avoid damage.
- 3) Hoist the cylinder head carefully and put it sideways.
- 4) Remove the gasket and discard it.
- 5) Be sure that gasket residue does not remain on the surfaces of the cylinder head and cylinder block.
(besides, the gasket joining surfaces should be free from any scar)

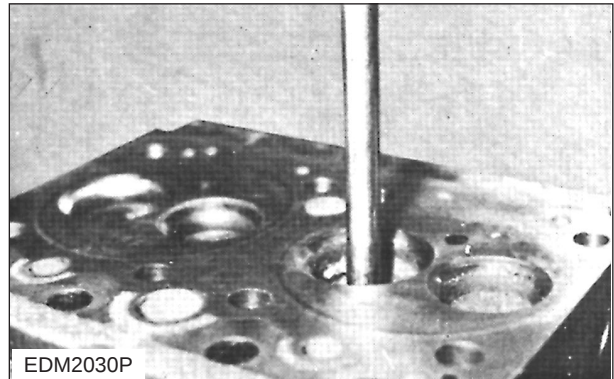
6) Optional Disassembly

- (1) Place the cylinder head assembly on a individual shelf.
- (2) As pressing the valve spring with a special tool, remove the cotter pin, valve spring.



<Fig.24> Valve Spring Disassembling

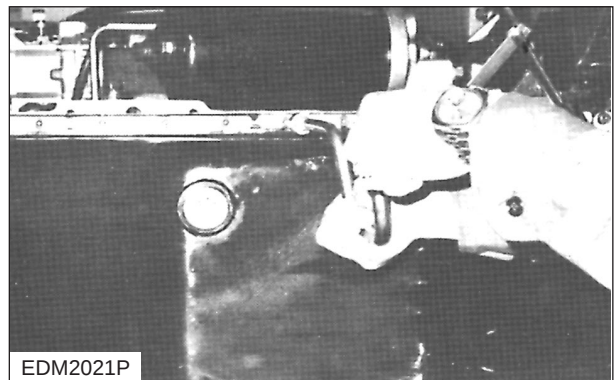
- (3) Take out the intake and exhaust valves.
- (4) For removal of valve seat, apply welding bead to the valve seat, and pull out the valve seat with a special tool.
- (5) The disassembled parts are to be kept laid in turn.
- (6) Remove the valve stem seals.
- (7) By means of a special tool, punch, pull out the valve guide.



<Fig. 25> Valve Guide Disassembling

3.1.25. Oil Pan

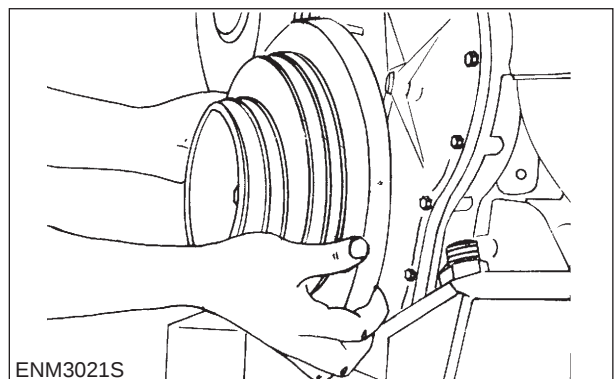
- 1) Unscrew the oil pan fixing bolts and remove the oil pan.
- 2) Remove the oil pan gasket and discard it.



<Fig.26> Oil Pan Disassembling

3.1.26. Vibration Damper

- 1) Unscrew the vibration damper fixing bolts in reverse sequence of installing sequence and remove the vibration damper assembly.



<Fig.27> Vibration Damper Disassembling

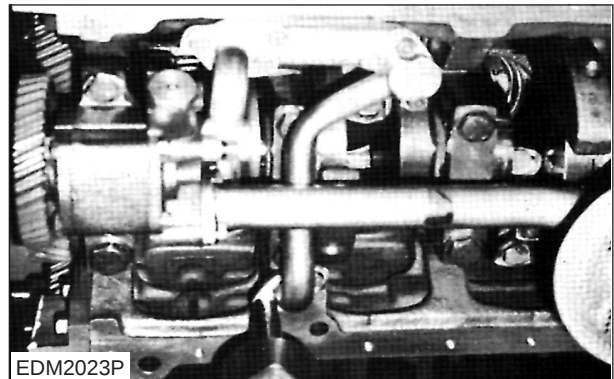
3.1.27. Timing Gear Case Cover

- 1) Unscrew the timing gear case fixing bolts.
- 2) To disassemble the timing gear case cover, Near the locations of dowel pin, insert a sharp scraper into the crevice between timing gear case and its cover. and tap the scraper lightly from right and left directions in an alternate manner.

(Be sure no damage or crack takes place)

3.1.28. Oil Pump

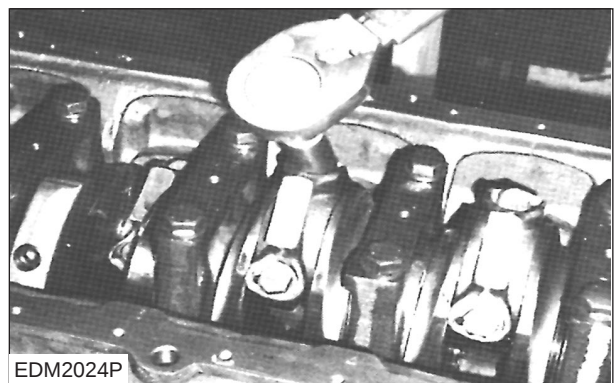
- 1) Unscrew the bracket fixing bolts of the oil suction pipe.
- 2) Unscrew the bolts fixing the oil suction pipe and remove the oil suction pipe.



<Fig.28> Oil Pipe Disassembling

3.1.29. Piston

- 1) Unscrew the bolts clamping the connecting-rod bearing cap on reverse sequence of assembling sequence while taking the same steps as disassembling way of cylinder head bolts.

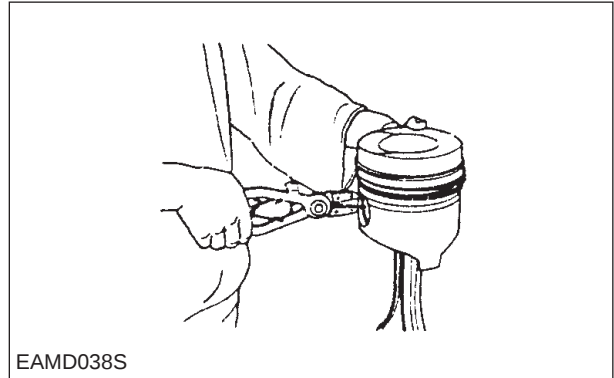


<Fig.29> Of Connecting-rod Cap Disassembling

- 2) As tapping the upper and lower portions of the bearing cap with a urethane hammer, remove the bearing cap and take off the bearing inside.
- 3) Disassemble the piston assembly by pushing the connecting-rod with a wooden bar toward cylinder head side from oil pan side.
- 4) Prevent disassembled piston assembly from being interchanged or colliding with each other.
- 5) Semi-Assemble the bearing caps to their respective connecting-rod to avoid their interchange.

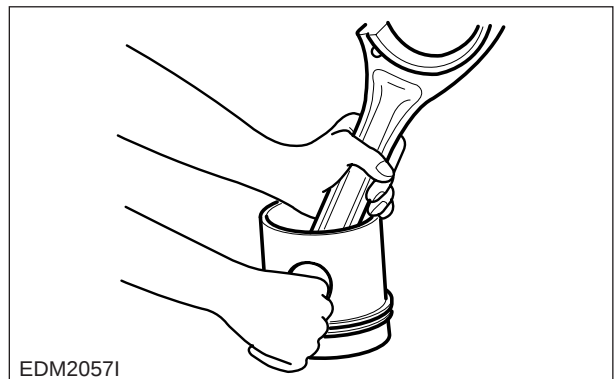
6) Optional Disassembly of Piston

- (1) Remove the snap rings by means of a plier.



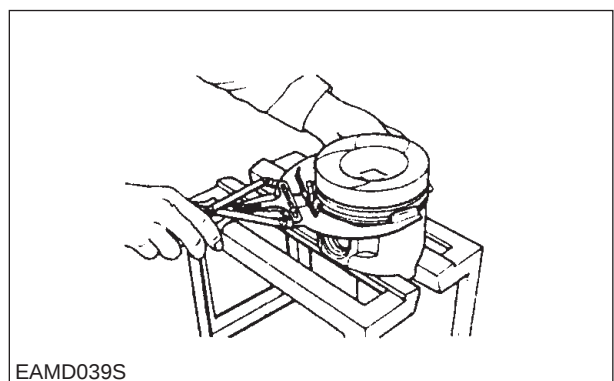
<Fig.30> Snap Ring Removal

- (2) Heat the piston with a electric heater, then take out the piston pin from the piston as tapping it with a round wooden bar.



<Fig.31> Piston Pin Removal

- (3) Remove the piston ring with a plier.

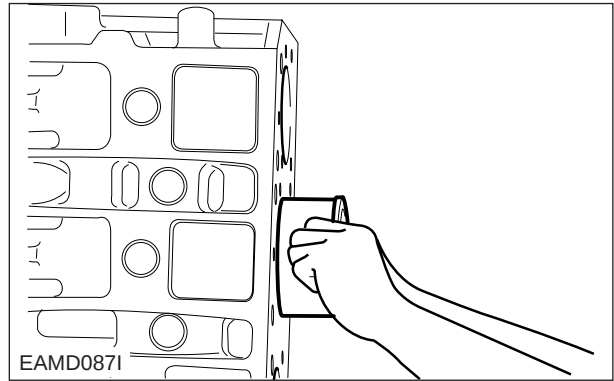


<Fig.32> Piston Ring Removal

- (4) Wash clean the piston thoroughly.

3.1.30. Cylinder Liner

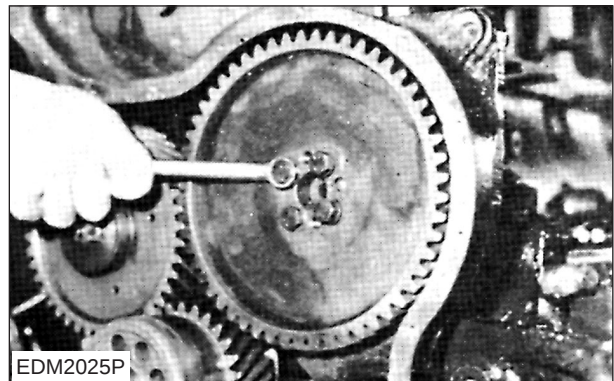
- 1) Pull out the cylinder liner by means of a special tool or by hands carefully so as not to damage the cylinder bore.



<Fig.33> Liner Extracting

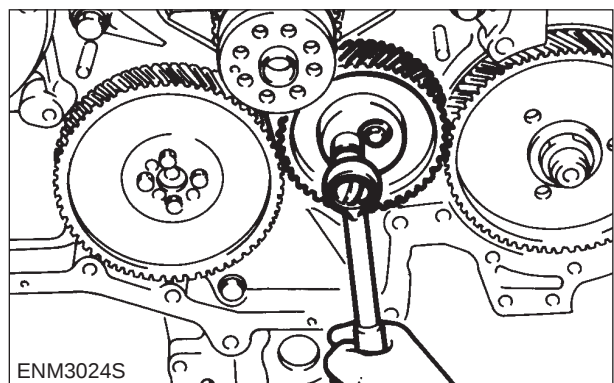
3.1.31. Cam Shaft Gear and Idle Gear

- 1) Unscrew the fixing bolts and remove the cam shaft gear.



<Fig.34> Camshaft Gear Disassembling

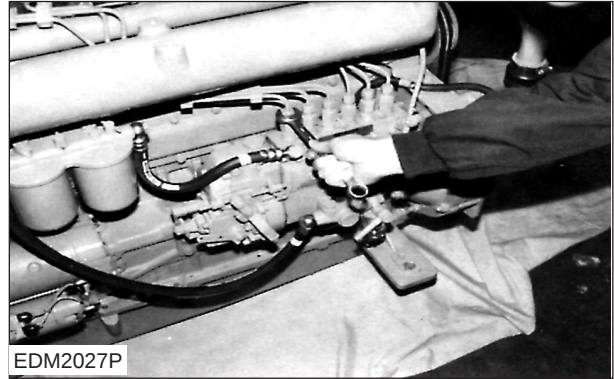
- 2) Unscrew two bolts fixing the idle gear, then remove the idle gear and its pin.



<Fig.35> Idle Gear Disassembling

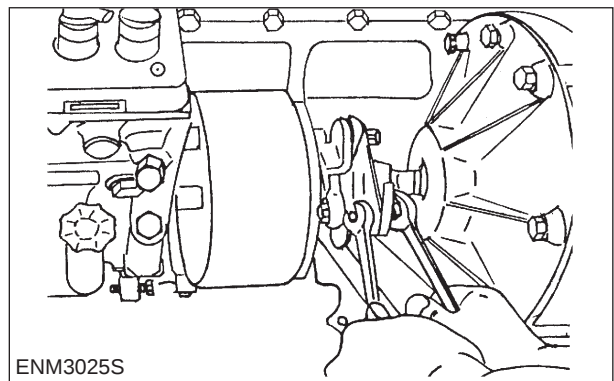
3.1.31. Fuel Injection Pump

- 1) Remove the oil hose for lubrication.
- 2) Unscrew the injection pipe fixing bolts and remove the injection pipe.



<Fig.36> Injection Pipe Removal

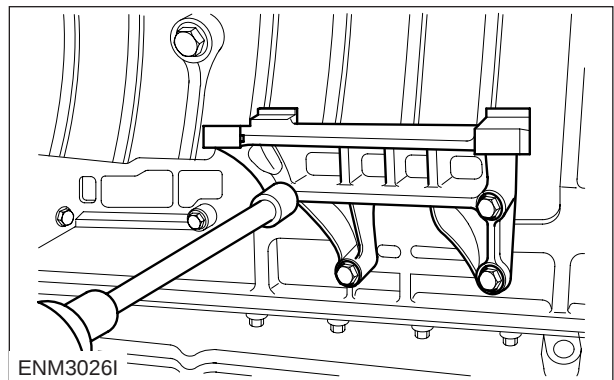
- 3) Remove the bolts and nuts which connect the coupling flange. To the injection pump.



<Fig.37> Coupling Disassembling

- 4) Unscrew the injection pump fixing bolts and remove the injection pump by lifting it up.

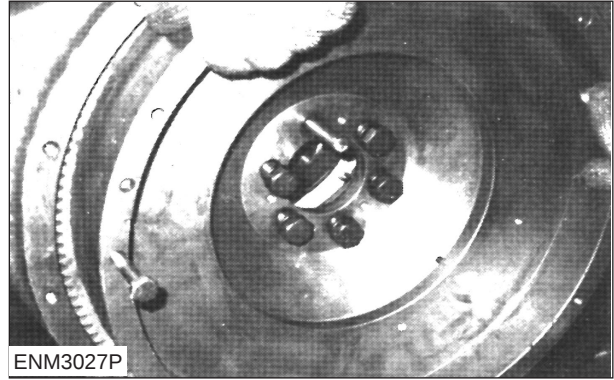
- 5) Unscrew the bracket fixing bolts and remove the bracket while tapping it lightly with a urethane hammer.



<Fig.38> Bracket Disassembling

3.1.32. Flywheel

- 1) Remove the fixing bolts by loosening them in diagonal sequence.
- 2) Remove the flywheel.



<Fig.39> Flywheel Disassembling

3.1.33 Flywheel Housing

- 1) Remove the fixing bolts of the flywheel housing, then remove the flywheel housing by tapping it lightly with a copper or urethane hammer.
- 2) Remove the rear oil seal.

3.1.34. Injection Pump Drive Gear

- 1) Unscrew the bolts fixing the drive gear and remove the gear.
- 2) Unscrew the bolts fixing the drive gear housing and remove the drive gear assembly.

3.1.35. Timing Gear Case

- 1) Unscrew the bolts fixing the timing gear case.
- 2) With a urethane hammer, remove the timing gear case as tapping the rear side of the case lightly from right and left directions in an alternate manner.

3.1.36. Main Bearing Cap

- 1) Remove the bearing cap bolts by loosening them in sequence beginning with the outer ones. and take out the main bearing caps.
(Be sure to take the same steps as disassembling way of cylinder head bolts)
- 2) Keep the disassembled main bearing cap sequentially according to their designated No.

3.1.37. Crank Shaft

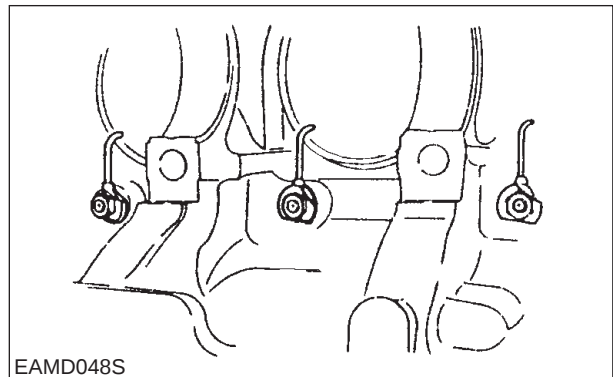
- 1) Tighten bolts temporarily on the both sides of the crank shaft.
- 2) Carefully hoist the crank shaft with a wire rope.
- 3) Keep the removed crank shaft on a individual shelf so as to avoid its bending and damage.
- 4) Take the metal bearings out of the cylinder block and keep them according to their designated No.

3.1.38. Cam Shaft and Tappet

- 1) Remove the cam shaft as carefully turning it out to the engine front.
- 2) Keep the removed crank shaft on a individual shelf so as to avoid its bending and damage.
- 3) Take the tappets out of the cylinder block.
- 4) Press out the cam shaft bush from the cylinder block if necessary
(Disassemble further if it is damaged, scratched or worn away)

3.1.39. Oil Spray Nozzle (For D1146T & D1146TI)

- 1) Unscrew the bolts and remove the oil spray nozzle.



<Fig.40> Oil Spray Nozzle

3.2. Measurement and Inspection

3.2.1. Cylinder Block

- 1) Clean the cylinder block and visually check it for cracks or any damage.
- 2) Replace if cracked or severely damaged, and correct if lightly damaged.
- 3) Check oil and water flow lines for restriction or corrosion.
- 4) Make a hydraulic test to check for any cracks or air leak. (Hydraulic test) Close each outlet port of water and oil passage in the cylinder block, apply air pressure of approx. 4 kg/cm² into the inlet port, then immerse the cylinder block in water for about 1 minute to check any leak (water temperature : 70°C)

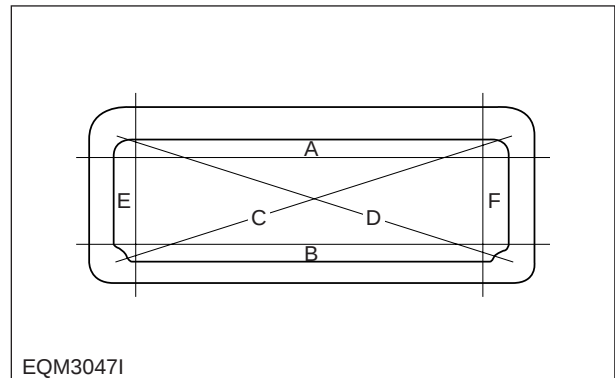
3.2.2. Cylinder Head Assembly

1) Cylinder Head

- (1) Inspect the cylinder head for cracks or damage.
- (2) Carefully remove the carbon residue from the lower surface of the cylinder head by means of nonmetallic material to prevent any scratches of the valve seat face.
- (3) In case very fine crack or damage may be suspected which is invisible, Make a test with a hydraulic tester or a magnetic flaw detector.

2) Distortion of Bottom Face

- (1) Measure the amount of distortion by means of a straight edge and a feeler gauge in 6 directions as illustrated.

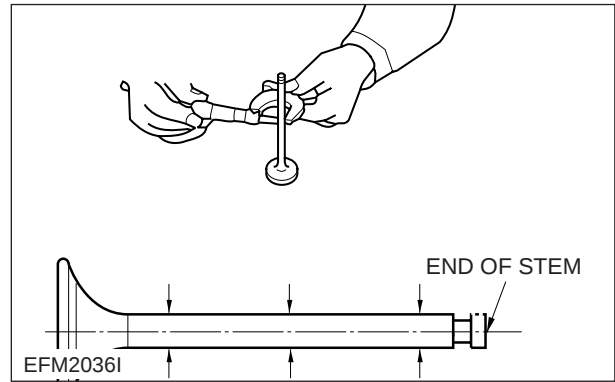


<Fig.41> Measuring Cylinder Head for Distortion

- (2) If the measured value exceeds the standard for use (0.2mm), resurface the head with grinding paper of fine grain size to correct such defect.
 - (3) If the measured value exceeds the limit for use (0.3mm), replace the cylinder head.
- 3) Measure the flatness of the joining surfaces to the intake and exhaust manifolds by means of a straight edge and a feeler gauge.
 - 4) Hydraulic test for the cylinder head is the same as that for the cylinder block.

5) Valve

- (1) clean the valves with clean diesel oil,
- (2) Measure the diameter of valve stem at 3 locations (top, middle and bottom) if the amount of wear exceeds the limit for use (0.02mm), replace the valve and valve guide.

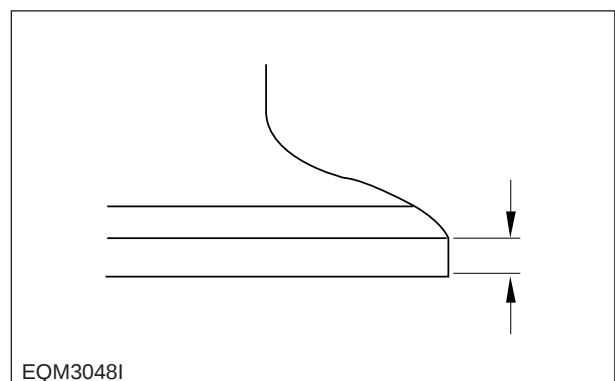


<Fig.42> Valve Stem Measurement

Valve stem wear	standard	Limit
Intake valve stem (mm)	$\phi 8.950 \sim 8.970$	$\phi 8.93$
Exhaust valve stem (mm)	$\phi 8.935 \sim 8.955$	$\phi 8.91$

- (3) Inspect the valve seat faces for scratch or wear, and refinish the faces with grinding paper as necessary, replace the valve seat if severely damaged.

- (4) Measure the thickness of the valve head, and replace the valve head if the thickness is less than 1mm.



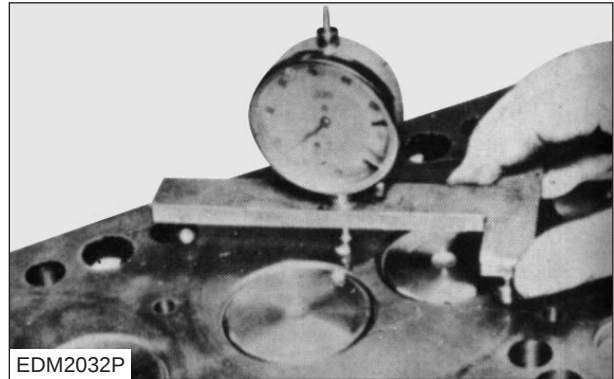
<Fig.43> Valve Head Thickness Measurement

6) Valve Guide

- (1) Insert the valve stem into the valve guide and measure the clearance between themselves by valve movement. if the clearance is too excessive, measure the outer diameter of valve stem and inner diameter of the valve guide, determining to replace either of the two, which ever is worn more.
- (2) Assemble the valve into the valve guide installed in the cylinder head, and see if it is being well centered with the valve seat by means of a special tool.

7) Valve Seat

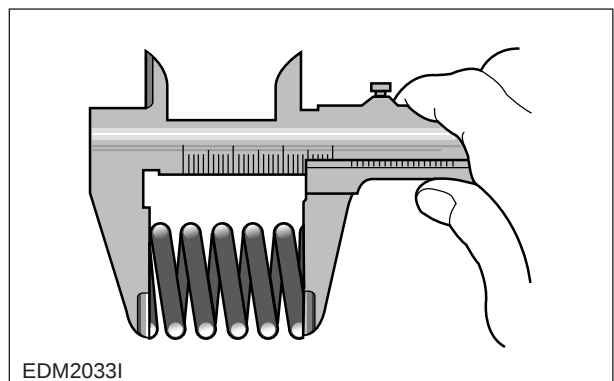
- (1) Measure the width of mating faces between the valve seats and intake/exhaust valves for valve seat wear, and replace the valve seat if measured value exceeds the limit for use.
- (2) Install the valve onto the valve seat of the cylinder head, and measure the amount of valve projection from the head face. if the measured value exceeds the limit for use, replace the valve seat.



<Fig.44> Valve Projection Measurement

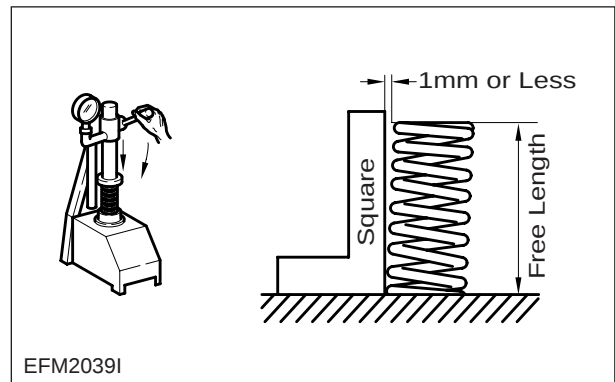
8) Valve Spring

- (1) Visually inspect the appearance of the valve spring, and replace it if necessary.
- (2) With a venier calipers,measure the free length of the spring.



