

Operation & Maintenance Manual

DIESEL GENERATOR, POWER UNIT ENGINE

**P158LE, P180LE, P222LE,
PU158TI, PU180TI, PU222TI**
















FOREWORD

This manual is designed to serve as an instruction for Diesel generator engine and Power Unit engine of HD Construction Equipment series (P158LE /P180LE /P222LE, PU158TI/ PU180TI/ PU222TI).

The engines are 4 strokes, 2 valves per cylinder, V-type, and direct injection mode and thus, are also satisfying with various features required as generator and power unit engine such as quiet operation, economical fuel consumption, durability in high speed operation and so forth.

We are very confident that these engine series are quite superior to any high speed engines in economy and efficiency. However, high performance and long life cycle will be accomplished when a proper handling and administration of periodic inspections and maintenance should be observed. Readers are desired to know for your reference that those kinds of maintenance matters are explained here in detail by means of figures and diagrams.

In this manual, the following symbols are used to indicate the type of service operations to be performed.

	Removal		Adjustment
	Installation		Cleaning
	Disassembly		Pay close attention-Important
	Reassembly		Tighten to specified torque
	Align the marks		Use special tools of manufacturer's
	Directional Indication		Lubricate with oil
	Inspection		Lubricate with grease
	Measurement		

If you have any question or recommendation in connection with this manual, please do not hesitate to contact our head office, dealers or authorized service shops near by your location for any services.

For the last, the contents of this instruction manual may be changed without prior notice for some quality improvement.

Thank you.

2026. 02.

950106-036017EN

HD Construction Equipment

* Items exempted from warranty coverage

- Malfunctions resulting from failing to comply with the proper handling instructions, regular inspections, and machine storage techniques specified in the user manual
- Malfunctions resulting from failing to have the machine repaired at a designated dealer or center, or resulting from the use of non-genuine parts
- Malfunctions resulting from unauthorized modifications, changes, or external hardware
- Malfunctions resulting from incorrect operation by the user, delayed repairs, accidents, and natural disasters

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1. Safety Regulations & Engine Specifications

1.1. Safety Regulations

1.1.1. General notes

Handling diesel engines and the necessary resources is no problem when the personnel commissioned with operation and maintenance are trained accordingly and use their common sense.

This summary is a compilation of the most important regulations, These are broken down into main sections which contain the information necessary for preventing injury to persons, damage to property and pollution. In addition to these regulations those dictated by the type of engine and its site are to be observed also.



IMPORTANT :

If despite all precautions, an accident occurs, in particular through contact with caustic acids, fuel penetrating the skin, scalding from oil, antifreeze being splashed in the eyes etc, consult a doctor immediately.

1.1.2. Regulations designed to prevent accidents

1) During commissioning, starting and operation

- Before putting the engine into operation for the first time, read the operating instructions carefully and familiarize yourself with the “critical” points, If you are unsure, ask your DHI representative.
- For reasons of safety we recommend you attach a notice to the door of the engine room prohibiting the access of unauthorized persons and that you draw the attention of the operating personal to the fact that they are responsible for the safety of persons who enter the engine room.
- The engine must be started and operated only by authorized personnel. Ensure that the engine cannot be started by unauthorized persons.
- When the engine is running, do not get too close to the rotating parts. Wear close-fitting clothing.
- Do not touch the engine with bare hands when it is warm from operation risk of burns.
- Exhaust gases are toxic. Comply with the instructions for the installation of DHI Diesel engines which are to be operated in enclosed spaces. Ensure that there is adequate ventilation and air extraction.
- Keep vicinity of engine, ladders and stairways free of oil and grease. Accidents caused by slipping can have serious consequences.

2) During maintenance and care

- Always carry out maintenance work when the engine is switched off. If the engine has to be maintained while it is running, e.g. changing the elements of change-over filters, remember that there is a risk of scalding. Do not get too close to rotating parts.
- Change the oil when the engine is warm from operation.



CAUTION :

There is a risk of burns and scalding. Do not touch oil drain plug or oil filters with bare hands.

- Take into account the amount of oil in the sump. Use a vessel of sufficient size to ensure that the oil will not overflow.

- Open the coolant circuit only when the engine has cooled down. If opening while the engine is still warm is unavoidable, comply with the instructions in the chapter “Maintenance and Care”.
- Neither tighten up nor open pipes and hoses (lube oil circuit, coolant circuit and any additional hydraulic oil circuit) during the operation. The fluids which flow out can cause injury.
- Fuel is inflammable. Do not smoke or use naked lights in its vicinity. The tank must be filled only when the engine is switched off.
- When using compressed air, e.g. for cleaning the radiator, wear goggles.
- Keep service products (anti-freeze) only in containers which can not be confused with drinks containers.
- Comply with the manufacturer’s instructions when handling batteries.



CAUTION :

Accumulator acid is toxic and caustic. Battery gases are explosive.

3) When carrying out checking, setting and repair work

- Checking, setting and repair work must be carried out by authorized personnel only.
- Use only tools which are in satisfactory condition. Worn open-end wrench slip. which could lead to Injury.
- When the engine is hanging on a crane, no-one must be allowed to stand or pass under it. Keep lifting gear in good condition.
- When working on parts which contain asbestos, comply with the notes at the end of this chapter.
- When checking injectors do not put your hands under the jet of fuel. Do not inhale atomized fuel.
- When working on the electrical system disconnect the battery earth cable first. Connect it up again last in prevent short circuits.

1.1.3. Regulations designed to prevent damage to engine and premature wear

- 1) Never demand more of the engine than it was designed to yield for its intended purpose.
 - Detailed information on this can be found in the sales literature. The injection pump must not be adjusted without prior written permission of DHI.
- 2) If faults occur, find the cause immediately and have it eliminated in order to prevent more serious of damage.
- 3) Use only genuine DHI spare parts. DHI will accept no responsibility for damage resulting from the installation of other parts which are supposedly “just as good”.
- 4) In addition to the above, note the following points.
 - Never let the engine run when dry, i.e. without lube oil or coolant.
 - Use only DHI-approved service products (engine oil , anti-freeze and anticorrosion agent).
 - Pay attention to cleanliness. The Diesel fuel must be free of water. See “Maintenance and care”.
 - Have the engine maintained at the specified intervals.
 - Do not switch off the engine immediately when it is warm, but let it run without load for about 5 minutes so that temperature equalization can take place.
 - Never put cold coolant into an overheated engine. See “Maintenance and care”.
 - Do not add so much engine oil that the oil level rises above the max. marking on the dipstick. Do not exceed the maximum permissible tilt of the engine. Serious damage to the engine may result if these instructions are not adhered to.
 - Always ensure that the testing and monitoring equipment (for battery charge, oil pressure, coolant temperature) function satisfactorily.
 - Comply with instructions for operation of the alternator. See “Commissioning and operation”.

- Do not let the raw water pump run dry, If there is a risk of frost, drain the pump when the engine is switched off.



CAUTION :

Do not spray high-pressure water directly on the engine. It may damage engine parts, electronic parts, and wiring.

- 5) Keep no-load operation to a minimum. During no-load operation combustion chamber temperatures drop to the point where fuel does not burn completely, causing slobbering and white smoke. Always have some load connected when the gen set is run for long periods.

1.1.4. Regulations designed to prevent pollution

1) Engine oil, filter elements, fuel filters

- Take old oil only to an oil collection point.
- Take strict precautions to ensure that oil does not get into the drains or into the ground. The drinking water supply could be contaminated.
- Filter elements are classed as dangerous waste and must be treated as such.

2) Coolant

- Treat undiluted anti-corrosion agent and / or antifreeze as dangerous waste.
- When disposing of spent coolant comply with the regulations of the relevant local authorities.

3) Cold Start

- The preheat lamp turns on when the key switch is set to "ON." When the preheat lamp goes off, proceed as follows. The preheater device activates when the coolant temperature is below 25°C, and the preheating system is automatically adjusted based on the coolant temperature. (The max. preheating time is around 25 seconds) It does not activate when the coolant temperature is over 25°C.



CAUTION :

The engine is equipped with a preheating system for enhancing cold start ability.

- In order to start the engine after the preheat lamp turns off, turn the key switch to the ignition position. When the key switch is turned to the ignition position, the preheater plug or air heater runs continuously to make starting the engine easier and reduce white exhaust gas. If the coolant temperature is over 25°C, it is not necessary to operate the preheater plug or air heater.
- When the engine starts, set the key switch in the ON position. The timer runs for another 5 minutes even after the engine starts to heat the intake air and quickly eliminate white exhaust gas.



CAUTION :

Do not run the start motor for over 10 seconds. If the engine still cannot be started after preheating, wait for 30 seconds and then perform preheating again before the second attempt to start the engine.

1.1.5. Notes on safety in handling used engine oil

Prolonged or repeated contact between the skin and any kind of engine oil decreases the skin.

Drying, irritation or inflammation of the skin may therefore occur. Used engine oil also contains dangerous substances which have caused skin cancer in animal experiments. If the basic rules of hygiene and health and safety at work are observed, health risks are not to the expected as a result of handling used engine oil.



Health precautions :

- Avoid prolonged or repeated skin contact with used engine oil.
- Protect your skin by means of suitable agents (creams etc.) or wear protective gloves.
- Clean skin which has been in contact with engine oil.
 - Wash thoroughly with soap and water, A nailbrush is an effective aid.
 - Certain products make it easier to clean your hands.
 - Do not use petrol, Diesel fuel, gas oil, thinners or solvents as washing agents.
- After washing apply a fatty skin cream to the skin.
- Change oil-soaked clothing and shoes.
- Do not put oily rags into your pockets.



Ensure that used engine oil is disposed of properly.

- Engine oil can endanger the water supply -

For this reason do not let engine oil get into the ground, waterways, the drains or the sewers.

Violations are punishable.

Collect and dispose of used engine oil carefully. For information on collection points please contact the seller, the supplier or the local authorities.

1.1.6. General repair instructions



1. Before performing service operation, disconnect the grounding cable from the battery for reducing the chance of cable damage and burning due to short-circuiting.
2. Use covers for preventing the components from damage or pollution.
3. Engine oil and anti-freeze solution must be handled with reasonable care as they cause paint damage.
4. The use of proper tools and special tools where specified is important to efficient and reliable service operation.
5. Use genuine HD Construction Equipment parts necessarily.
6. Used cotter pins, gaskets, O-rings, oil seals, lock washer and self-lock nuts should be discarded and new ones should be prepared for installation as normal function of the parts can not be maintained if these parts are reused.
7. To facilitate proper and smooth reassemble operation, keep disassembled parts neatly in groups. Keeping fixing bolts and nut separate is very important as they vary in hardness and design depending on position of installation.
8. Clean the parts before inspection or reassembly. Also clean oil ports, etc. using compressed air to make certain they are free from restrictions.
9. Lubricate rotating and sliding faces of parts with oil or grease before installation.
10. When necessary, use a sealer on gaskets to prevent leakage.
11. Carefully observe all specifications for bolts and nuts torques.
12. When service operation is completed, make a final check to be sure service has been done properly.

1.2. Engine Specification

1.2.1. Specification for generator engine

Engine Model		P158LE series	P180LE series	P222LE series
Items				
Engine type		Water-cooled, 4 cycle Vee type Turbo charged & intercooled		
Combustion chamber type		Direct injection type		
Cylinder liner type		Wet type, chromated or casting liner		
Timing gear system		Gear driven type		
No. of piston ring		Compression ring 2, oil ring 1		
No. of cylinder-bore × stroke (mm)		8 – 128 × 142	10 – 128 × 142	12 – 128 × 142
Total piston displacement (cc)		14,618	18,273	21,927
Compression ratio		P158LE/-1/-2, P180LE/-1, P222LE/-1 => 14.9 : 1 P158LE-S/-III, P180LE-S/-II, P222LE-S/-II => 14.2 : 1 P222LE-II(EAYQD) => 13.6 : 1		
Engine dimension (length × width × height) (mm)		1,484 × 1,389 × 1,161.5	1,557 × 1,389 × 1,248	1,717 × 1,389 × 1,288
Engine dry weight (kg)		P158LE/-1/-2 : 950 P158LE-S/-III : 961	P180LE/-1 : 1,175 P180LE-S/-II : 1,188	P222LE/-1 : 1,575 P222LE-S/-II : 1,591
Fuel injection order		1-5-7-2-6-3-4-8	1-6-5-10-2-7-3-8-4-9	1-12-5-8-3-10-6-7-2-11-4-9
Injection pump type		WEIFU in-line P type	BOSCH in-line P type	
Governor type		Electric type		
Injection nozzle type		Multi-hole type (4 holes)		
Fuel injection pressure (kg/cm ²)		285		
Compression pressure (kg/cm ²)		28 (at 200 rpm)		
Valve clearance (at cold)	Intake valve (mm)	0.25 ±0.05		
	Exhaust valve (mm)	0.35 ±0.05		
Intake valve	Open at	24° (B.T.D.C)		
	Close at	36° (A.B.D.C)		
Exhaust valve	Open at	63° (B.B.D.C)		
	Close at	27° (A.T.D.C)		
Lubrication method		Fully forced pressure feed type		
Oil pump type		Gear type		
Oil filter type		Full-flow, cartridge type		
Lubricating oil capacity (max./min.) (lit)		21 / 17	35 / 28	40 / 33
Oil cooler type		Water cooled		
Water pump		Centrifugal type driven by belt		
Cooling Method		Pressurized circulation		
Cooling water capacity (engine only) (lit)		24	27	33
Thermostat type		Wax pallet type (71 ~ 85 °C)		
Alternator voltage – capacity (V – A)		24 – 45		
Starting Motor voltage – output (V – kW)		24 – 7.0		
Battery capacity (V – AH)		24 – 200		

1.2.2. Specification for power unit engine

Engine Model		PU158TI	PU180TI	PU222TI
Items				
Engine type		Water-cooled, 4 cycle Vee type Turbo charged & intercooled		
Combustion chamber type		Direct injection type		
Cylinder liner type		Wet type, chromated or casting liner		
Timing gear system		Gear driven type		
No. of piston ring		Compression ring 2, oil ring 1		
No. of cylinder-bore x stroke	(mm)	8 – 128 x 142	10 – 128 x 142	12 – 128 x 142
Total piston displacement	(cc)	14,618	18,273	21,927
Compression ratio		14.9 : 1		
Engine dimension (length x width x height)	(mm)	1,484 x 1,389 x 1,161.5	1,557 x 1,389 x 1,248	1,717 x 1,389 x 1,288
Engine dry weight	(kg)	950	1,175	1,575
Fuel injection order		1-5-7-2-6-3-4-8	1-6-5-10-2-7-3-8-4-9	1-12-5-8-3-10-6-7-2-11-4-9
Injection pump type		WEIFU in-line P type	BOSCH in-line P type	
Governor type		Mechanical type		
Injection timing		BTDC 16 ±1°	BTDC 18 ±1°	
Injection nozzle type		Multi-hole type (4 holes)		
Fuel injection pressure	(kg/cm ²)	285		
Compression pressure	(kg/cm ²)	28 (at 200 rpm)		
Valve clearance (at cold)	Intake valve (mm)	0.25 ±0.05		
	Exhaust valve (mm)	0.35 ±0.05		
Intake valve	Open at	24° (B.T.D.C)		
	Close at	36° (A.B.D.C)		
Exhaust valve	Open at	63° (B.B.D.C)		
	Close at	27° (A.T.D.C)		
Lubrication method		Pressurized circulation		
Oil pump type		Gear type		
Oil filter type		Full-flow, cartridge type		
Lubricating oil capacity (max./min.)	(lit)	21 / 17	35 / 28	40 / 33
Oil cooler type		Water cooled		
Water pump		Centrifugal type driven by belt		
Cooling Method		Pressurized circulation		
Cooling water capacity (engine only)	(lit)	24	27	33
Thermostat type		Wax pallet type (71 ~ 85 °C)		
Alternator voltage – capacity	(V – A)	24 – 45		
Starting Motor voltage – output	(V – kW)	24 – 7.0		
Battery capacity	(V – AH)	24 – 200		

1.2.3. Engine power for generator

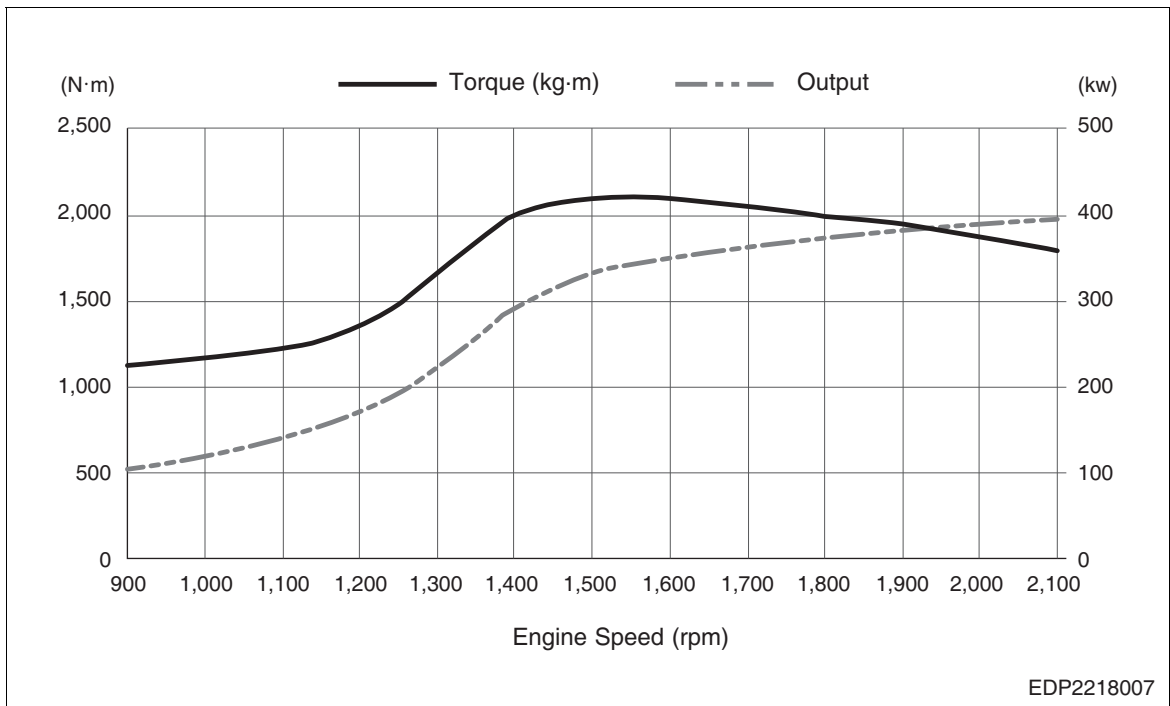
Production tolerance : ±5%

Engine model		Condition			
		HZ	Timing (BTDC)	Prime Output	Stand by Output
P158LE	P158LE-2 (EAZOC/QC)	50 HZ(1,500 rpm)	16	399 PS(293 kW)	437 PS(321 kW)
		60 HZ(1,800 rpm)	16	470 PS(346 kW)	510 PS(375 kW)
	P158LE-1 (EAZOB/QB)	50 HZ(1,500 rpm)	16	444 PS(327 kW)	492 PS(362 kW)
		60 HZ(1,800 rpm)	16	498 PS(366 kW)	546 PS(402 kW)
	P158LE (EAZOA/QA)	50 HZ(1,500 rpm)	16	494 PS(363 kW)	563 PS(414 kW)
		60 HZ(1,800 rpm)	16	547 PS(402 kW)	623 PS(458 kW)
	P158LE-S (EAZOG/H/QG)	50 HZ(1,500 rpm)	12	546 PS(402 kW)	600 PS(441 kW)
60 HZ(1,800 rpm)		16	600 PS(441 kW)	654 PS(481 kW)	
P158LE-III (EAZOF)	60 HZ(1,800 rpm)	16	–	690 PS(508 kW)	
P180LE	P180LE-1 (EASOB/QB)	50 HZ(1,500 rpm)	16	548 PS(403 kW)	601 PS(442 kW)
		60 HZ(1,800 rpm)	16	617 PS(454 kW)	677 PS(498 kW)
	P180LE (EASOA/QA)	50 HZ(1,500 rpm)	16	602 PS(443 kW)	674 PS(496 kW)
		60 HZ(1,800 rpm)	16	676 PS(497 kW)	734 PS(540 kW)
	P180LE-S (EASOE/F/QE)	50 HZ(1,500 rpm)	16	615 PS(452 kW)	674 PS(496 kW)
		60 HZ(1,800 rpm)	16	705 PS(519 kW)	771 PS(567 kW)
P180LE-II (EASOD)	60 HZ(1,800 rpm)	16	–	827 PS(608 kW)	
P222LE	P222LE-1 (EAYOB/QB)	50 HZ(1,500 rpm)	16	696 PS(512 kW)	752 PS(553 kW)
		60 HZ(1,800 rpm)	16	765 PS(563 kW)	850 PS(625 kW)
	P222LE (EAYOA/QA)	50 HZ(1,500 rpm)	16	723 PS(532 kW)	781 PS(574 kW)
		60 HZ(1,800 rpm)	16	803 PS(591 kW)	883 PS(649 kW)
	P222LE (EAYOC)	60 HZ(1,800 rpm)	16	803 PS(591 kW)	898 PS(660 kW)
	P222LE-S (EAYOE/F/QE)	50 HZ(1,500 rpm)	20	750 PS(552 kW)	820 PS(603 kW)
		60 HZ(1,800 rpm)	19	850 PS(625 kW)	927 PS(682 kW)
P222LE-II (EAYOD/QD)	50 HZ(1,500 rpm)	13	–	886 PS(652 kW)	
	60 HZ(1,800 rpm)	19	–	1000 PS(736 kW)	

* Note : All data are based on operation without cooling fan at ISO 3046

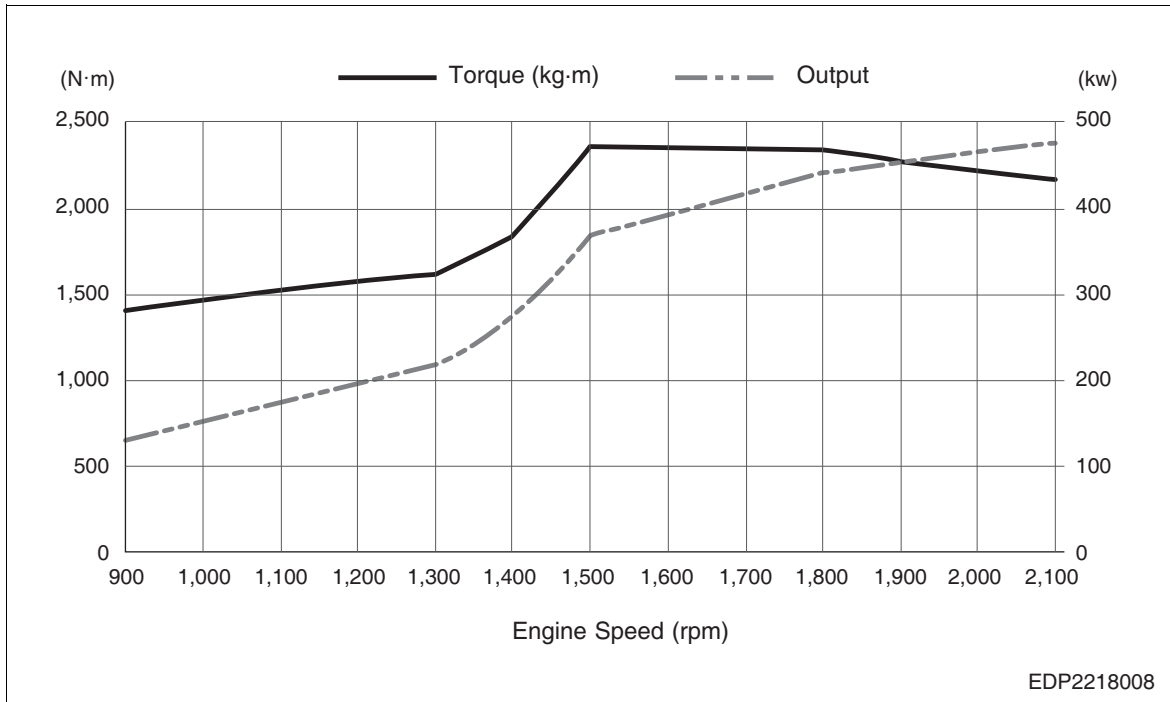
1.2.4. Engine performance curve

1) PU158TI engine



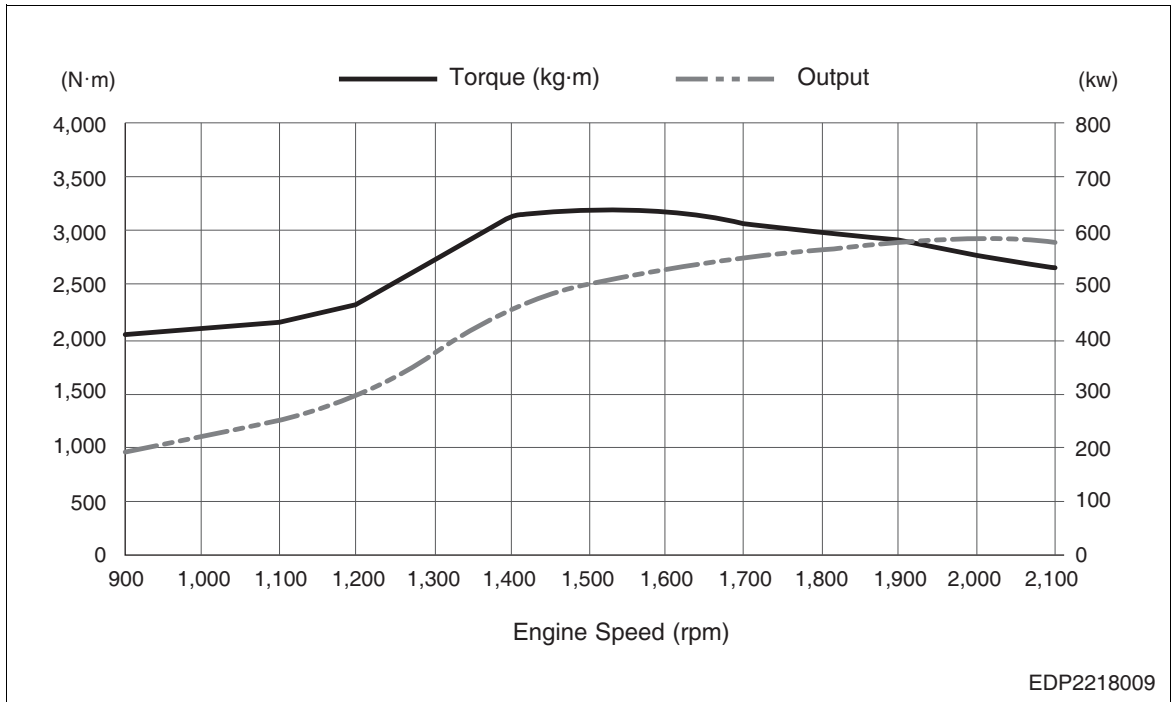
Performance		ISO 3046, DIN 6270B
Output	(max.)	397 kW (540 PS) / 2,100 rpm
Torque	(max)	2,117 N·m (216 kg·m) / 1,500 rpm