<Fig.45> Spring's Free Length Measurement

- (3) With a spring tester, measure the tension force of the spring.
- (4) Measure the straightness of the spring with an L square.



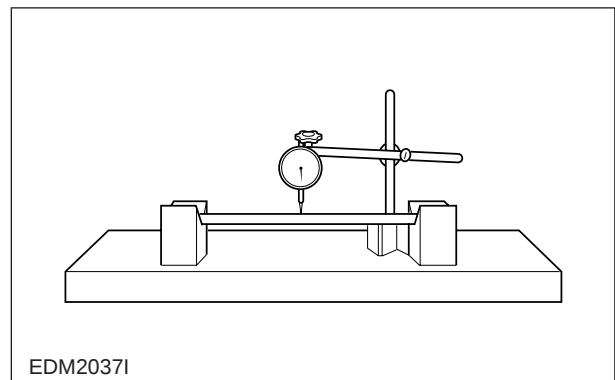
<Fig.46> Spring's Tension & Straightness Measurement

- (5) Compare the measured value with the limit for use, determining to repair or replace the valve spring.

3.2.3. Rocker Arm Shaft Assembly

1) Run Out of the Rocker Arm Shaft

- (1) Place the rocker arm shaft on two V-blocks and Measure its shaft for bending with a dial indicator. If the amount of run-out is under the limit for use, correct the bending with a press. If the amount of run-out is beyond the limit for use, replace the rocker arm shaft.



<Fig.47> Rocker Arm Run-Out Measurement

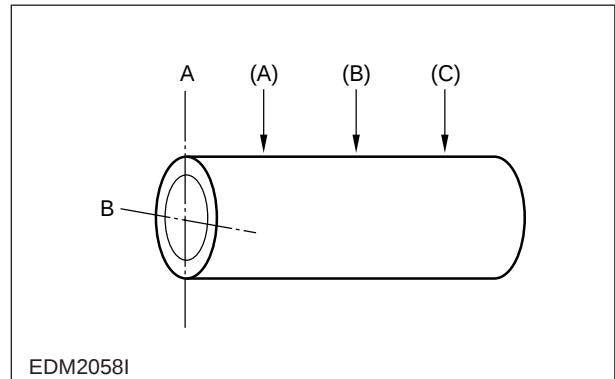
- (2) With an outside micrometer, measure the diameter of rocker arm shaft at the position where it was assembled. if the measured value deviates the limit, replace the rocker arm shaft.

2) Inspection of Rocker Arm

- (1) Visually inspect the rocker arm face in contact with valve stem ends for scores and stepped wear. then correct them with oil stone or fine grinding paper if necessary.
- (2) With an inner diameter or vernier calipers, measure the inner diameter of the rocker arm bush and compare the measured value with rocker arm shaft diameter, determining the clearance. if the clearance is exceeds the limit for use, replace either rocker arm shaft or bush.

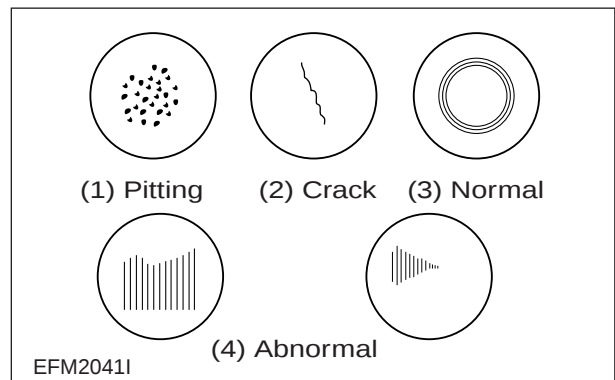
3) Inspection of Tappet and Push Rod

- (1) With an outer diameter, measure the diameter of the tappets. if the amount of wear exceeds the limit for use, replace the tappet.



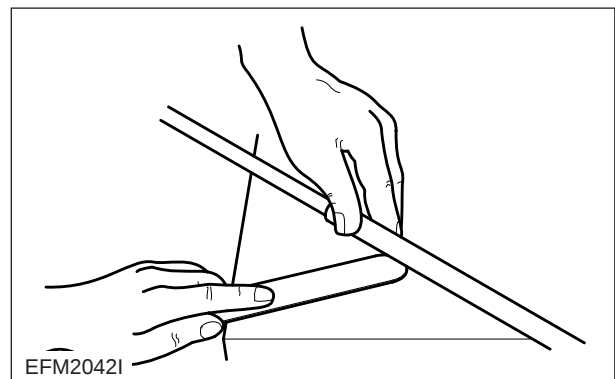
<Fig.48> Tappet Dia. Measurement

- (2) Visually inspect the face of the tappets in contact with the cam for pitting, scores or crack. then correct them with oil stone or fine grinding paper if necessary. Replace the tappet if severely damaged.



<Fig.49> Tappet Surface Inspection

- (3) While laying the push rod down the surfasce plate for measurement, check the push rod for bend by means of clearance gauge and if abnormal, replace the push rod with a new one.

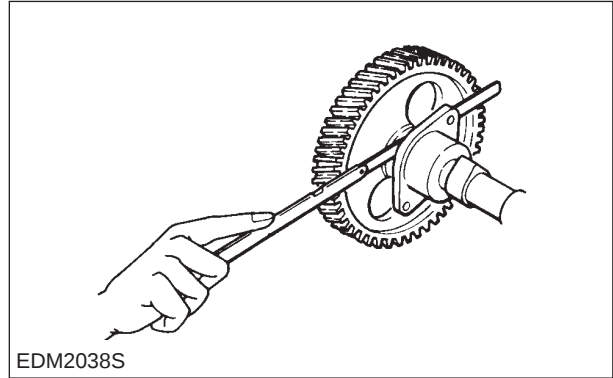


<Fig.50 > Push Rod Inspection for Bend

3.2.4. Cam Shaft

1) Measuring End Play

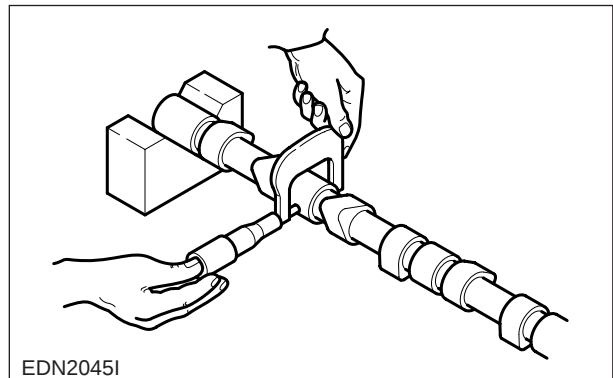
- (1) Push the thrust washer toward the cam shaft gear side.
- (2) With a feeler gauge, measure the clearance between the thrust washer and cam shaft journal
- (3) if the end-play exceeds the limit for use, replace the thrust washer.



<Fig.51> Cam Shaft End-Play Measurement

2) Inspection of Cam Profile

- (1) Measure the height of the cam and replace it if the cam nose is severely worn out.
- (2) Inspect the cam face for scratch or damage. minor wear on the cam face may be corrected with oil stone or oiled grinding paper, however, replace the cam shaft if severely damaged.

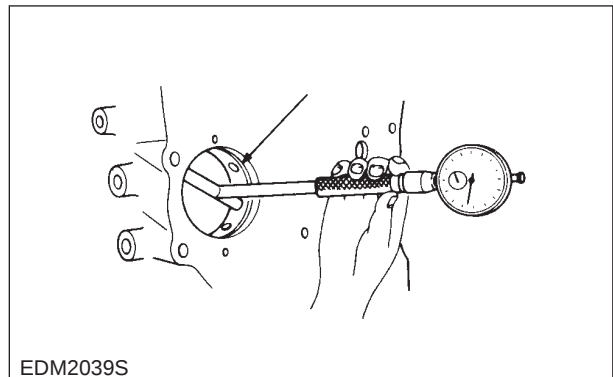


<Fig.52 > Cam Height Measurement

3) Clearance Between Cam Shaft and Cam Shaft Bush

- (1) With an outer diameter, measure the diameter of the cam shaft journal.
- (2) With a cylinder gauge, measure the inside diameter of cam shaft bush in the cylinder block,
- (3) Compare the two measured value, determining the clearance between them.

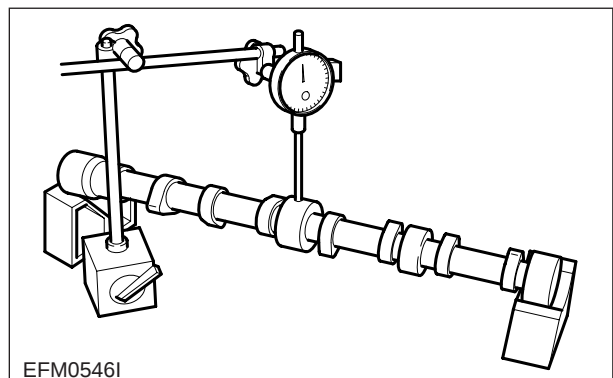
If the clearance exceeds the limit for use, replace the cam shaft bush.



<Fig.53> Cam Bush Inner Dia. Measurement

4) Run-Out of Cam Shaft

Place the cam shaft on two V-blocks and measure its run-out, and correct or replace the cam shaft if the run-out exceeds the limit for use.



<Fig.54 > Cam Shaft Run-Out Measurement

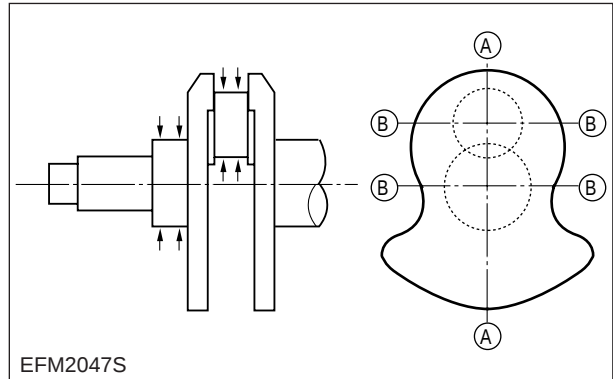
3.2.5. Crank Shaft

1) Inspection of Crank Shaft for Scratch or Crack

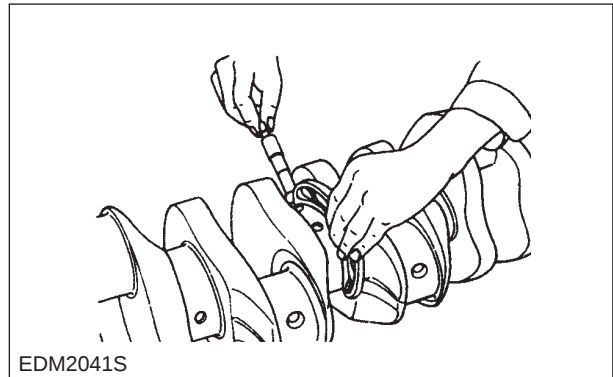
- (1) visually check the crank shaft journal and pin for wear or damage.
- (2) Check the crank shaft for any crack by means of magnetic powder or red check, and replace the crankshaft if cracked.

2) Measurement of crank shaft for wear

- (1) With an outside micrometer, measure the diameter of the crank shaft journals and pins in the directions and at the location as illustrated.



- (2) If the amount of wear exceeds the limit for use, grind the crankshaft and install undersized bearings.



<Fig.55> Crankshaft's Dia. Measurement

3) Undersized Bearings Available

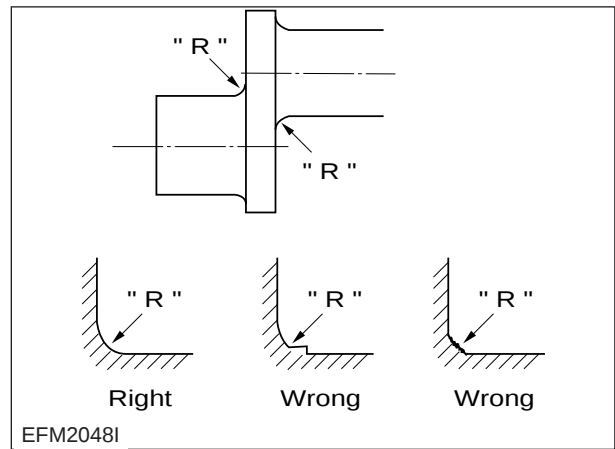
- (1) STD (Standard bearing)
- (2) 0.25 (inner diameter is smaller than STD by 0.25mm)
- (3) 0.50 (inner diameter is smaller than STD by 0.50mm)
- (4) 0.75 (inner diameter is smaller than STD by 0.75mm)
- (5) 1.00 (inner diameter is smaller than STD by 1.00mm)

4 different undersized bearings are available as indicated above, and the crank shaft also can be reused through the regrinding like above.

Note : When regrinding the crank shaft, the fillet "R" should be correctly finished. Avoid stepped portion or rough surface on it.

Standard Value for "R" Portion

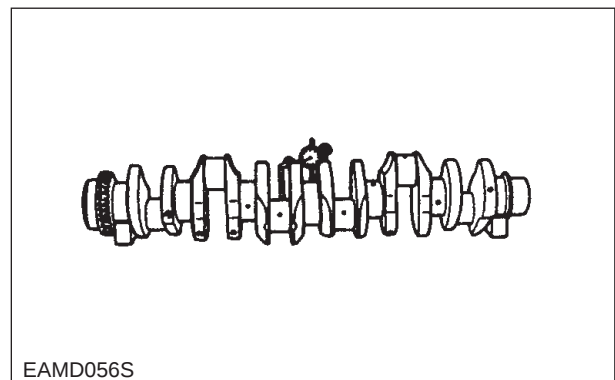
Crankshaft pin "R" (mm)	4.5
Crankshaft journal "R" (mm)	4.0



<Fig.56> "R" Formation of Crank Shaft

3) Run-Out of Crank Shaft

- (1) Place the crank shaft with its No.1 and No.7 journals on two V-blocks respectively.
- (2) Measure the run-out of crank shaft as turning the crank shaft slowly in one direction with the probe of a dial indicator on a crank shaft journal.



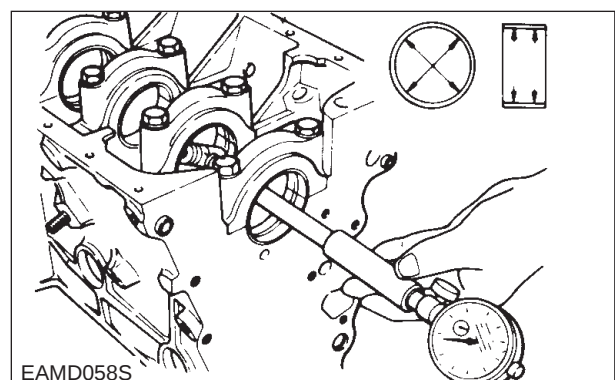
<Fig. 57> Crank Shaft Run-Out Measurement

4) Inspection of Crank Shaft Bearing and Connectingrod Bearing

- (1) Visually inspect the surfaces of crank shaft bearing and connectingrod bearing for scores, scratch or uneven wear.

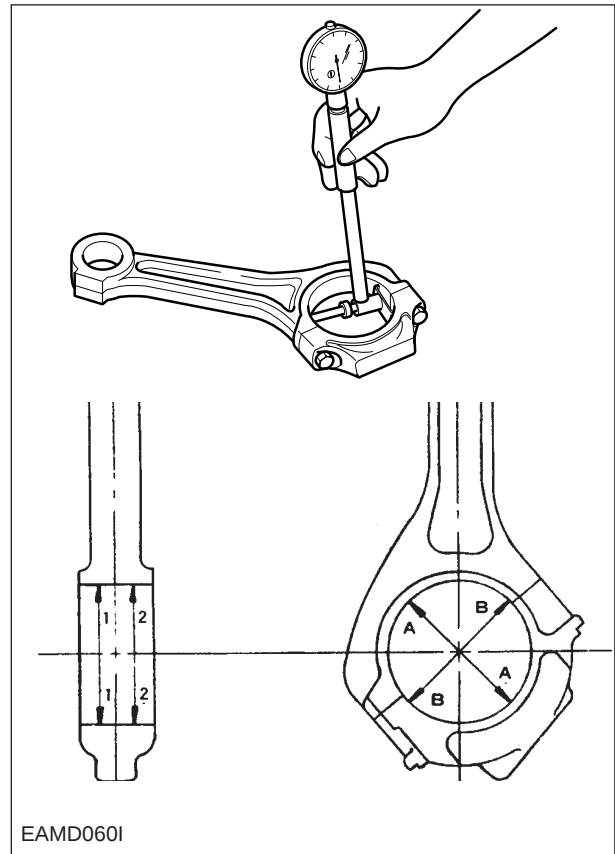
5) Measurement of Oil Clearance

- (1) Install the main bearing onto the cylinder block and tighten the bearing cap to the specified torque and measure its inner diameter.



<Fig.58> Main Bearing Inner Dia. Measurement

- (2) Insert the bearing into the big-end of connectingrod and tighten the cap bolt to the specified torque, and measure its inside diameter.



<Fig.59> Connecting Rod Bearing Inner Dia.
Measurement

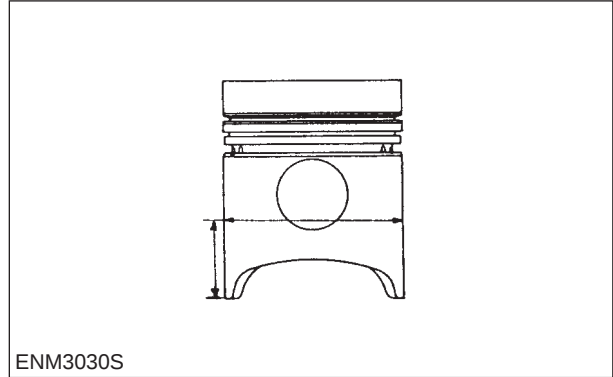
- (3) Compare two values through (1) and (2) with two inner diameter of crank shaft journal and pin respectively, determining the two clearances for oil passage.
- (4) If the calculated clearances exceed the limit for use, grind the crank shaft and adopt undersized bearing.

3.2.6. Piston

1) Visually check the piston for cracks, scuff and wear.

2) Clearance Between Piston and Liner

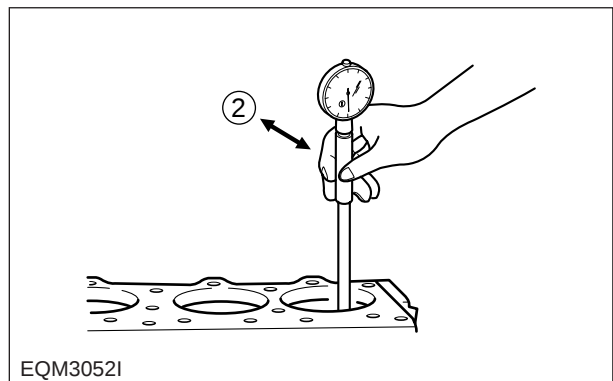
- (1) With an outside micrometer, measure the piston diameter at the location 13mm away from its bottom end and at the right angle against the piston pin direction.



<Fig. 60> Piston Dia. Measurement

- (2) With a cylinder bore gage, measure the inside diameter of cylinder liner at 3 locations, that is, top ring joining portion, middle portion and oil ring joining portion of BDC in every 45° direction respectively.

Among the obtained values, rule out the largest and smallest and take an average of the rest.



<Fig.61> Liner's Inner Dia. Measurement

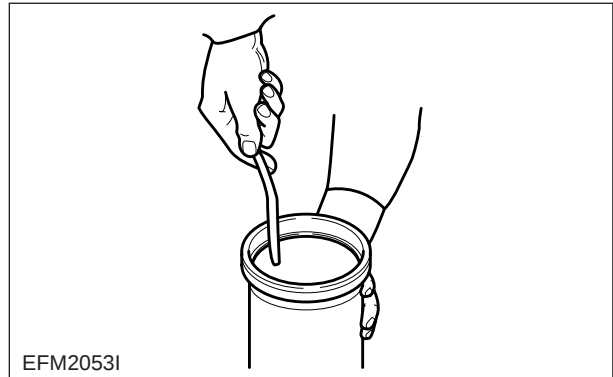
- (3) The difference between inner diameter of cylinder liner and outer diameter of piston is defined as clearance. If the clearance deviates the limit for use, replace either the piston or liner whichever is worn more.

3) Visual Inspection of Piston Ring

- (1) Replace the piston ring with a new one when found be worn or broken, or in case of overhauling work.

4) Piston Ring Gap

- (1) Insert the piston ring into the upper portion of cylinder liner so that the ring is secured at the right angle to the cylinder liner wall.
- (2) With a filler gauge, measure the gap of piston ring.



<Fig.62> Piston Ring Gap

- (3) If the measured gap exceeds the limit for use, replace the piston with a new one.

Item	Dimension	Standard (mm)	Limit (mm)
1st ring		0.40 ~0.65	1.5
2nd ring		0.40 ~ 0.65	1.5
Oil ring		0.30 ~ 0.60	1.5

5) Side Clearance of Piston Ring

- (1) Assemble the compression rings (1st / 2nd rings) and oil ring into the piston ring grooves.
- (2) With a feeler gauge, measure the side clearance of each ring. if the measured value exceeds the limit, replace either the ring or the piston whichever is worn more.

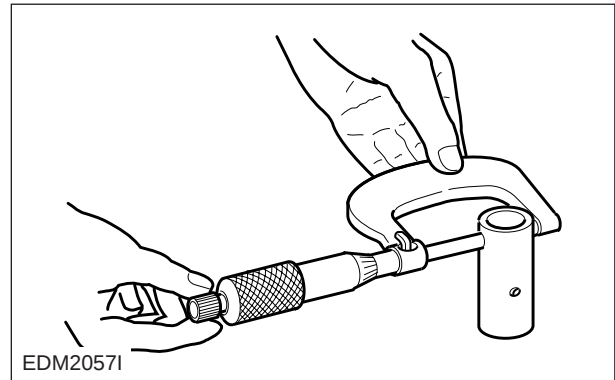
Item	Dimension	Standard (mm)	Limit (mm)
1st ring		-	-
2nd ring		0.07 ~0.102	0.15
Oil ring		0.05 ~ 0.085	0.15

6) Tension of Piston Ring

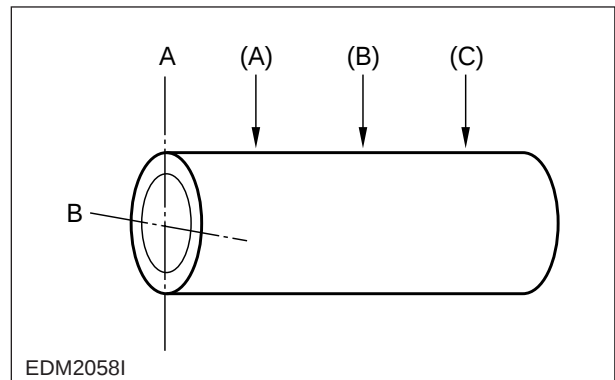
Measure the tension of piston ring with a tension tester, if the measured value exceeds the limit, replace the piston ring with a new one.

7) Piston Pin

- (1) Measure the diameter of piston pin at several portions illustrated in Fig.64
Replace the piston pin if the measured value exceeds the limit for use.



<Fig.63> piston Pin Outer Dia. Measurement



<Fig.64> Piston Pin Outer Dia. Measurement locations

- (2) With a cylinder bore gauge, measure the inner diameter of the bush in the connecting rod, and compare the measured value with piston pin diameter, determining the clearance.
if the clearance exceeds the limit for use, replace either the piston pin or its bush whichever is worn more.
- (3) Inspect the fitting condition of piston pin with piston.
The piston pin fitting interference may be regarded as normal when it is fitted into the piston with fingered pressure after heating the piston to a certain temperature.
When replacing the piston, it's necessary to replace the piston pin alike.

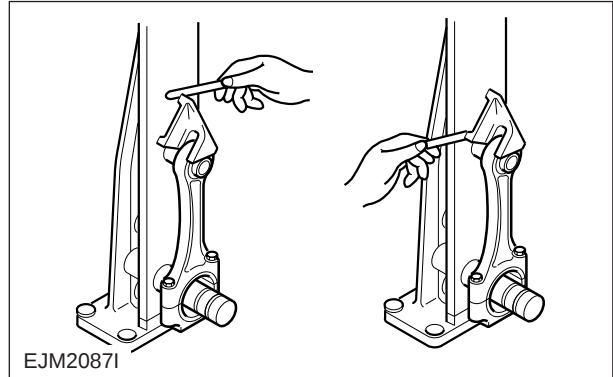
3.2.7. Connecting Rod

1) Distortion;

Install the connecting rod on a individual tester and measure its distortion with a feeler gauge.

If the connecting rod is twisted or bent, a new connecting rod should be substituted for.

No attempt would be allowed to straighten the connecting rod.