2) PU180TI engine



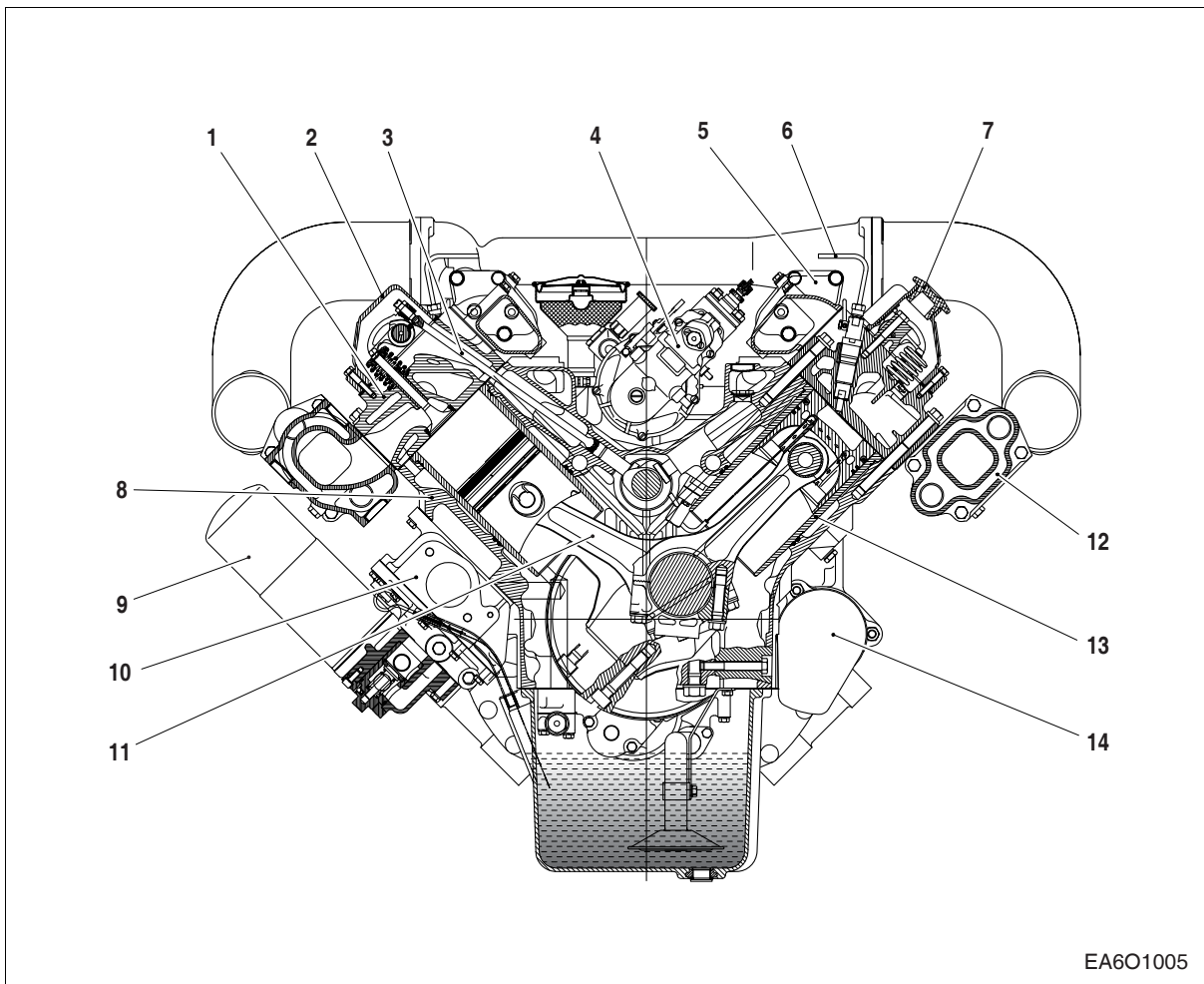
Performance		ISO 3046, DIN 6270B
Output	(max.)	478 kW (650 PS) / 2,100 rpm
Torque	(max)	2,350 N·m (240 kg·m) / 1,500 rpm

3) PU222TI engine



Performance		ISO 3046, DIN 6270B
Output	(max.)	587 kW (798 PS) / 2,100 rpm
Torque	(max)	3,200 N·m (327 kg·m) / 1,500 rpm

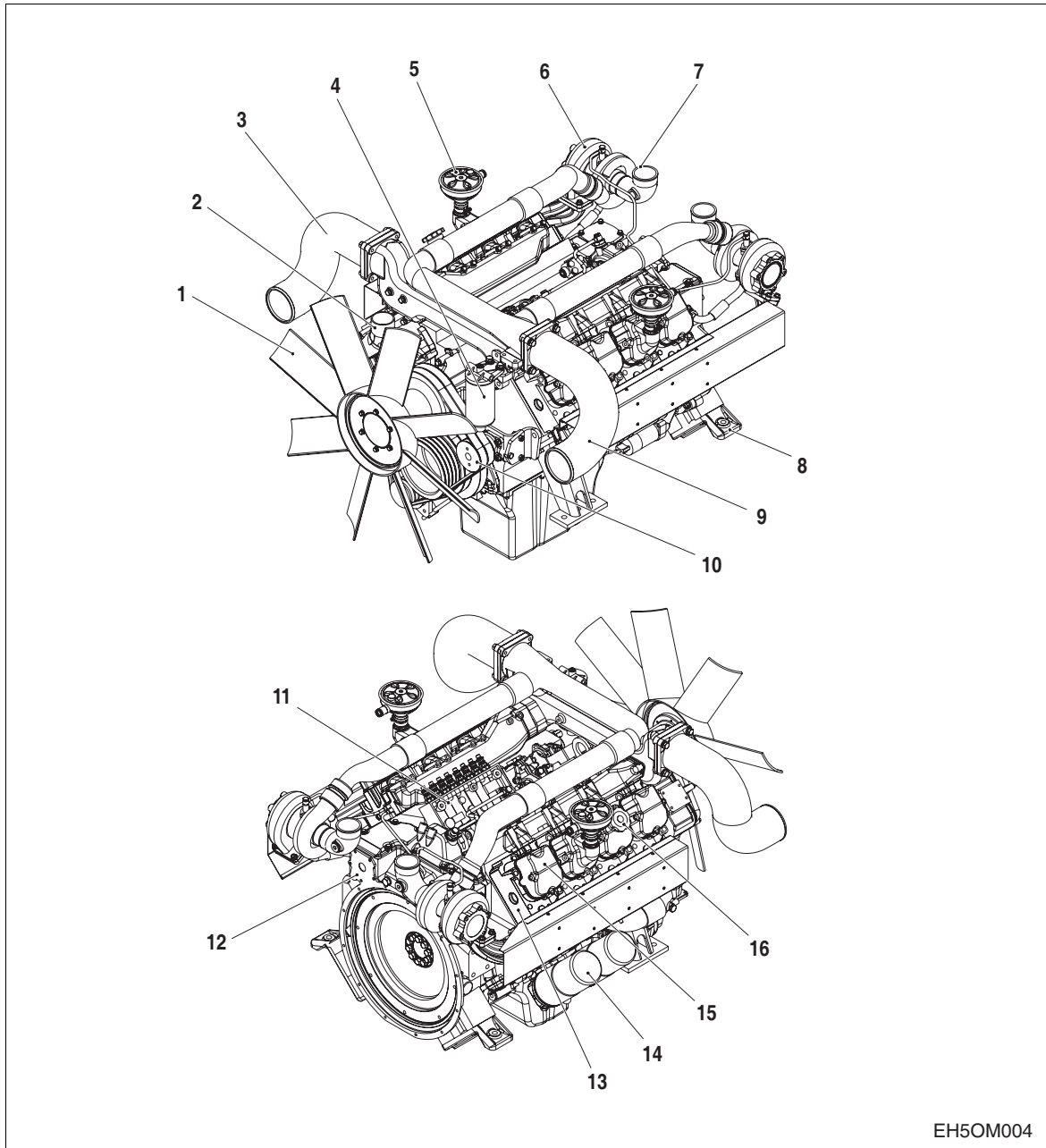
1.3.2. Engine sectional view (Cross)



- | | |
|------------------------|----------------------|
| 1. Cylinder head | 8. Cylinder block |
| 2. Cylinder head cover | 9. Oil filter |
| 3. Push rod | 10. Oil cooler |
| 4. Injection pump | 11. Connecting rod |
| 5. Intake manifold | 12. Exhaust manifold |
| 6. Injection pipe | 13. Cylinder liner |
| 7. Oil filler cap | 14. Starter |

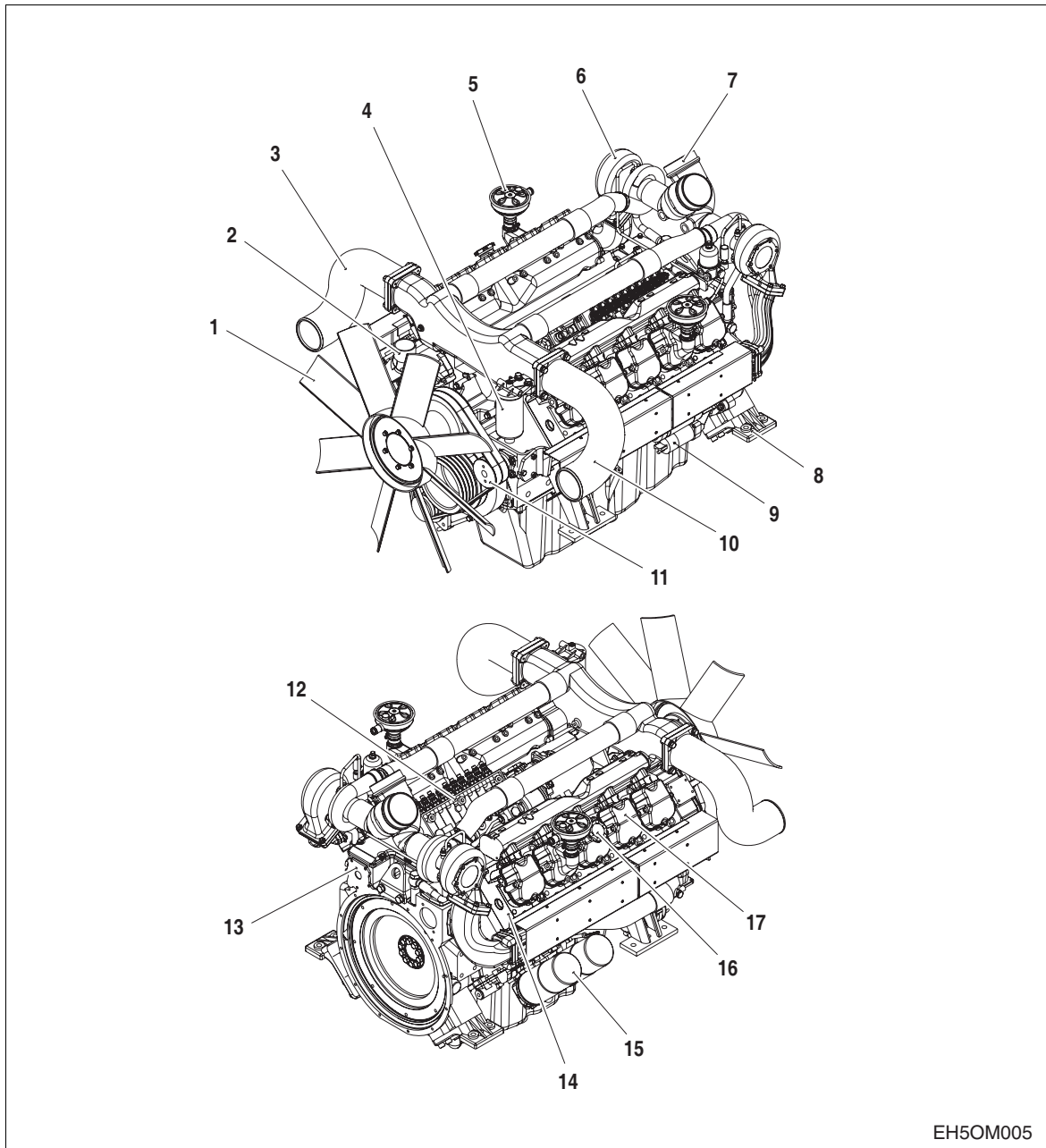
1.3.3. Engine assembly views

1) PU158TI : Power unit engine



- | | |
|---|---|
| 1. Cooling fan | 9. Air pipe
(Turbocharger to inter cooler) |
| 2. Water outlet | 10. Idle pulley |
| 3. Air pipe
(Intercooler to intake manifold) | 11. Injection pump |
| 4. Fuel filter | 12. Fly wheel housing |
| 5. Breather | 13. Cylinder head |
| 6. Turbo charger | 14. Oil filter |
| 7. Air pipe
(Air cleaner to turbocharger) | 15. Cylinder head cover |
| 8. Mounting bracket | 16. Oil filler cap |

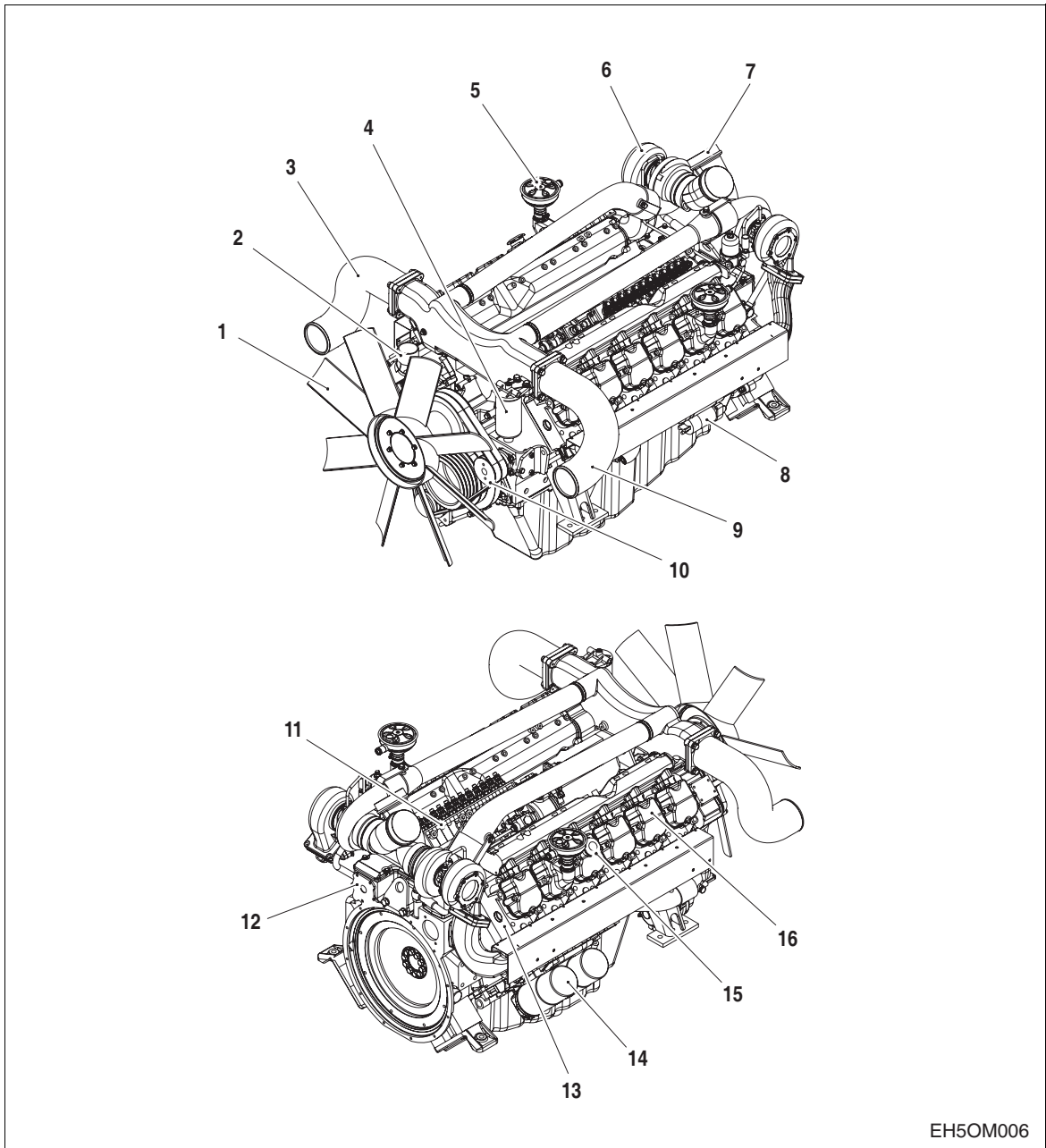
2) PU180TI : Power unit engine



EH5OM005

- | | |
|----------------------------------|--------------------------------|
| 1. Cooling fan | 9. Air pipe |
| 2. Water outlet | (Turbocharger to inter cooler) |
| 3. Air pipe | 10. Starter |
| (Intercooler to intake manifold) | 11. Idle pulley |
| 4. Fuel filter | 12. Injection pump |
| 5. Breather | 13. Fly wheel housing |
| 6. Turbo charger | 14. Cylinder head |
| 7. Air pipe | 15. Oil filter |
| (Air cleaner to turbocharger) | 16. Oil filler cap |
| 8. Mounting bracket | 17. Cylinder head cover |

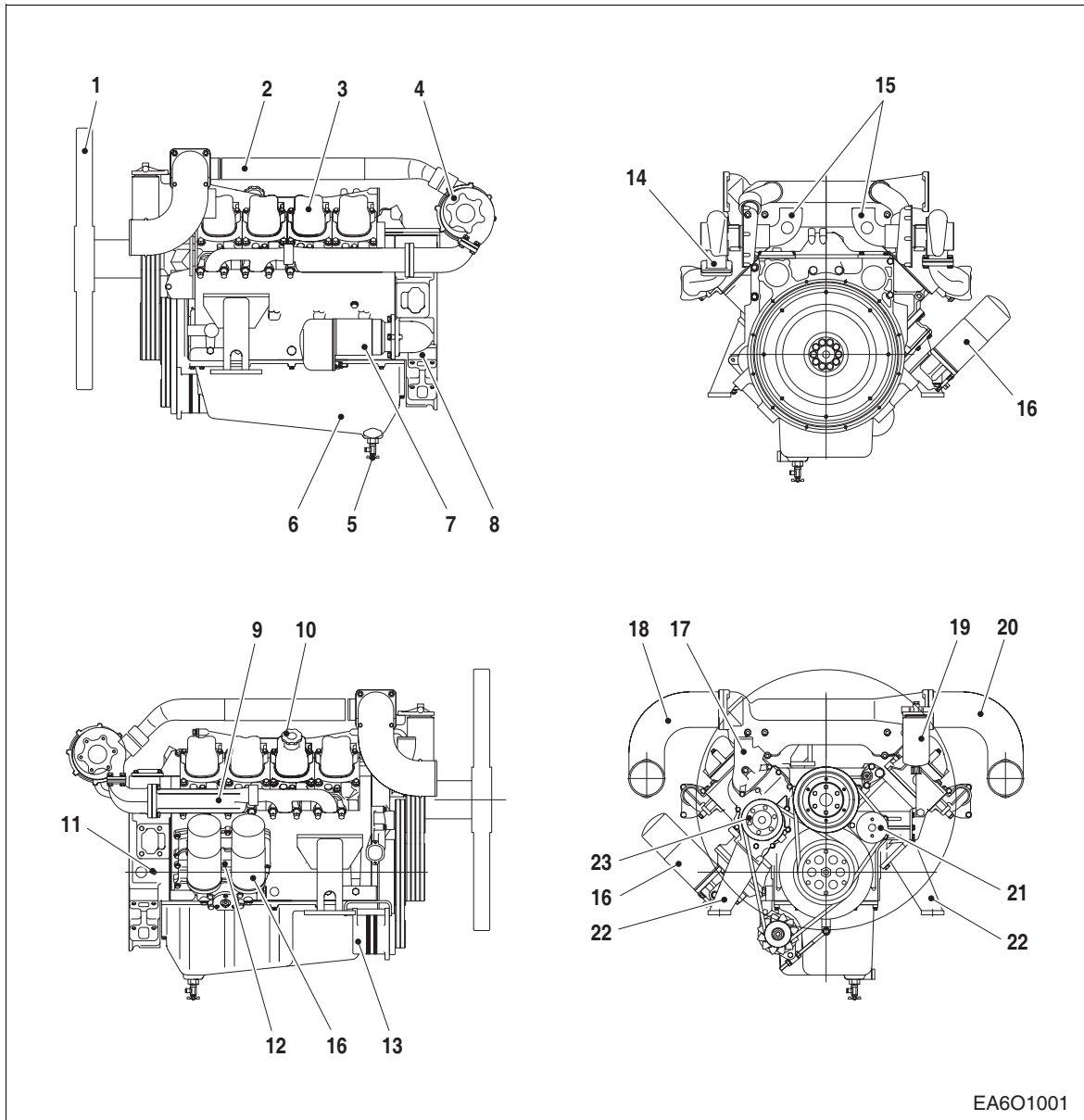
3) PU222TI : Power unit engine



- | | |
|---|---|
| 1. Cooling fan | 9. Air pipe
(Turbocharger to inter cooler) |
| 2. Water outlet | 10. Idle pulley |
| 3. Air pipe
(Intercooler to intake manifold) | 11. Injection pump |
| 4. Fuel filter | 12. Fly wheel housing |
| 5. Breather | 13. Cylinder head |
| 6. Turbo charger | 14. Oil filter |
| 7. Air pipe
(Air cleaner to turbocharger) | 15. Oil filler cap |
| 8. Starter | 16. Cylinder head cover |

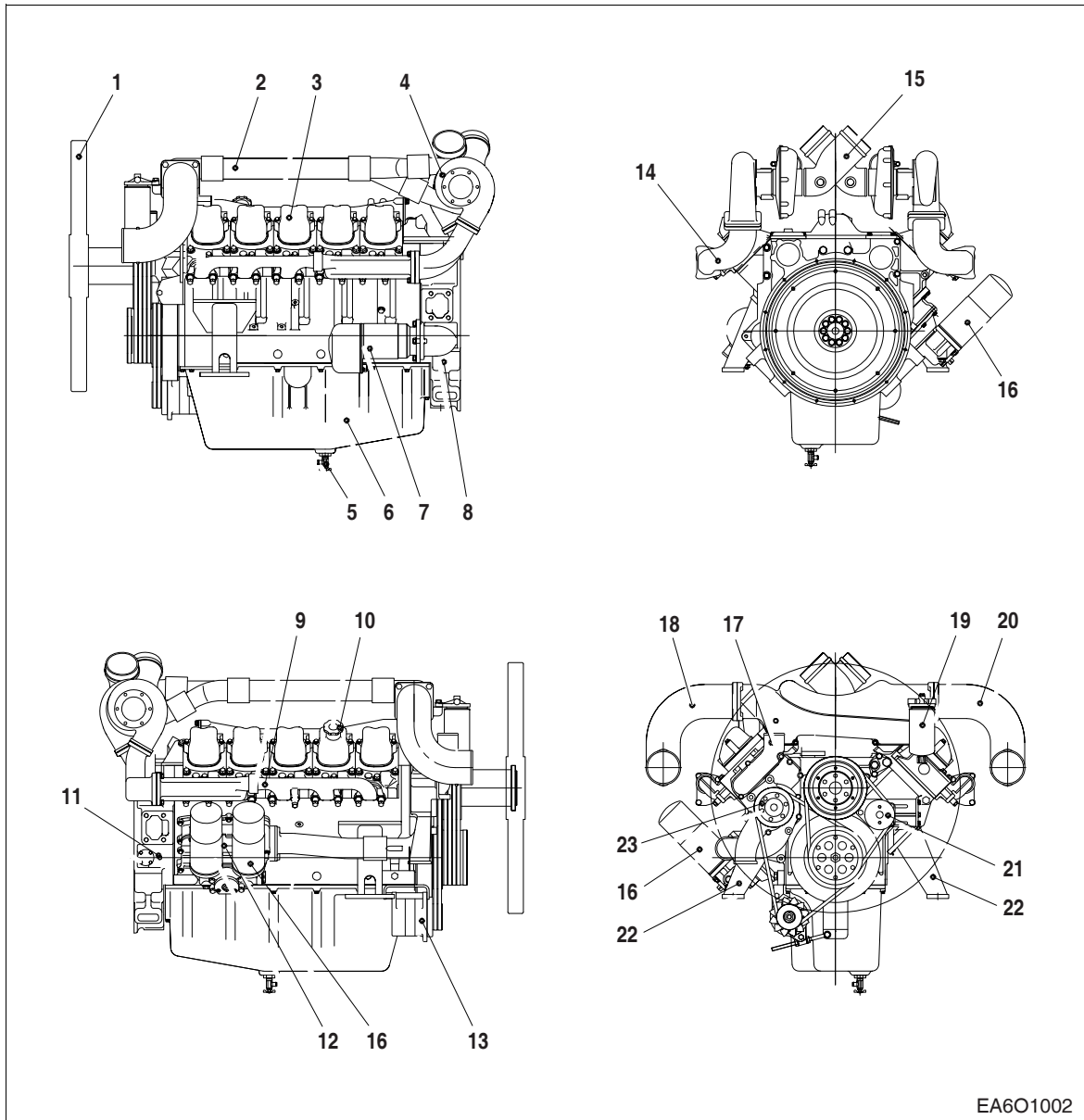
EH5OM006

4) P158LE : Generator engine



- | | | |
|------------------------|---|---|
| 1. Cooling fan | 10. Oil filler cap | 18. Air pipe
(Inter cooler to intake manifold) |
| 2. Air pipe | 11. Pick up sensor | 19. Fuel filter |
| 3. Cylinder head cover | 12. Oil cooler | 20. Air pipe
(Turbocharger to inter cooler) |
| 4. Turbocharger | 13. Alternator | 21. Idle pulley |
| 5. Oil drain valve | 14. Exhaust elbow | 22. Engine mounting bracket |
| 6. Oil pan | 15. Air pipe
(Air cleaner to turbocharger) | 23. Water pump |
| 7. Starter | 16. Oil filter | |
| 8. Flywheel housing | 17. Cooling water outlet | |
| 9. Exhaust manifold | | |

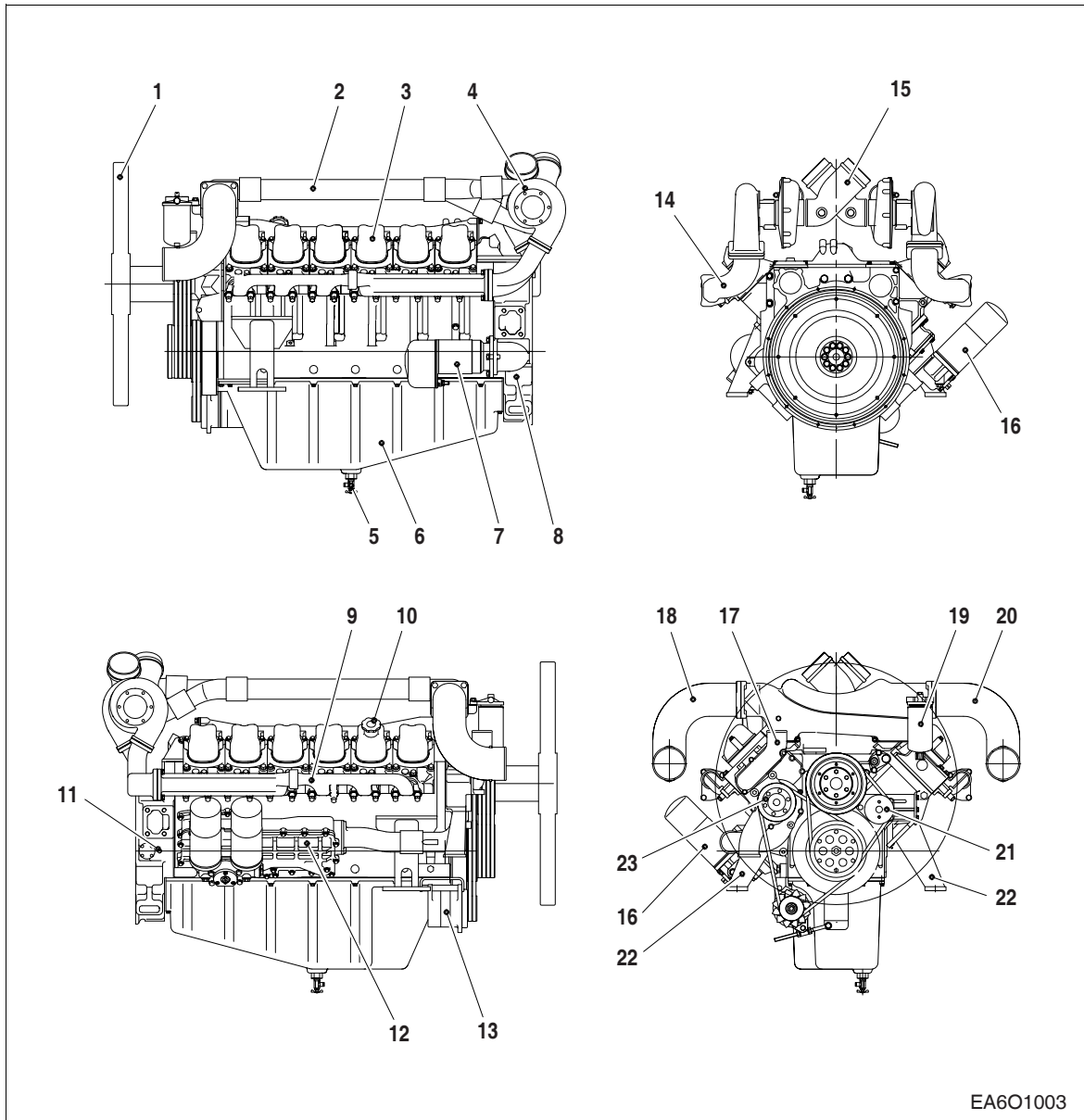
5) P180LE : Generator engine



EA6O1002

- | | | |
|------------------------|---|---|
| 1. Cooling fan | 10. Oil filler cap | 18. Air pipe
(Inter cooler to intake manifold) |
| 2. Air pipe | 11. Pick up sensor | 19. Fuel filter |
| 3. Cylinder head cover | 12. Oil cooler | 20. Air pipe
(Turbocharger to inter cooler) |
| 4. Turbocharger | 13. Alternator | 21. Idle pulley |
| 5. Oil drain valve | 14. Exhaust elbow | 22. Engine mounting bracket |
| 6. Oil pan | 15. Air pipe
(Air cleaner to turbocharger) | 23. Water pump |
| 7. Starter | | |
| 8. Flywheel housing | 16. Oil filter | |
| 9. Exhaust manifold | 17. Cooling water outlet | |

6) P222LE : Generator engine

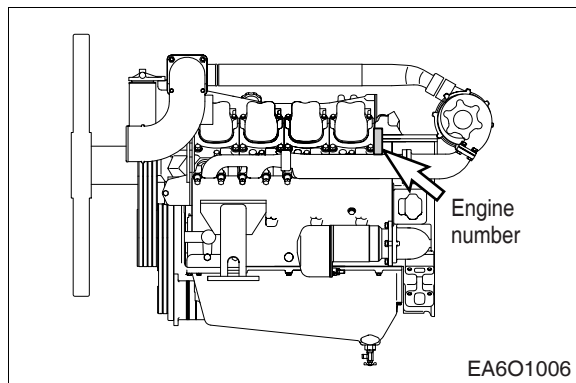


- | | | |
|------------------------|-------------------------------|-----------------------------------|
| 1. Cooling fan | 10. Oil filler cap | 18. Air pipe |
| 2. Air pipe | 11. Pick up sensor | (Inter cooler to intake manifold) |
| 3. Cylinder head cover | 12. Oil cooler | 19. Fuel filter |
| 4. Turbocharger | 13. Alternator | 20. Air pipe |
| 5. Oil drain valve | 14. Exhaust elbow | (Turbocharger to inter cooler) |
| 6. Oil pan | 15. Air pipe | 21. Idle pulley |
| 7. Starter | (Air cleaner to turbocharger) | 22. Engine mounting bracket |
| 8. Flywheel housing | 16. Oil filter | 23. Water pump |
| 9. Exhaust manifold | 17. Cooling water outlet | |

2. Technical Information

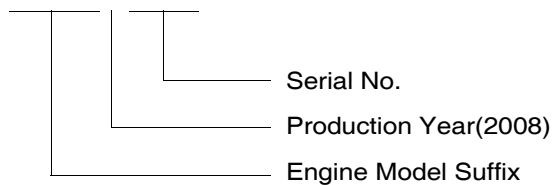
2.1. Engine Model and Serial Number

- The engine model and serial number is located on the engine as illustrated. These numbers are required when requesting warranty and ordering parts. They are also referred to as engine model and serial number because of their location.



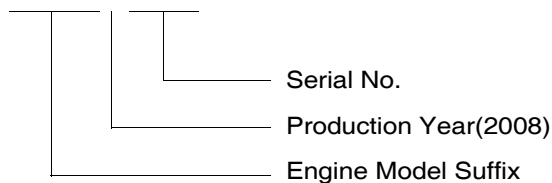
- **Engine serial No. (example 1 : P158LE)**

EAZOA 8 00001



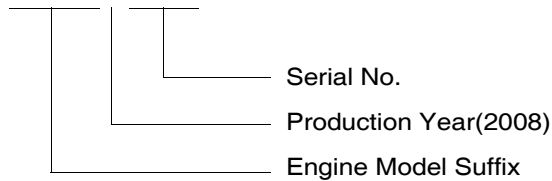
- **Engine serial No. (example 2 : P180LE)**

EASOA 8 00001

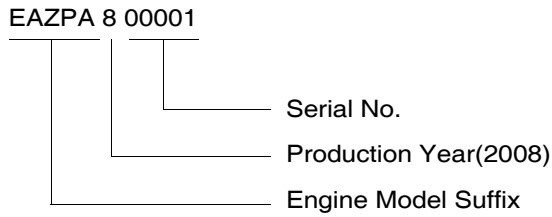


- **Engine serial No. (example 3 : P222LE)**

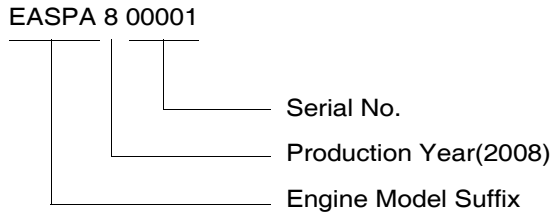
EAYOA 8 00001



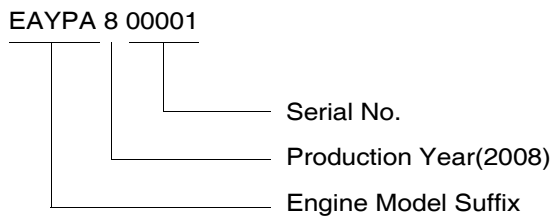
- **Engine serial No. (example 4 : PU158TI)**



- **Engine serial No. (example 5 : PU180TI)**



- **Engine serial No. (example 6 : PU222TI)**

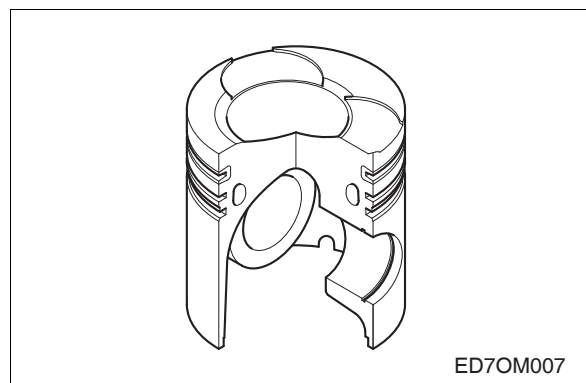


2.2. Engines Characteristic

- The generator engine(P158LE/P180LE/P222LE) and power unit engine(PU158TI/PU180TI/PU222TI) series are V-type liquid-cooled 8/10/12-cylinder four-stroke Diesel engines with direct injection.

2.2.1. Oil gallery cooling type piston

- Oil gallery cooling is used for the piston of the engine.
- When thermal loading is high, piston cooling by means of an oil gallery in the crown is normally necessary to prevent crown cracking and ring sticking. The design of the gallery, the design and location of the oil spray nozzle and the quantity of oil flowing in the gallery are critical in order to achieve the desired temperature reduction.
- The cross section shape of the gallery should be designed to achieve sufficient oil movement to maximize cooling efficiency.



2.2.2. Engine block

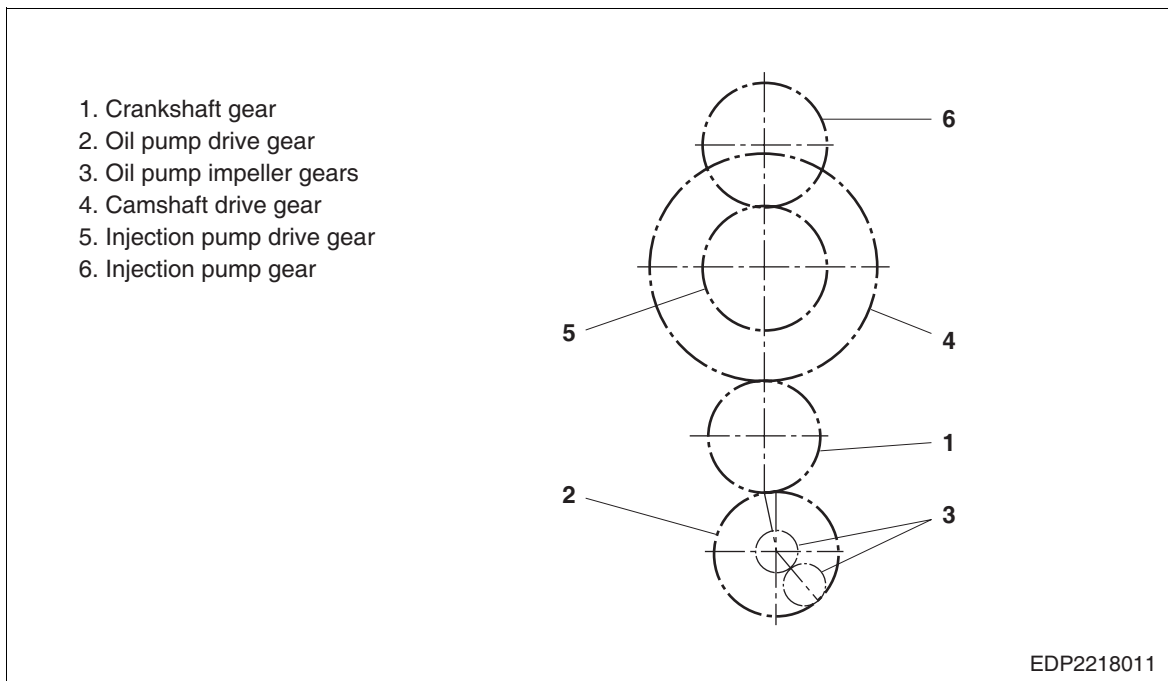
- The cylinder block is a single piece of alloy cast iron. To increase its stiffness, it is extended to a level below the crankshaft center line. The engine has replaceable wet cylinder liners and individual cylinder heads with sprung-in valve seat rings and replaceable valve guides.

2.2.3. Piston / Connecting rod / Crank assembly

- The forged crankshaft has screwed-on counterweights. Radial seals with replaceable wearing rings on crankshaft and flywheel are provided to oil seal the crankcase penetrations.
- The connecting rods are die-forged, diagonally split and can be removed through the top of the cylinders together with the pistons. Crankshaft and connecting rods run in bearings.

2.2.4. Engine timing

- Camshaft, oil pump and injection pump are driven by a gear train arranged at the flywheel end.



2.2.5. Valves

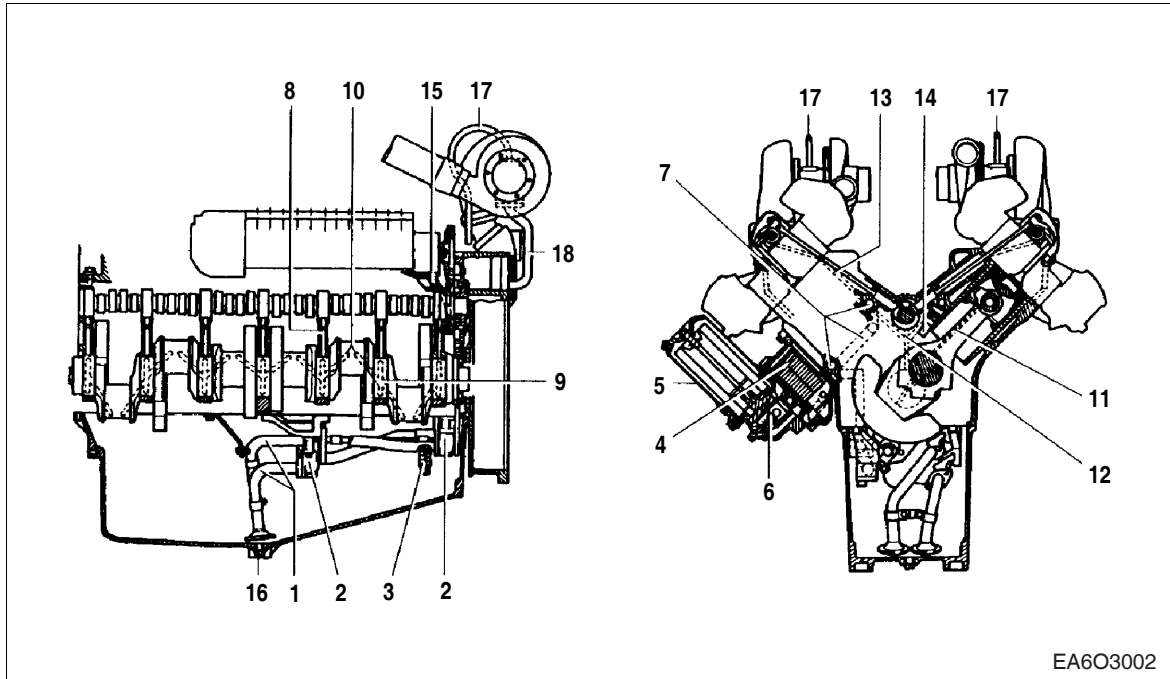
- The overhead valves are actuated via chilled cast iron tapets, push rods and rocker arms from the camshaft.

2.2.6. Engine lubrication

- The engine is equipped with force-feed lubrication.

The pressure is produced by a gear pump whose drive gear is in direct mesh with the crankshaft gear at the flywheel end.

- The oil pump draws the oil from the oil sump and delivers it through the oil cooler and oil filter to the main distributor gallery and from there to the main bearings, big-end bearings and camshaft bearings as well as to the small-end bearings and the rocker arms.



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- | | |
|---------------------------------------|---|
| 1. Oil suction pipes | 10. Ports for big end bearing lubrication |
| 2. Oil pumps | 11. Small end bearing lubrication |
| 3. Oil relief valves | 12. Camshaft bearing lubrication |
| 4. Oil cooler | 13. Rocker arm lubrication |
| 5. Oil filter | 14. Spray nozzle |
| 6. Bypass valve | 15. Injection pump lubrication |
| 7. Main oil galleries | 16. Oil drain plug |
| 8. Oil gallery to crankshaft | 17. Lube oil pipes to turbochargers |
| 9. Ports for main bearing lubrication | 18. Oil return from turbochargers |

- The injection pump and the turbocharger are also connected to the engine lubricating system. The cylinder walls and timing gears are splash-lubricated.

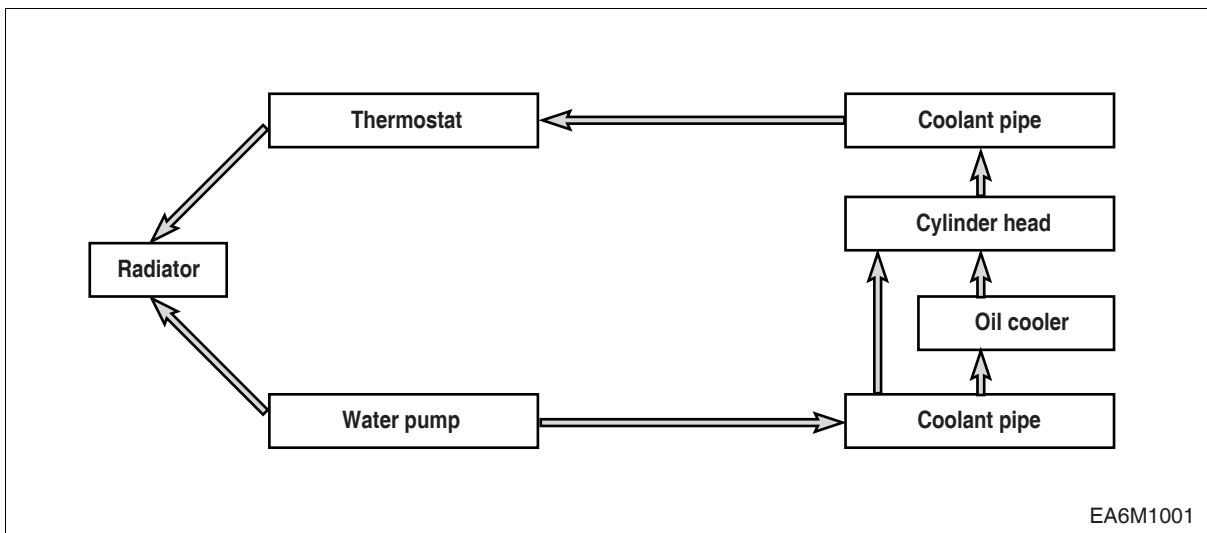
Each cylinder has an oil jet provided for cooling the underside of the pistons.

The lube oil is cleaned in a full-flow oil filter. Depending on the agreed extent of delivery and the design of the engine, the lube oil circuit can be equipped with oil pressure monitors (advance warning and cut-off function) which shut the engine down in the event of a sudden loss of pressure.