<Fig. 65> Connecting Rod Distortion Measurement

2) Alignment;

Check the alignment between the piston pin bush hole and bearing hole in big-end portion.

A individual aligner and a filler gauge are also necessary to do this.

3) Side Clearance;

- (1) Assemble the connecting rod to the crank shaft and measure the side clearance of its big-end.
- (2) Assemble the connecting rod to the cam shaft and measure the side clearance of its small-end.
- (3) If the above measured values exceed the limit for use (0.5mm), Replace the connecting rod.

3.3. Reassembly

3.3.1. Precautions Before and After Engine Reassembly

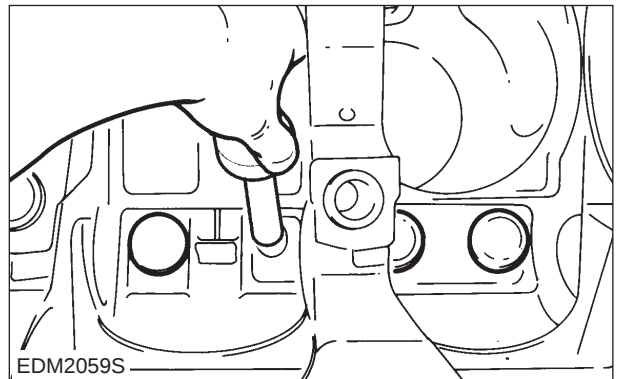
- 1) Clean up disassembled parts, particularly oil ports and water passages of each part applying compressed air, then check that they are all free from any restrictions.
- 2) Arrange all the general and special tools sequentially.
- 3) Prepare clean engine oil for spreading on every sliding parts.
- 4) Prepare side materials such as an adhesive.
- 5) Discard used gaskets and seal rings and replace them with new ones at reassembly.
- 6) Check to see if the motions of moving parts are smooth after reassembly.
- 7) Check to see if the tightness of every fastenings is achieved after reassembly.

3.3.2. Oil Spray Nozzle <For D1146T & D1146TI>

- 1) Place the oil spray nozzle in position onto the cylinder block and tighten its fixing bolts. Make sure that the oil spray nozzle be stall at assembly with a special jig.

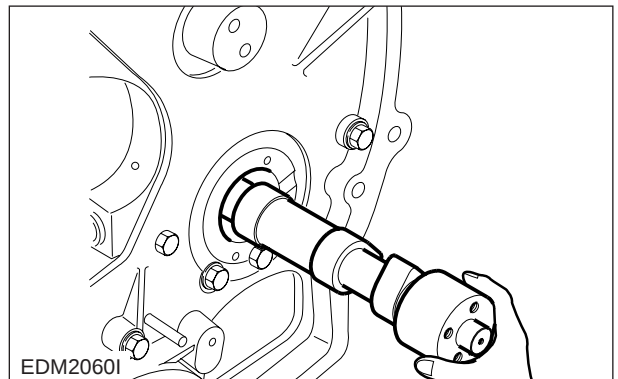
3.3.3. Cam Shaft and Tappet

- 1) When replacing the cam shaft bush, undercool a new bush in dry ice for about 2 hours and press it into the cylinder block.
- 2) After pressing the cam shaft bush into the block, measure the inner diameter of the bush. if any discrepancy is found, replace the bush again.
- 3) Apply engine oil over the tappet holes and tappets, then install the tappets in cylinder block.



<Fig.66> Tappet Assembling

- 4) Apply engine oil over the cams and journals of the cam shaft and the inside of cam shaft bush as well, then install the cam shaft in position into the cylinder block while turning the cam shaft. (When installing the cam shaft, exercise care not to scratch the cam shaft and the bush)

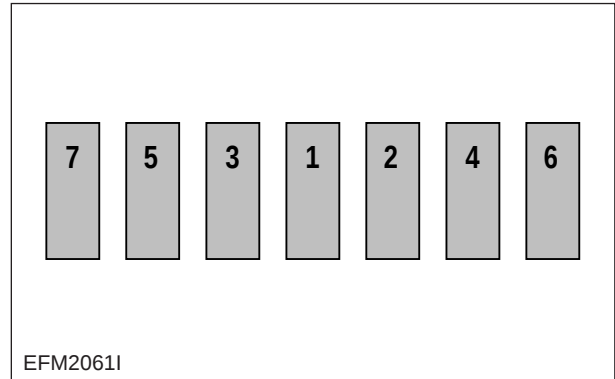


<Fig.67> Cam Shaft Assembling

- 5) When the cam shaft has been installed, turn the cam shaft to see if the cam shaft turns smoothly.

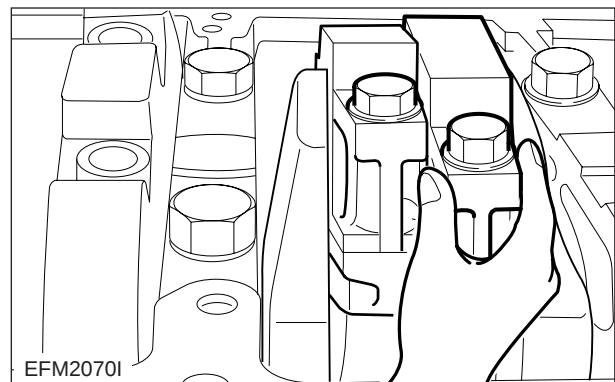
3.3.4. Crank Shaft

- 1) Press the locating ring into the cylinder block.
- 2) Place the metal bearing onto the cylinder block and lubricate it with engine oil.



<Fig.68> Metal Bearing Assembling Sequence

- 3) Tighten bolts temporarily on the both sides of the crank shaft, then carefully hoist the crank shaft, installing it onto the cylinder block as keeping its balance.
(Apply engine oil over the pin and journal of the crankshaft)
- 4) Assemble the bearing and thrust washer to the bearing cap.
- 5) Place the pre-assembled bearing cap to the cylinder block as identifying their assembly No. (Apply engine oil over the bearing)
- 6) coat the cap bolt with engine oil, then tighten the cap bolt to the specified torque of 30kg·m in the following manner;

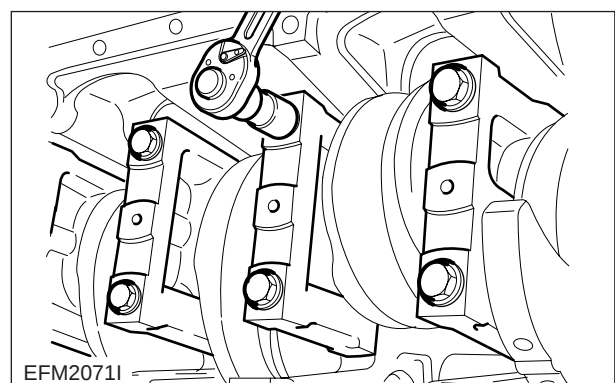


<Fig. 69> Bearing Cap Assembling

- (1) 1st step : coat the cap bolt with engine oil.
- (2) 2nd step : Tighten the bolt in 1 ~ 2 threads.
- (3) 3rd step : Tighten the bolt to the torque of approx. 15kg·m with a wrench.
- (4) 4th step : Tighten the bolt to the torque of approx. 25kg·m with a wrench.
- (5) 5th step : Finally, tighten the bolts to the specified torque of 30kg·m with a torque wrench in sequence of bearing cap number,

4→3→5→2→6→1→7

- 7) As a final check, Turn the crank shaft to check that the crankshaft turns smoothly with hands.



<Fig. 70> Bearing Cap Tightening

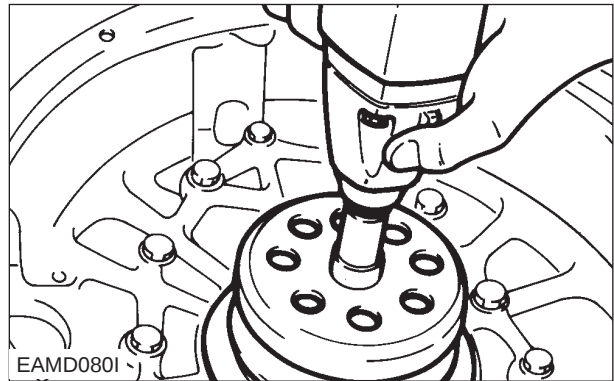
3.3.5 Flywheel Housing

- 1) Temporarily install guide bars to the cylinder block and attach the gasket on the cylinder block.
- 2) Hoist the flywheel housing and attach it to the cylinder block as sliding the housing holes along outside of the guide bars.
- 3) Assemble the flywheel housing fixing bolts and tighten them in diagonal sequence to the specified torque.

(Remove the guide bars when bolts fixing)

- 4) With a oil seal fitting jig, Press a new rear oil seal lubricated with engine oil in the flywheel housing. If the crankshaft is skid marked with old oil seal, shift new oil seal location by inserting a shim which has about 1mm thickness.

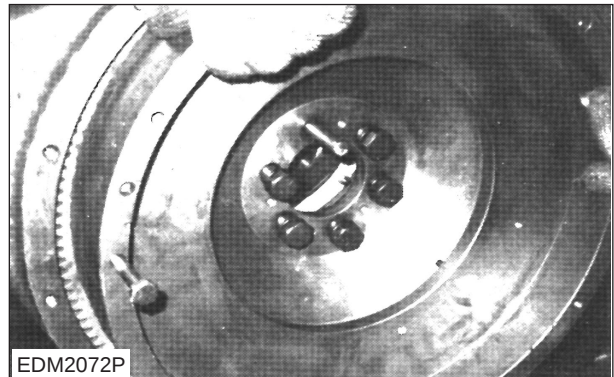
Be sure to avoid damage of oil seal when assembling.



<Fig.71> Rear Oil Seal Press In

3.3.6. Flywheel

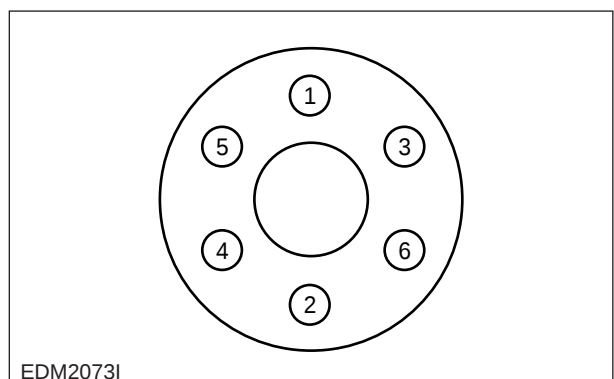
- 1) Temporarily install guide bars to crankshaft bolt holes, then hoist the flywheel and attach it to the crankshaft as sliding flywheel with its holes along the guide bars.



<Fig. 72> Flywheel Assembling

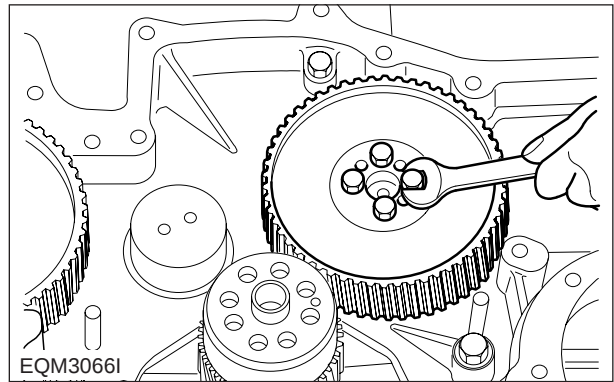
- 2) Coat the flywheel fixing bolts with adhesive (#271 Loctite) and tighten them in numerical sequence to the specified torque of 21.5kg·m, while taking the same steps as those of bearing cap bolts tightening procedure mentioned in section 3.3.4.

(Remove the guide bars when bolts fixing)



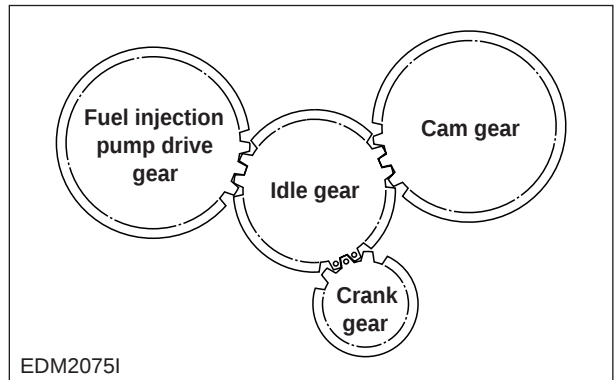
<Fig. 73> Flywheel Bolt Tightening Sequence

- 3) Install the camshaft thrust washer on the timing gear case, then install the cam gear by tapping it lightly with a urethane hammer.
- 4) Tighten the fixing bolts in diagonal sequence to the specified torque.



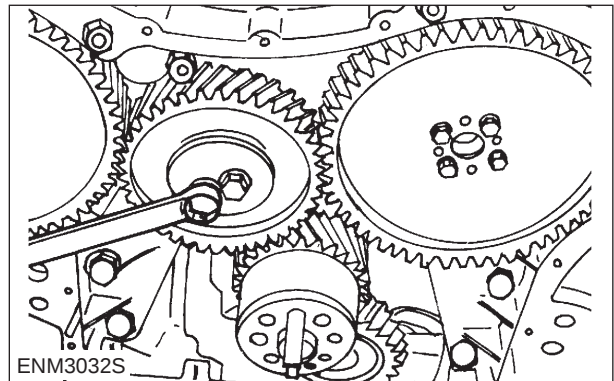
<Fig.77> Cam Gear Assembling

- 5) Install the idle gear, so that the marks on the idle gear are exactly met with marks on the camshaft gear and crankshaft gear respectively.



<Fig.78> Timing Gear Train

- 6) Install the thrust washer on the idle gear and tighten the fixing bolts to the specified torque.
- 7) When assembling the timing gear in position, check the amount of backlash between gears by means of a thickness gauge. If the amount of backlash exceeds the specified value, correct or replace the defective gear.



<Fig. 79> Gear Mark and Idle Gear Assembling

Measuring Position	Backlash (mm)
Between Cam gear & Idle gear	0.16 ~0.28
Between Crank gear & Idle gear	0.16 ~ 0.28
Between Injection pump drive gear & Idle gear	0.16 ~ 0.28

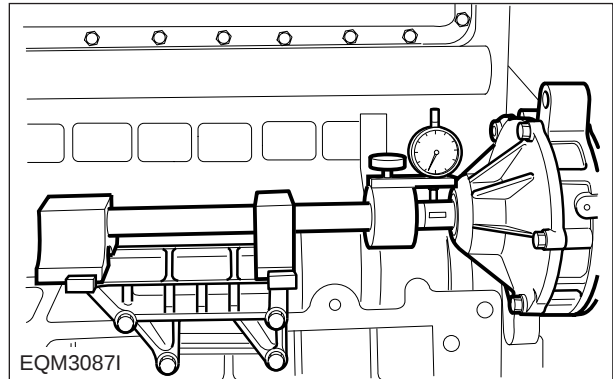
3.3.7. Injection Pump

- 1) Install the injection pump mounting bracket with a shim between the bracket and cylinder block and tighten the bolts.

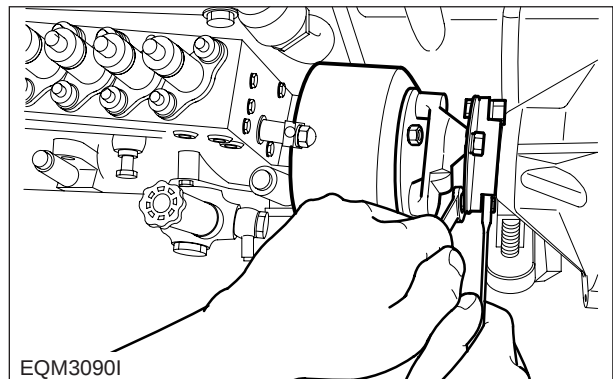
If the thickness of the original shim is not correct, determine which new shim is to be used.

There are 4 types of shim for adjusting the horizontal alignment such as 0.1mm, 0.15mm, 0.2mm and 0.5mm in thickness and there are also 3 types of shim for adjusting the vertical alignment such as 0.1mm, 0.2mm and 0.3mm in thickness.

- 2) Mount the injection pump on the bracket, then tighten the bolts to the specified torque.
- 3) Assemble the coupling as checking the alignment between injection pump shaft and drive gear shaft.
If the alignment is not achieved, do disassembling and replace the shim with correct one and reassemble the mounting bracket and the injection pump.
- 4) Rotate the flywheel in direction of rotation until the mark on the vibration damper exactly meets the pointer.
- 5) Align the pointer on the injection pump with the line on timer, and couple the injection pump to the coupling drive shaft by tightening fixing bolts and nuts.



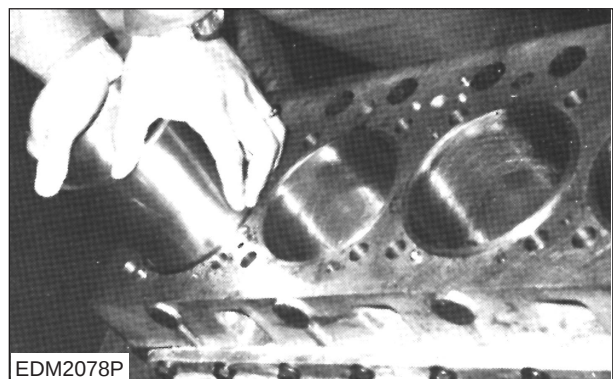
<Fig. 80> Injection Pump Assembling



<Fig.81> Injection Pump Marking

3.3.8. Cylinder Liner

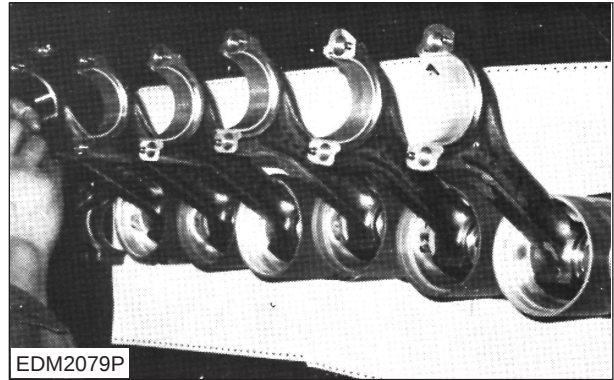
- 1) Completely clean the cylinder liners and blow off the dust and water by compressed air.
- 2) Insert the cylinder liner into the cylinder block and push the cylinder liner with hands. (Be careful that no foreign objects get in the bottom side of liner flange when assembling)
- 3) Coat engine oil inside the liner.



<Fig.82> Cylinder Liner Assembling

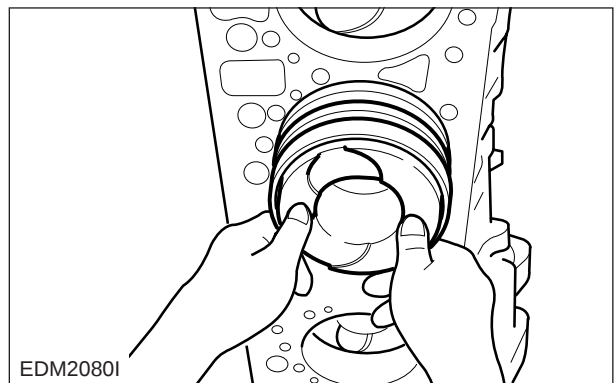
3.3.9. Piston

- 1) Array the pistons sequentially according to their designated No. and insert the bearing onto the piston.
- 2) Coat engine oil over the pistons.



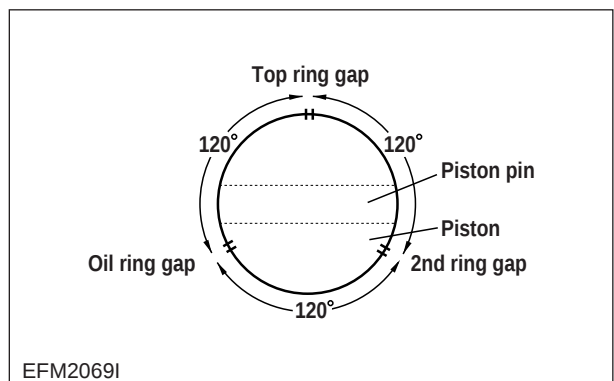
<Fig.83> Piston Arrangement Before Assembling

- 3) Insert the special tool for piston assembling to the piston and hang the piston in the cylinder block.



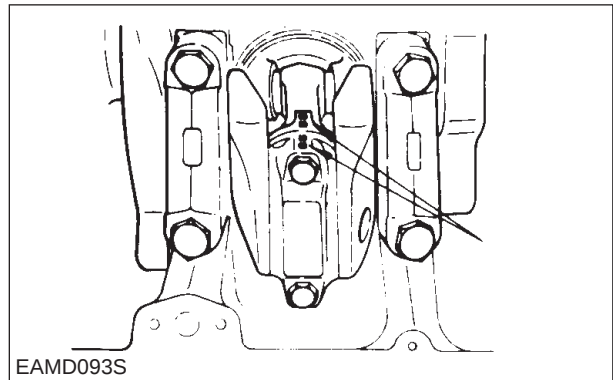
<Fig.84> Piston Hanging

- 4) The gap of each piston ring should be positioned so that it is 120° opposite that of the preceding ring. Make sure that rings are installed with "Y" mark turned up and piston ring gap is away from pin direction.



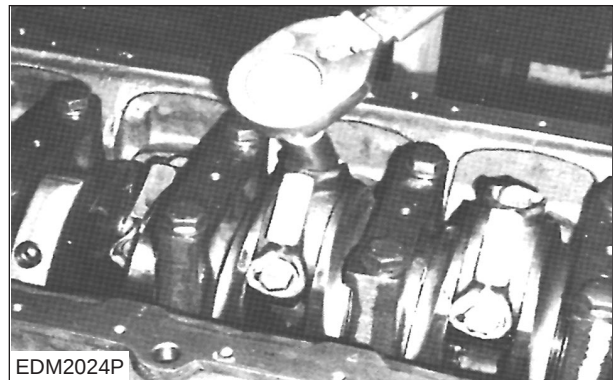
<Fig.85> Angles Between Piston Ring Gaps

- 5) Push the piston into the cylinder block until the connecting rod bearing is brought into contact with the crankshaft pin, taking care not to scratch the piston or cylinder liner wall.
- 6) Install the bearing cap on the connecting rod and Coat engine oil over it.



<Fig.86> Connecting Rod Bearing Cap Assembling

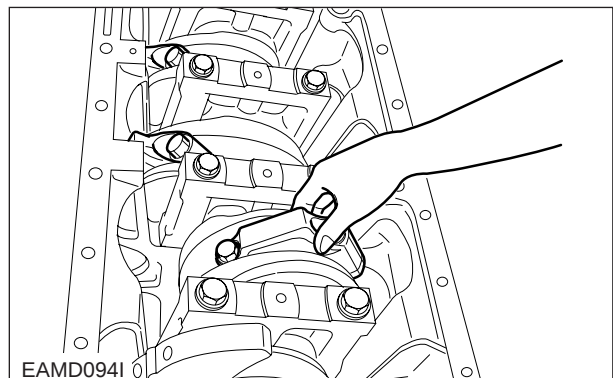
- 7) Turn the crankshaft until connecting rod big end rides on the crankshaft pin, and assemble the connecting rod bearing cap with a urethane hammer.
- 8) Coat engine oil over the connecting rod bearing cap bolts and tighten them to the specified torque in a following manner;
 - (1) 1st step : Lubricate the cap bolt with engine oil.
 - (2) 2nd step : Tighten the bolt in 1 ~ 2 threads.
 - (3) 3rd step : Tighten the bolt to the torque of approx. 10kg·m with a wrench.
 - (4) 4th step : Tighten the bolt to the torque of approx. 15kg·m with a wrench.
 - (5) 5th step : Finally, tighten the bolts to the specified torque of 18kg·m with a torque wrench.



<Fig.87> Connecting Rod Bearing Cap Tightening

However, tighten both sides of bolts simultaneously as above steps.

- 9) When the connecting rod bearing cap bolts are tightened, check the connecting rod end play to the right and left with hand. If no end play is found, remove and reinstall or replace the connecting rod bearing cap.



<Fig.88> Connecting Rod End Play Inspection

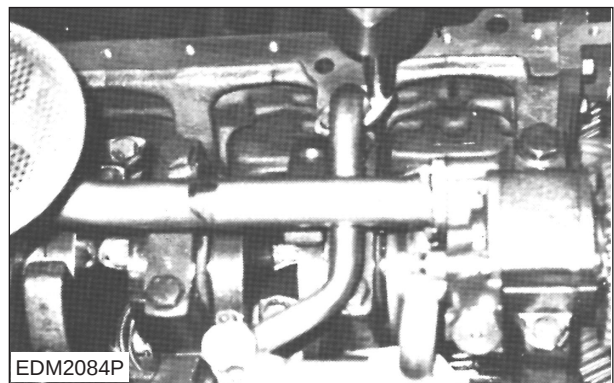
3.3.10 Oil Pump

- 1) Install the oil pump assembly in position on #7 bearing cap, as tapping lightly with a urethane hammer.