(1) Oil cooler

An oil cooler is provided between the oil filter and the crankcase. This cooler is of the flat tube type with turbulence inserts and operated by the coolant.

2.2.7. Engine cooling system

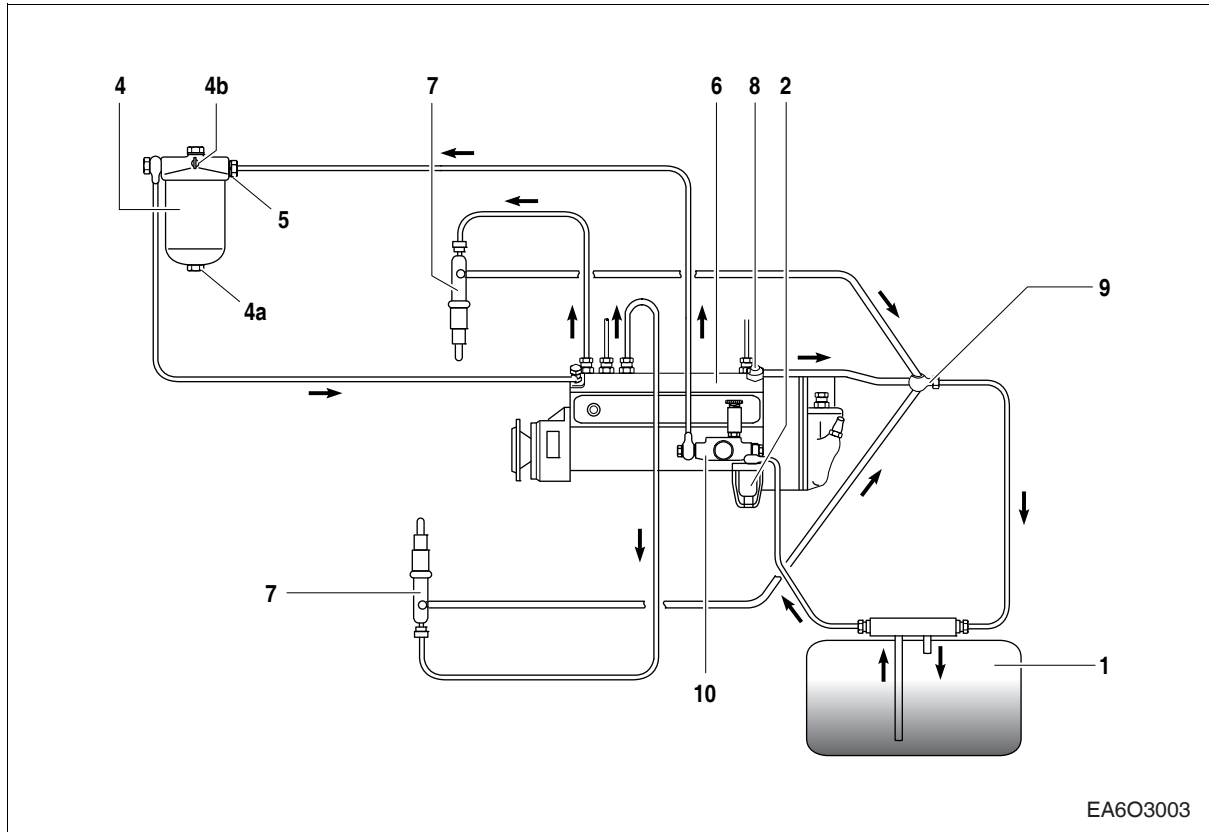


2.2.8. Fuel system

The fuel is delivered by the fuel lift pump via the fuel filter to the injection pump and from there to the injectors.

The fuel is sprayed into the cylinder through nozzles fitted in screw-fit injections in the cylinder heads.

Excessive fuel delivered and leak fuel from the injectors flow through the return pipe back to the tank.



- | | |
|--|-------------------------------|
| 1. Fuel tank | 5. Fuel pipe connector |
| 2. Strainer | 6. Injection pump |
| 3. Fuel Filter | 7. Injector |
| 4. Fuel filter assembly | 8. Fuel pressure relief valve |
| 4a. Fuel water drain plug | 9. Fuel return pipe |
| 4b. Air bleeding plug
(for fuel filter) | 10. Fuel feed pump |

If Diesel fuel which contains moisture is used the injection system and the cylinder liners / pistons will be damaged. This can be prevented to some extent by filling the tank as soon as the engine is switched off while the fuel tank is still warm (formation of condensation is prevented). Drain moisture from storage tanks regularly. Installation of a water trap upstream of the fuel filter is also advisable.

● **Fuel oil selection chart**

Property	ASTM D975 2GRADE		EN 590:2013	
Flash point, min	No 2D 52°C	D923	55°C	EN2719
Water & sediment, max.	0.05% vol.	D2709		
Water, max.			200 mg/kg	EN ISO 12937
Total contamination, max.			24 mg/kg	EN 12662
Distillation temperature (% vol recovered)	90%	D86	65%: 250°C	EN ISO 3405
	2D 282-338°C		85%: 350°C	
Kinematic viscosity (at 40°C)	2D 1.9-4.1 mm ² /s	D445	2.0-4.5 mm ² /s	EN ISO 3104
Density (at 15°C)			820-845 kg/m ³	EN ISO 3675
				EN ISO 12185
Ester content	5% vol. max.	EN14078	7% vol. max. FAME	EN 14078
Ash, max.	0.01% wt	D482	0.01% wt	EN ISO 6245
Sulfur, max. (by mass)	2D	D5453	10	EN ISO 20846
	S15 15 mg/kg	D2622		EN ISO 20884
	S500 0.50%	D129 ²		EN ISO 13032
	S5000 0.50%			
Copper strip corrosion, max.	No 3	D130	Class 1	EN ISO 2160
Cetane number, min.	40	D613	51	EN ISO 5165
Cetane index, min.			46	EN ISO 4264
- Cetane index	40 min.	D976-80		
- Aromaticity	35% vol. max.	D1319		
PAH, max.			11% wet	EN 12916
Operability, one of:	Report	D2500		
- Cloud point		D4539		
- LTFT/CFPP		D6371		
Cloud point			Location & sea- son dependant	EN 23015
CFPP			Location & sea- son dependant	EN 116
Carbon residue on 10% distillation residue, max.		D524	0.30% wt	EN ISO 10370
	2D: 0.35% wt			
Oxidation stability, max.			25 g/m ³	EN ISO 12205
Lubricity (at 60°C), max.	520 μm	D6079 D7688	460 μm	ISO 12156-1
Conductivity, min.	25 pS/m	D2624 D4308		

* If the sulfur content of the fuel is more than 0.5%, the replacement and inspection cycle should be cut in half.



NOTE :

The cloud point should be -12°C (10°F) below the lowest expected fuel temperature to prevent clogging of fuel fitters by crystals.

● **HVO (Hydro treated Vegetable Oil)**

HVO is a synthetic diesel which is manufactured through the hydrogenation of plants and animal fats.

To the user, HVO is reminiscent of diesel in accordance with EN590, apart from HVO having a somewhat lower density.

HD Construction Equipment approves the use of up to 100% HVO for engines in accordance with the EU standard EN15940.

2.2.9. Injection pump

No alterations must be made to the injection pump. If the lead seal is damaged the warranty on the engine will become null and void.

- **Faults**

We strongly recommend that any faults developing in the injection pump should be taken care of by authorized specialist personnel.

- **Bleeding the fuel system**

Bleeding the fuel filter is by releasing the bleed screws and operating the manual primer.

The suction chamber of the injection pump is continuously bled via the relief valve during operation. If the suction chamber is completely empty, e.g., when fitting a new pump, filling and bleeding it is by actuating the manual primer.

- **Fuel lift pump**

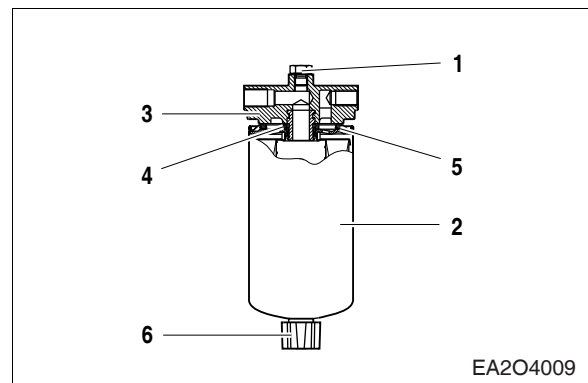
The fuel lift pump is operated by the injection pump camshaft via the roller tappet.

- **Strainer**

After every 200 hours of operation the fuel strainer connected upstream of the fuel lift pump should be cleaned.

2.2.10. Fuel filter

- After every 200 hour of operation, drain the water and sediment from the fuel-water separator.
- Shut off the engine. Use your hand to open the drain valve(6).
Turn the valve counter clockwise approximately 2 ~ 3 turns until draining occurs. Drain the filter sump of water until close fuel is visible.
- Turn the valve clockwise to close the drain valve. Do not over tighten the valve, overtightening can damage the threads.



2.2.11. Replacement of fuel filter

- Clean the area around the fuel filter head(3).
- Remove the fuel filter(2).
- Remove the fuel filter thread adapter seal ring(4).

Use a clean lint free cloth to clean the gasket surface of the fuel filter head(3).

- Install the new thread adapter seal ring(4)supplied with the new filter.
Use clean oil to lubricate the filter seal(5), and fill the new filter with clean fuel.
- Install the filter on the filter head(5).

Tighten the filter until the gasket contacts the filter head surface.

Tighten the filter on additional one-half to three-fourths of a turn, on as specified by the filter manufacturer.



NOTE :

Mechanical over tightening of the filter can distort the thread or damage the filter element seal.

2.2.12. Injector maintenance

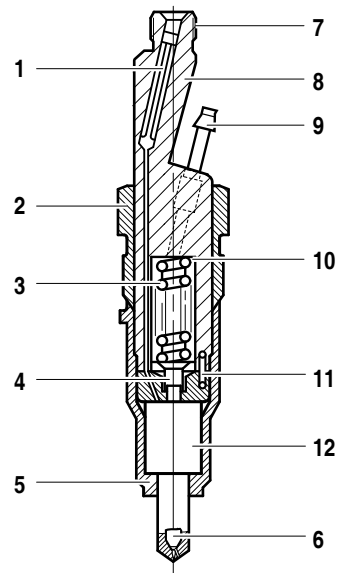
The injectors are designed to spray the fuel delivered by the injection pump directly into the spherical combustion chamber in the piston crown.

The injector consists of the nozzle and the nozzle holder.

A copper gasket fitted to the injector ensures gas-tight seating and good heat dissipation.

The opening pressure of the nozzle is adjusted by means of shims at the compression spring.

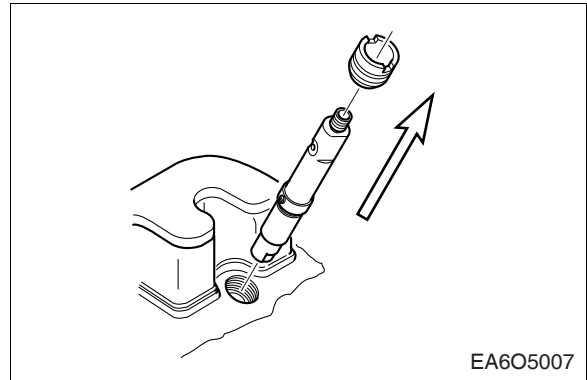
1. Rod type filter
2. Cap nut
3. Compression spring
4. Compression pin
5. Cap nut for fixed nozzle
6. Nozzle needles
7. Connect hole for fuel delivery
8. Nozzle holder
9. Connect tube for overflow
10. Shim
11. Pin
12. Nozzle bush



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2.2.13. Removal, dismantling and cleaning

- Unscrew delivery pipe at nozzle holder and at the injection pump.
- Remove leak-off pipe.
- Release union screw of nozzle holder with special wrench. (65.99705-0002)
- Remove nozzle holder with gasket from the cylinder head.



Note for cleaning nozzles

- Clean nozzle body externally from soot and carbon, When cleaning several nozzles at the same time, make sure nozzle bodies and needles are not mixed up. Visually inspect needle and body.
- Cleaning is useless if the seat of the needle is indented or the pintle is damaged and the nozzle should be replaced.
- Clean annular groove with scraper over full circumference. Wash out dislodged carbon deposits and dirt.
- Scrape needle seat with cleaning cutter, Dip cutter in test oil before use. The cutter can also be clamped in a lathe.
- Polish needle seat with wooden cleaning tool, preferably by chucking the needle in a lathe at the pintle end.
- Clean the spray holes of nozzles by chucking a cleaning needle of suitable diameter in the collect. If the carbon deposits in the spray holes cannot be removed by rotating and pressing, have the needle project only slightly from the collect and drive out the carbon by lightly tapping on the tool.
- Before reassembly thoroughly wash nozzle body and needle in clean test oil.
- Hold the needle at the pintle end only ; to avoid corrosion, do not touch the lapped surfaces of the needle with you fingers.
- Thoroughly clean all other parts of the nozzle holder with clean fuel.
- Check nozzle discharge pressure in nozzle tester.

The edge-type filter should not be pressed into the nozzle holder by more than about 5mm. If this depth is exceeded the injector must be replaced.

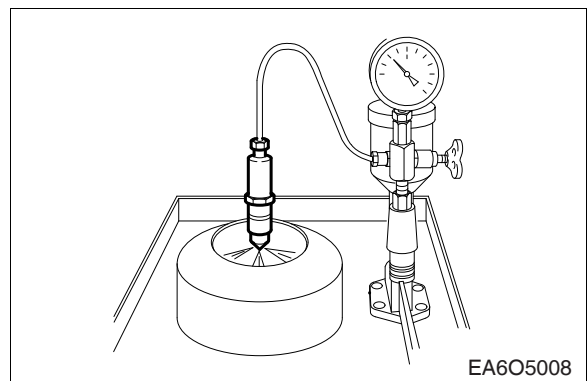
<Operating pressure>

New nozzle holder	300 + 8 kg/cm ²
Used nozzle holder	285 + 8 kg/cm ²



CAUTION :

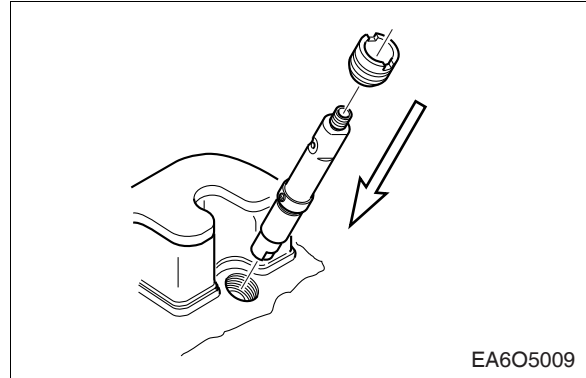
Do not hold your hands under the fuel jet, as there is a rise of injury.
Do not inhale the atomized oil fuel.
If possible, work under an extraction system.



2.2.14. Installation

- Clean seat in cylinder head.
- Insert nozzle holder with new gasket.
Tighten union nut.
- Install injection lines free of constraint.
Install leak fuel lines. screw delivery pipe at nozzle holder and at the injection pump.

Torque	7 kg·m
--------	--------



CAUTION :

The injection lines are designed for high operating pressures and should thus be handled with particular care.

- When mounting the pipes to the engine take care of good fitness.
- Do not bend pipes to permanent deformation. (not for replacing the nozzles either)
- Do not mount any heavily bent pipes.
- Avoid bending the pipes at the ends by more than 2 to 3 degrees.
- In case of faults in the injection system which might have resulted in excessive operating pressures, not only the failed part but also the injection line has to be replaced.

2.2.15. Fan belt



- Use a fan belt of specified dimensions, and replace if damaged, frayed, or deteriorated.
- 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 ~ 15 mm when pressed down with thumb)

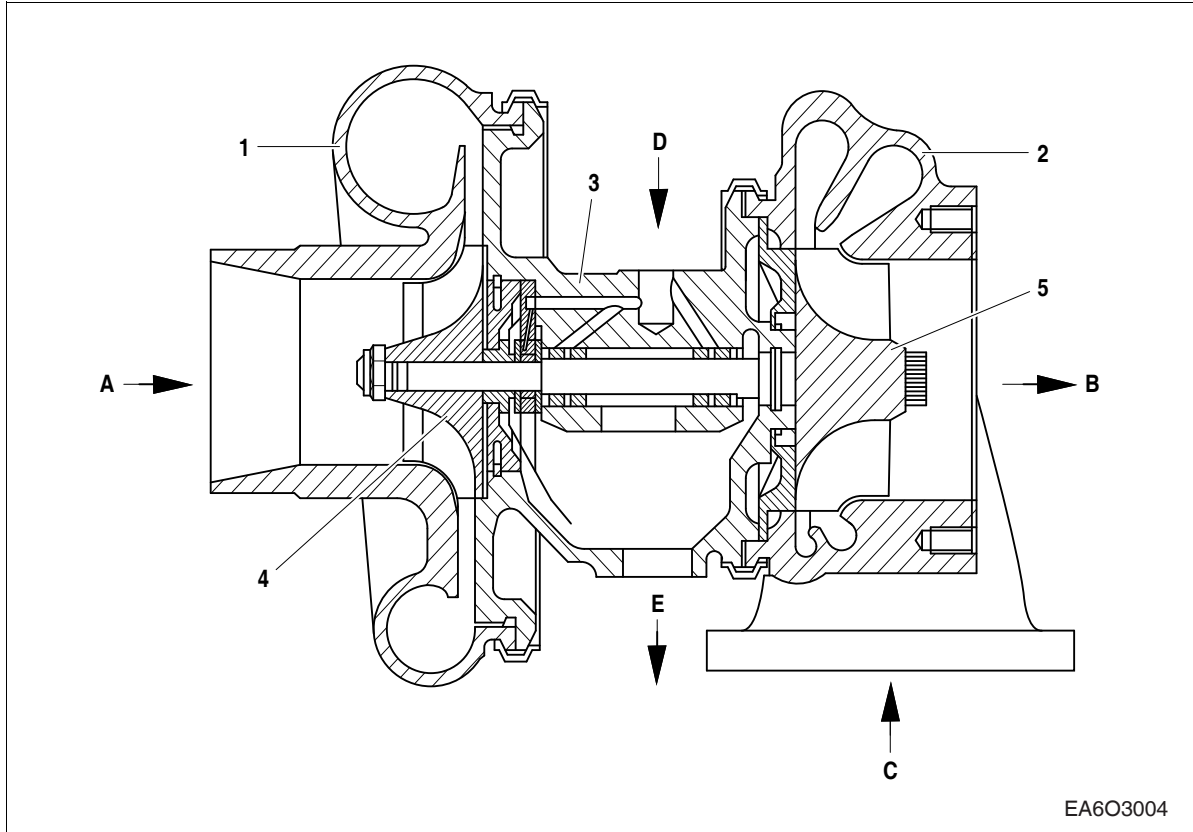
2.2.16. Engine oil



- Check oil level with the oil level gauge and replenish if necessary.
- Check the oil level with the engine cooled. If the engine is warm, allow time for 5 ~ 10 minutes for oil drain into the crankcase before checking oil level. The oil level must be between Max and Min. lines on the gauge.
- Engine oil should be changed at the specified intervals. (200 hr)
Oil in the oil filter should be changed simultaneously.
– First oil change : 50 hr operating
- The oil viscosity grades should be selected SAE10W40 and API CH or CI.

2.2.17. Turbo charger

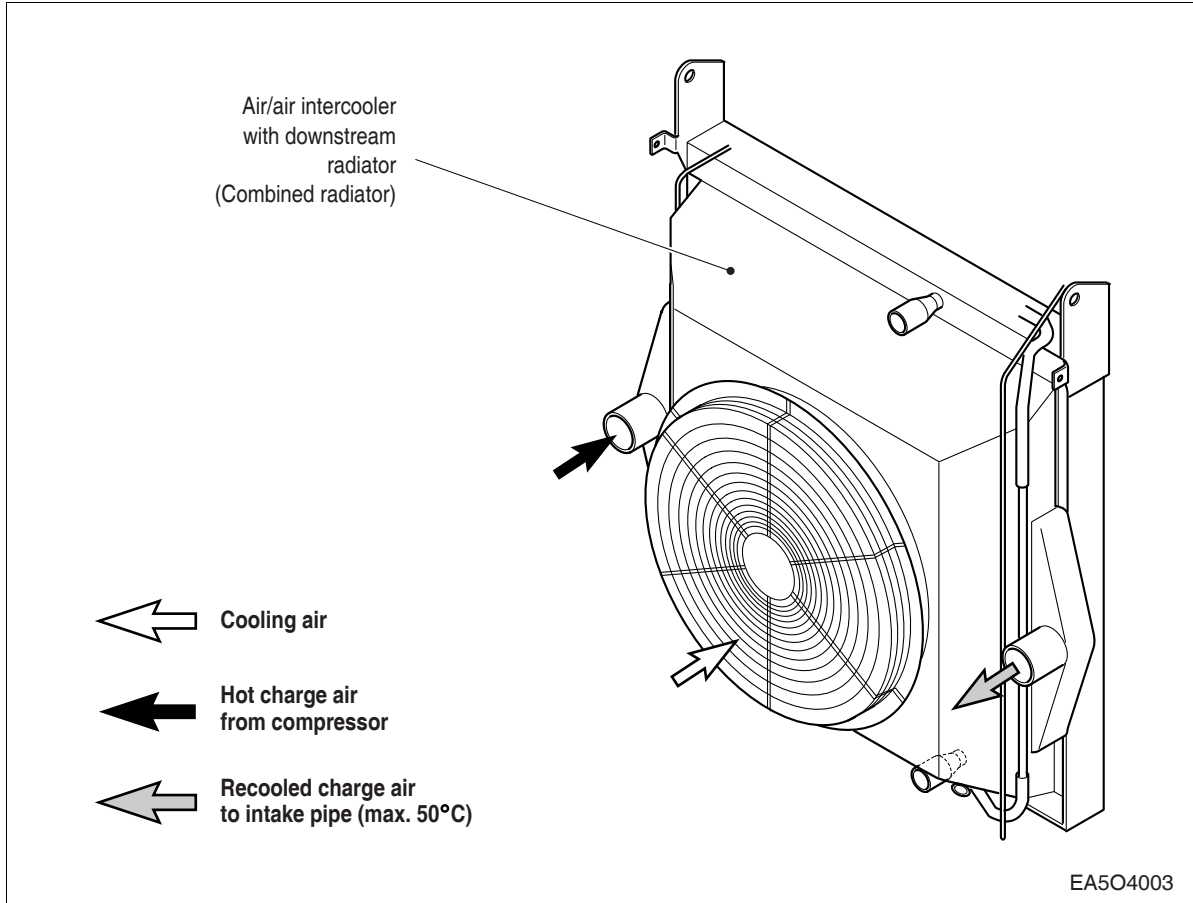
The exhaust gases of the engine are passed through the turbine rotor of the turbo charger Air impeller mounted on the same shaft draws in fresh air and delivers it at a higher pressure to the cylinders. The turbo charger is air-cooled. Lubrication of the main bearing is by oil under Pressure from the engine lubricating system.



- | | |
|----------------------|---------------|
| 1. Compressor casing | A. Air inlet |
| 2. Turbine casing | B. Gas outlet |
| 3. Bearing casing | C. Gas inlet |
| 4. Impeller | D. Oil supply |
| 5. Turbine | E. Oil return |

2.2.18. Intercooler

The intercooler is air to air type and has a large cooling fan capacity. The intercooler life and performance depends on the intake air condition greatly. Fouled air pollutes and clogs the air fins of intercooler. As a result of this, the engine output is decreased and engine malfunction is occurred. So you always check whether the intake air systems like air filter element are worn or polluted.



– Cleaning of intercooler fins : Every 600 hours.

2.2.19. Cooling system

The engine has a liquid-cooling system.

The water pump is a maintenance-free impeller pump driven by V-belts from the crankshaft pulley. Depending on the agreed extent of delivery and the design of the engine, the coolant circuit can be equipped with temperature monitors which, in the event of loss of coolant, shut the engine down.

2.2.20. Filling-in of coolant

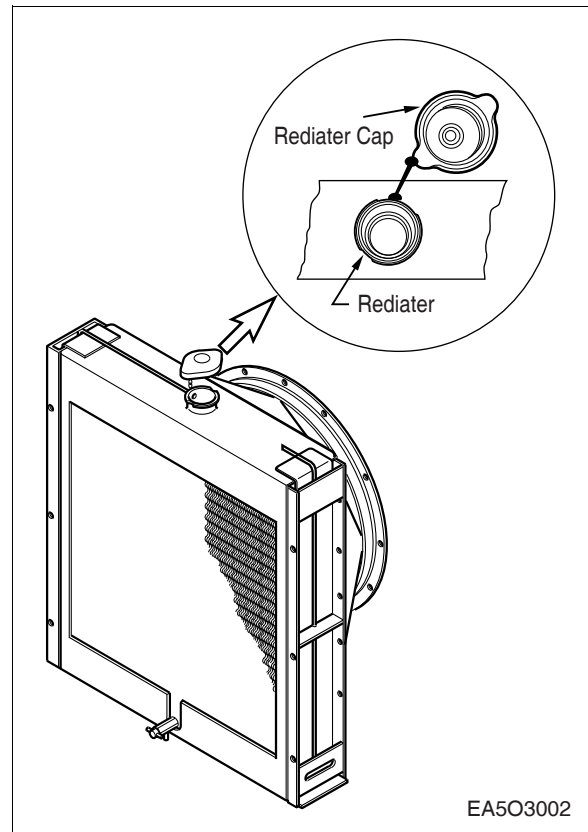
(only when engine has cooled down)

- Fill in the coolant slowly.
- Make sure that all air can escape from the cooling system.
- Run the engine briefly and then check coolant level once more.

If, in an exceptional case, the coolant level has to be checked when the engine is warm from operation, first turn the somewhat smaller cap with working valves to the first notch. Let off pressure and then close this cap again. After this the cap on filler neck can be removed without risk of scalding.

Coolant must be added at the filler neck only. Do not put cold coolant into an engine which is warm from operation. If no hot water (80 °C) is available, add normal warm water very slowly as the engine runs until the coolant level is correct.

Ensure that the ratio of water to antifreeze is correct. Find the cause of the loss of coolant and have it eliminated.



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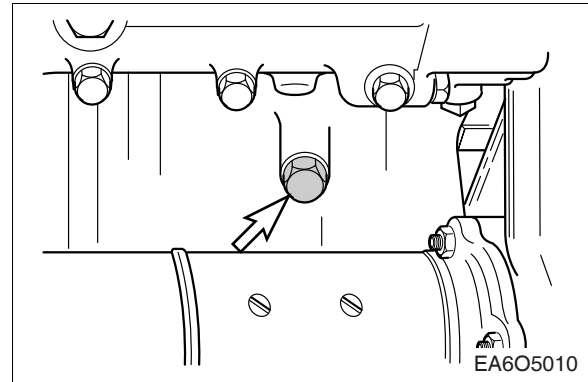
WARNING :

If the cap with the working valves is opened, there is the rise that it will not close tightly again afterwards. The excess pressure required in the system will then no longer build up. Premature boiling occurs and coolant is lost. To prevent damage to the engine, open this cap only in exceptional circumstances and fit a new one as soon as possible afterwards.

2.2.21. Draining of coolant

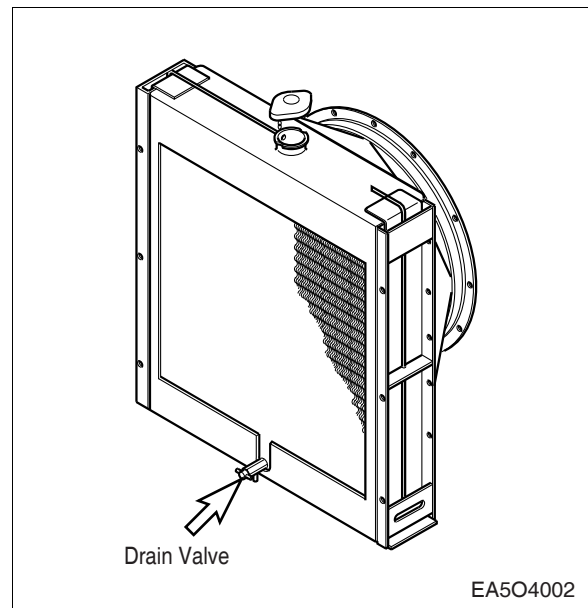
Drain coolant as follows when cooling system has cooled down;

- Remove cover from filler neck of radiator.
- Remove drain plug in the cylinder block.



Improper mixing of anti-freeze and corrosion inhibitors may lead to lime and corrosion deposits in the engine cooling system which can jeopardize cooling efficiency.

In such cases it is necessary to clean the cooling system at suitable intervals.



2.2.22. Cooling water

- Regarding the cooling water that is to be used for engine, the soft water not the hard water must be used.
- The engine cooling water can be used diluting it with antifreezing solution 40 % and the additive for rust prevention (DCA4) 3 ~ 5 %.
- The density of above solution and additive must be inspected every 500 hours to maintain it properly.



NOTE :

The proper density control of antifreezing solution and rust preventing additive will be able to prevent the rusting effectively and maintain the stable quality of engine. For the improper control might give the fatal damage to the cooling water pump and cylinder liners, detail care is needed.

- Since P158LE/P180LE/P222LE/PU158TI/PU180TI/PU222TI cylinder liner is wet type, particularly the cooling water control should be applied thoroughly.
- The density of antifreezing solution and additive for rust prevention is able to be confirmed by the cooling water test kit (Fleetguard CC2602M)
- **How to use the cooling water test kit**
 - (1) When the cooling water temp. of engine is in the range of 10 ~ 55 °C, loosen the plug for cooling water discharge and fill the plastic cup about a half.



NOTE :

In taking the cooling water sample, if the water in auxiliary tank were taken, it is hard to measure the accurate density. Take the cooling water sample necessarily loosening the cooling water discharge plug.

- (2) At the state of a test paper soaked in the sampled water, after taking the paper out through water agitation, shake off the water.
- (3) Wait for about 45 sec. till the color change of test paper.



NOTE :

However, it should not elapse longer than 75 sec, and if it did, the hue would change.

- (4) Make the numerical value by comparing the test paper which hue has changed with the color list of label on storage bottle.
- (5) By comparing the hue changed into yellowish green or so with the green color indication of test paper storage bottle, confirm the density. (Then, the density indication must be in the hue range of 33 % to 50 %).
- (6) The brown at the middle of test paper and the lower pink color indication represent the additive state for rust prevention, and the proper range is that the meeting numerical value of brown (vertical) and pink color (horizontal) locates in the range of 0.3 to 0.8 at the color list of label on the test paper storage bottle.
- (7) In case of less than 0.3, replenish the additive for rust prevention (DCA4), and in case of more than 0.8, pour out the cooling water about 50 % and then readjust the density after refilling with clean fresh water.

● **Amount of Anti-freeze in winter**

Ambient Temperature (°C)	Cooling water (%)	Anti-freeze (%)
Over -10	85	15
-10	80	20
-15	73	27
-20	67	33
-25	60	40
-30	56	44
-40	50	50

- **Antifreeze specifications**

We recommend using HD Construction Equipment genuine antifreeze, and since HD Construction Equipment genuine antifreeze satisfies the global standard, there is no need to add a separate additive.

- SAE J1034, ASTM D3360, ASTM D6210, JIS K2234

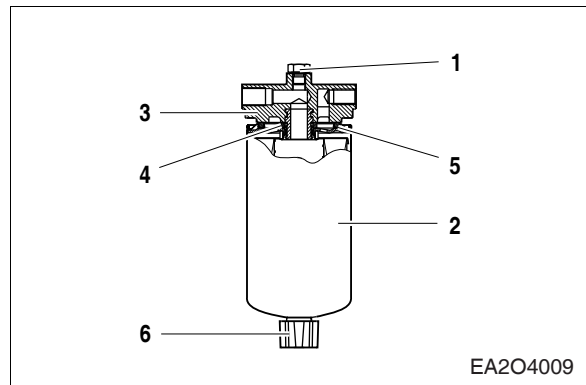
If you do not use HD Construction Equipment genuine antifreeze, you must select a product that satisfies the global standard, and you must not mix different types of antifreeze.

- Among products that meet the global standard, we recommend specifications that do not contain "Amin" and "Borate" as additives.

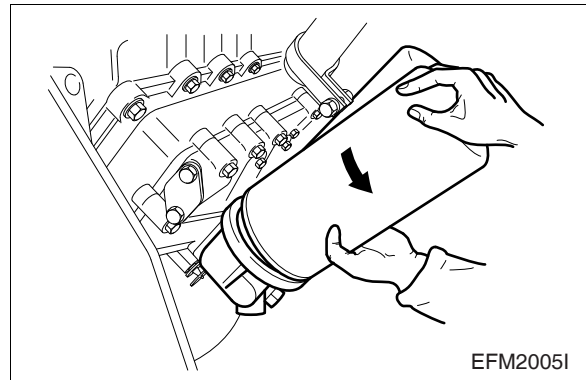
2.2.23. Fuel filter



- Drain water in cartridge with loosening the cock under filter manually (6) from time to time.
- The fuel filter should be replaced at every 500 hours.



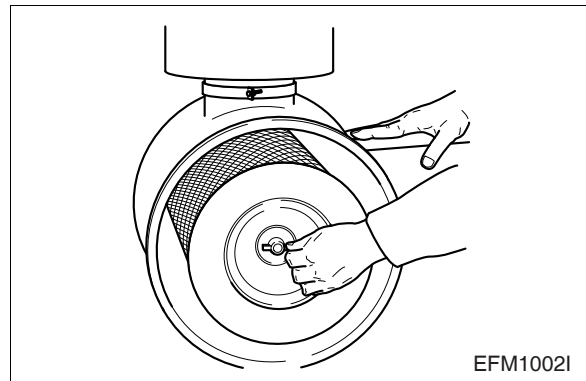
- Check for oil pressure and oil leaks, and repair or replace the oil filter if necessary.
- Change the oil filter cartridge simultaneously at every replacement of engine oil (200 hours).



2.2.24. Air cleaner



- In case that elements are deformed, damaged or if the air cleaner has a crack, replace it.
- By the definite interval, the elements must be cleaned and replaced.



2.2.25. Valve clearance adjust procedure

Method 1

- 1) Rotate the crankshaft so that #1. cylinder may be positioned at the compression TDC (Top Dead Center).

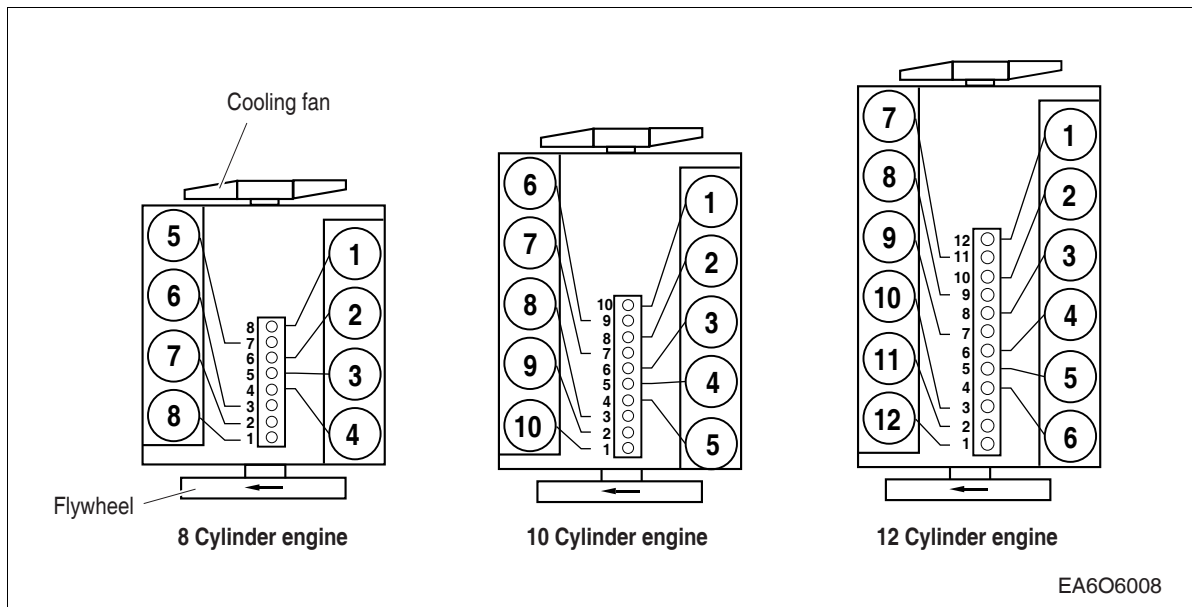


Note

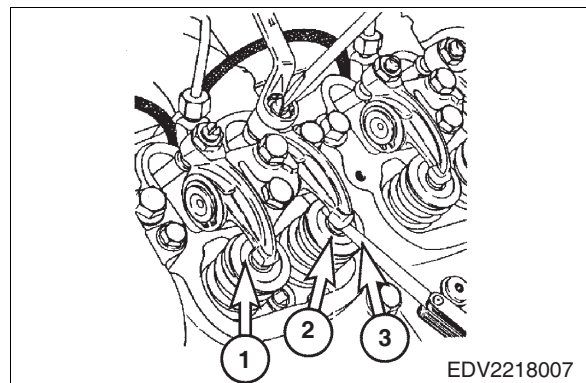
#1. Cylinder is located at the side where cooling water pump was installed.

In case of 8/12 cylinder engine, #6. cylinder is positioned at the valve overlap when #1. cylinder is positioned at the compression TDC (Top Dead Center).

In case of 10 cylinder engine, #7. cylinder is positioned at the valve overlap when #1. cylinder is positioned at the compression TDC (Top Dead center).



- 2) Loosen the lock nut of the #1. cylinder rocker arm.
- 3) Push the feeler gauge between a rocker arm and a valve stem.
- 4) Adjust the clearance screw respectively and then tighten with the lock nut.



- 5) As for the valve clearance, adjust it when in cold, as follows.

Specified Value		Measurement Tolerance	
In. Valve	Ex. Valve	In. Valve	Ex. Valve
0.25 mm	0.35 mm	±0.05 mm	

- 6) Rotate the crankshaft. When a cylinder reaches the compression TDC (Top Dead Center), adjust the valve clearance of the cylinder

7) When a cylinder valve overlap, adjust the valve clearance cylinder of the compression TDC (Top Dead Center), as follow.

*** 8 cylinder engine (P158LE/PU158TI)**

Valve Overlap Cylinder No.							
1	5	7	2	6	3	4	8
6	3	4	8	1	5	7	2
Adjusting Valve Cylinder No. (In./Ex. Valve)							

*** 10 cylinder engine (P180LE/PU180TI)**

Valve Overlap Cylinder No.									
1	6	5	10	2	7	3	8	4	9
7	3	8	4	9	1	6	5	10	2
Adjusting Valve Cylinder No. (In./Ex. Valve)									

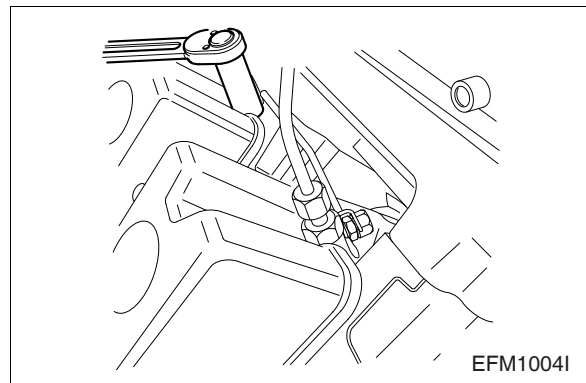
*** 12 cylinder engine (P222LE/PU222TI)**

Valve Overlap Cylinder No.											
1	12	5	8	3	10	6	7	2	11	4	9
6	7	2	11	4	9	1	12	5	8	3	10
Adjusting Valve Cylinder No. (In./Ex. Valve)											

2.2.26. Cylinder compression pressure



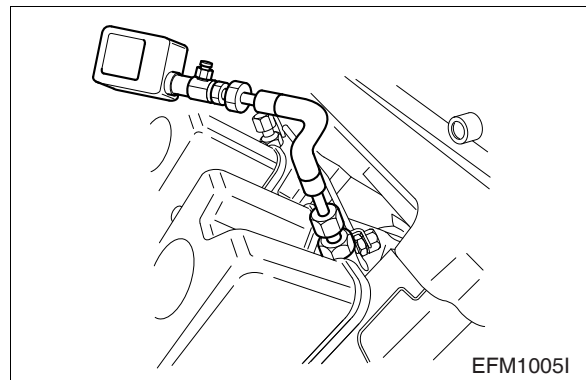
- Stop the engine after warming up, and take out nozzle holder assembly.



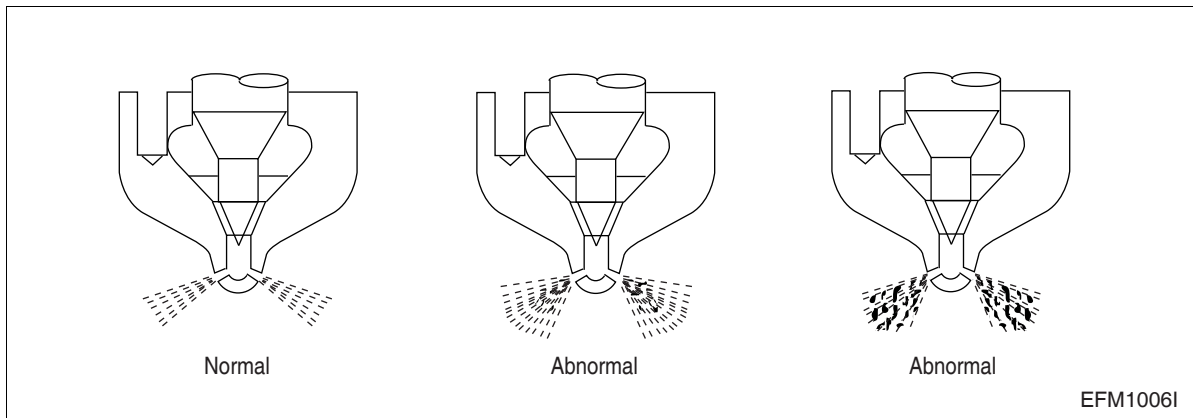
- Install the special tool (compression gauge adapter) at the nozzle holder hole, and connect the compression pressure gauge there.

Standard value	28 kg/cm ² over
Limit value	24 kg/cm ²
Difference between each cylinder	Within $\pm 10\%$

- Condition : Water temperature 20 °C,
Engine rotation 200 rpm



2.2.27. Injection nozzle



- Install a nozzle on the nozzle tester.
- If the inspected injection pressure is less than the specified value (285 kg/cm²), adjust using the adjusting shims.
- Check the atomizing state and replace it if abnormal.

2.2.28. Fuel injection pump

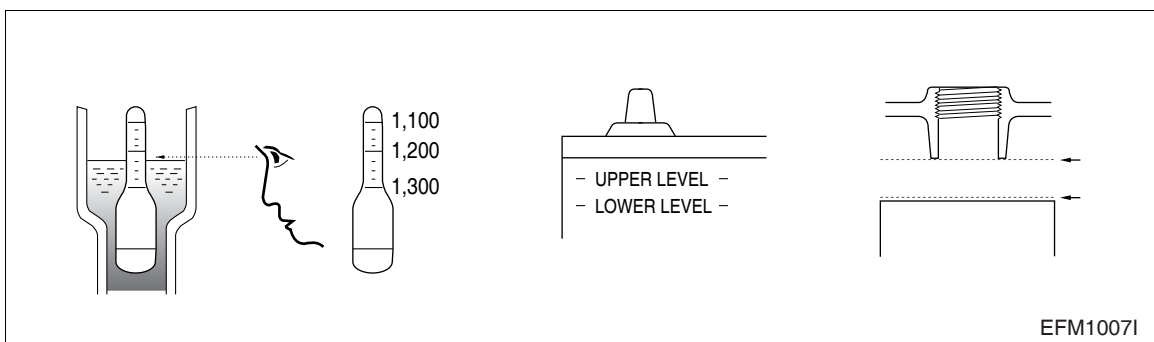


- Check the housing crack, damage etc. and replace it if abnormal.
- Check if the idle operation and speed regulating lever's sealing is removed.
- The adjustment and testing of fuel injection pump should necessarily be done at the test bench.

2.2.29. Battery



- Inspect for any leakage of electrolytic solution owing to battery crack, and replace the battery in case of poor condition.
- Inspect for amount of electrolytic solution, and replenish if insufficient.
- Measure the gravity of electrolytic solution, if less than specified value (1.12 ~ 1.28), replenish.



2.2.30. Air removal of fuel system



The suction room of fuel injection pump has the function of air removal continuously during the operation through a relief valve.

In case that the suction room lacks fuel at all, for instance, in case of new installation of injection pump, after loosening the air removing screws of cartridge filter respectively, remove the air by operating the manual pump of fuel supply pump until bubble will disappear.

2.2.31. Fuel supply pump



Every time of engine oil replacement, the fuel strainer installed at the fuel supply pump should be removed and cleaned.

2.2.32. Supercharger



The supercharger needs not any special equipment

Every time of engine replacement, a leakage or clogging of oil pipes should be inspected. Air cleaner should be maintained carefully for nut or foreign material not to get in. Periodic inspection should be applied on the compressed air and exhaust gas pipes, For leaking air will bring the overheat engine, an immediate repair must be done.

During the operation that is surrounded by the dust and oil mixed air, frequent cleaning must be done on the impellers. Tear down the impeller casing (attention: be careful not to bend) and must clean with non-acid solvent solution. If necessary, use plastic scraper If impeller is severely polluted, dip the impeller into solution and may be better to clean it with stiff brush.

Then one thing to beware is to dip only impeller part and so do not support by impeller but bearing housing.

2.2.33. Air cleaner

Air cleaner is mounted on the engine to purify the air for combustion.

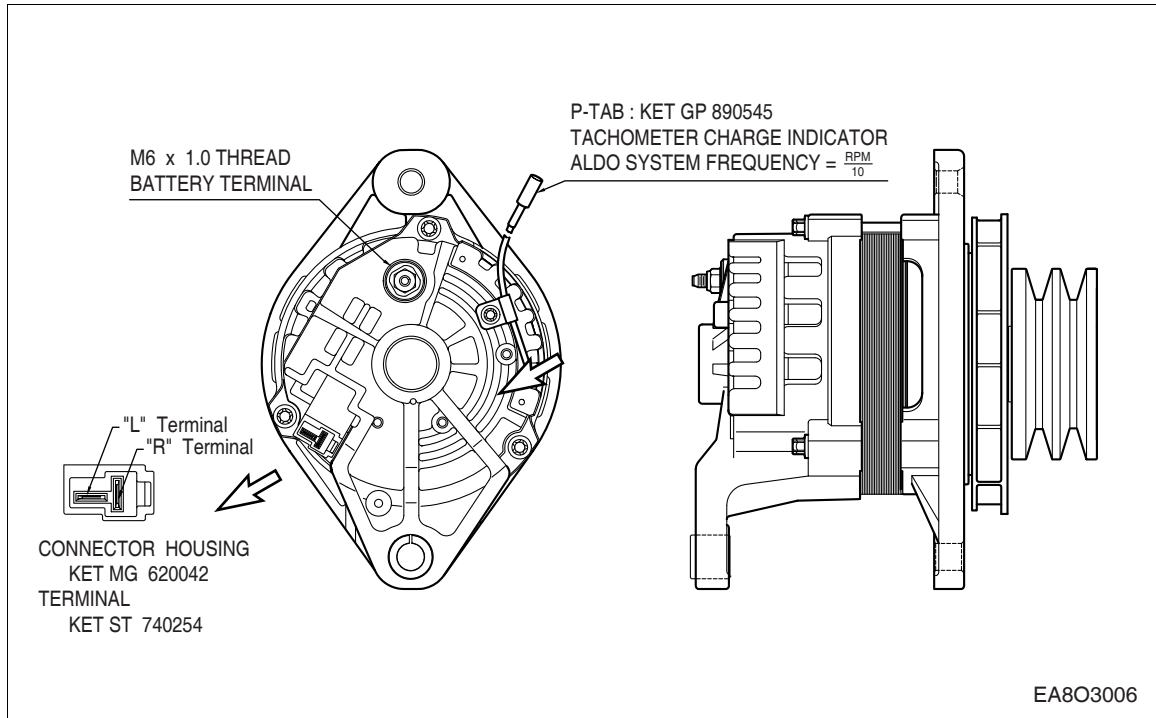
The intervals at which the air cleaner requires servicing depend on the specific operating conditions encountered. Clogged air filters may cause black smoke and reduce power.