<Fig.89> Oil Pump Assembling

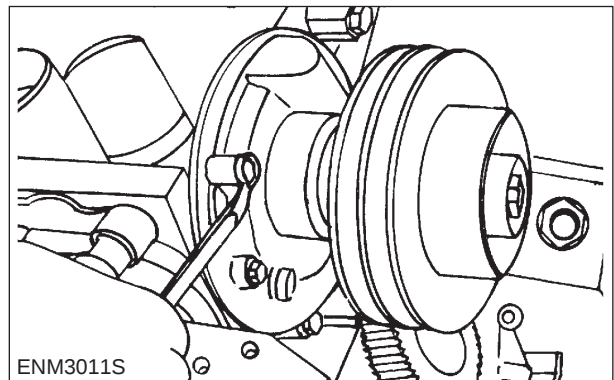
- 2) Install the nut with lock washer and tighten the bolts to the specified torque.
- 3) Bend the lock washer toward the bolt to prevent its release.
- 4) Connect the oil suction pipe and supply pipe to the oil pump.



<Fig.90> Oil Pipe Assembling

3.3.11. Water Pump

- 1) Attach a new gasket on the water pump, then place the water pump to the cylinder block.
- 2) Tighten the fixing bolts to the specified torque.

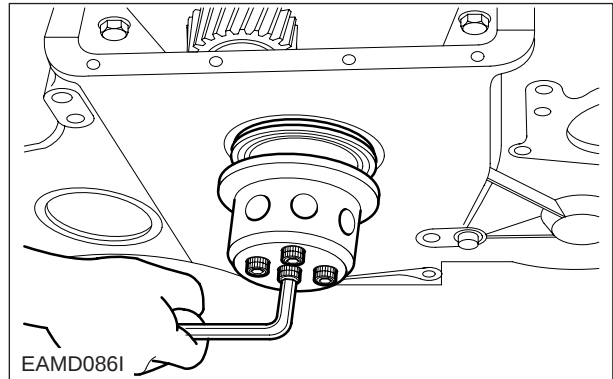


<Fig.91> Water Pump Assembling

3.3.12. Timing Gear Case Cover

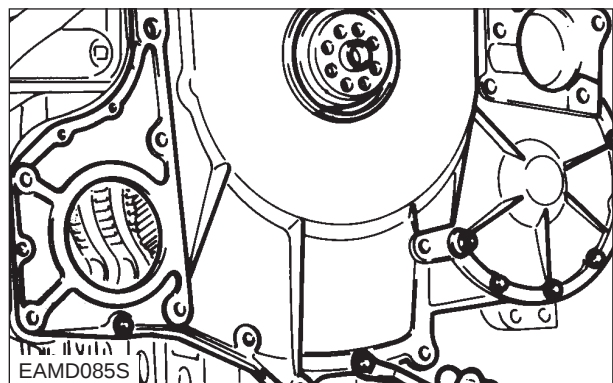
- 1) Coat engine oil over the bore of the timing gear case cover, where the front oil seal is to be installed.
- 2) Assemble a new front oil seal by means of a oil seal fitting jig and press it into the bore carefully.

Be sure to avoid damage of the front oil seal when assembling.



<Fig.92> Oil Seal Press In

- 3) Attach new gasket on the timing gear case cover, and assemble the case as tapping the locating pin side lightly with a urethane hammer.



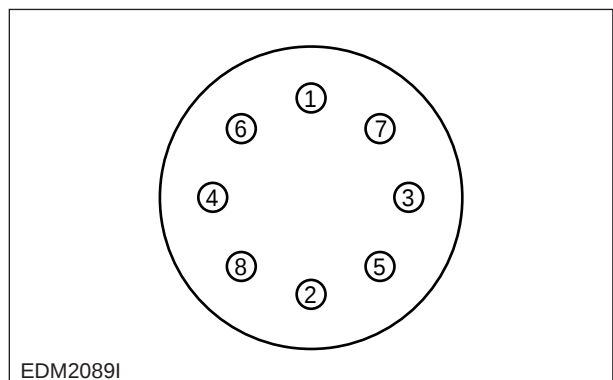
<Fig.93> Timing Gear Case Cover Assembling

3.3.13. Vibration Damper

- 1) Install the vibration damper on the crankshaft, then tighten the bolts in numerical sequence as shown in the right to the specified torque.



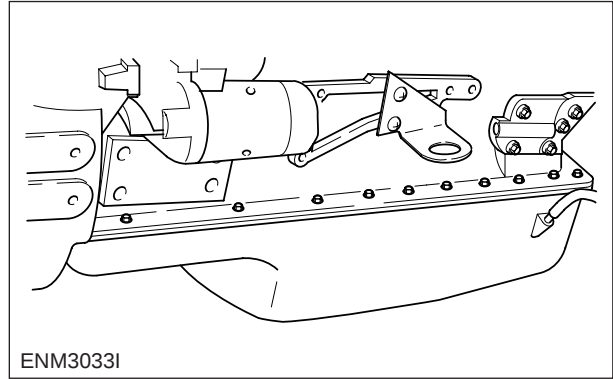
<Fig.94> Vibration Damper Assembling



<Fig.95> Vibration Damper Bolt Tightening Sequence

3.3.14 Oil Pan

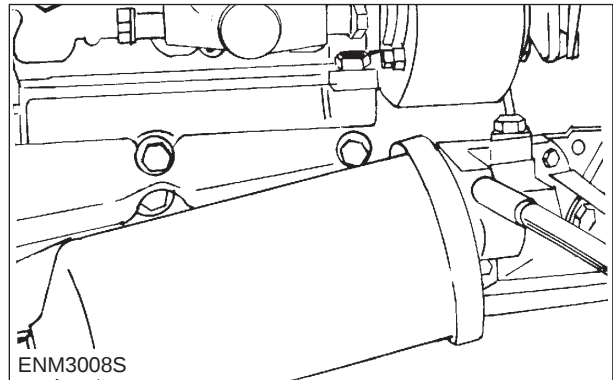
- 1) Remove gasket residue on the joining surface of timing gear case, timing gear case cover, flywheel housing in cylinder block by means of a scraper.
Be sure that gasket residue do not enter inside the engine.
- 2) Coat the silicone on the joining surfaces and place a new oil pan gasket.
- 3) Assemble the oil pan, and tighten primarily the bolts located at both the ends of the cover (4EA at both sides) and middle bolts (upper, lower 2EA), then tighten the rest.



<Fig.96> Oil Pan Assembling

3.3.15. Oil Filter

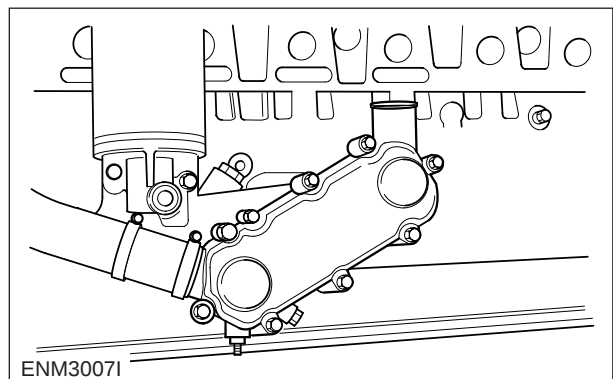
- 1) Install the oil filter with a new gasket on the cylinder block and tighten the bolts in diagonal sequence to the specified torque so as to prevent oil leakage.



<Fig. 97> Oil Filter Assembling

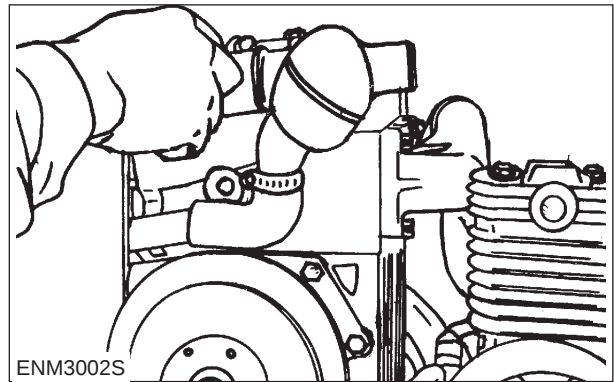
3.3.16. Oil Cooler

- 1) Coat the grease on the oil hole of oil cooler housing insert O-ring in it.
- 2) Assemble the oil cooler on the cylinder block and tighten the nuts.



<Fig. 98> Oil Cooler Assembling

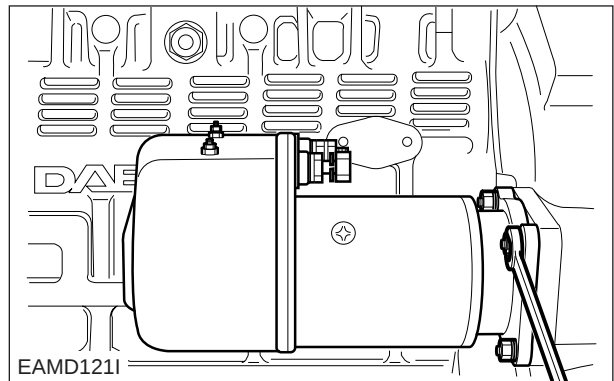
- 3) Connecting the cooling water pipe between oil cooler and water pump, and tighten the hose clamp securely.



<Fig. 99> Rubber Hose Clamping

3.3.17. Starter

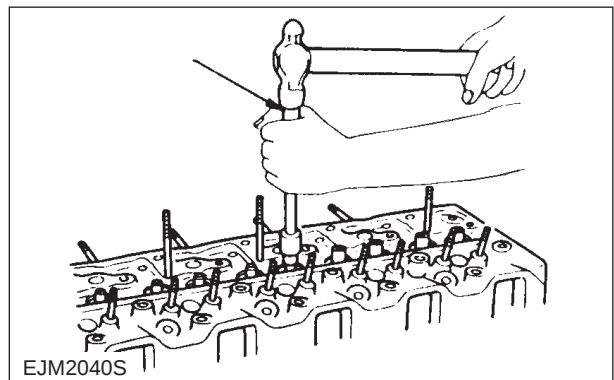
- 1) Insert the starter inside the flywheel housing then tighten the fixing nuts.



<Fig.100> Starter Assembling

3.3.18. Cylinder Head Assembly

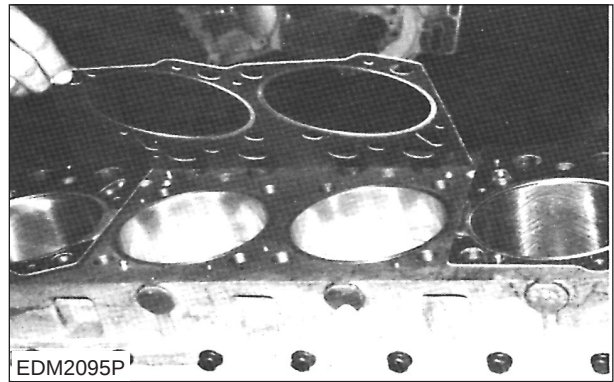
- 1) Cylinder head assembling;
 - (1) Clean the cylinder head thoroughly.
 - (2) Replace the valve stem seal with a new one, and by means of a special tool press the stem seal into the valve guide of cylinder head.



<Fig.101> Stem Seal Press In

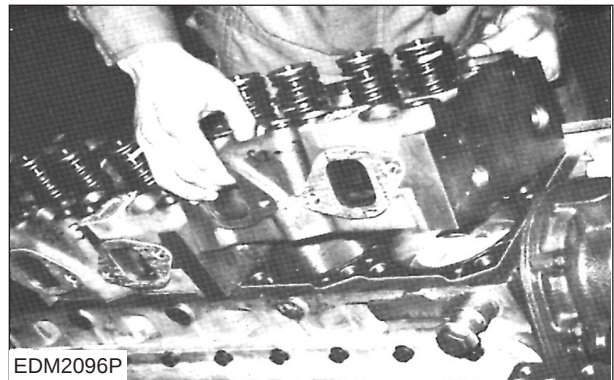
- (3) Coat engine oil over valve stem and valve guide and assemble the valve.
However, be careful for the damage of valve stem seal.
- (4) Install the lower seat of valve spring to the valve guide of cylinder head.
- (5) After putting inner, outer spring, install the retainer on it.
- (6) Assemble the valve by inserting the valve cotter pin, while pressing the retainer with a special tool.
- (7) After installinng the valve, check whether the valve is correctly installed or not, tapping it lightly with a urethane hammer.

- 2) Clean up the cylinder head bolt holes with compressed air.
- 3) Wipe out the gasket joining surface of cylinder block.
Be sure that gasket residue do not enter inside the engine.
- 4) Attach a new gasket on the cylinder block as aligning its locating pins.



<Fig.102> Cylinder Head Gasket Assembling

- 5) Install the cylinder head on the cylinder block as aligning it with locating pins of cylinder block.
If the cylinder head does not engage with locating pins well, Lift up the cylinder head again and retry to settle the cylinder head on the cylinder block.
(Be careful not to damage the cylinder head gasket during this attempt)



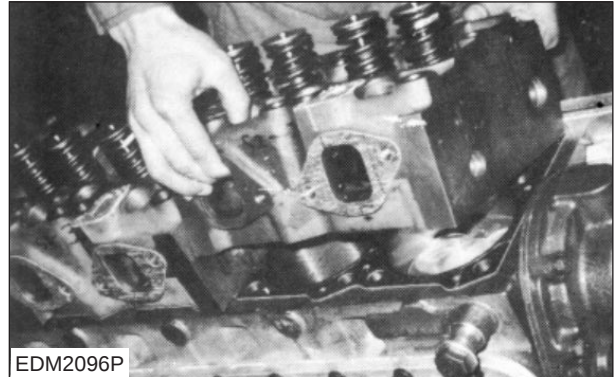
<Fig.103> Cylinder Head Assembling

- 6) When having to disassemble the cylinder head even after tightening the cylinder head bolts, cylinder head gasket should be replaced with a new one.

7) Clean the cylinder head bolts and dip them in engine oil, then install the bolts on the cylinder head to the specified torque of 24.5kg·mm in a following manner;

- (1) 1st step : Coat the cylinder head bolts with engine oil.
- (2) 2nd step : Tighten the bolt in 1 ~ 2 threads.
- (3) 3rd step : Tighten the bolt to the torque of approx. 15kg·m with a wrench.
- (4) 4th step : Tighten the bolt to the torque of approx. 20kg·m with a wrench.
- (5) 5th step : Finally, tighten the bolts to the specified torque of 24.5kg·m with a torque wrench.

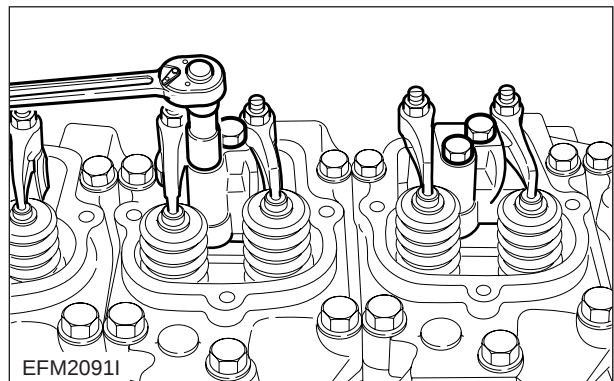
However, tighten all the bolts simultaneously as above steps.



<Fig. 104> Cylinder Head Bolt Tightening Sequence

3.3.19. Rocker Arm

- 1) Insert the push rod coated with engine oil into the cylinder head.
- 2) Place the rocker arm assembly on the cylinder head and tighten the fixing bolts to the specified torque in diagonal sequence.

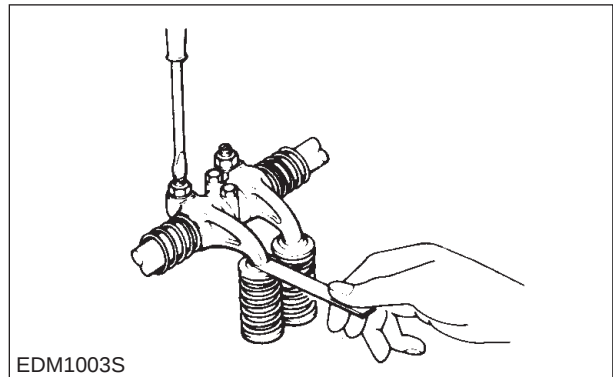


<Fig. 105> Rocker Arm Assembling

3) Adjust the valve clearance in the following manner;

CYLINDER NUMBER	1		2		3		4		5		6	
	I	E	I	E	I	E	I	E	I	E	I	E
#1 TDC	○	○	○			○	○			○		
#6 TDC				◎	◎			◎	◎		◎	◎

I : Intake valve E : Exhaust valve



<Fig. 106> Valve Clearance Adjustment

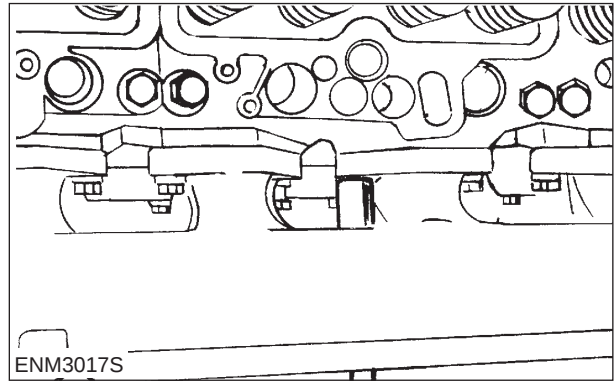
- (1) Turn the crankshaft until intake/exhaust valves of #6 cylinder (1st cylinder from water pump) are overlapped (that is, #1 piston is at TDC position).
Adjust the valve clearance marked with ○ in the table.
- (2) Conversely, Turn the crankshaft until intake/exhaust valves of #1 cylinder are overlapped (that is, #6 piston is at TDC position),
Adjust the valve clearance marked with ◎ in the table.
- (3) In performing the valve clearance adjustment operation, Insert the feeler gauge of 0.3mm thickness into the clearance between the valve stem and rocker arm, then adjust the clearance with the adjust screw. Fully tighten the rock nut when a correct adjustment is achieved.

<Cautions>

- (1) Turning the crankshaft is to be done by hands not by the starter.
- (2) Turn the crankshaft in the direction of engine rotation, but do not use the fixing bolts at the turn.
- (3) The cylinder No. and the sequence of intake and exhaust can be nominated from the flywheel housing.

3.3.20. Intake Manifold

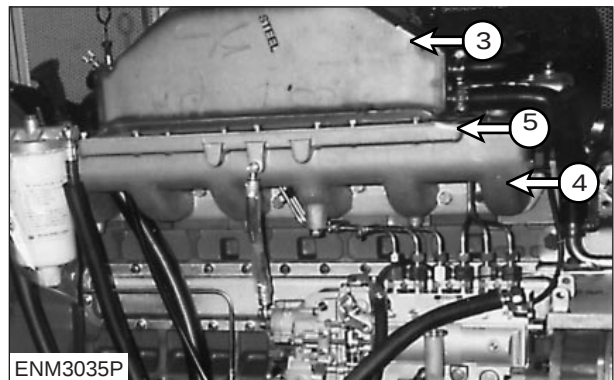
- 1) Install the manifold gasket on the cylinder head by aligning its openings with the intake port in the cylinder head.
- 2) Install the intake manifold on the cylinder head by means of bolts and tighten them to the specified torque.



<Fig. 107> Intake Manifold Assembling

3.3.21. Inter Cooler < For D1146TI only>

- 1) Remove gasket residue on the joining surface of inter cooler by means of a scraper.
- 2) Coat the surface with silicon adhesive (spec: TB1107) using a brush.
- 3) Insert a new gasket (5) between intake manifold(4) and intercooler(3), then tighten the fixing bolts to the specified torque of 2.2kg·m

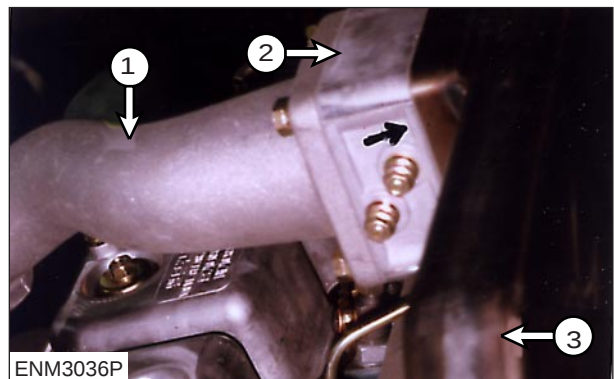


<Fig. 108> Intercooler Assembling

Notice : For overland use, the inter cooler is mounted on the vehicle side.

3.3.22. Air Heater

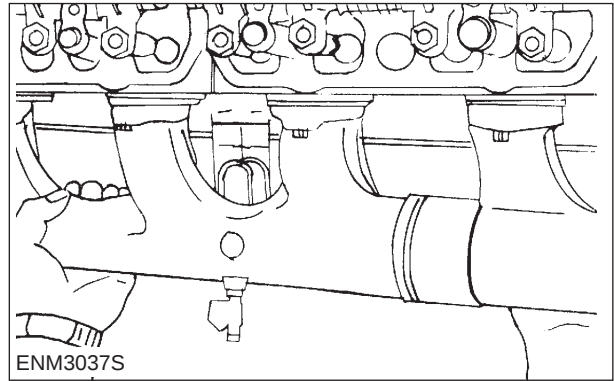
- 1) The air heater(2) is ,in the direction of arrow mark on it, assembled to the inter cooler(3).
- 2) Attach the gaskets on both sides of air heater and tighten the fixing bolts respectively.



<Fig.109> Air Heater Assembling

3.3.23. Exhaust Manifold

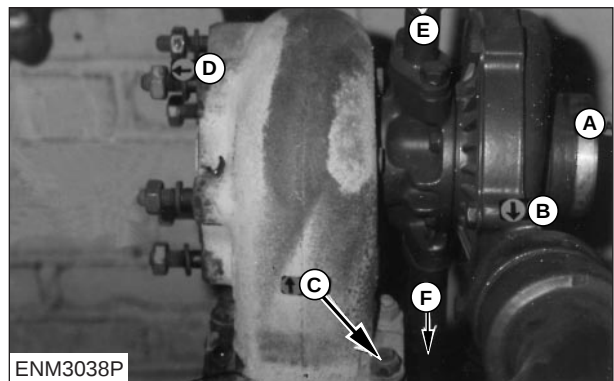
- 1) Check the seal ring on the jointing face of the exhaust manifold and replace it if found to be defective.
- 2) Attach a new gasket on the cylinder head, and temporarily place the exhaust manifold on the cylinder head and tighten the fixing bolts securely.



<Fig.110> Exhaust Manifold Assembling

3.3.24. Turbo Charger (For D1146T, D1146TI)

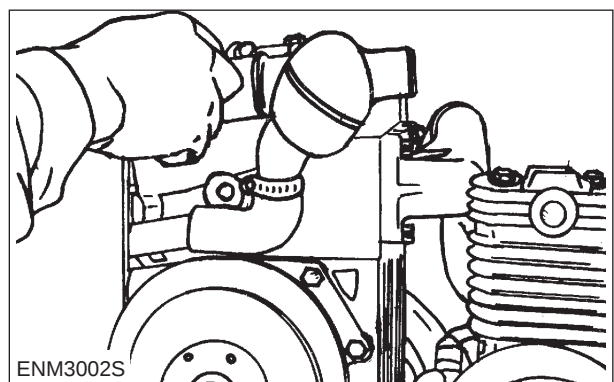
- 1) Install the turbo charger(D) with a new gasket to the exhaust manifold(C). then tighten the nuts in diagonal sequence to the specified torque.
- 2) Align the air inlet portion of the turbo charger with the intake manifold (A), and connect the rubber hose to intake manifold.
- 3) Assemble the oil feed pipe(E) and oil return pipe (F).



<Fig.111> Turbo Charger Assembling

3.3.25. Cooling Water Pipe

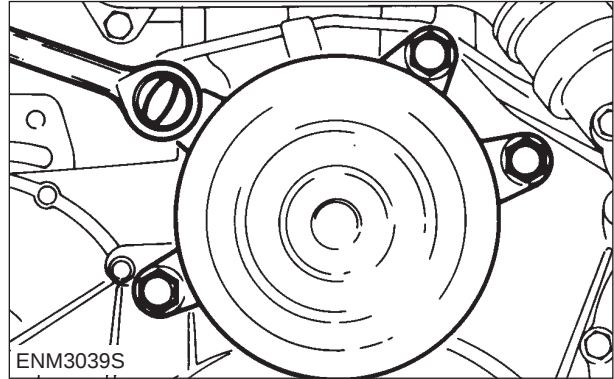
- 1) Attach a new gasket on the cylinder head.
- 2) Install the cooling water pipe as tightening the fixing bolts of it



<Fig.112> Cooling Water Pipe Assembling

3.3.26. Idle Pulley

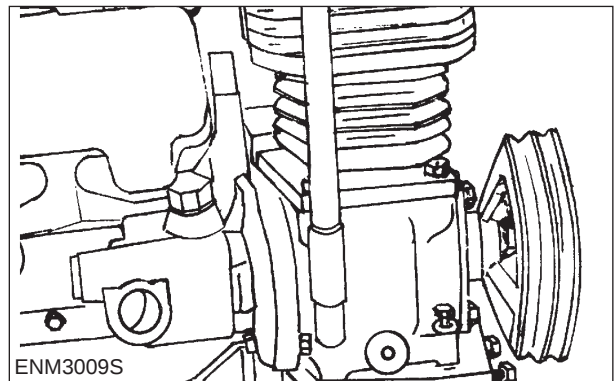
- 1) Install the air compressor mounting bracket to the timing gear case.
- 2) Assemble the idle pulley to the air compressor mounting bracket.