A check should be made from time to time to see that the fastening elements securing the air cleaner to the intake manifold seal the connection tightly. Any ingress of unfiltered air is liable to cause a high rate of cylinder and piston wear.

2.2.34. Electrical equipment

1) Alternator

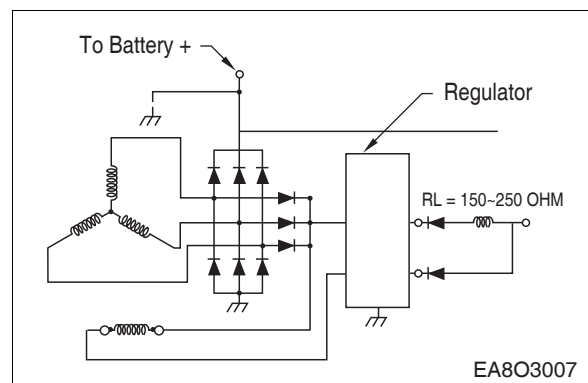
The alternator is fitted with integral silicon rectifiers. A transistorized regulator mounted on the alternator body interior limits the alternator voltage. The alternator should not be operated except with the regulator and battery connected in circuit to avoid damage to the rectifier and regulator.



The alternator is maintenance-free, nevertheless, it must be protected against dust and, above all, against moisture and water.



Operate the alternator according to the instructions given in the chapter "Commissioning and operation".



2) Starter motor

The sliding-gear starter motor is flanged to the rear of the flywheel housing on the left-hand side. As part of every engine overhaul, the starter pinion and ring gear should be cleaned with a brush dipped in fuel and then a coat of grease should be applied again. Always protect starter motor against moisture.



WARNING :

Always disconnect the battery earth cable before starting work on the electrical system.

Connect up the earth cable last, as there is otherwise a rise of short-circuits.

2.2.35. Starting motor



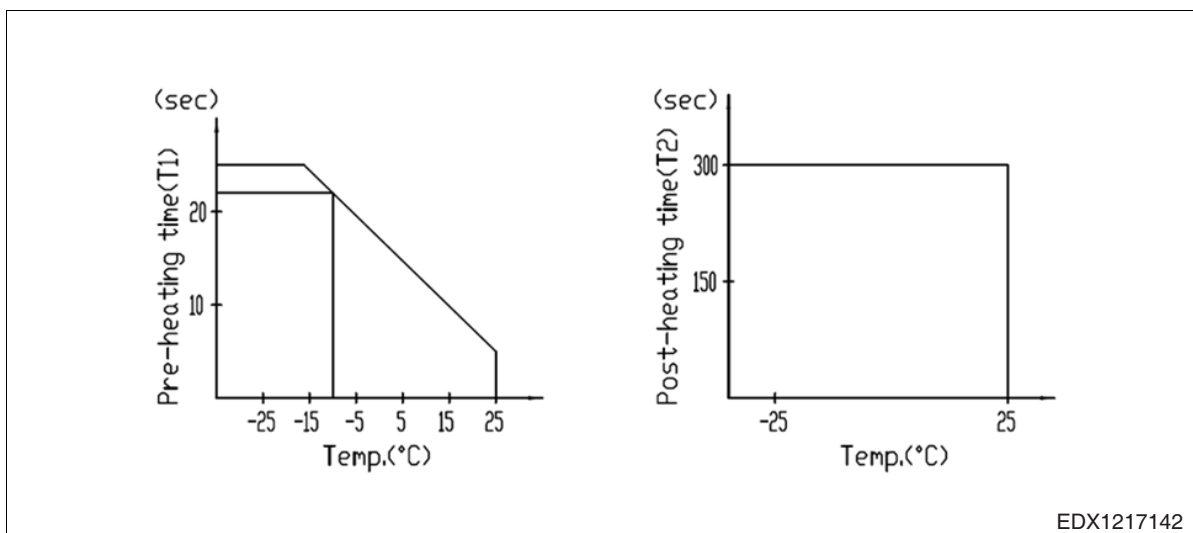
- In case of engine maintenance, clean pinion and ring gear thoroughly putting in the fuel, and coat them with grease.

Also, In case of washing car and so forth, inspect the wiring state being careful for not to get.

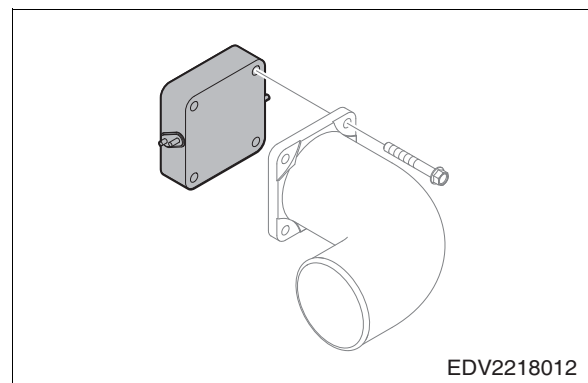
2.2.36. Air Heater

1) Air heater Operating Conditions

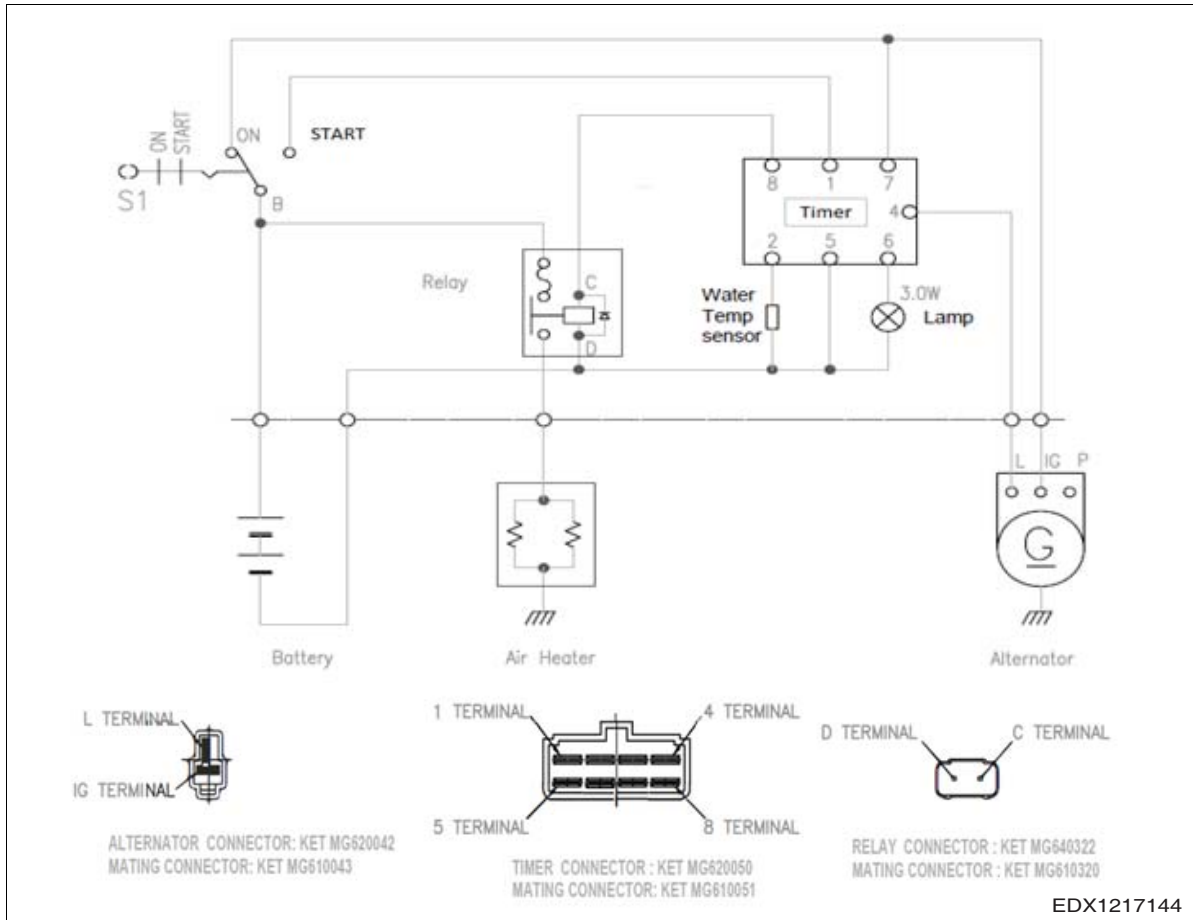
- It is recommended to use the air heater when the cooling water temperature is below 5 degrees.
- Air heater, Timer, Relay is supplied, and the heater operation time is automatically adjusted according to the cooling water temperature.
- Preheating / Post-heating time