<Fig.113> Idle Pulley Assembling

3.3.27. Air Compressor

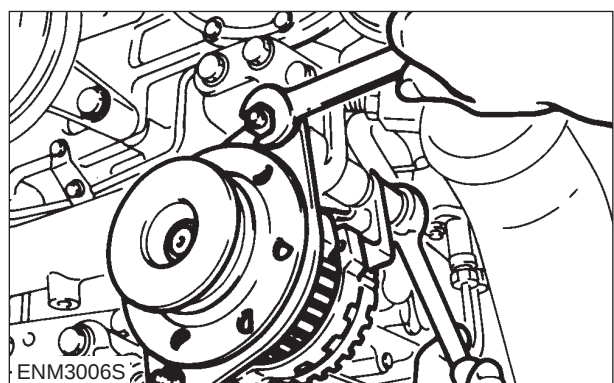
- 1) Couple the power steering oil pump to the air compressor with the driving dog engaged.
- 2) Insert the O-ring coated with grease into the oil outlet of the air compressor.
- 3) Place the air compressor on the mounting bracket carefully and tighten the fixing bolts to the specified torque.
(Exercise care not to damage the O-ring)
- 4) Assemble the oil feed pipe.



<Fig.114> Air Compressor Assembling

3.3.28 Alternator

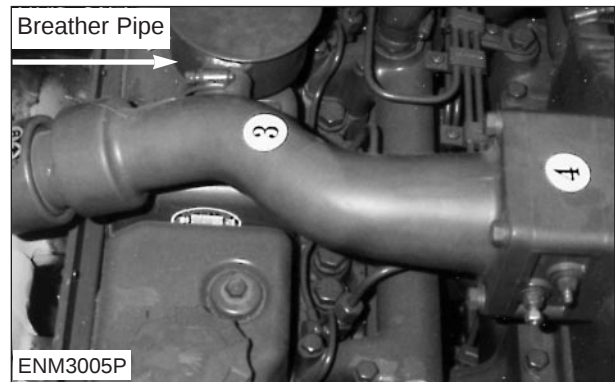
- 1) Install the mounting bracket and supporter to cylinder block, then tighten the fixing bolts.
- 2) Install the alternator to the mounting bracket and to supporter, then tighten the fixing bolts.



<Fig.115> Alternator Assembling

3.3.29. Breather Pipe

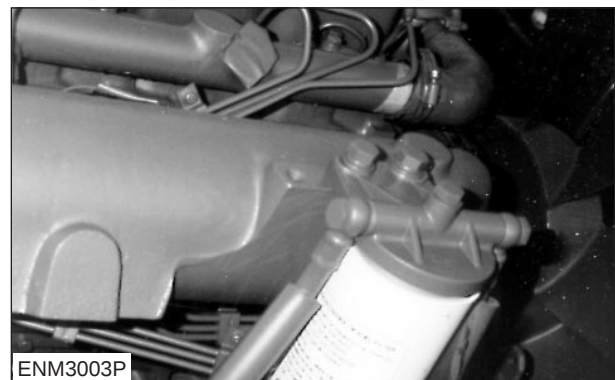
- 1) Assemble the breather pipe and tighten its hose clamp.



<Fig.116> Breather Pipe Assembled

3.3.30. Fuel Filter

- 1) Install the fuel filter to the intake manifold and tighten the bolts to the specified torque.



<Fig.117> Fuel Filter Assembled

- 2) Connect the fuel inlet hose and outlet hose to the fuel filter respectively by tightening hollow screws.
Be sure not to damage the connection part due to over-tightening the hollow screw.

3) Fuel filter (cartridge type)

- (1) Remove the used cartridge(2) from the head(3).

(Fuel should be drained into a container so as not to stain the ground and the engine)

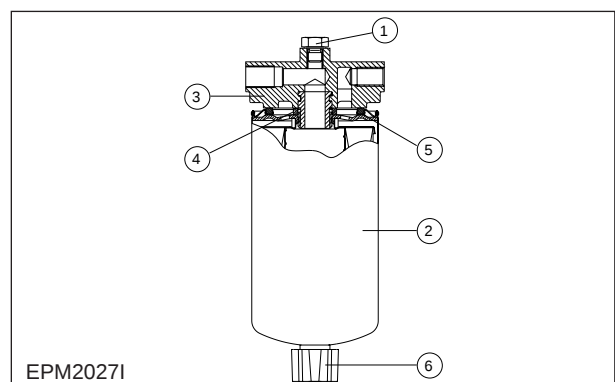
- (2) Fill a new cartridge with fresh diesel fuel.
- (3) Lubricate the surface of rubber packing (5) of the cartridge.

- (3) Clean the joining face of the head, and spin the cartridge until the surface of its packing comes into contact with the head face.

- (4) From this position, additionally, tighten the cartridge by 1/2 turn.

- 5) Loosen the air bleeding screw on the head of the fuel filter and feed fuel by manually operating the priming pump of the feed pump until the air bubbles completely expel in the fuel flowing from the filter.

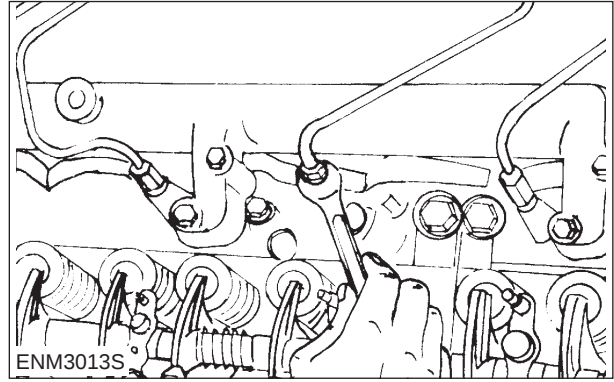
- 6) Tighten the plug screw, and spin engine over with key and check for any fuel leakage.



<Fig.118> Fuel Filter (Cartridge Type)

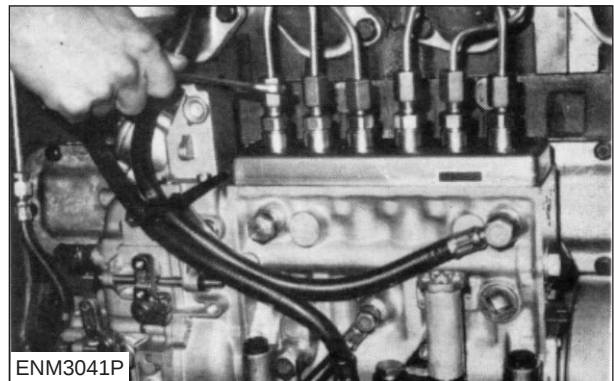
3.3.31. Injection Nozzle

- 1) Install a new seal ring in the nozzle hole of cylinder head,
- 2) As aligning the ball of nozzle with a groove in the nozzle hole, Insert the nozzle into the cylinder and tighten the nozzle.



<Fig.119> Nozzle Assembling

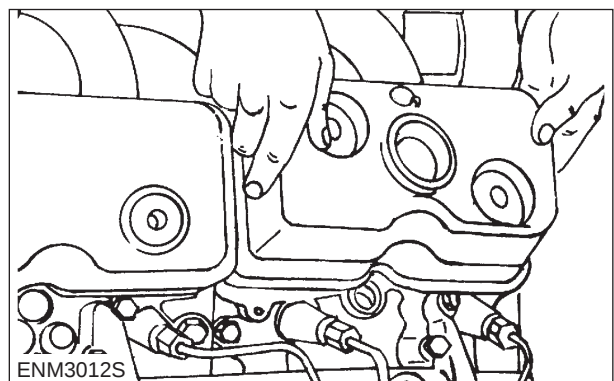
- 3) Connect the fuel injection pipe to the fuel injection pump and to the nozzle, and tighten them with nuts.
 - 4) Assemble the fuel return hose to the nozzle.
 - 5) Connect the injection pump lubricating oil hose with a hollow screw.
- Be sure not to damage the connection part due to over-tightening the hollow screw.



<Fig.120> Fuel Injection Assembling

3.3.32. Cylinder Head Cover

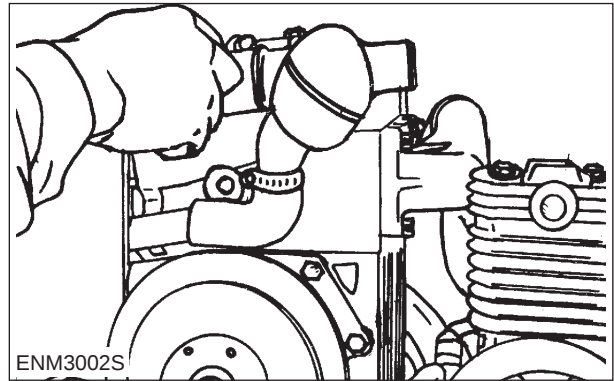
- 1) Attach a new gasket on the cylinder head cover.
- 2) Assemble the cylinder head cover to the cylinder head by tightening the cap bolts for fixing the cylinder head cover.
- 3) Fit the oil filler cap on the cylinder head cover.



<Fig.121> Cylinder Head Cover Assembling

3.3.33. Thermostat

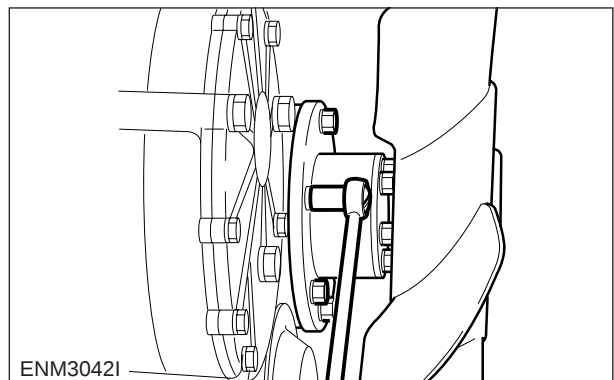
- 1) Connect the thermostat housing to the cooling water pipe with rubber hose engaged, then tighten the hose clamps.
- 2) Connect the thermostat housing to the water pump with rubber hose engaged, then tighten the hose clamps.



<Fig.122> Thermostat Assembling

3.3.34. Cooling Fan

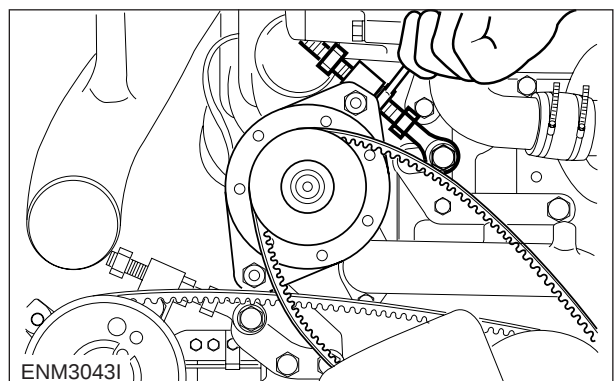
- 1) Install the flange to the water pump pulley, then assemble the cooling fan to the pulley by tightening the fixing bolts .



<Fig.124> Cooling Fan Assembling

3.3.35. V-Belt

- 1) Check the V-belt for fraying or damage and replace it with a new one if necessary.
- 2) Wind one V-belt around the alternator pulley, water pump pulley and crankshaft pulley, and then adjust the V-belt tension by shifting the tension adjusting bolt of the alternator.
- 3) Wind the other V-belt around the idle pulley, crankshaft pulley and air compressor pulley, then adjust the V-belt tension by shifting the tension adjusting bolt of the idle pulley.



<Fig.125> V-Belt Assembling

3.3.36. Oil Dipstick

- 1) Insert the oil dipstick into the guide tube.

3.3.37. Miscellaneous Items

- 1) Connect all the rest pipes and hoses for lubrication and fuel system.

3.3.38. Injection Timing Adjustment

- 1) Turn the crankshaft until #6 cylinder is overlapped.
- 2) Open the rubber cap of the inspection hole located in the flywheel housing, and adjust the injection timing by rotating the crankshaft.
- 3) Loosen the flange bolt in the injection pump, and align the timing mark on the injection pump timer with the pointer on the inspection of the flywheel housing.
- 4) Reassemble the flange bolts and the rubber cap.

3.4 Breaking-In

3.4.1. Preparations Prior to Breaking-In

- 1) Fill fresh engine oil through the oil filler cap.
- 2) Check the oil level with the oil dipstick. the oil level should be about 10mm above the MAX. line.
- 3) Connect the cooling water hose and replenish cooling water.
- 4) Further on, connect the fuel hose to the fuel tank, and bleed the fuel system (refer to section 3.3.34.)

3.4.2. Execution of Breaking-In

- 1) Attach the engine to the test bench.
- 2) Execute the breaking-in according to breaking-in regulations.
- 3) Any problem in assembly or performance of engine could be detected and corrected by breaking-in test.
- 4) After breaking-in, readjust the valve clearance.

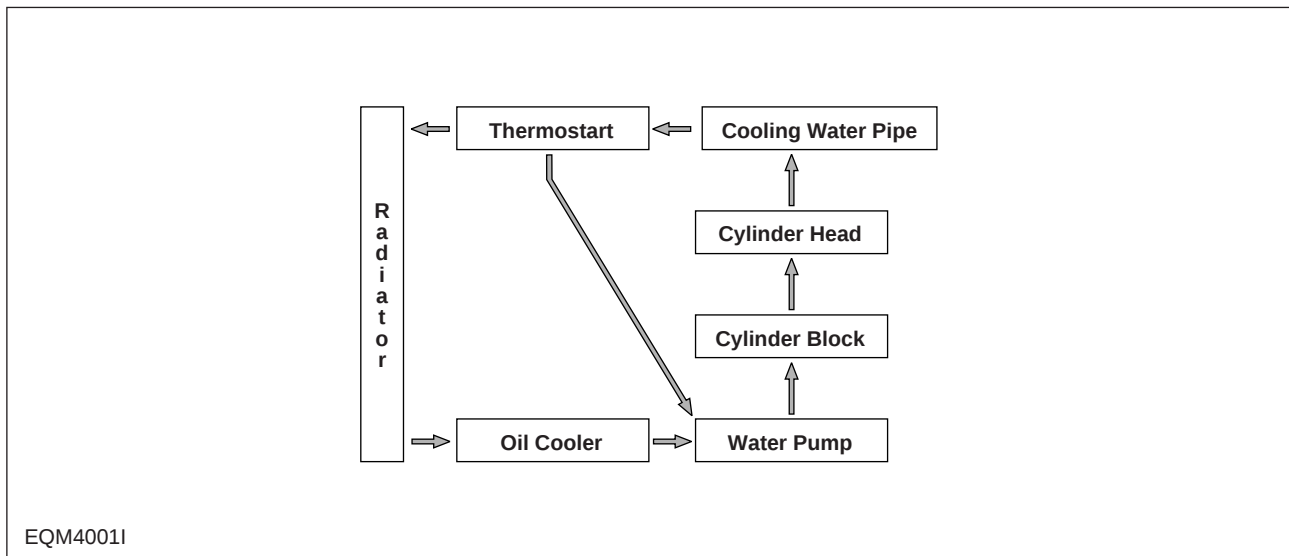
4. Maintenance of Major Components

4.1. Cooling System

4.1.1. General Description

This Engine is of Water-cooled type.

Heat generated from combustion chamber and Engine oil is cooled down by coolant, and radiated to the outside, which enables the normal operation of the Engine. When it comes to cooling system, the coolant pumped up by the water pump goes through the oil cooler along the cooling water pipe to absorb the oil heat, flowing through the water jacket of the cylinder block and water passages of the cylinder head to absorb the heat of the combustion chamber. then the coolant moves on to the thermostat through the cooling water pipe, where the coolant returns to the water pump if the coolant temperature is lower than the valve opening temperature of the thermostat, otherwise further circulating to the radiator, where the heat of the coolant is radiated and the cooled coolant again returns to the water pump, completing 1 cycle of cooling system.



<Fig.1> Cooling Circuit Diagram

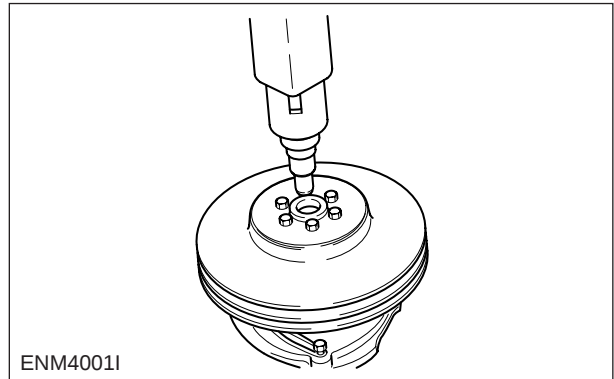
4.1.2. Specification

Item	Specification
1. Water Pump	
Type	Centrifugal
Delivery (ℓ/min.)	Approx.190 (At Pump Speed of 2000 rpm)
pump Back Pressure	0.5 bar
2. Thermostat	
Opening Temperature	79°C
Valve Lift	8mm or More (At 94°C)
Operating Temperature	79 ~ 94°C
3. Cooling Fan and Belt	
Fan Dia. X No. of Blades	528 X 6
Fan Belt Tension	15mm / Deflection by Thumb

4.1.3. Water Pump

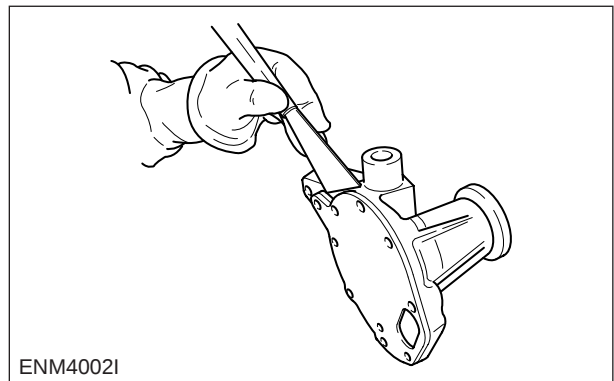
1) Disassembly

- (1) Unscrew the nuts of the pulley, then remove the pulley.



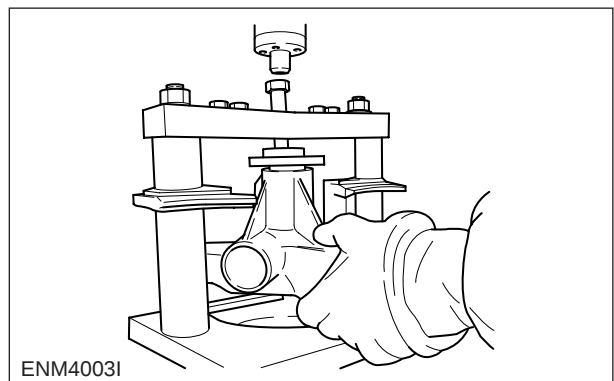
<Fig. 2> Water Pump Pulley Removal

- (2) Loosen the bolts and disassemble the water pump cover.



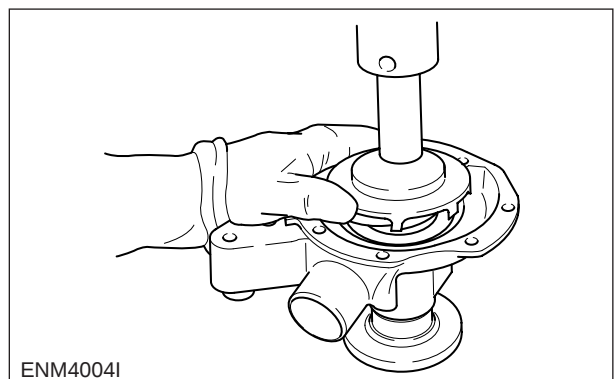
<Fig.3> Water Pump Cover Removal

- (3) Remove the hub by means of a suitable extractor or press, then remove the snap ring with a plier. (the hub is securely fitted on the shaft of the unit bearing)



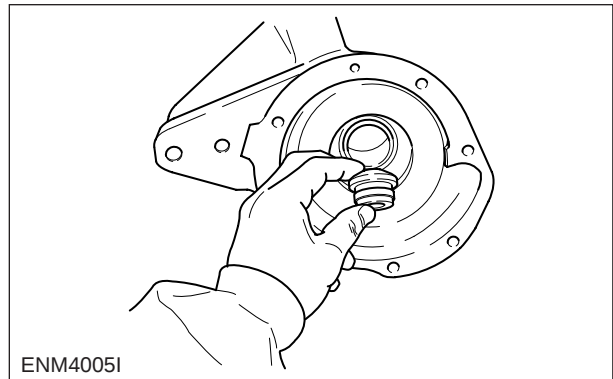
<Fig.4> Water Pump Hub Removal

- (4) Press out the unit bearing from the housing.



<Fig.5> Unit Bearing Removal

- (5) Take out the mechanical seal from the housing.



<Fig.6> Mechanical Seal Removal

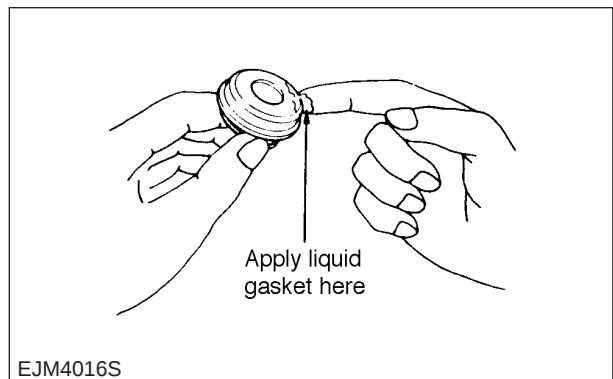
- (6) Wash clean disassembled parts.

2) Inspection

- (1) Inspect the bearing for wear and scores. turn the bearing with hand to see if it rotates smoothly without noise.
- (2) Replace the bearing with a new one if the radial movement of the shaft exceeds the limit for use (0.2mm)
- (3) Inspect the impeller and shaft for wear, corrosion, bending, and damage.
Pay a special attention to the surface of impeller and seal unit fitting face for wear and corrosion.

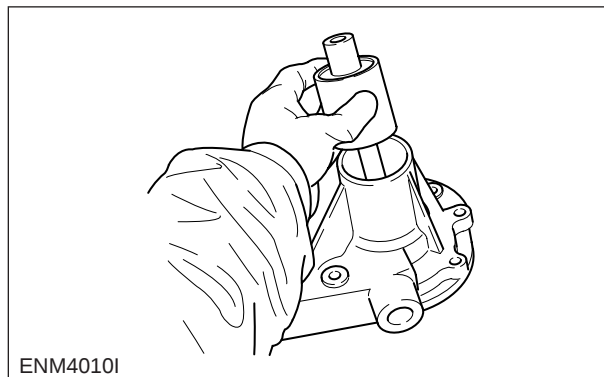
3) Reassembly

- (1) Coat the selant over the periphery of the mechanical seal and press it onto the housing.



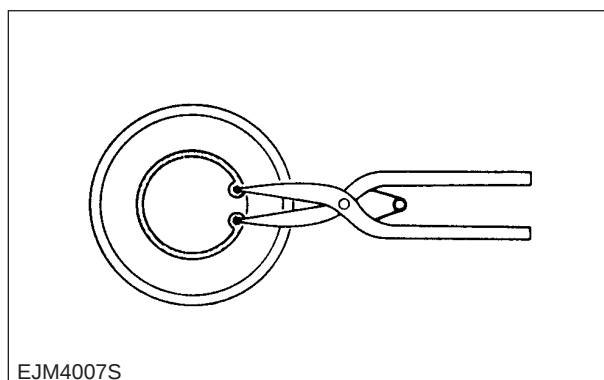
<Fig. 7> Mechanical Seal

- (2) Coat the multipurposable grease over the periphery of unit bearing body and press it into the housing.



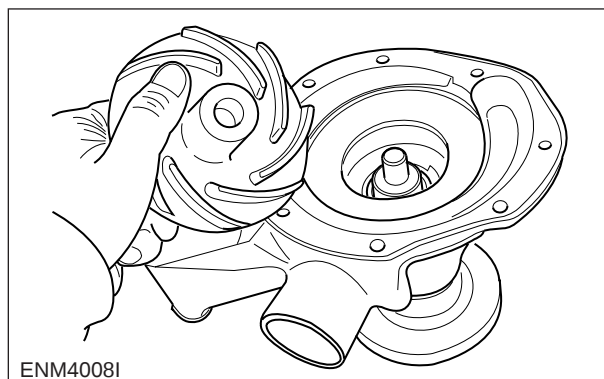
<Fig. 8> Unit Bearing Assembling

- (3) Insert the snap ring into the housing to secure the unit bearing.

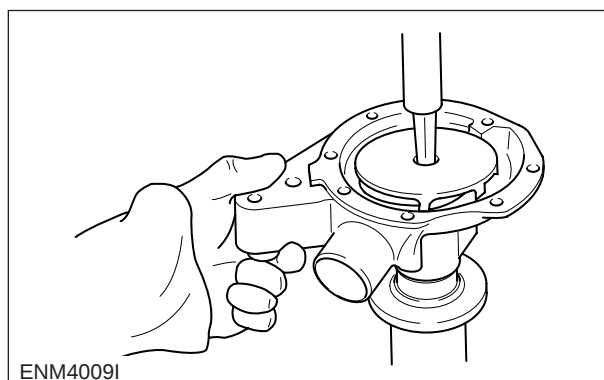


<Fig.9> Snap Ring Inserting

- (4) Press the impeller into the shaft of the unit bearing.