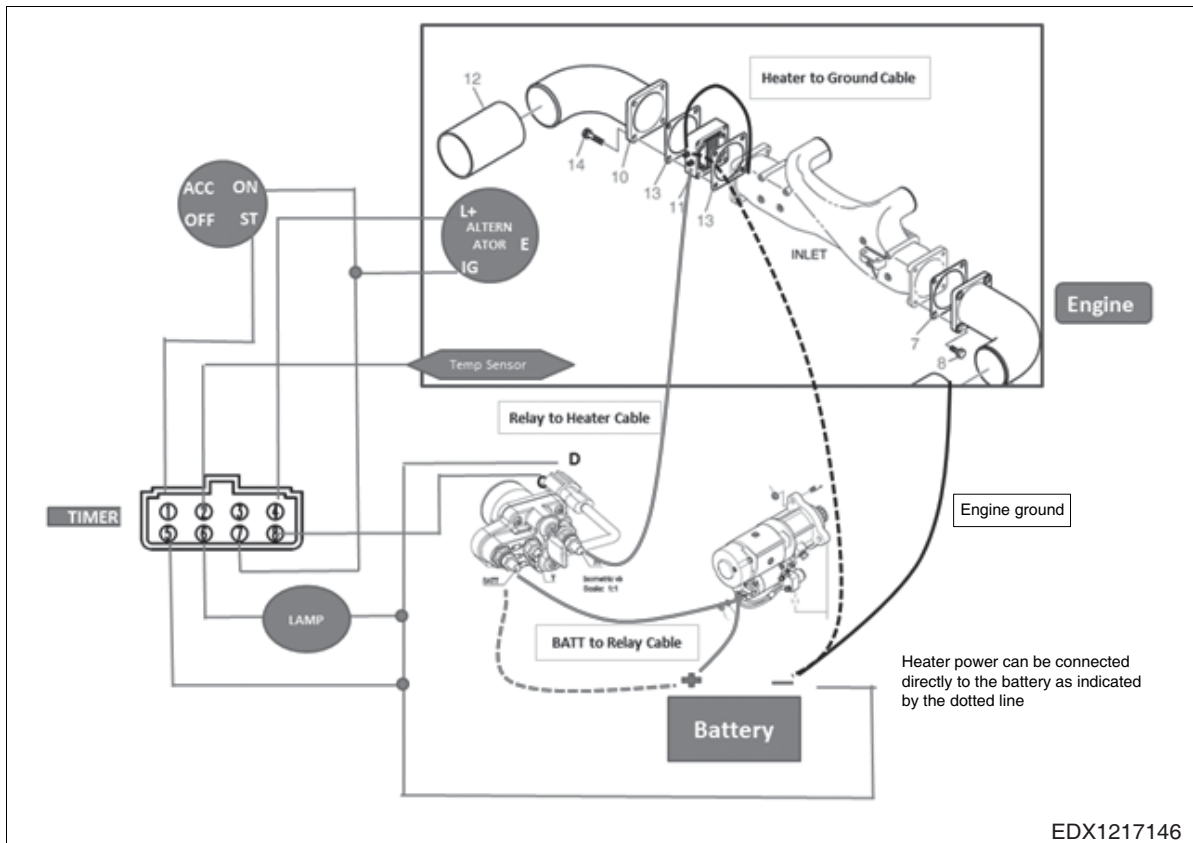
2) Air heater Mounting parts



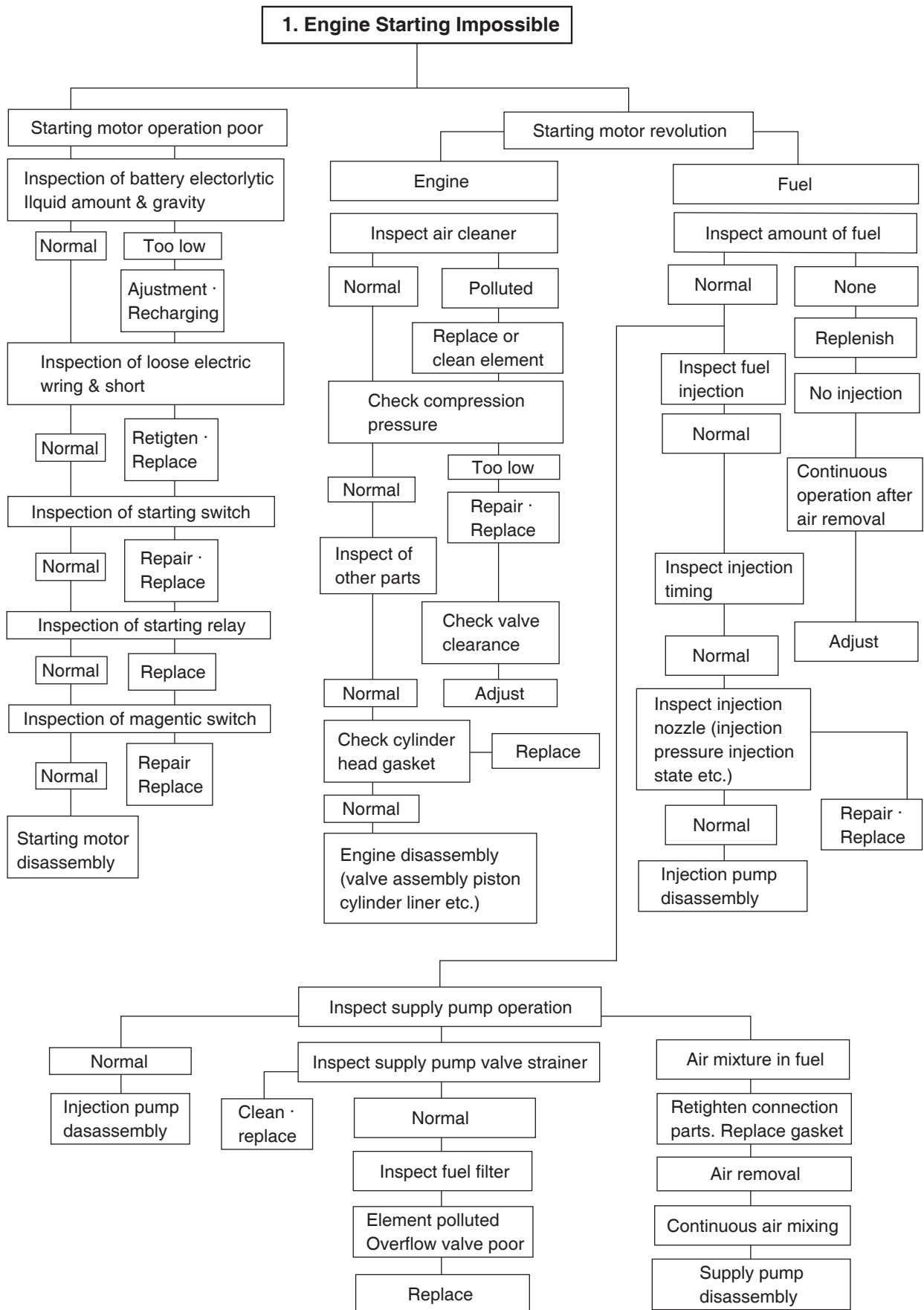
3) Air heater Diagram

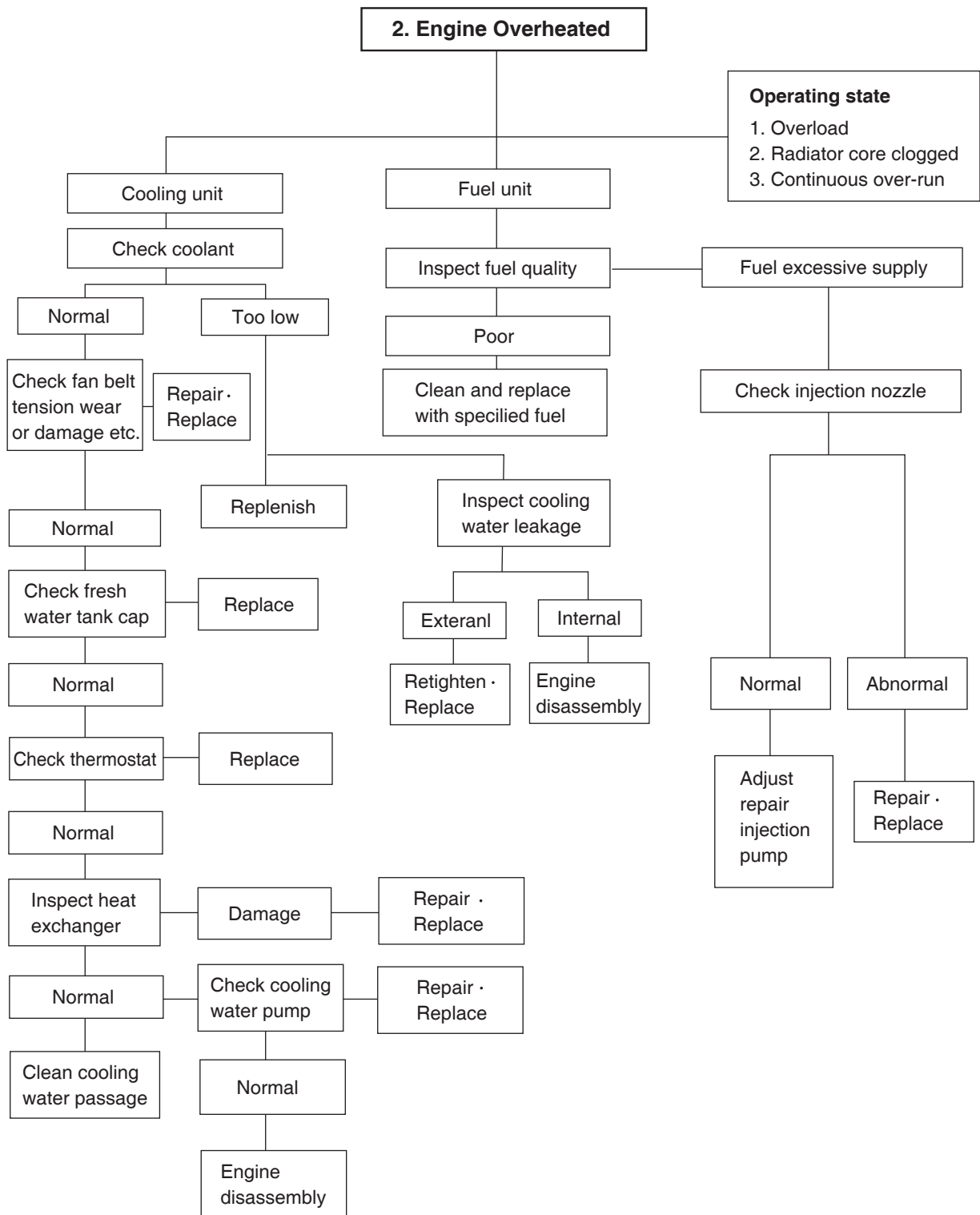


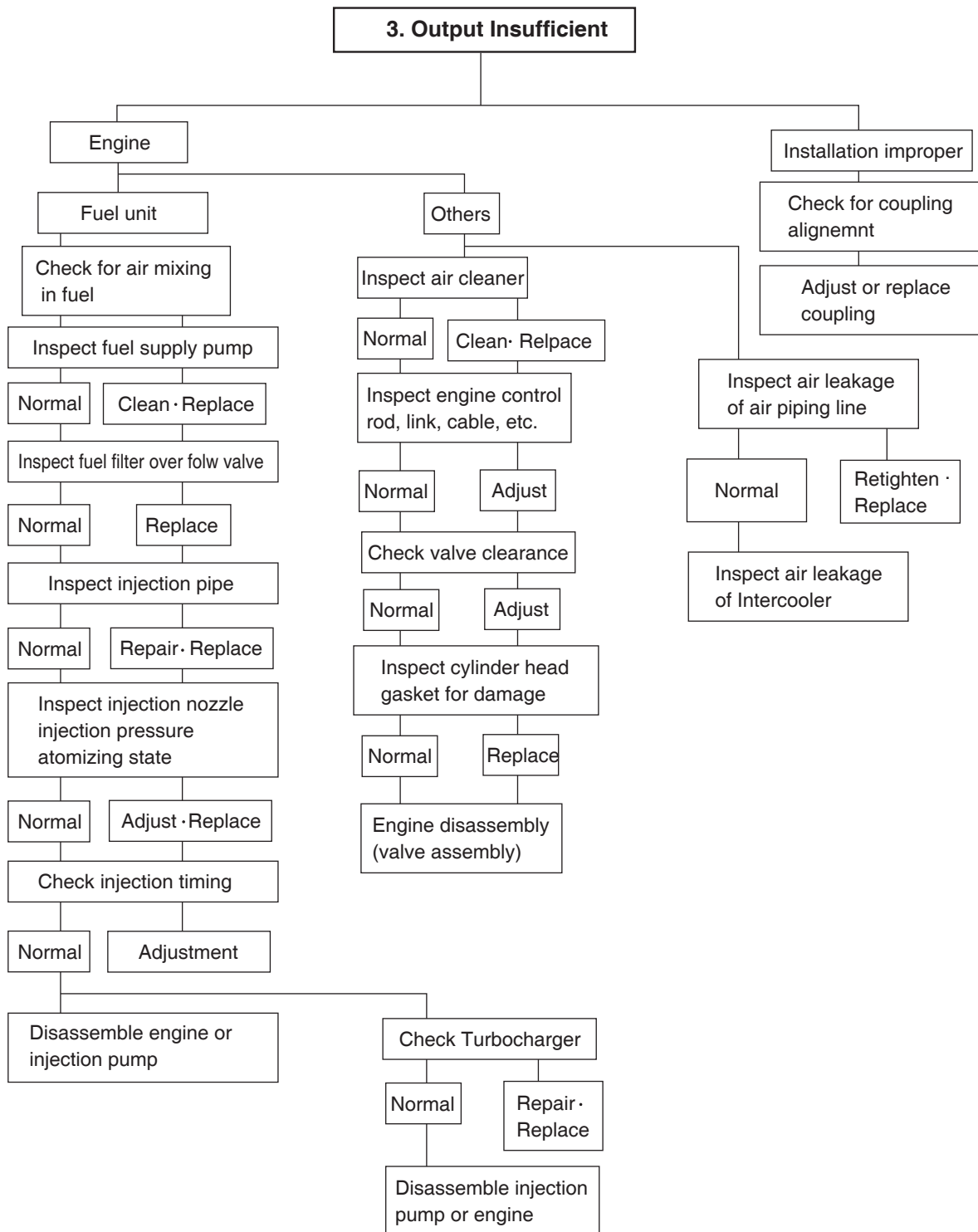
4) Air heater schematic

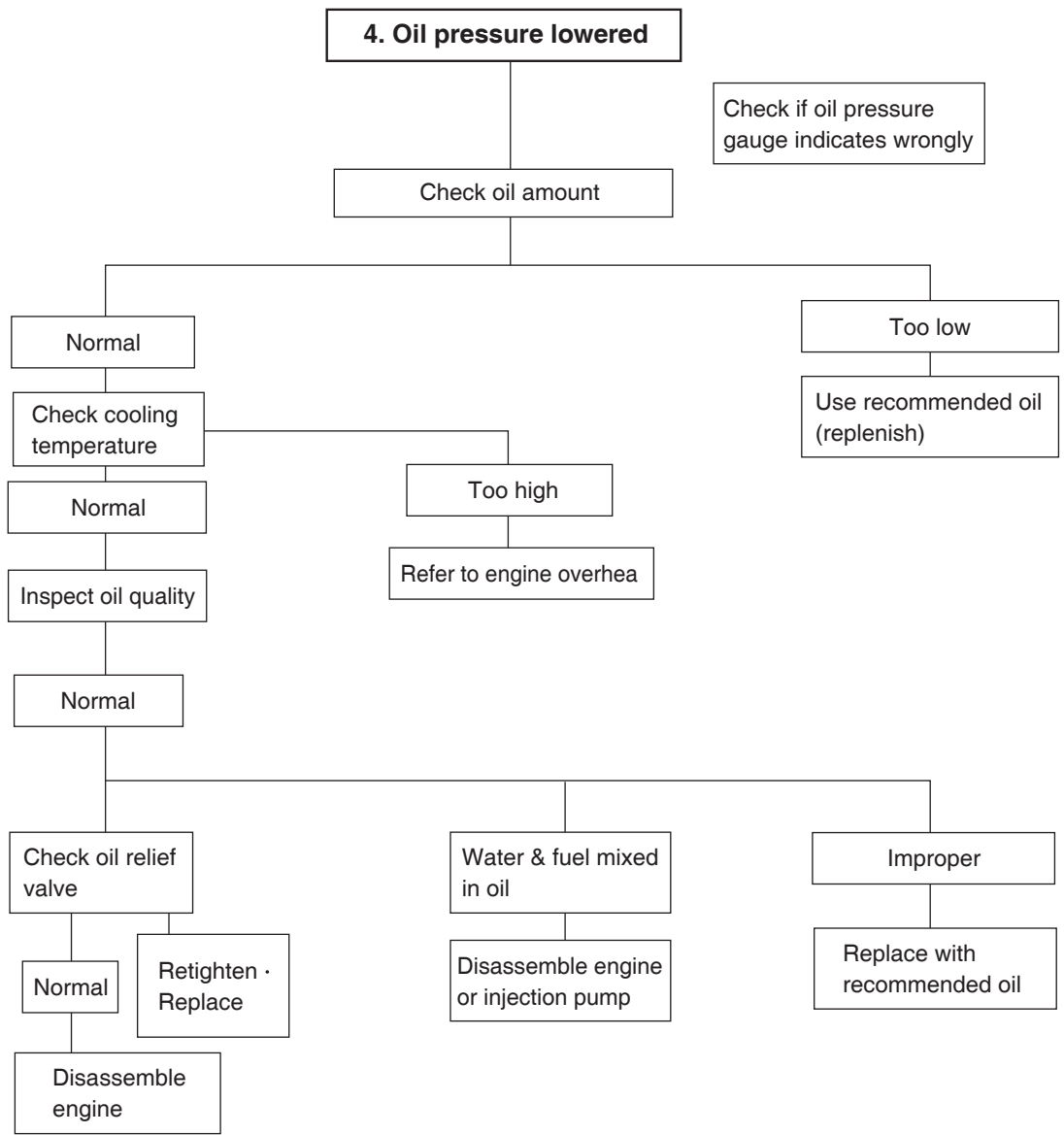


2.3. Troubleshooting





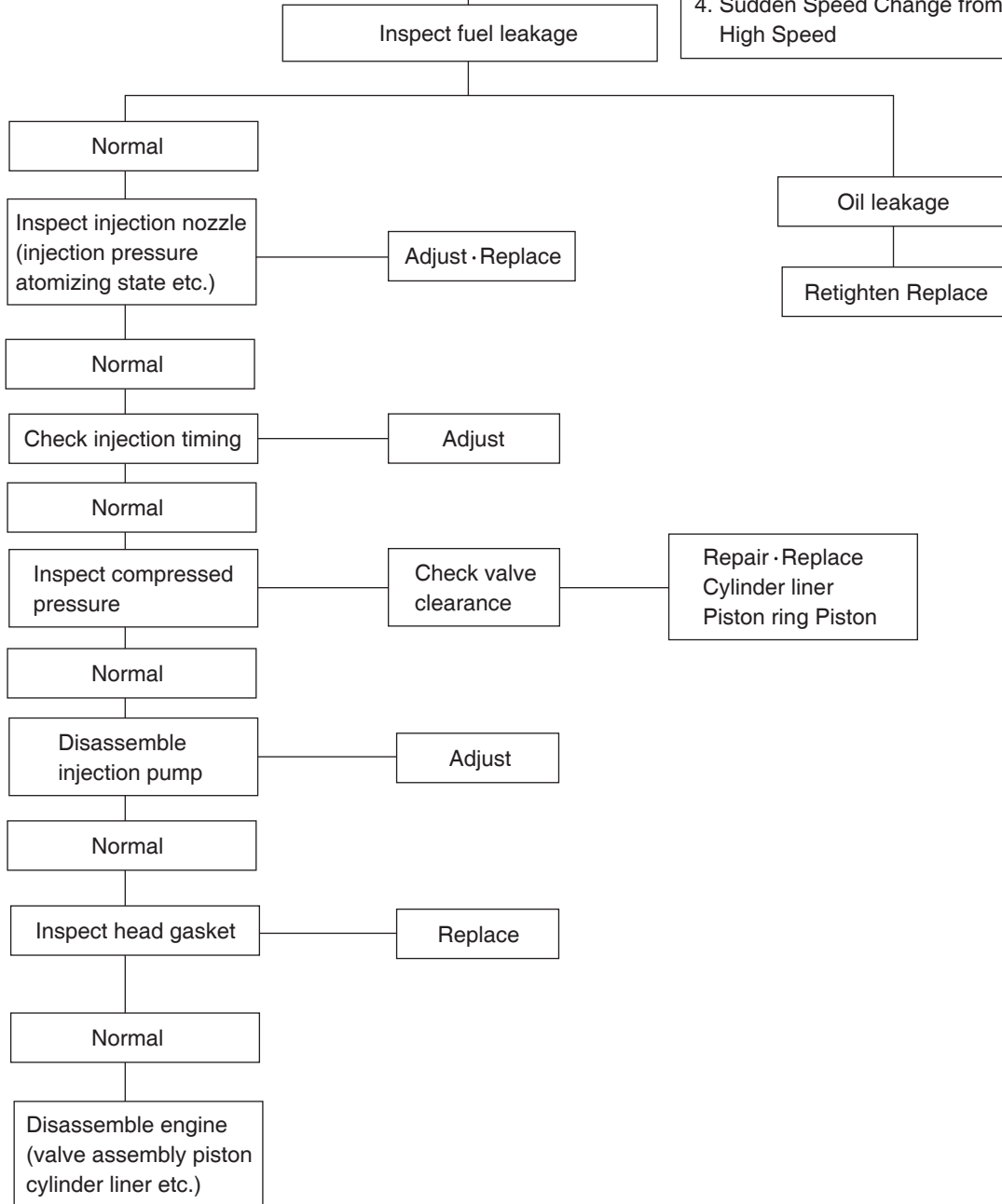




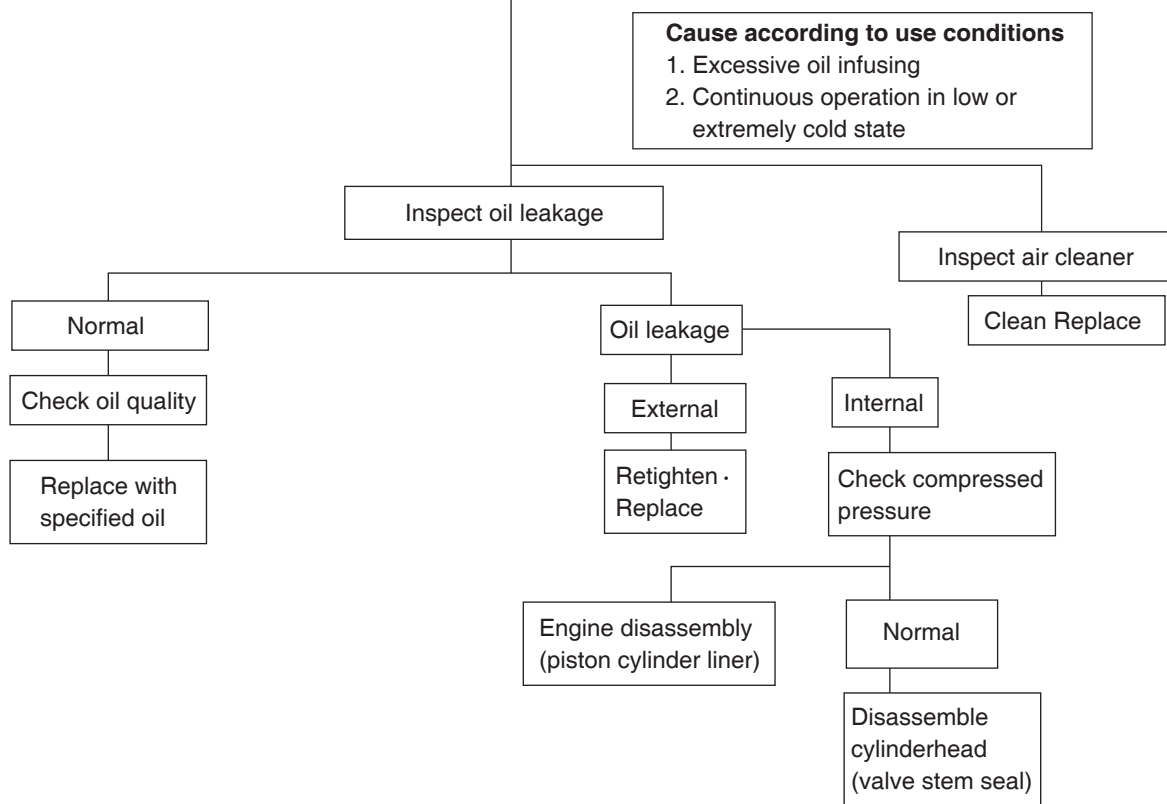
5. Fuel Consumption Excessive

Causes according to Use Conditions

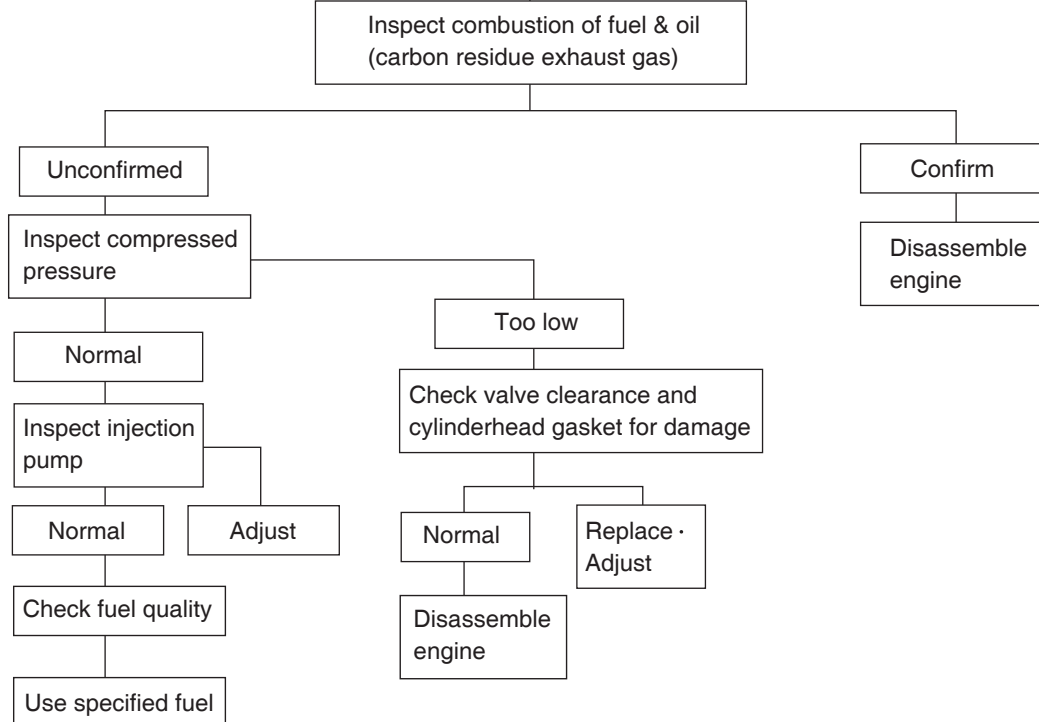
1. Overload
2. Governor's Arbitrary Adjustment
3. Full Speed Operation for Long time
4. Sudden Speed Change from Low to High Speed

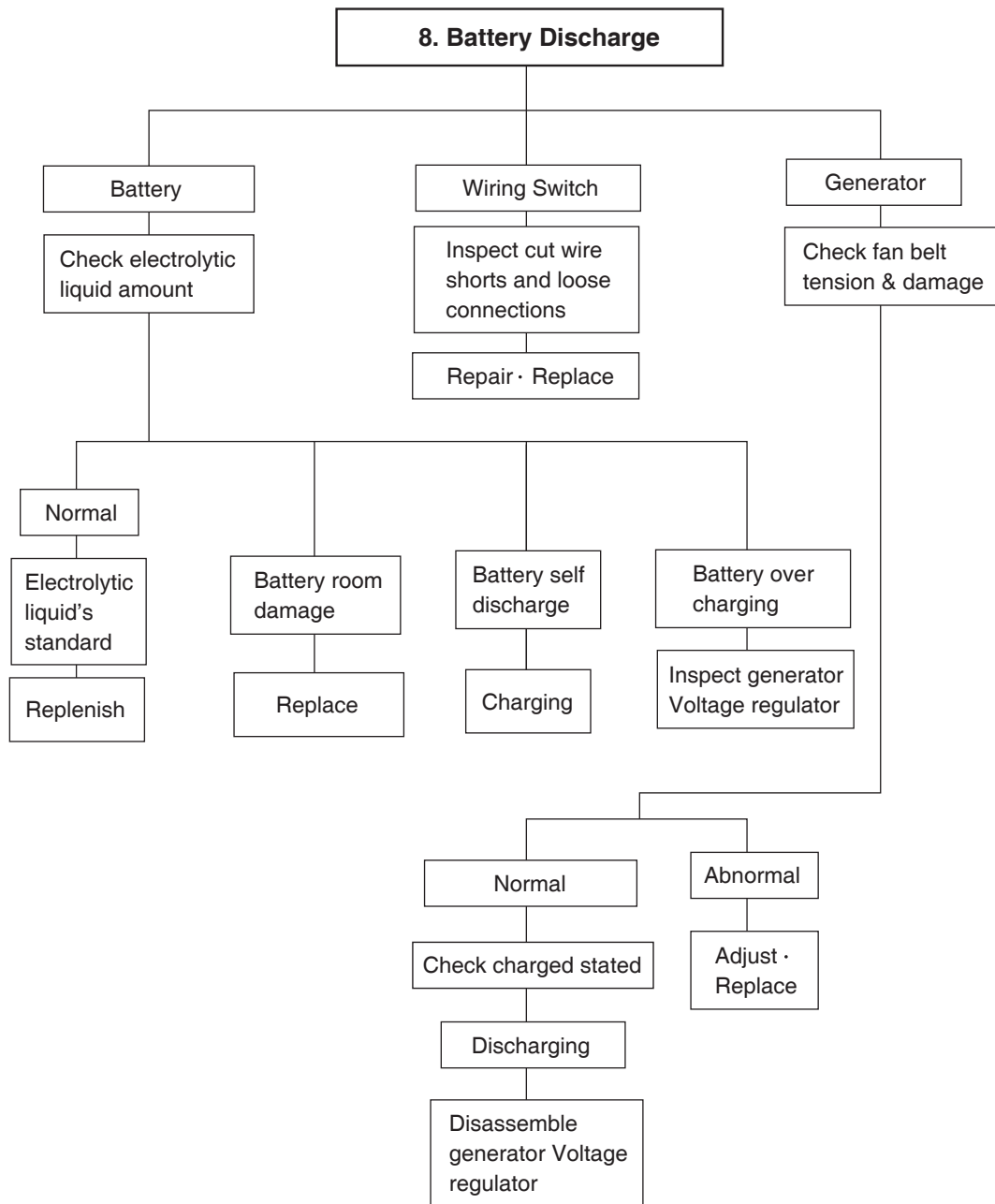


6. Oil Consumption Excessive



7. Engine Knocking





Condition	Causes	Remedies
5) Engine noisy	For noises arise compositely such as rotating parts, lapping parts etc., there is necessity to search the cause of noises accurately.	
(1) Crankshaft	<ul style="list-style-type: none"> ● As the wear of bearing or crankshaft progress, the oil clearances increase. ● Lopsided wear of crankshaft ● Oil supply insufficient due to oil passage clogging ● Stuck bearing 	Replace bearing & grind crankshaft Grind or replace Clean oil passage Replace bearing & Grind
(2) Con rod and Con rod bearing	<ul style="list-style-type: none"> ● Lopsided wear of con rod bearing ● Lopsided wear of crank pin ● Connecting rod distortion ● Stuck bearing ● Oil supply insufficiency as clogging at oil passage progresses 	Replace bearing Grind crankshaft Repair or replace Replace & grind crankshaft Clean oil passage
(3) Piston, piston pin & piston ring	<ul style="list-style-type: none"> ● Piston clearance increase as the wear of piston and piston ring progresses ● Wear of piston or piston pin ● Piston stuck ● Piston insertion poor ● Piston ring damaged 	Replace piston & piston ring Replace Replace piston Replace piston Replace piston
(4) Others	<ul style="list-style-type: none"> ● Wear of crankshaft, thrust bearing ● Camshaft end play increased ● Idle gear end play increased ● Timing gear backlash excessive ● Valve clearance excessive ● Abnormal wear of tappet, cam ● Supercharger inner part damaged 	Replace thrust bearing Replace thrust plate Replace thrust washer Repair or replace Adjust valve clearance Replace tappet, cam Repair or replace
6) Fuel Consumption Excessive	<ul style="list-style-type: none"> ● Injection timing incorrect ● Fuel injection amount excessive 	Adjust Adjust injection pump

Condition	Causes	Remedies
7) Oil Consumption Excessive (1) Oil level elevated	<ul style="list-style-type: none"> ● Clearance between cylinder liner & piston ● Wear of piston ring, ring groove ● Piston ring's damage, stick, wear ● Piston ring opening's disposition improper ● Piston skirt part damaged or abnormal wear ● Oil ring's oil return hole clogged ● Oil ring's contact poor 	Replace Replace piston, piston ring Replace piston ring Correct position Replace piston Replace piston ring Replace piston ring
(2) Oil level lowered	<ul style="list-style-type: none"> ● Looseness of valve stem & guide ● Wear of valve stem seal ● Cylinder head gasket's leak 	Replace in set Replace seal Replace gasket
(3) Oil leak	<ul style="list-style-type: none"> ● Looseness of connection parts ● Various part's packing poor ● Oil seal poor 	Replace gasket, repair Replace packing Replace oil seal

2.4. Operation Tip

2.4.1. Periodic Inspection cycle

○ : Check & adjust ● : Replace

Inspection		Daily	Inspection time (hours)						Remark
			50	200	500	600	800	1,200	
Cooling System	Check for leakage (hoses, clamp)	○							Every 2 year
	Check the water level	○							
	Change the coolant water							●	
	Adjust the V-belt tension	○							Every 2,000 hrs
	Replace V-belt								Every 1,600 hrs / Every 2 year
	Clean the radiator							○	
Lubrication System	Check for leakage	○							
	Replace oil hoses, clamps								Every 2 year
	Check the oil level gauge	○							
	Change the lubricating oil		● 1st	●					Every 200 hrs / Every 1 year
	Replace the oil filter cartridge			●					Every 200 hrs / Every 1 year
Intake & Exhaust System	Check the leakage for intercooler (hoses, clamp)	○							Every 2 year
	Clean and change the air cleaner element			○ clean					Every 400 hrs
	Clean the inter-cooler air fins					○			
	Clean the turbo-charger								Every 2,000 hrs
Fuel System	Check the leakage fuel line	○							
	Clean the fuel strainer of fuel feed pump							○	
	Remove sediment from fuel tank							○	
	Drain the water in separator			○					
	Replace the fuel filter element		● 1st		●				
	Check fuel Injection timing			○					When necessary
	Check the injection nozzles			○					When necessary
	Replace fuel hoses, clamps								Every 2 year
Engine Adjust	Check the state of exhaust gas	○							
	Check the battery charging	○							
	Check the compression pressure							○	When necessary
	Adjust Intake / Exhaust valve clearance		○ 1st						Every 1,000 hrs

* If the sulfur content of the fuel is more than 0.5%, the replacement and inspection cycle should be cut in half.

3. Disassembly and Reassembly of Major Components

3.1. Engine Disassembly



- Engine part's disassembly procedures are as follows;



- For the various tool storage before disassembly and parts storage after disassembly, the shelf for parts is prepared.
- At the time of disassembly and reassembly, do the work with the naked and clean hand, and also the working place must be maintained clean.
- The torn parts after disassembly must be kept not to collide each other.
- In disassembling, torn parts should be laid in disassembled order.

3.1.1. Oil level gauge

- Take out the oil level gauge

3.1.2. Engine oil

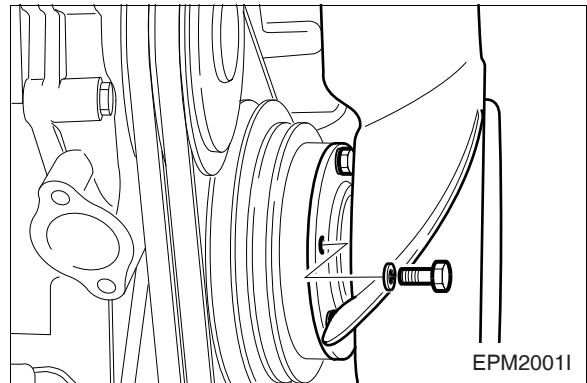
- Remove an oil drain cock from the oil pan, and let engine oil discharge into the prepared vessel.

3.1.3. Cooling water

- Remove the cooling water drain plug from the cylinder block and oil cooler, various pipes, etc. and let the cooling water discharge into the prepared vessel.

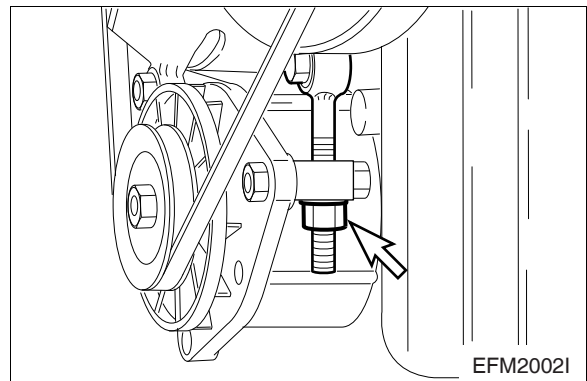
3.1.4. Cooling fan

- Remove fan fixing bolts, then take off the cooling fan.



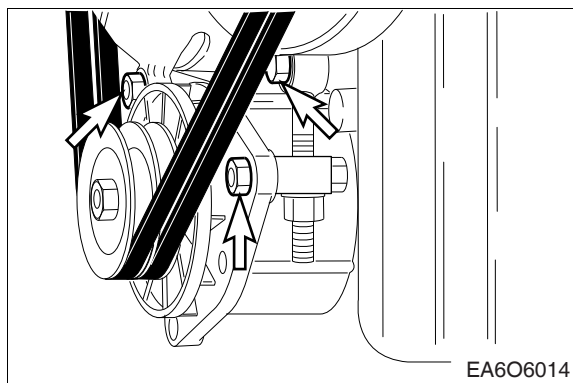
3.1.5. V-belt

- Loosen the V-belt tension adjusting bolts, and remove the V-belt.



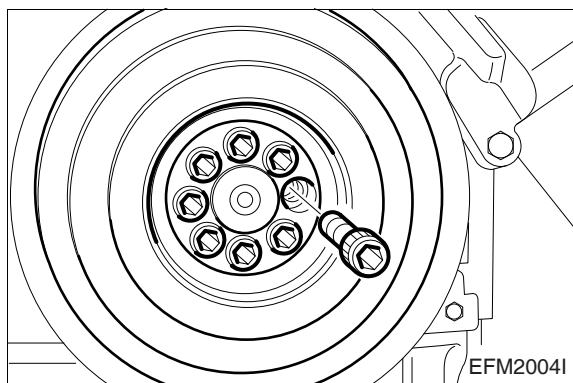
3.1.6. Alternator

- Remove the supporting guide piece for installing the alternator and the bracket bolts.
- Disassemble the alternator.



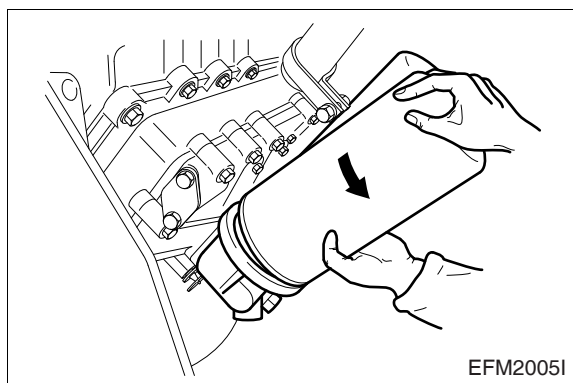
3.1.7. Vibration damper

- Remove the fixing bolts for crankshaft pulley in reverse order of assembling and disassemble the crankshaft pulley and vibration damper.