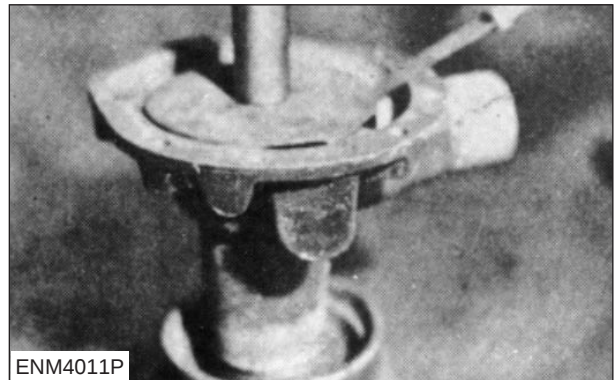


<Fig.10> Impeller



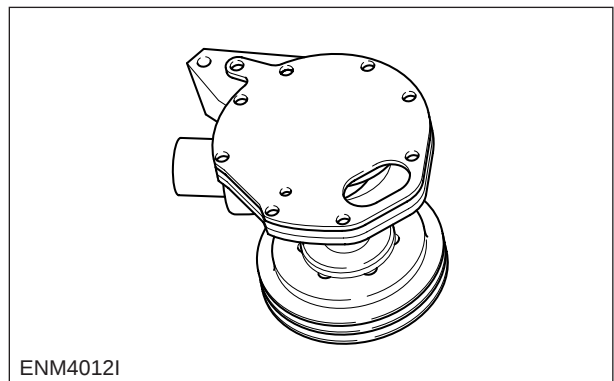
<Fig.11> Impeller Press In

- (5) Press the hub into the other part of the shaft of the unit bearing.
- (6) Measure the clearance between the impeller and the housing with a feeler gauge the clearance can be adjusted by a bench press or by a puller when the clearance exceeds the limit for use. (0.35mm)



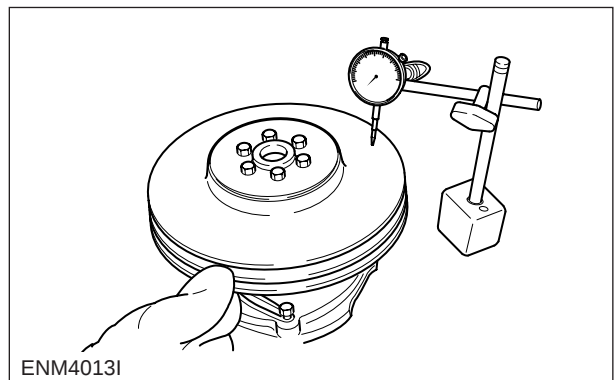
<Fig.12> Clearance Measurement

- (7) Coat adhesive on the either side of a new gasket, and assemble the water pump cover to the housing with the gasket engaged.



<Fig.13> Water Pump Cover Assembling

- (8) Press the pulley into the shaft of the unit bearing and measure its perpendicularity around the shaft axis.
The measured value can be adjusted by a bench press or by a puller when the value exceeds the limit for use. (0.3mm)



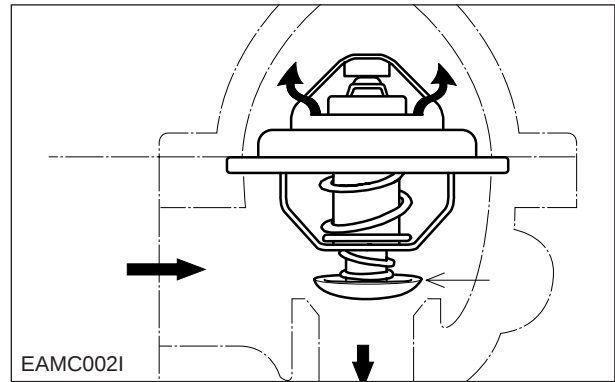
<Fig.14> Pulley Perpendicularity Measurement

4.1.4. Thermostat

1) General description and specification

The thermostat is designed to maintain a constant temperature of coolant (79 ~ 94°C) and enhance the thermal efficiency of the Engine by deterring heat loss.

In other words, when the coolant temperature is low, the thermostat is closed to make the coolant bypass to the water pump directly. when the coolant temperature rises to open wide the thermostat valve, the bypass circuit is closed and the water passage to the radiator opens instead so that the coolant is forced to flow into the radiator.



<Fig. 15> Thermostat

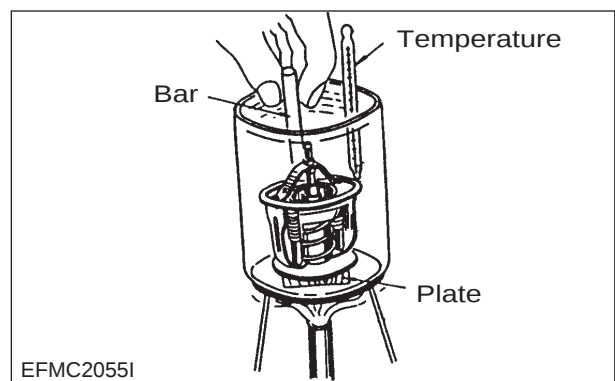
Item	Specification
Type	Wax-Pallet
Open At (°C)	79 (71)
Full Open At (°C)	94 (85)
Valve Lift	8mm or More

There are 2 kinds of thermostats according to surrounding and operating conditions.

One is named by 71°C type and the other is 74°C.

2) Inspection

- (1) Inspect the Wax-pallet and spring for damage.
- (2) Check valve lift and valve opening temperature by submerging the thermostat in the water and increasing the water temperature gradually. Check if the valve lift is 0.1mm at 79°C (starting to open) and 8mm at 94°C (full open)



<Fig. 16> Thermostat Inspection

3) Precautions and Replacement

(1) Precautions for handling the thermostat;

The wax-pallet type thermostat does not respond as quickly as bellows type ones do. That is mainly due to its higher heat capacity. Therefore, to avoid a stiff uprise of coolant temperature, it is necessary to have the Engine under idling sufficiently before running it, do not run the Engine at overload or overspeed right after starting-up.

- (2) When draining out or replenishing coolant, do it slowly so that the air is bled sufficiently from the entire cooling system.

(3) Replacement of thermostat;

If the thermostat is found defective, replace it with a new one. It is preferable to replace the thermostat every 50,000~70,000 km run as it varies according to the running condition.

4.1.5. Diagnostics and Troubleshooting

Complaints	Possible causes	Corrections
1. Engine overheating	(1) Lack of coolant (2) Radiator cap pressure valve spring weakened (3) Fan belt loosened or broken (4) Fan belt fouled with oil (5) Thermostat inoperative (6) Water pump defective (7) Restrictions in water passages due to deposit of scales (8) Injection timing incorrect (9) Restriction in radiator core (10) Gases leaking into water jacket due to broken cylinder head gasket	(1) Replenish coolant (2) Replace cap (3) Adjust or replace fan belt (4) Replace fan belt (5) Replace thermostat (6) Repair or replace (7) Clean radiator and water passages (8) Adjust injection timing correctly (9) Clean exterior of radiator (10) Replace cylinder head gasket
2. Engine overcooling	(1) Thermostat inoperative (2) Ambient temperature too low	(1) Replace thermostat (2) Install radiator curtain
3. Lack of coolant	(1) Radiator leaky (2) Radiator hoses loosely connected or damaged (3) Radiator cap valve spring weakened (4) Water pump leaky (5) Heater hoses loosely connected or broken (6) Cylinder head gasket leaky (7) Cylinder head or cylinder block cracked	(1) Correct or replace (2) Retighten clamps or replace hoses (3) Replace cap (4) Repair or replace (5) Tighten or replace hoses (6) Replace cylinder head gasket (7) Replace cylinder head block
4. Cooling system noisy	(1) Water pump bearing defective (2) Fan loosely fitted or bent (3) Fan out of balance (4) Fan belt defective	(1) Replace bearing (2) Retighten or replace fan (3) Replace fan (4) Replace fan belt

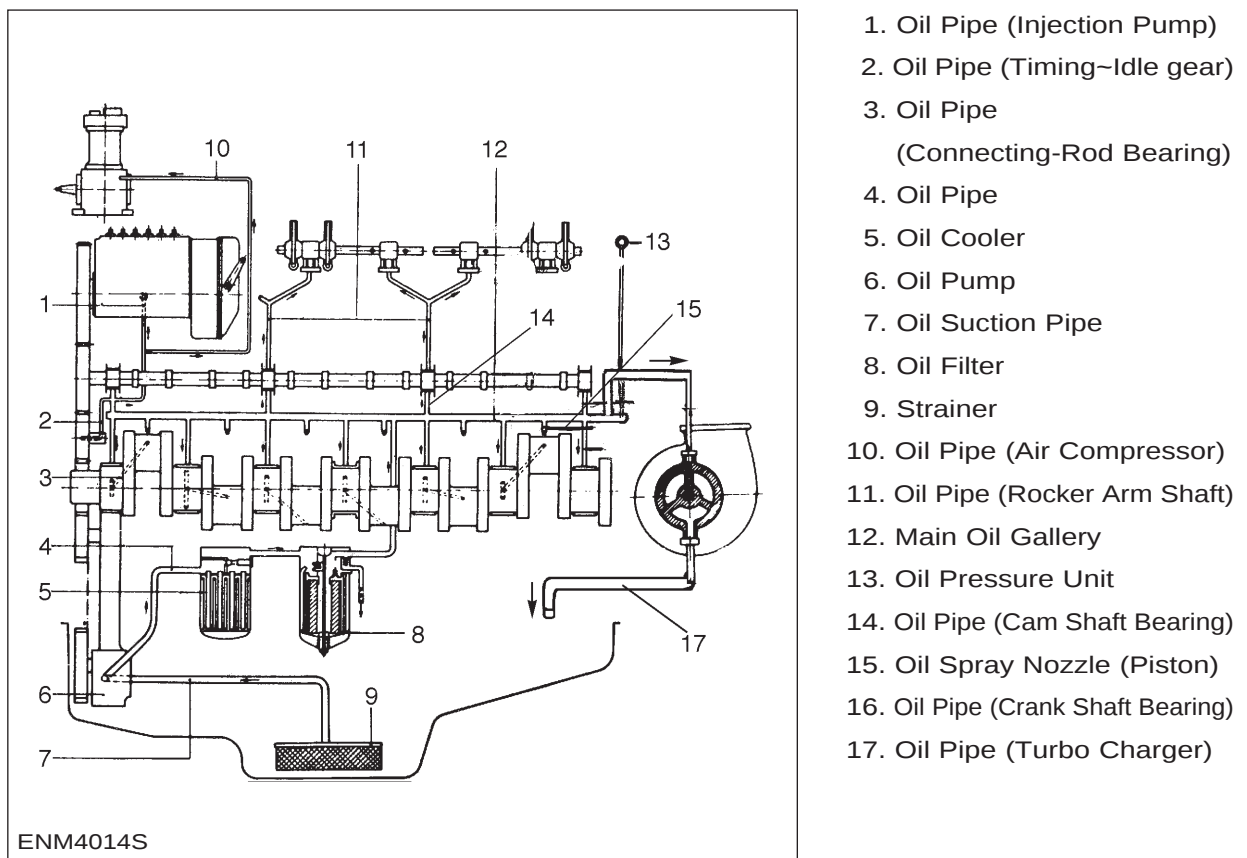
4.2. Lubrication System

4.2.1. General Description

Engine oil pumped up from the oil pan by the gear type oil pump is filtrated through the oil cooler and oil filter, and the filtrated oil is forced to go through the main oil gallery in the cylinder block, from where it is distributed evenly to lubricated the various sliding parts, fuel injection pump, and air compressor in sequence to keep the Engine in normal condition.

4.2.2. Specification and Diagram

Item	Specifications	Item	Specifications
Lubricating System	Forced Pressure Circulation	Oil Filter Type	Full-Flow
Oil Pump Type	Gear Type	Bypass for Filter Element	
Relief Valve Opening Pressure (kg/cm ²)	10±1.5	Valve Opening Pressure(kg/cm ²)	1.8~2.3
Bypass for Oil Cooler		Bypass for Entire Oil Filter	
Opening Pressure (kg/cm ²)	5+1	Valve Opening Pressure(kg/cm ²)	4.0~4.8
Adjusting Valve for Spray Nozzle			
Opening Pressure (kg/cm ²)	1.5~1.8		

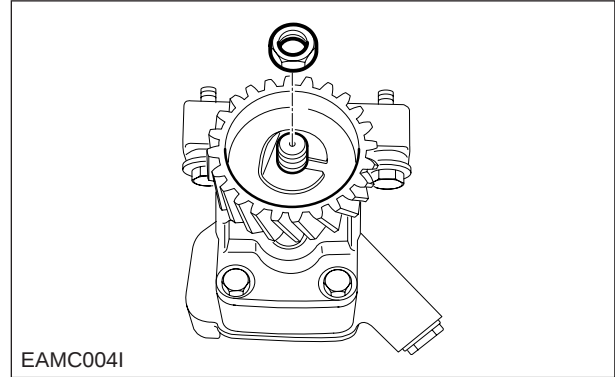


<Fig.1> Lubrication System

4.2.2. Oil Pump

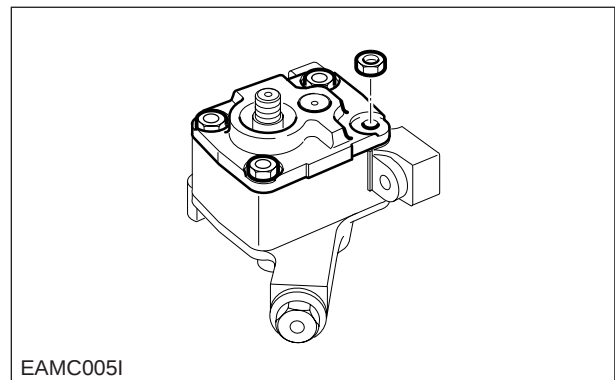
1) Disassembly

- (1) Unscrew the screw and disassemble the oil relief valve
- (2) Unfold the lock washer and remove the nut.
- (3) Disassemble the oil pump drive gear.



<Fig.2> Drive Gear Disassembling

- (4) Remove the oil pump cover fixing nuts and disassemble the oil pump cover.
The oil pump cover is secured to the pump housing with two dowel pins.
- (5) Remove the pump gears.

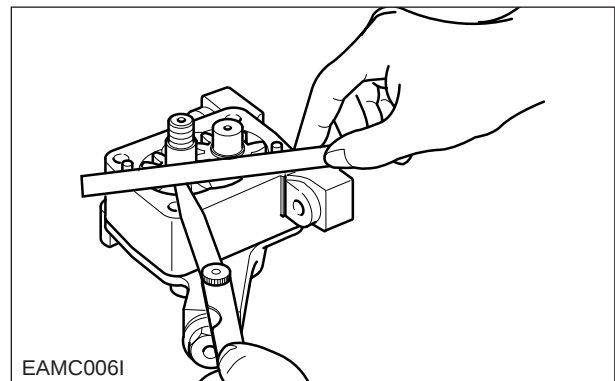


<Fig.3> Pump Cover Disassembling

2) Measurement and Inspection

- (1) With a steel rule and a feeler gauge, measure the axial end play of the oil pump gear. Replace if the measured value exceeds the limit for use.

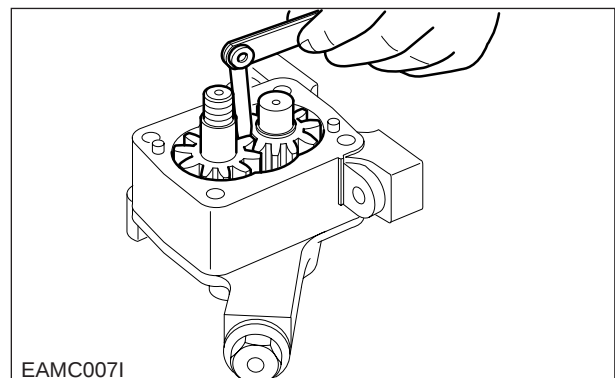
Limit (mm)	0.025 ~ 0.089
------------	---------------



<Fig.4> End Play Measurement

- (2) With the feeler gauge, measure the back-lash between the driving gear and driven gear in the oil pump housing. Replace if the measured value exceeds the limit for use.

Limit (mm)	0.50 ~ 0.64
------------	-------------



<Fig.5> Gear Back Lash Measurement

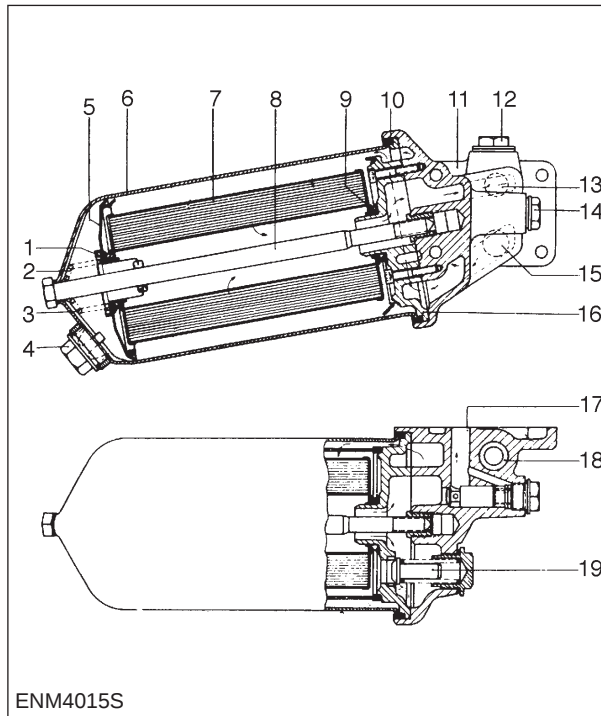
- (3) Measure the diameters of driving shaft and driven shaft, and replace if the measured values are under the limit for use ($\phi 16.95\text{mm}$)
- (4) Measure the inner diameter of the pump housing bush to determine the clearance between the bush and shaft, and compare the measured value with the standard value ($0.032 \sim 0.077\text{mm}$) to determine if they are to be replaced or not.

3) Reassembly

- (1) To reassemble, follow the disassembly procedures in the reverse sequence.

4.2.3. Oil filter

1) construction



1. Packing
2. Spring
3. Packing
4. Drain Plug
5. Seating Plate
6. Filter Housing
7. Filter Element
8. Center Bolt
9. Packing
10. O-Ring
11. Filter Head
12. Plug Screw
13. Oil Outlet
14. Over Flow Valve
15. Oil Inlet
16. Seating Plate
17. Oil Drain Gallery
18. Valve Seat
19. By-Pass Valve

<Fig.6> Oil filter

2) Disassembly

- (1) Drain out the oil by removing the drain plug
- (2) Remove the oil filter assembly from the Engine
- (3) Loosen the center bolt and take out the filter element
- (4) Remove the by-pass valve from the filter head.

3) Inspection

- (1) Visually Inspect the filter housing and head for cracks or damage and replace as necessary.
- (2) Visually check its spring for damage.
- (Opening pressure of over flow valve for paper filter element : $1.8 \sim 2.3 \text{ kg/cm}^2$)
- (3) Visually Inspect the full flow by-pass valve
- (Opening pressure of by-pass valve : $5.3 \sim 6.3 \text{ kg/cm}^2$)

4) Reassembly

- (1) To reassemble, follow the disassembly procedures in the reverse sequence.

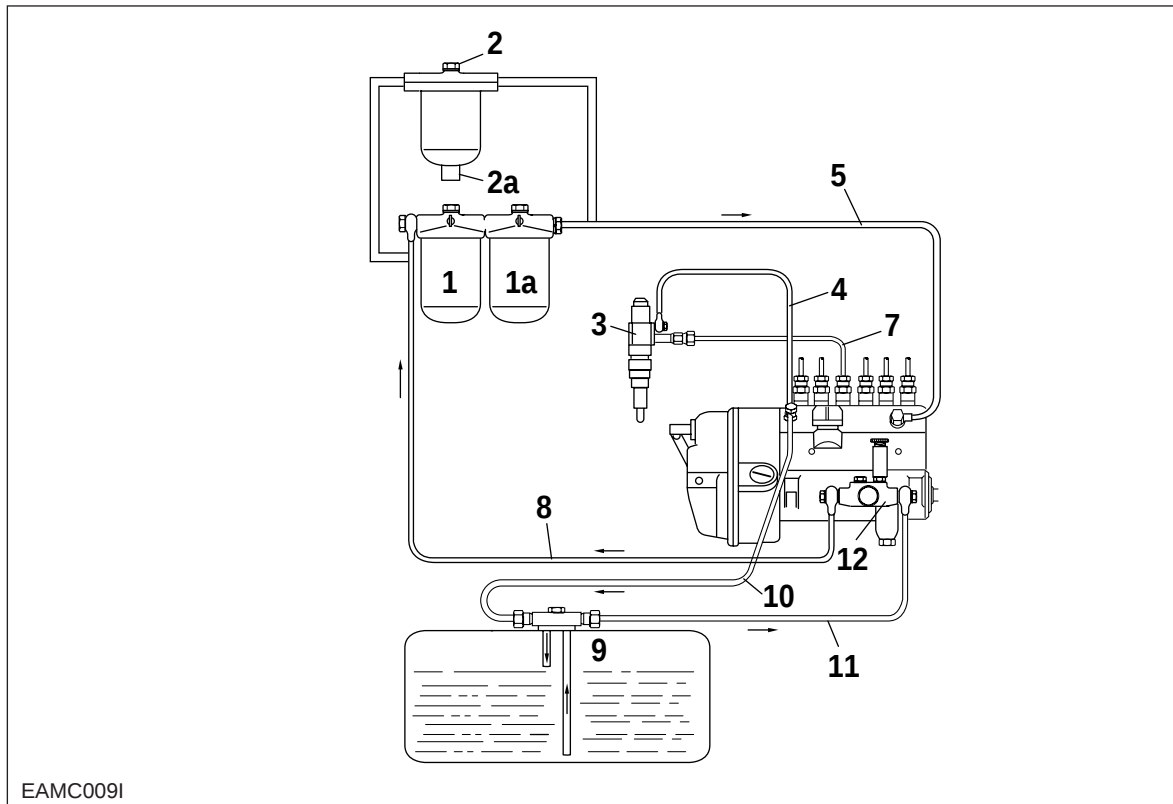
4.2.4. Diagnostics and Troubleshooting

Complaints	Possible causes	Corrections
Excessive Oil Consumption	(1) Wrong oil in use (2) Leakage from oil seal or packing (3) Piston ring and piston ring groove worn (4) Cylinder liner worn (5) Piston ring sticking (6) Valve guide oil seal, valve guide, or valve stem worn	(1) Drain and refill with recommended oil (2) Repair or replace (3) Replace piston ring or piston (4) Replace Cylinder liner (5) Replace pistons and/or piston rings (6) Replace valve guide oil seal, valve guide, or valve stem worn
Low Oil Pressure	(1) Wrong oil in use (2) Relief valve sticking (3) Strainer clogged (4) Pump gear worn (5) Oil pump defective (6) Oil pressure gauge defective (7) Crankshaft or connecting rod bearings worn	(1) Drain and refill with recommended oil (2) Replace (3) Clean strainer (4) Replace (5) Repair or Replace (6) Repair or Replace (7) Replace bearings
Quick Oil Contamination	(1) Clogged oil filter (2) Gas leakage (3) Wrong oil in use	(1) Replace filter element (2) Replace piston rings and cylinder liners (3) Drain and refill with recommended oil

4.3. Fuel System

4.3.1. General Description

The fuel system is composed of the fuel tank, injection pump, injection nozzle, fuel filter and the certain connecting fuel lines such as pipes and hoses.



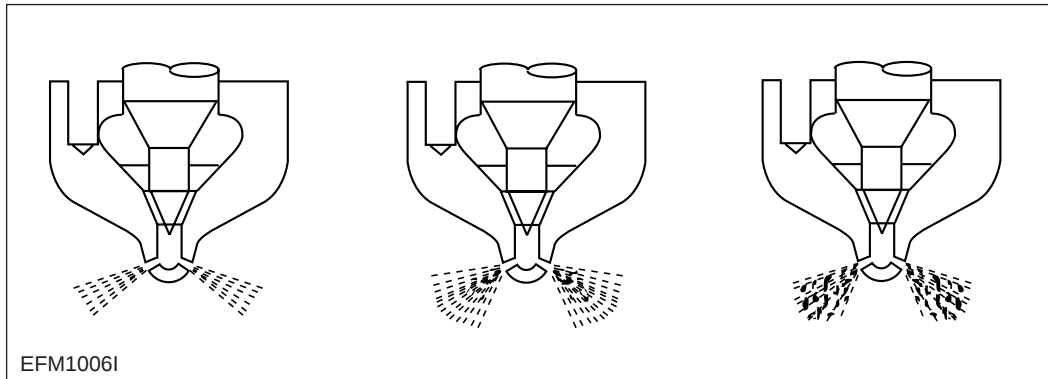
<Fig. 1> Fuel System

- | | |
|--|-----------------------------------|
| 1. Primary Fuel Filter (Felt Type) | 6. Over Flow Valve |
| 1a. Secondary Fuel Filter (Paper Type) | 7. Injection Pipe |
| 1b. Cartridge Fuel Filter (Equals Both 1 and 1a) | 8. Fuel Hose (Feed Pump → Filter) |
| 2. Air Bleeding Screw | 9. Fuel Tank |
| 2a. Water Drain Screw | 10. Fuel Return Line |
| 3. Injection Nozzle | 11. Suction Pipe |
| 4. Over Flow Hose | 12. Feed Pump |
| 5. Fuel Hose (Filter → Injection Pump) | 13. Injection Pump |

4.3.2. Fuel Injection nozzle

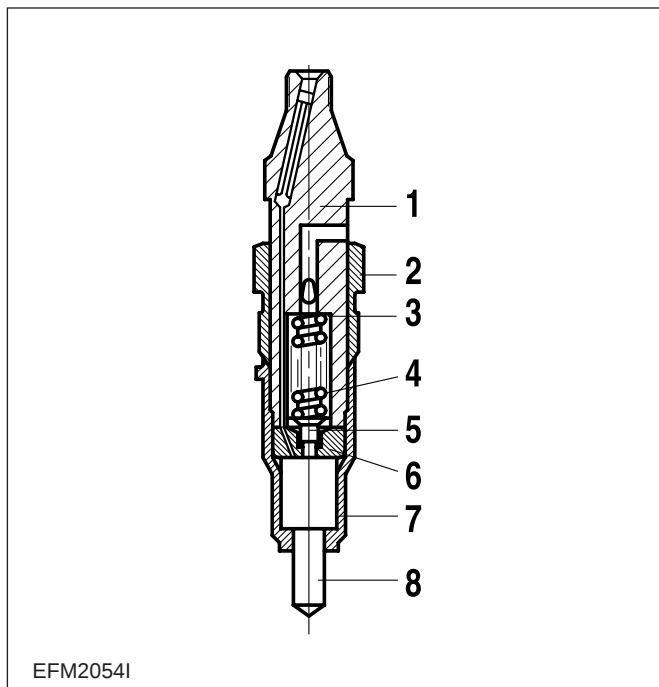
1) General Description

The fuel injection nozzle assembly is so designed that pressurized fuel from the injection pump is injected into the combustion chamber with a certain pressure and angle for the normal operation of the Engine.



<Fig.2> Nozzle Spray Condition

2) Construction



1. Nozzle Holder
2. Union Nut
3. Shim
4. Coil Spring
5. Guide Bush
6. Intermediate Washer
7. Nozzle

<Fig.3> Section View of Injection Nozzle Assembly

3) Disassembly

- (1) Clamp the nozzle assembly and remove the nozzle holder.
- (2) Remove the nozzle nut and components inside.

4) Inspection

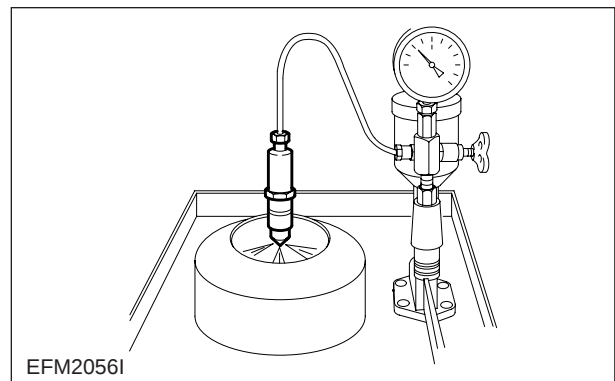
- (1) Visually Inspect the disassembled components for damage.

5) Reassembly

- (1) To reassemble, follow the disassembly procedures in the reverse sequence.

6) Nozzle Spray Test

- (1) After reassembly, install the nozzle on a tester.
- (2) Operate the hand lever 2 or 3 times to see if the nozzle is properly set in position.
- (3) When the injection pressure deviates from the specified range. adjust the spring tension by means of the shim. Besides, spray pattern should be uniform and free of spattering.



<Fig.4> Nozzle Spray Test

4.3.3. Injection Pump

1) D1146

(1) Main Data and Specification

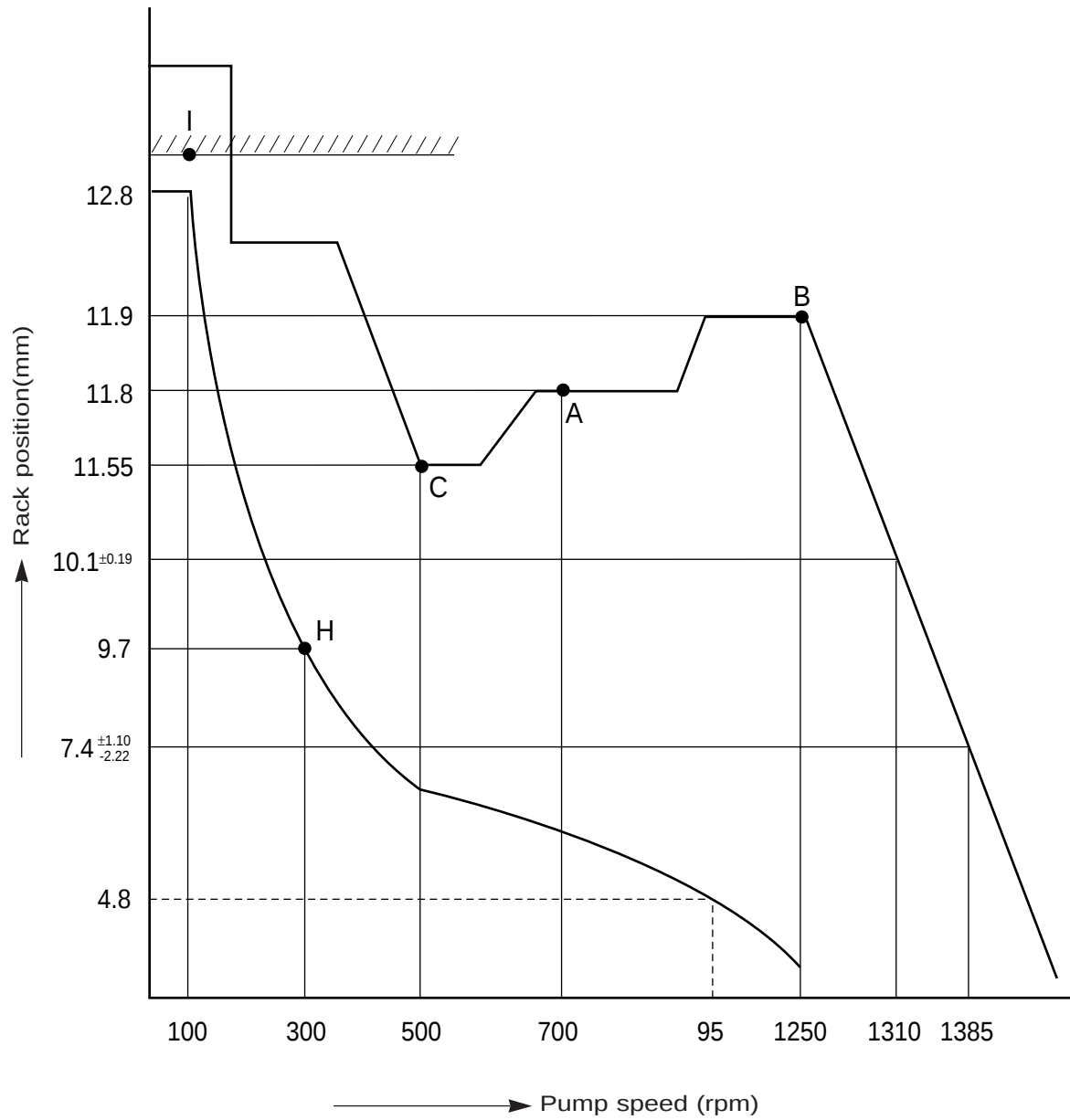
Part No. : 65.11101-7259(101603-9980)
 Model : PE6P type
 Governor : KP-EP/RLD250-1400A1FFL(105931-5901)
 Timer : KP-EP/SA900-1250B4DR(105644-0520)
 Plunger :
 Delivery valve :
 Feed pump : KP-EP/KE-ADS(105210-5280)
 Prestrock :
 Rotation direction : C.W at driving gear side
 Injection older : 1-5-3-6-2-4
 Injection timing : BTDC 15 $\pm$ 1°

(2) Calibration Data

Adjusting point	Rack position	Pump speed(rpm)	Injection volume (mm ³ /1,000st)	Variation rate (%)	Pressure
H	9.7	300	8.5	$\pm$ 1.5	
A	11.8	700	79.5	$\pm$ 1	
B	11.9	1250	84.0	$\pm$ 2	
C	11.5	500	65.0	$\pm$ 2	
I	-	100	115.0	$\pm$ 15	

Adjusting point	Contents	Specification	Engine application
	Nozzle holder ass'y		65.10101-7050
	Nozzle		
	Nozzle holder		
	Opening pressure	175 kg/cm ²	
	Injection pipe	ϕ 6.0 $\times$ ϕ 2.0-600 mm	
	Fuel delivery pressure		
	Fuel temperature	40 $\pm$ 5°C	

(3) Adjusting Governor



HAM40171

2) D1146TI

(1) Main Data and Specification

Part No. : 65.11101-7298(101608-9531)
 Model : PE6P type
 Governor : KP-RLD2501400A1FXL(105932-2490)
 Timer : KP-EP/SA700-1100B3DR(105644-0570)
 Plunger : $\phi=10\text{mm}$, 20+50 LEAD
 Delivery valve :
 Feed pump : KP-EP/KE-ADS(105210-5280)
 Prestrock : 4.6mm
 Rotation direction : C.W at driving gear side
 Injection older : 1-5-3-6-2-4
 Injection timing : BTDC $9 \pm 1^\circ$

(2) Calibration Data

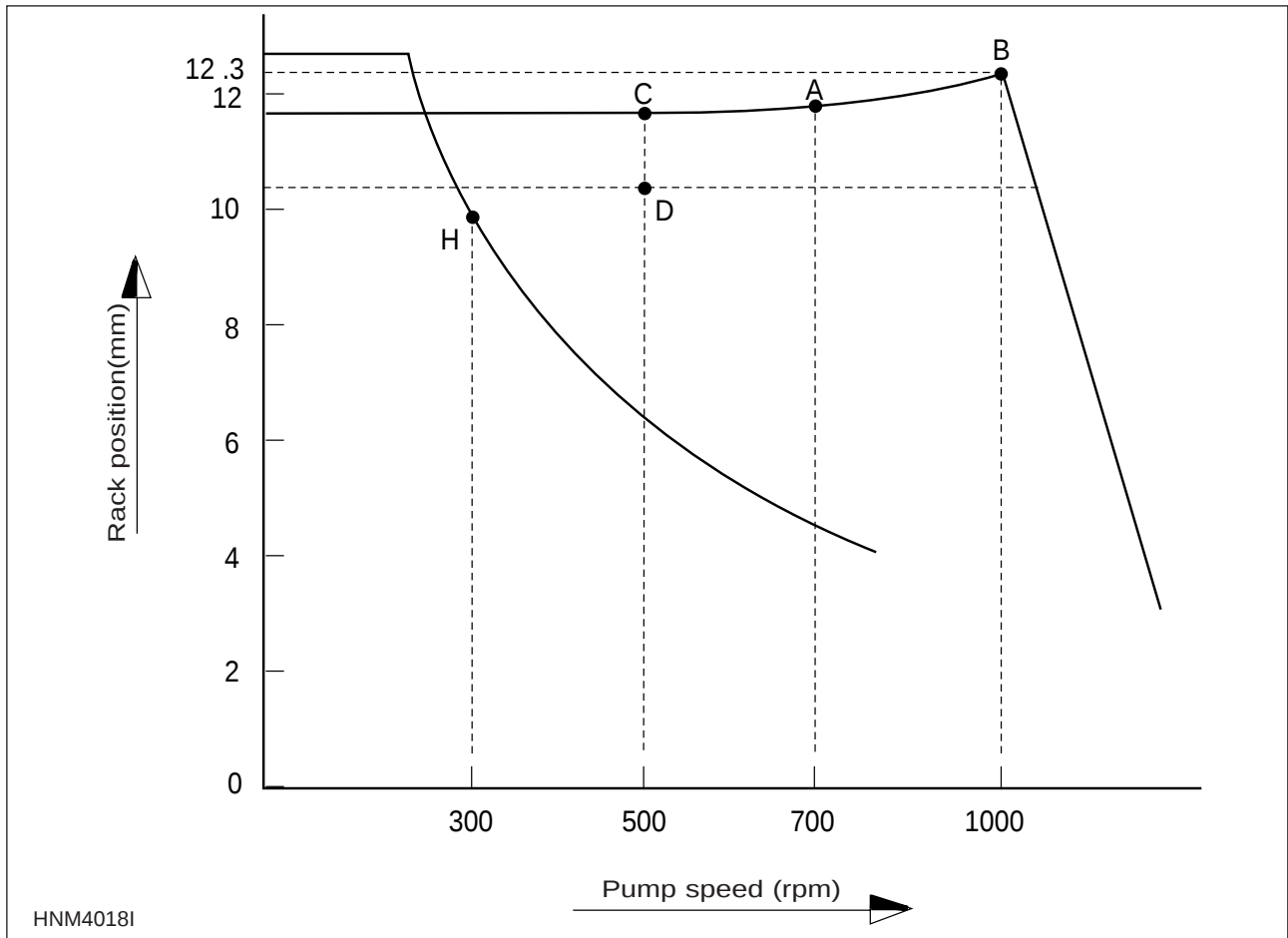
Adjusting point	Rack position	Pump speed(rpm)	Injection volume (mm ³ /1,000st)	Variation rate (%)	Pressure
H	9.7	300	8.5	± 1.5	
A	11.9	700	98.5	± 1.6	
B	12.3	1100	106.5	± 2	
C	11.7	500	82.0	± 2	
D	10.5	100	58.7	± 2	

(3) LDA Calibration data

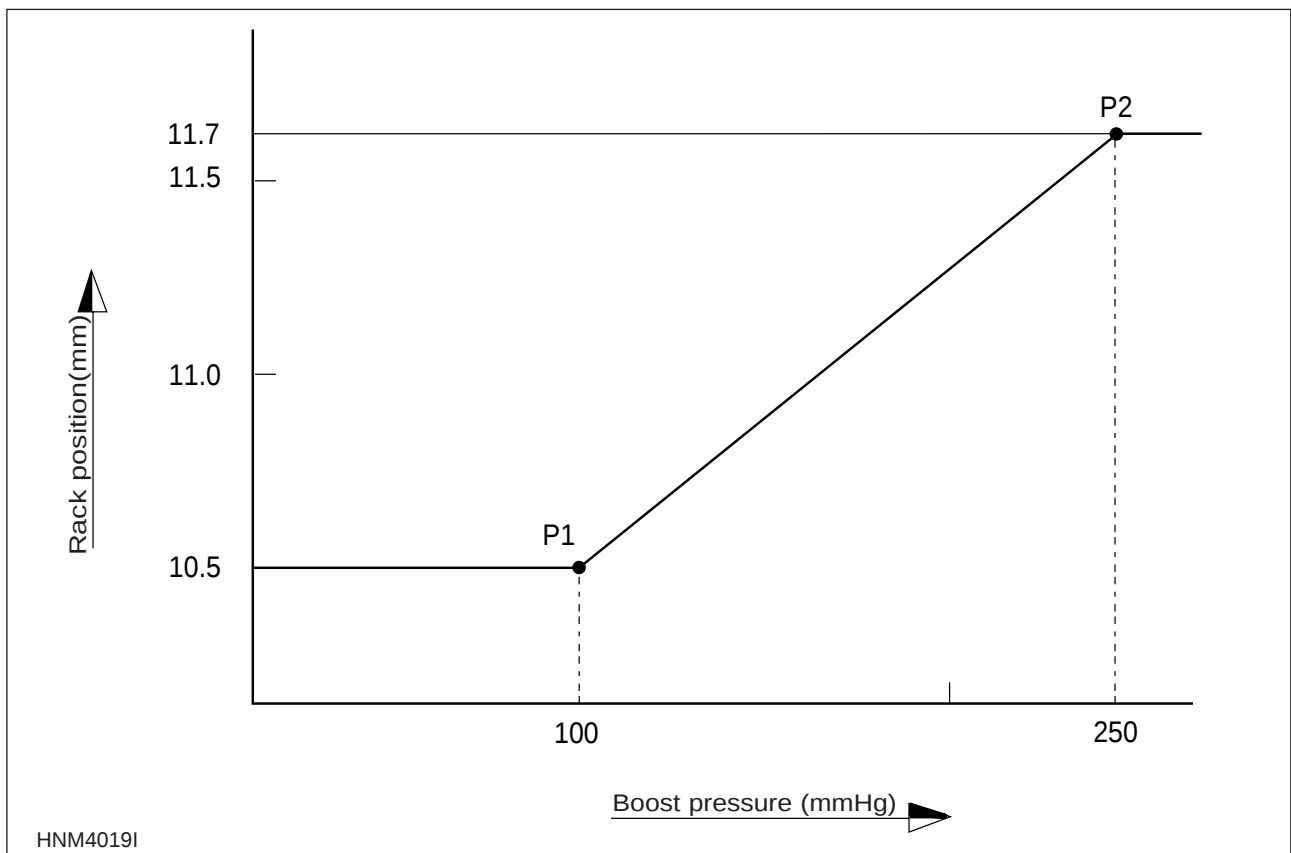
Adjusting point	Rack position	Pump speed(rpm)	Injection volume (mm ³ /1,000st)	Variation rate (%)	Pressure
P ₁	10.5	500	-	-	100
P ₂	11.7	500	-	-	250

Adjusting point	Contents	Specification	Engine application
	Nozzle holder ass'y		65.10101-7293
	Nozzle		65.10102-6032
	Nozzle holder		
	Opening pressure	175 kg/cm ²	214+8 kg/cm ²
	Injection pipe	$\phi 6.0 \times \phi 2.0$ -600 mm	
	Fuel delivery pressure		
	Fuel temperature	$40 \pm 5^\circ\text{C}$	

(4) Adjusting Governor



(5) B-COM Calibration



4.3.4. Diagnostics and Troubleshooting

Complaints	Possible Causes	Corrections
1. Engine won't start		
1) Fuel not being pumped out from feed pump	(1) Fuel pipes clogged or air into pipe line (2) Feed pump valve defective (3) Feed pump piston or push rod sticking	Correct Replace Disassemble, correct
2) Fuel not being injected from injection pump	(1) Fuel filter element restricted (2) Air in fuel filter or injection pump (3) Plunger and/or delivery valve sticking or defective	Clean Bleed Disassemble, correct
3) Fuel injection timing incorrect	(1) Injection pump not properly installed on pump bracket (2) Injection pump tappet incorrectly adjusted (3) Cams on cam shaft worn excessively	Check, correct Check, correct Replace
4) Injection nozzles inoperative	(1) Needle valves sticking (2) Fuel leaking past clearance between nozzle and needle valve (3) Injection pressure incorrect	Correct or replace Correct or replace Adjust
2. Engine starts but stalls immediately	(1) Pipe from feed pump to injection pump clogged or filter clogged (2) Air in fuel (3) Feed pump delivery insufficient (4) Fuel delivery insufficient due to clogging of fuel tank air breather	Clean Bleed Disassemble, correct Replace breather
3. Engine lacks power	(1) Plunger worn excessively (2) Injection timing incorrect (3) Delivery valves defective (4) Nozzle leaks excessively (5) Nozzle not working normally	Replace Adjust Replace Correct or replace Disassemble, correct
4. Engine knocking	(1) Injection timing too fast (2) Nozzle injection pressure too high (3) Nozzles not working normally	Adjust Adjust Disassemble, correct

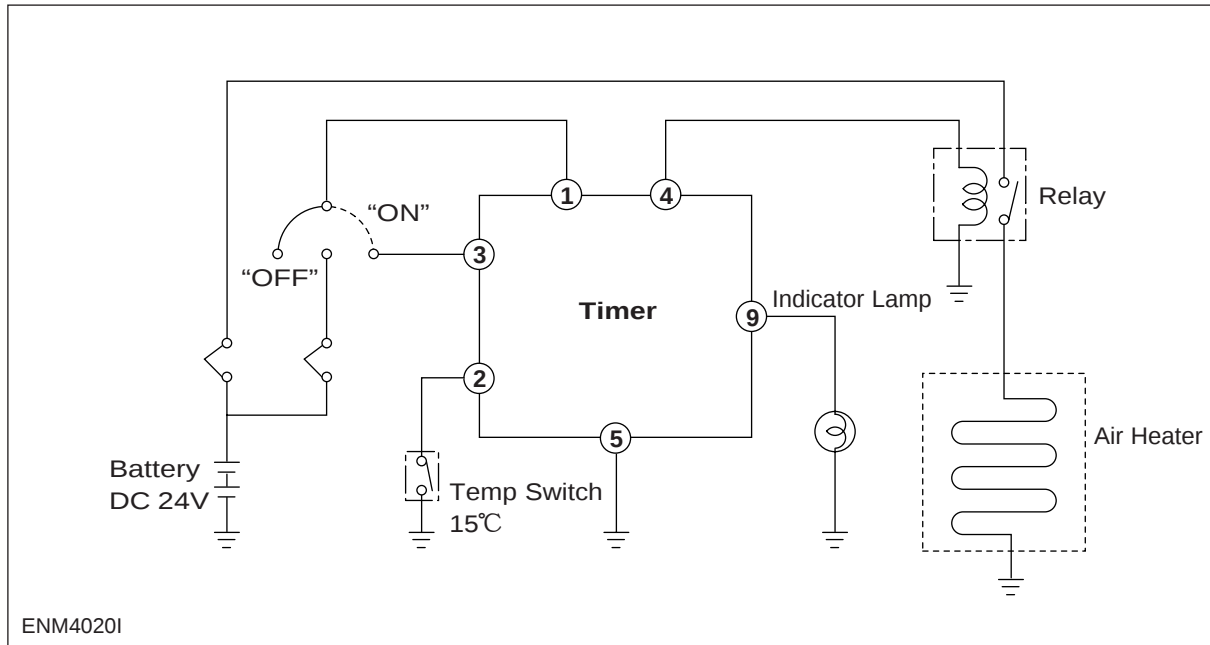
Complaints	Possible Causes	Corrections
5. Engine knocks seriously producing excessive exhaust smoke	(1) Injection timing incorrect (2) Nozzle injection pressure too low (3) Nozzle spring broken (4) Nozzle not working normally (5) Plungers worn excessively (6) Delivery valves seat defective (7) Supply of fuel excessively	Adjust Adjust Replace Replace Adjust Replace Check feed pump
6. Engine output unstable	(1) Supply of fuel insufficient (2) Air in fuel (3) Water in fuel (4) Operation of plungers unsmooth (5) Movement of control rack sluggish (6) Nozzles defective (7) Injection starting pressure of each barrel incorrect (8) Automatic timer defective	Check feed pump Bleed Replace fuel Disassemble, correct Disassemble, correct Disassemble, correct Adjust Disassemble, correct Disassemble, correct
7. Engine does not reach maximum speed	(1) Nozzles not working normally (2) Governor defective	Disassemble, correct Disassemble, correct
8. Engine idling unstable	(1) Movement of control rod sluggish (2) Operation of plungers unsmooth (3) Control pinions not engaged with control rod correctly	Disassemble, correct Disassemble, correct

4.4. Preheating system

4.4.1. General Description and Construction

When temperature of intake air is low or Engine is cold, temperature of compressed air is not sufficiently high, making it difficult for the Engine to start up.

As a auxiliary device of the Engine, Preheating system is introduced to ease Engine starting, which preheats intake air.



<Fig.1> Circuit Diagram of Preheating System

4.4.2. Key Switch

- 1) Step 1 : After Turning the key switch from "OFF" to "ON" position, check to see whether the preheating lamp is on or off.

If the lamp is on, wait until it turns off.

(Mechanism) : The heater is automatically preheated if temperature of Engine is low, and the lamp turns off about 20 seconds after its on.

When temperature of Engine is sufficiently high, the heater is not being preheated.

- 2) Step 2 : Turn the key switch from "ON" to "START" position on condition that the preheating lamp be off.

(Mechanism) : The heater is still heated for about 30 seconds even after Engine start, which function is for perfect fuel combustion.

4.5. Turbo Charge

4.5.1. General Descriptions

The engine output is determined by the fuel delivery volume and engine efficiency.

To burn the supplied fuel completely to change it into effective power for the engine, the volume of air enough to burn the fuel completely should be supplied into the cylinders.

Therefore, the engine output is determined substantially by the cylinder capacity, and the greater volume of compressed air is charged into the cylinders of given capacity, the greater engine output can be obtained as a greater volume of air charged into the cylinders burns so much more fuel.

As explained, the compressing of air to supply into the cylinders is called "Supercharging" and the making use of the energy of exhaust gas discharged from the combustion chamber to charge the compressed air into the cylinders is called "Turbocharging".

4.5.2. Functions

1) Turbine

Exhaust gas discharged from the combustion chamber distributes its own energy to the turbine blades while passing the inside of the turbine housing, with the result that the turbine shaft can get rotating force. This is the working principle of 'turbine', which is mounted with seal rings and heat protector to prevent exhaust gas from affecting the bearings adversely.

2) Compressor

The compressor, which is connected to the turbine over the one and same shaft to form a rotating body, takes in and compresses ambient air with rotating force transmitted from the turbine shaft. Then, the compressed air is delivered to the intake pipe. This is the working principle of the compressor.

3) Bearings

(1) Thrust Bearing

The turbine wheel creates thrust force. Therefore, exercise care so that the shaft is not deviated from its original position due to this thrust.

(2) Journal Bearing

This journal bearing of floating type forms a dual oil film on both the inside and outside of the bearing so that the bearing can rotate independently. As the dual oil film plays a role as a damper, the sliding speed of the bearing surface becomes lower than the rotating speed of the shaft, resulting in assurance of stability in its movement.

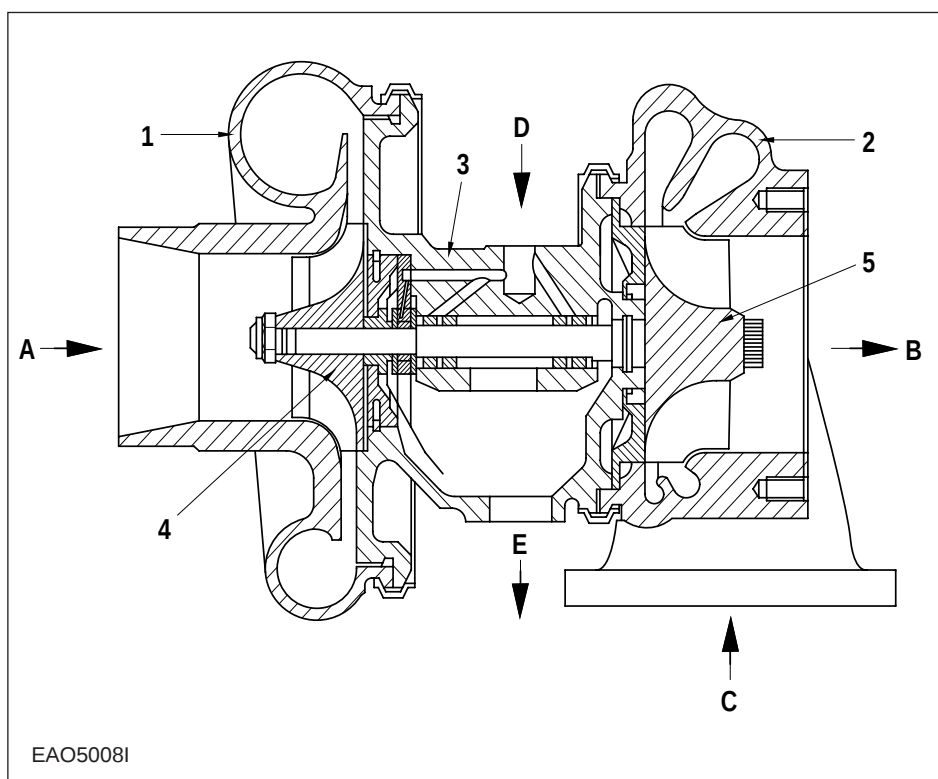
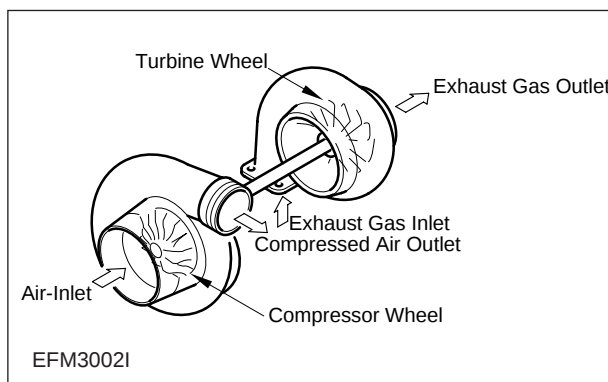
4) Sealing-Compressor Shaft

The compressor is of a dual construction type composed of seal plate and seal ring to prevent the leak of compressed air or lubricating oil.

4.5.3. Specification

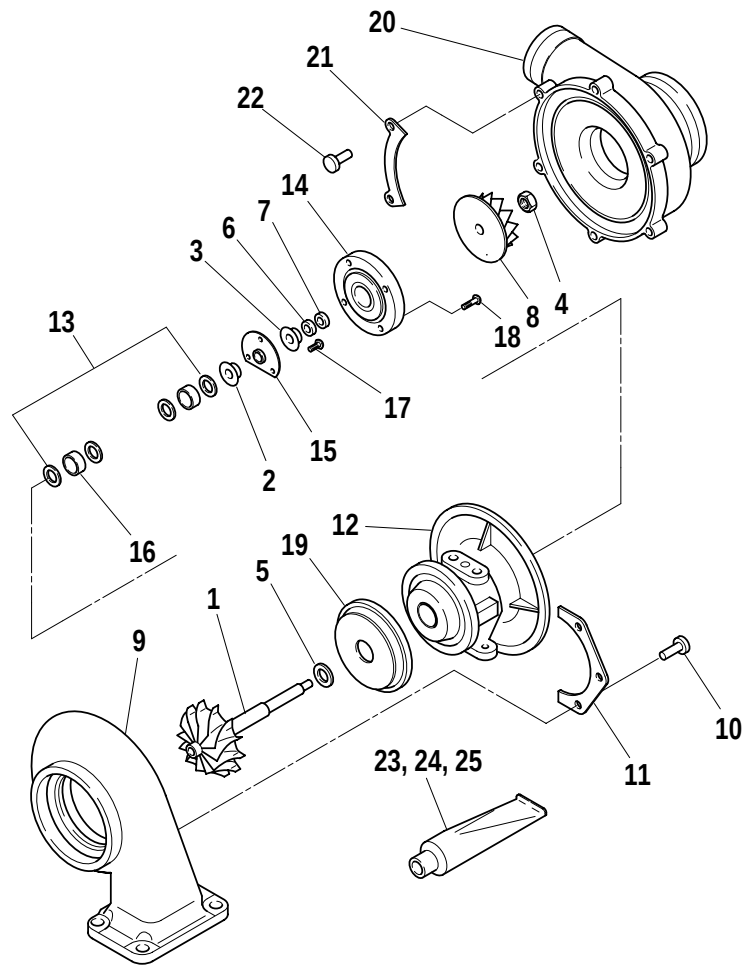
Item		Specifications
Type		1300VQ32NF BRL 557A
At maximum output	Air pressure (at compressor outlet)	Approx. 1,23kg/cm ² gauge
	Air suction volumetric speed	Approx. 13.6m ³ /min
	Turbine revolution	Approx. 110,000 rpm
Maximum speed (allowable)		120,000 rpm
Maximum temperature of exhaust gas at turbine inlet (allowable)		750°C
Lubrication system		External oil supply
Weight		10 kg

4.5.4. Working Mechanism



1. Compressor Housing
2. Turbine Housing
3. Bearing Housing
4. Compressor
5. Turbine
- A. Air Inlet
- B. Exhaust Gas Outlet
- C. Exhaust Gas Inlet
- D. Oil Inlet
- E. Oil Outlet

4.5.5. Construction



EAM3002I

No	Part	No	Part
1	Shaft & Turbine Wheel Ass'y	14	Seal Plate
2	Thrust Bush	15	Thrust Bearing
3	Oil Thrower	16	Journal Bearing
4	Lock Nut	17	Screw
5	Seal Ring; Turbine Side	18	Screw
6	Seal Ring; Large	19	Heat Protector
7	Seal Ring; Small	20	Compressor Housing
8	Compressor Wheel	21	Clamp
9	Turbine Housing	22	Bolt
10	Bolt	23	Liquid Gasket
11	Clamp	24	Loctite
12	Bearing Housing	25	Anti-seize Sealing Liquid
13	Retaining Ring		

5. Maintenance Specifications

5.1. Torque Values

5.1.1. Major Part Torque Values

Part	Dia.×Pitch(mm)	Grade	Torque Value	Remarks
Cylinder Head Bolt	M14×1.5	12.9X	24.5	
Conn. Rod Bearing Cap Bolt	M14×1.5	12.9X	18	
Crankshaft Main Bearing Cap Bolt	M16×1.5	12.9X	30	
Balance Weight Fixing Bolt	M12×1.5	10.9X	10	
Flywheel Fixing Bolt	M14×1.5	10.9X	21.5	
Crankshaft Gear Fixing Bolt	M12×1.5	10.9X	13	

5.1.2. Injection Pump System

- 1) Injection pump delivery valve holder : 2.5 ~ 3kg ·m
- 2) Nozzle holder fixing cap nut : 7kg ·m
- 3) Nozzle fixing cap nut : 6~8kg ·m
- 4) High pressure injection pipe fixing cap nut : Max. 2.9 ~ 3.2kg ·m

5.1.3. Standard Torque Value Table

Refer to the following table for bolts other than described above.

Diameter × pitch (mm)	Degree of Strength										
	3.6	4.6	4.8	5.6	5.8	6.6	6.8	6.9	8.8	10.9	12.9
	(4A)	(4D)	(4S)	(5D)	(5S)	(6D)	(6S)	(6G)	(8G)	(10K)	(12K)
	Limit Value for Elasticity (kg/mm ²)										
	20	24	32	30	40	36	48	54	64	90	108
	Torque Value(kg•m)										
M5	0.15	0.16	0.25	0.22	0.31	0.28	0.43	0.48	0.50	0.75	0.90
M6	0.28	0.30	0.45	0.40	0.55	0.47	0.77	0.85	0.90	1.25	1.50
M7	0.43	0.46	0.70	0.63	0.83	0.78	1.20	1.30	1.40	1.95	2.35
M8	0.70	0.75	1.10	1.00	1.40	1.25	1.90	2.10	2.20	3.10	3.80
M8×1	0.73	0.80	1.20	1.10	1.50	1.34	2.10	2.30	2.40	3.35	4.10
M10	1.35	1.40	2.20	1.90	2.70	2.35	3.70	4.20	4.40	6.20	7.40
M10×1	1.50	1.60	2.50	2.10	3.10	2.80	4.30	4.90	5.00	7.00	8.40
M12	2.40	2.50	3.70	3.30	4.70	4.20	6.30	7.20	7.50	10.50	12.50
M12×1.5	2.55	2.70	4.00	3.50	5.00	4.60	6.80	7.70	8.00	11.20	13.40
M14	3.70	3.90	6.00	5.20	7.50	7.00	10.00	11.50	12.00	17.00	20.00
M14×1.5	4.10	4.30	6.60	5.70	8.30	7.50	11.10	12.50	13.00	18.50	22.00
M16	5.60	6.00	9.00	8.00	11.50	10.50	15.50	17.90	18.50	26.00	31.00
M6×1.5	6.20	6.50	9.70	8.60	12.50	11.30	17.00	19.50	20.00	28.00	33.50
M18	7.80	8.30	12.50	11.00	16.00	14.50	21.00	24.20	25.00	36.00	43.00
M18×1.5	9.10	9.50	14.50	12.50	18.50	16.70	24.50	27.50	28.50	41.00	49.00
M20	11.50	12.00	18.00	16.00	22.00	19.00	31.50	35.00	36.00	51.00	60.00
M20×1.5	12.80	13.50	20.50	18.00	25.00	22.50	35.00	39.50	41.00	58.00	68.00
M22	15.50	16.00	24.50	21.00	30.00	26.00	42.00	46.00	49.00	67.00	75.00
M22×1.5	17.00	18.50	28.00	24.00	34.00	29.00	47.00	52.00	56.00	75.00	85.00
M24	20.50	21.50	33.00	27.00	40.00	34.00	55.00	58.00	63.00	82.00	92.00
M24×1.5	23.00	25.00	37.00	31.00	45.00	38.00	61.00	67.00	74.00	93.00	103.00

Others:

1. The above torque ratings have been determined to 70% or so of the limit value for bolt elasticity.
2. Tension is calculated by multiplying tensile strength by cross section of thread.
3. Special screws should be tightened to 85% or so of the standard value.

For example, a screw coated with MOS2 should be tightened to 60% or so of the standard value.

5.2. Maintenance Specification Table

Division	Part Name	Inspected Item	Nominal Value	Standard Value for Assembly	Limit for Use	Repairing Pointer	Remarks
Engine Body	Cylinder Block	Inner dia. of liner for wear	φ111	φ111 ~ 111.022	φ111.122	Replace liner	Measure unworn portion beneath the rim of the upper side
		Amount of liner projection		0.03~0.08		Must exist	Projection difference between adjacent liners : 0.15 ↓
	Cylinder Head	The flatness of upper surface of cyl. block		0.05	0.05	Correct with a surface grinder	Referenced length : 200mm
		Hydraulic test for 1 minute (kg/cm ²)		4		Replace if leaky	
		Thickness of cyl. head gasket		1.4 1.2		Check torque value or replace gasket	Torque value for cyl. head bolt : 24.5 kg-m
Major Moving Parts	Piston	Cam height	110	109.9 ~ 110.1	108.4	Replace cyl. head	
		Hydraulic test for 1 minute (kg/cm ²)		4		Replace if leaky	
		Outer dia. of piston		φ110.801 ~ 110.959		Replace liner	Measure at 13mm away from lower surface of piston
		Clearance between piston and liner		0.041~0.221	0.3	Replace one worn more	
		Width of piston ring grooves		3.50 3.06~3.08 4.04~4.06		Replace piston if groove width is beyond specified value	
	Piston Ring	Piston projection from cylinder block upper surface		0~0.12		Must exist	Measure unworn portion beneath the rim of the upper side
		1st ring		0.40~0.65	1.5	Replace ring	Standard gauge inside diameter : φ108
		2nd ring		0.40~0.65	1.5		
		Oil ring		0.30~0.60	1.5		
		Weight difference of pistons		96g ↓		Replace piston	
		Piston ring side clearance		- 0.07~0.102 0.05~0.085	- 0.15 0.15	Replace ring or piston	Limit for use is for standard clearance
Piston Pin	Piston Pin	Direction of ring gap				Cross install by 120°	
		Outer diameter of piston pin	φ42	φ41.994~42		Replace piston pin	
		Clearance between piston pin and its bush		0.009~0.015		Replace one worn more	

Division	Part Name	Check Items	Nominal Value	Standard Value for Assembly	Limit for Use	Correction	Remarks
Major Moving Parts	Crank Shaft	Radial run-out of journal & pin			0.01	Correct with a grinder	Measure in horizontal and vertical direction (against axial direction)
		Diameter of journal	φ84	φ83.966~83.988	φ83	Use under-sized bearings respectively (0.25, 0.5, 0.75, 1.0)	
		Diameter of pin	φ71	φ70.971~70.990	φ70		
		Ellipticity of journal & pin		0.008			
		Concentricity of journal & pin		0.010			
		Taper of journal & pin		0.010			
		Clearance between crank shaft & bearing		0.052~0.122	0.25	Replace bearing	Measure at crown part not parting line
		End play of crank shaft		0.15~0.325	0.5	Replace thrust bearing	
		Run-out of crank shaft		0.14		Adjust by a press if bended	Measure at No. 4 bearing (No. 1&7 bearing supported)
		Balance of crank shaft (g·cm)		60		Check dynamic balance	Measure at 400 rpm
	Con-Rod	Torque value journal bearing cap bolt (kg·m)		30		Coat the bolt with engine oil	Clean out foreign objects on joining surface
		Crush of journal bearing		0.19~0.22			Measure after tightening metal cap and releasing one stud
		Oil seal for wear (crank shaft rear)				Replace oil seal if oil leaking	
		End play of con-rod		0.170~0.248	0.50	Replace con-rod	
		Clearance between con-rod bearing & crank pin		0.034~0.098	0.25	Replace bearing	
		Clearance between small end bush & piston pin		0.050~0.081			Measure after installing the bearing and releasing one bolt
		Crush of con-rod		0.30~0.50			
		Side clearance of big-end & small-end					
		Allowable weight difference per con-rods		56g↓		Replace con-rod	
		Torque value of con-rod bearing cap bolt (kg·m)		18	0.50	Coat the bolt with engine oil	Clean out foreign objects on joining surface
Timing Gear	Cam Shaft	Diameter of cam shaft journal		φ57.86~57.88			
		Clearance between cam shaft & cam bush		0.12~0.17	0.24	Replace cam bush	
		End play of cam shaft		0.28~0.43	0.6	Replace thrust washer	
		Run out of cam shaft			0.1	Correct or replace the cam shaft	
		Clearance between idle shaft bush & idle shaft		0.025~0.091	0.15		
		End play of idle gear shaft		0.043~0.167	0.30	Replace thrust collar	
		Back-lash between gears (cam, idle, crank and injection)		0.16~0.28	0.35	Correct or replace gear	

Division	Part Name	Inspected Item		Nominal Value	Standard Value for Assembly	Limit for Use	Repairing Pointer	Remarks
Valve System	Valve	Diameter of intake valve stem		φ9	φ8.950~8.970	φ8.93	Replace valve & valve guide	When replacing valve, replace valve guide alike
		Diameter of exhaust valve stem		φ9	φ8.935~8.955	φ8.91		
		Clearance between valve stem and valve guide	Intake		0.030~0.065	0.15	Replace valve or valve guide	Replace one worn more.
			Exhaust		0.045~0.080	0.15		
		Thickness of valve head	Intake	2.2		1 or more	Replace valve	
			Exhaust	2.2		1 or more		
		Valve seat depression	Intake	-	0~0.3		Replace valve seat	
			Exhaust	-	0~0.3			
		Clearance between valve guide & cyl. head installing hole				0.03		Spread oil over valve guide and press it into the hole
		Concentricity between valve stem & valve head			0.01~0.39			Without spring seat
		Clearance between valve guide & valve spring seat	Intake		26		Replace valve spring	
			Exhaust		26			
		Intake valve spring	Free length		Approx. 64		Replace valve spring	
			Tension force (when pressed to 41 mm)	70	66.5~73.5	66.5		
		Exhaust valve spring	Straightness (along free length direction)			1.0	Replace valve spring	
			Inner		Approx. 60			
		Exhaust valve spring	Outer		27.2~30.0	26.2	Replace valve spring	
			Straightness (along free length direction)			1.0		
		Valve clearance (at cold)			Approx. 71		Adjust	
		Joining surfaces of valve stem & rocker arm	Intake		0.30			
			Exhaust		0.30		Grind or replace if severely pitted on tip of rocker arm and stem	
		Clearance between rocker arm shaft & rocker arm bush			0.020~0.093			
		Diameter of rocker arm shaft for wear		φ24		φ23.75	Replace	
		Run out of push rod				0.3	Replace	

Division	Part Name	Inspected Item	Nominal Value	Standard Value for Assembly	Limit for Use	Repairing Pointer	Remarks
Lubricating System	Tappet	Clearance between tappet & tappet hole of cyl. block		0.035~0.077	0.1	Replace tappet	
		Diameter of tappet	φ20	φ19.944~19.965		Replace tappet	
		Tappet face in contact with cam	-	-	-	Replace/Replace if severely worn or deformed	
	Oil Pressure	Oil pressure(at nominal speed) (kg/cm ²)	-	4.8↓		Check oil leakage and clearance between each part	
		Oil pressure(at idling speed) (kg/cm ²)		0.8~1.4	0.6	Use recommended oil	
	Oil Temp	Max. oil temp (°C)	-	-	90		Must not exceed this value
		Short term peak oil temp (°C)	-	-	100		
	Oil Pump	Axial play of oil pump gear		0.055~0.105	-	Replace gear or cover	
		Clearance between gear shaft & oil pump cover hole		0.032~0.077		Replace gear shaft or cover	
		Clearance between driving gear bush & cover hole	-	0.040~0.094	-	Replace bush or cover	
		Diameter of gear shaft	φ17e7	φ16.950~16.968	φ16.950	Replace gear shaft	
		Diameter of driving gear bush	φ28e8	φ27.939~27.960	φ27.939	Replace bush	
		Back lash	-	0.15~0.25	0.8	Adjust back-lash	
			-	0.15~0.25	0.8		
		Oil pressure control valve kg/cm ²	-	4.0~4.8	-	Replace valve	
	Valve Opening Pressure	By-pass valve for filter element kg/cm ²		1.8~2.3	-	Replace valve	
		By-pass valve for full oil filter kg/cm ²	-	4.0~4.8	-	Replace valve	
		Relief valve for oil pump kg/cm ²	-	8.5~11.5	-	Replace valve	
		Spray nozzle control valve kg/cm ²	-	1.5~1.3	-	Replace valve	
	Oil Filter	Damage of oil filter element				Clean or replace	

Division	Part Name	Inspected Item	Nominal Value	Standard Value for Assembly	Limit for Use	Repairing Pointer	Remarks		
Cooling System	Water Pump	Dilivery(ℓ /min) pump speed 2000rpm water temp. 80 negative pressure 0.5 bar		Approx. 190		Check the water passage	For any restrictions		
		Clearance between impeller & housing		0.35		Replace if impeller & housing are intact			
		Perpendicularity of pulley		0.3		Adjust by a bench press			
		Fan belt depression (with thumb)		Approx. 15		Adjust			
	Cooling Water Temp.	Operating temp $^{\circ}\text{C}$		80~85	95	must not exceed this value			
		short term peak temp $^{\circ}\text{C}$		105					
	Thermostat	Initiating temp. (1 atm) $^{\circ}\text{C}$		71	-	Replace			
		Full opening temp $^{\circ}\text{C}$		86 or less	-	Replace if defective stroke : minimum 8 mm	At normal operating temp, over 200 rpm		
	Fuel System	Compression Pressure	Cylinder compression pressure kg/cm^2		28	24	Overhaul the engine		
			Fuel pipe, injection pipe & nozzle holder for damage, crack, improper packing, etc.				Repair or replace		
Piping & Others		Fuel filter element for damage or dimple				Replace fuel filter			
		Opening pressure of overflow valve kg/cm^2		1~1.5		Replace valve			
Projection height of nozzle from the head surface				3.6~4.1		Replace cyl.head & nozzle			
		Rotor	Shaft run-out			0.1	Replace rotor		
Electrical Devices		AC Alternator	Slip ring face for fouling	Bearing noise			Replace bearing		
							Correct by sand paper		
			Brush	Brush & its spring	14		7	Correct or replace if defective	
				Tension force g	300	255~345			
	Performance	Unload speed rpm	28V		950 $\downarrow$				
		Output speed rpm	28V, 40A		5000 $\uparrow$				
Voltage Regulator	Performance	Regulated voltage V		27.5~29.5		Correct if terminal point is defective			
		Field relay cut-in voltate V		8~12					

Division	Part Name	Inspected Item		Nominal Value	Standard Value for Assembly	Limit for Use	Repairing Pointer	Remarks
Electrical Devices	Starter	Bolt tightening for loose					Correct	
		Armature	Shaft run-out	φ14		0.1↓		
			Front bearing	φ14		0.1		
			Center bearing	φ20.4		0.1		
			Pinion bearing	φ14		0.1		
		Diameter of commutator		φ48		φ45	Replace	
		Commutator	Out of round of commutator		0.05↓	0.4↓	Correct	
			Depth from undercut insulator to surface of commutator		0.5~0.8	0.2↓	Correct	
			Surface of commutator				Correct by sand paper if fouled or damaged	
		Brush	Brush and spring	19.5	1300	12.5	Correct or replace if •Surface of commutator is defective •Spring force or strength is improper •Brush is severely damaged or worn •Contact between brush & brush holder is improper	
			Operating voltage	-	16	-		
			Holding voltage	-	8	-		
		Pinion stroke		22	22~23	+1↓	Correct or replace if severely worn or damaged	
		Gap between pinion and ring gear			3~5			
		Performance	Unload speed		4000 ↑	105		when 24V, 79A ↓
			Load torque		1.5	-	Replace	when 390A ↓
			Constrained torque		3.3 ↑	-		when 750A ↓

Division	Part Name	Inspected Item	Nominal Value	Standard Value for Assembly	Limit for Use	Repairing Pointer	Remarks
Electrical Devices		Battery terminal				Replace if affected by rust or corrosion	
		Pole plate, separator, cell, etc.				Correct if found to be defective	
		Electrolyte for muddiness					
		Specific gravity of electrolyte		1.12~1.28	1.200	Adjust specific gravity	Temp conversion coefficient (based on 20°C) Every extra +1°C : -0.007 Every extra -°C : +0.003
		Capacity (20 hrs rate) V-AH		24-65×2			
		Terminal voltage		12.6 ↑	10.8 ↑	Recharging	
		Height of electrolyte level		Specified level		Replenish distilled water if low level	
	Charging Indication	Warning lamp				Correct electrical devices if abnormal noise	
	Wiring	The terminal of electrical wire for loosening or short				Correct	
	Running-in engine					Authorized agency (KR, KF...)	Retighten head bolt after running in
Inspection at Completion	Compression pressure of cylinder	kg/cm ²		24~28	24	Correct	at 200 rpm ↑
	Compression pressure difference of each cylinder			10% ↓ against average		Correct	at 200 rpm, 20°C
	Oil pressure	kg/cm ²		3~4.8		Adjust	
	Test of output			Continuous max. output			Values for brand-new engine are referred to as 100%
	Fuel consumption			105% ↓			
	Idling speed	rpm		650~750		Adjust	