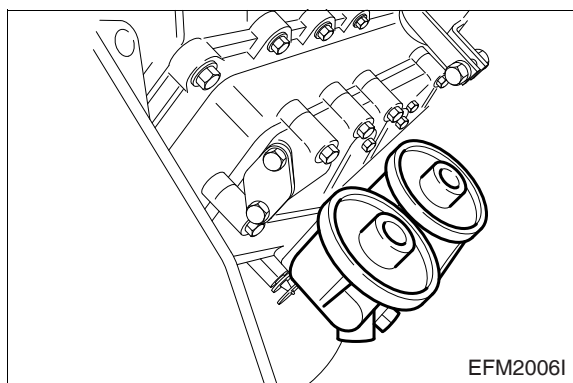


3.1.8. Oil filter assembly

- Disassemble the oil filter cartridge with filter wrench by means of a filter wrench.
- Do not use again the cartridge removed after use.

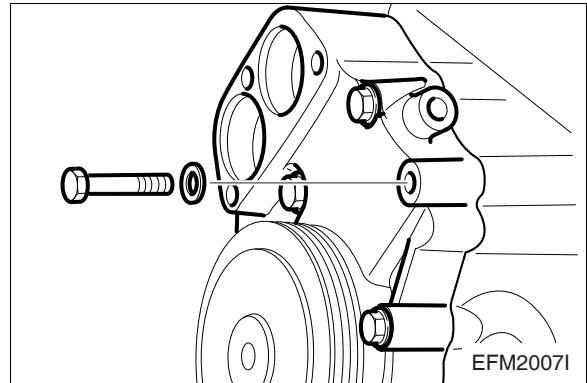


- Remove the oil filter head fixing bolts and disassemble the filter head.



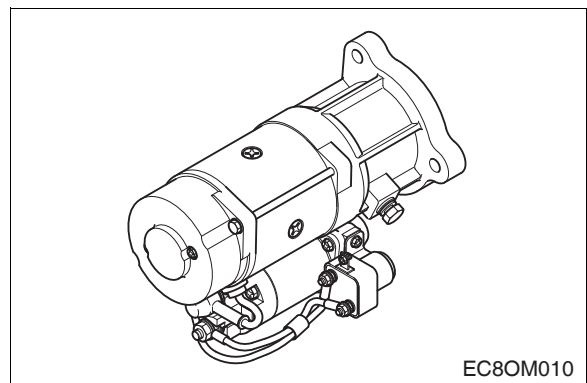
3.1.9. Cooling water pump

- Loosen the various hose clamps for the connections.
- Remove the cooling water discharging pipe and disassemble the thermostat.
- Remove the cooling water pump fixing bolts and disassemble the cooling water pump.



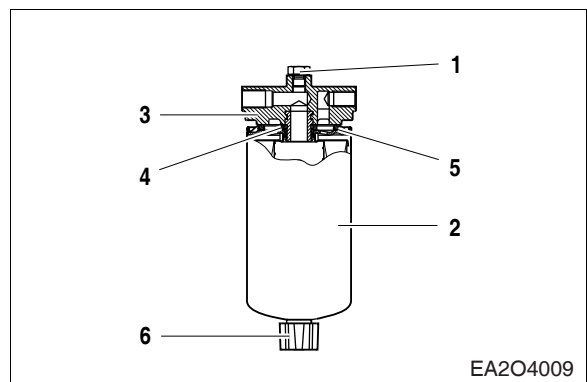
3.1.10. Starting motor

- Remove the starting motor fixing nuts and disassemble the starting motor.



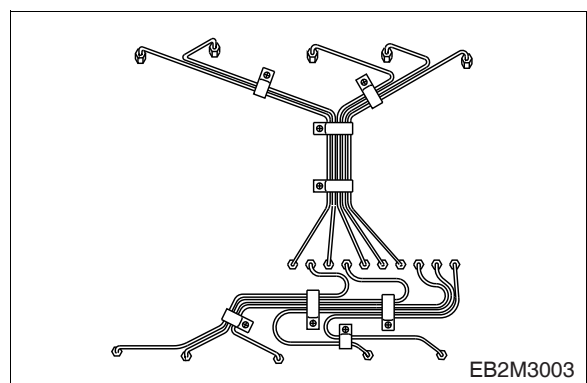
3.1.11. Fuel filter

- Disassemble the fuel hose for the fuel supply and suction.
- Remove the fuel filter fixing bolts and disassemble the filter.



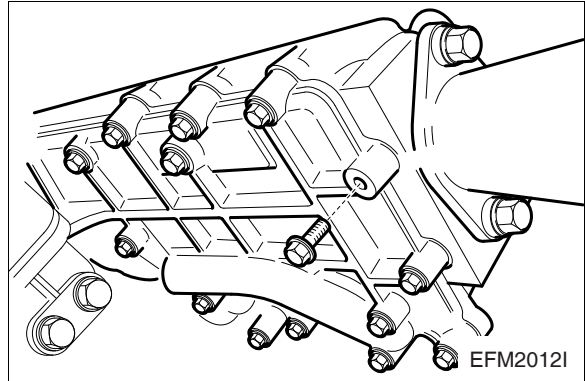
3.1.12. Injection pipe

- Disassemble various fuel pipe and hose.
- Disassemble the injection pipe from the nozzle holder and fuel injection pump.

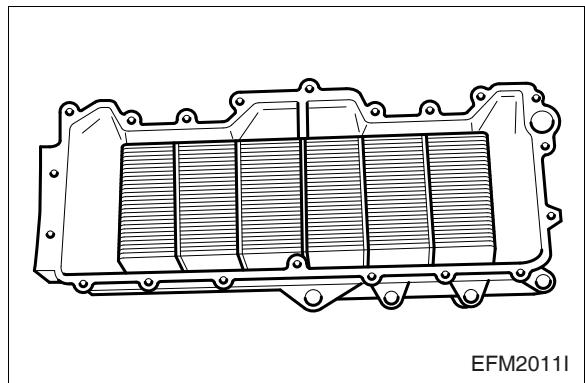


3.1.13. Oil cooler assembly

- By removing the plug screw of cooling water discharge port, the cooling water is discharged.

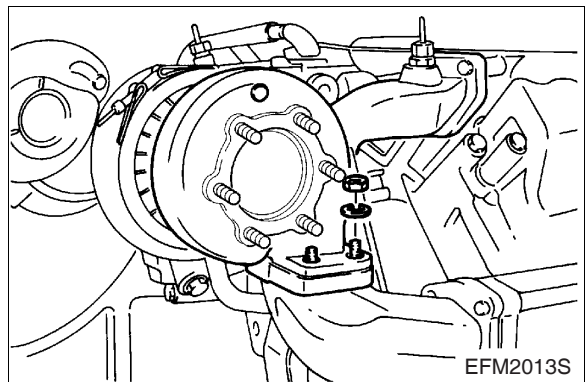


- Remove the oil cooler cover fixing bolts and disassemble the oil cooler.
- By removing the cooler housing fixing bolts and disassemble the oil cooler housing from the cylinder block.



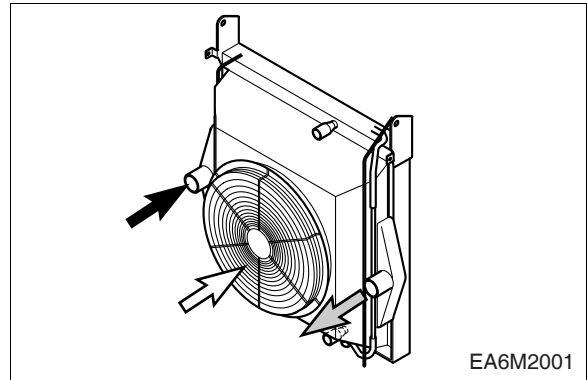
3.1.14. Turbo charger

- Loosen the hose clamp for connecting the intake stake and tear down the air intake stake.
- Loosen the clamp for connecting the air intake manifold.
- Remove the hollow screws of pipes for turbocharger lubrication and its discharge, and tear the pipes down.
- Remove the turbocharger fixing nuts and separate the turbocharger from the exhaust manifold.



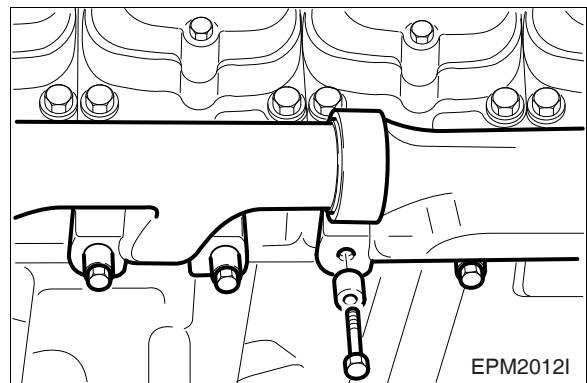
3.1.15. Intercooler

- Tear down the various hoses and air pipes from the inter cooler.
- Remove the intercooler fixing bolts and tear it down.



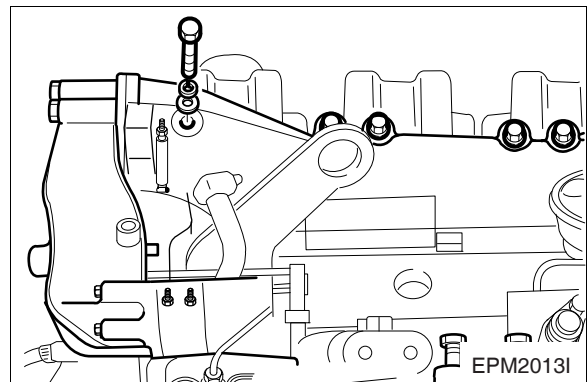
3.1.16. Exhaust manifold

- Remove the exhaust manifold fixing bolts and tear the manifold from the cylinder head.



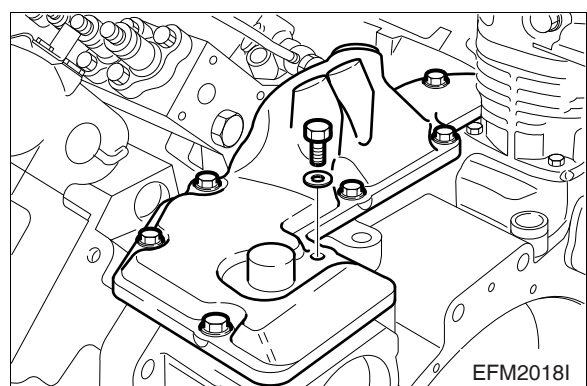
3.1.17. Intake manifold

- Remove the manifold fixing bolts and tear the manifold down from the cylinder head.



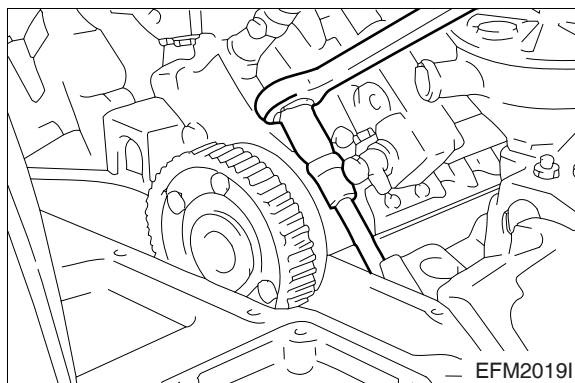
3.1.18. Flywheel housing cover

- Separate the side cover.
- Disassemble the flywheel housing cover.



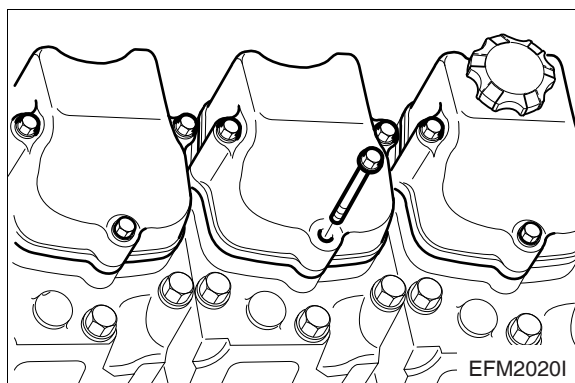
3.1.19. Fuel injection pump

- Remove the oil hoses for lubrication and the fuel hoses.
- Remove the fixing bolts of fuel injection pump and take out the fuel Injection pump.



3.1.20. Cylinder head cover

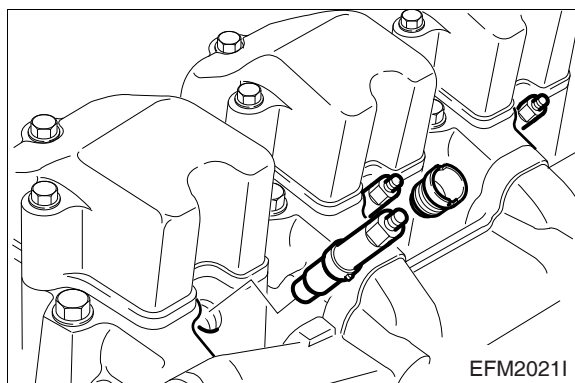
- Remove the fixing bolts and tear the cylinder head cover down.



3.1.21. Nozzle holder

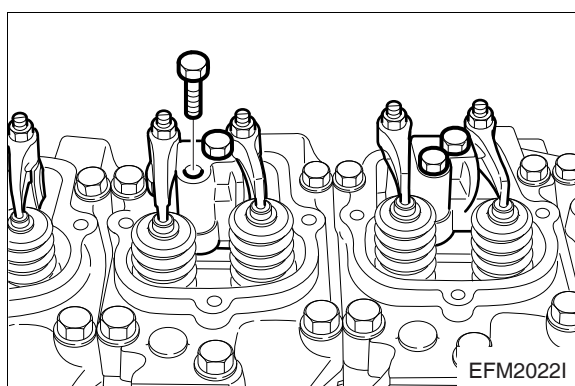


- By means of a special tool, loosen the nozzle holder assembly and take it out.



3.1.22. Rocker arm

- Remove the rocker arm bracket fixing bolts and take the rocker arm assembly out.
- Pull out the push rod.



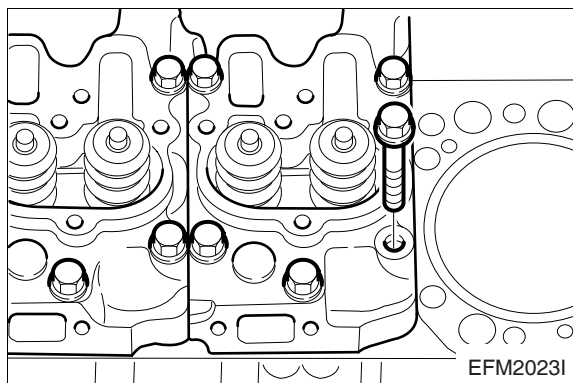
3.1.23. Cylinder head

- Loosen the cylinder head fixing bolts in the reverse order of assembling, and remove them all and then take the cylinder head out.
- Remove the cylinder head gasket and scrap it.
- Eliminate the residue from the cylinder head face and cylinder block face.



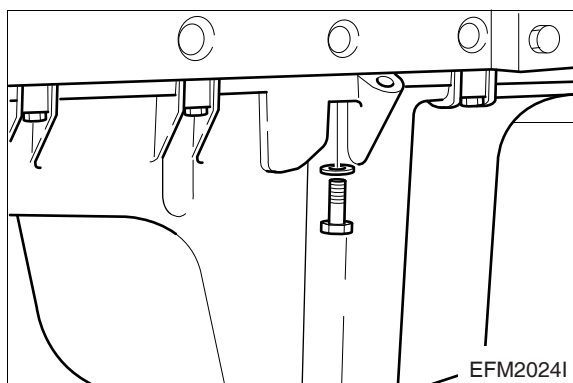
NOTE :

Be careful not to damage the cylinder head face where its gasket contacts.



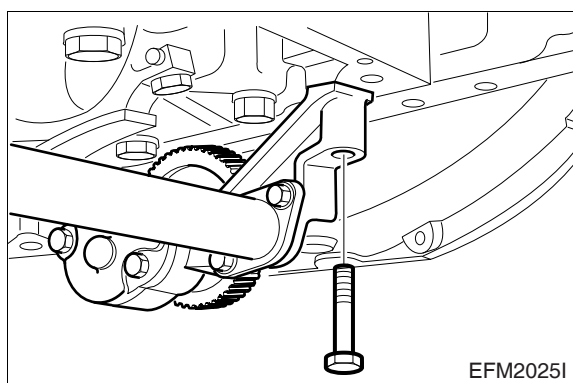
3.1.24. Oil pan

- Remove the oil pan fixing bolts and separate the pan.
- Remove the oil pan gasket and scrap it.



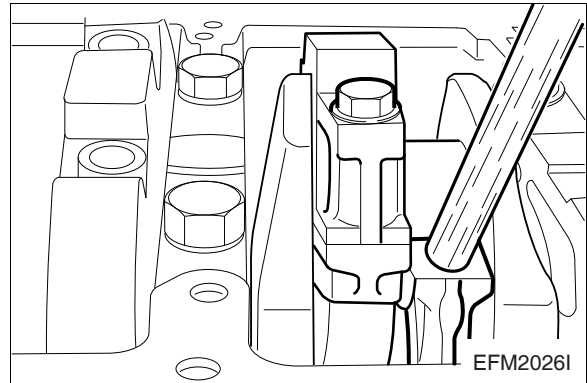
3.1.25. Oil pump

- Remove the oil suction pipe fixing bolts and tear them down.
- Remove the oil relief valve fixing bolts and take them out.
- Remove the oil pump fixing bolts and separate it.



3.1.26. Piston

- Remove the connecting rod cap bolts in the reverse order of assembling and follow the similar method as in the cylinder head bolt removal.
- Tapping the upper and lower connecting rod caps lightly with an urethane hammer, separate them and take the bearings out.
- By pushing the piston assembly with a wooden bar toward the cylinder head's direction remove the piston.

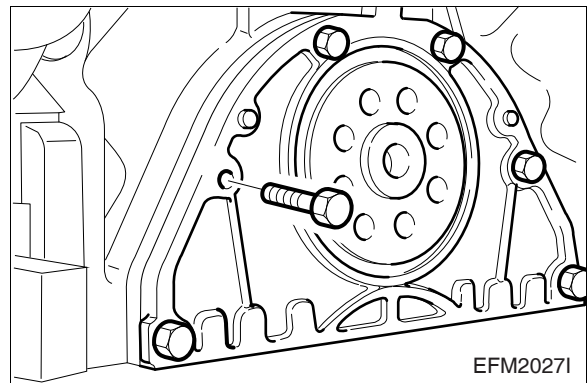


NOTE :

Be careful for the removed pistons not to collide each other or with the other parts. At the storage of pistons, maintain them in the order of cylinders.(In order for connecting rod caps not to mix one another, temporarily assemble them to the corresponding connecting rods.)

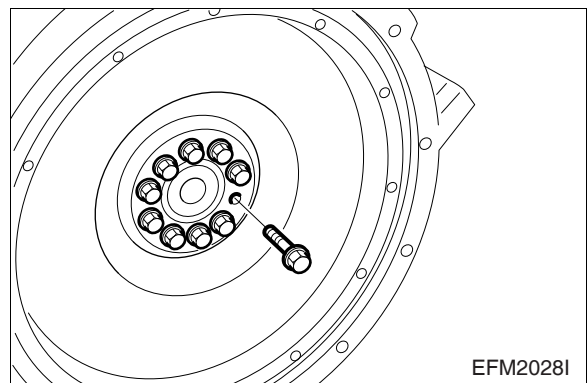
3.1.27. Front oil seal holder

- Remove the oil seal holder fixing bolts and tear down.
- Remove the oil seal and gasket from the oil seal holder and scrap them.



3.1.28. Flywheel

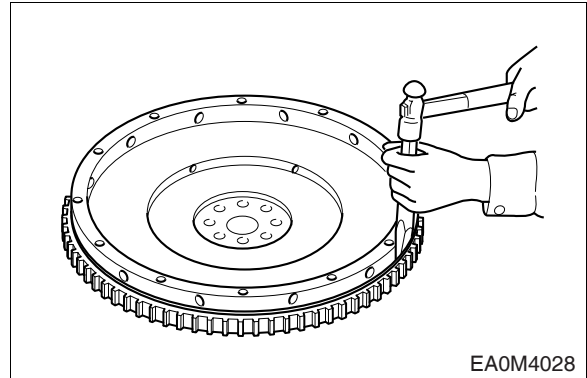
- Remove the flywheel fixing bolts in the order of disassembling and remove the flywheel.



- Remove the flywheel ring gear.
 - Heat the ring gear evenly with a gas burner (up to 200 °C) to invite volumetric expansion.
 - Tapping around the edges of the ring gear with a hammer and brass bar to remove it.



CAUTION :
Do not damage the flywheel.

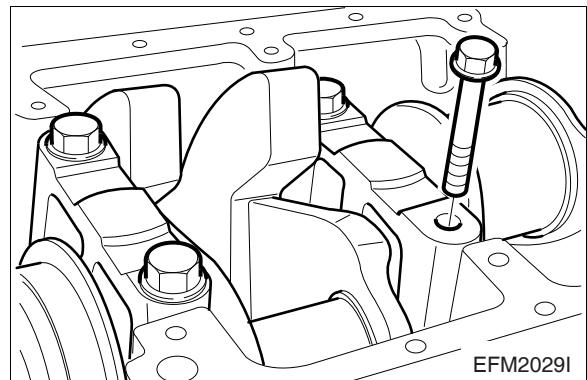


3.1.29. Flywheel housing

- Remove the flywheel housing fixing bolts and take them out.
- Remove the oil seal from the flywheel housing.

3.1.30. Crankshaft

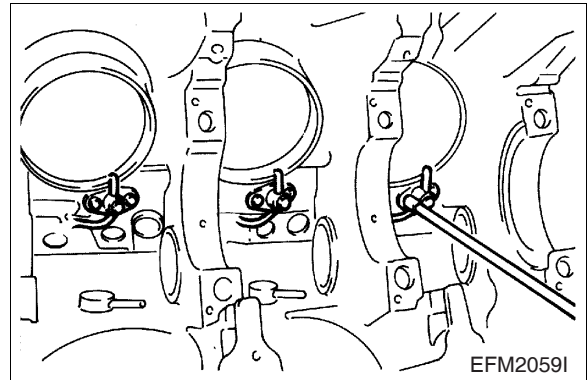
- Remove the bolts from bearing caps.
- Remove the main bearing cap fixing bolts in the order of assembling. (Remove them in /the same way of the cylinder head bolts.)
- Maintain the removed bearing caps in the order of cylinders.
- Temporarily install the bolts at the both side of crankshaft, and lift the shaft with a rope.



NOTE :
Do not mingle with the metal bearings and bearing caps randomly. To prevent mixing, temporarily assemble the metal bearings to the corresponding bearing caps in turn.

3.1.31. Camshaft and tappet

- Pull out the tappets from the cylinder block.
- Remove the camshaft being careful not to damage the camshaft and its bearings.



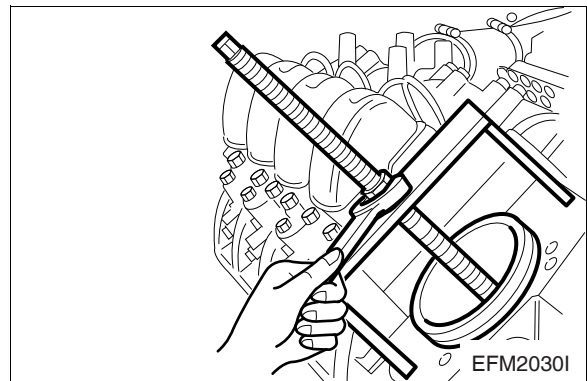
3.1.32. Oil spray nozzle

- Remove the oil injection nozzle fixing bolts and tear down the oil injection nozzles.

3.1.33. Cylinder liner



- By means of a special tool (Extractor), pull out the liner from the cylinder block.



3.2. Inspection

3.2.1. Cylinder block



- 1) Clean the cylinder block thoroughly and check a visual inspection for cracks or damage.
- 2) Replace if cracked or severely damaged, and correct if slightly damaged.
- 3) Check the oil and water passing lines for restriction or corrosion.
- 4) Inspect the cylinder block's camshaft bush to any damage and the alignment of oil supply holes and if abnormal or severe wears, replace it.
- 5) Make a hydraulic test to check for any cracks or air leaks.

Hydraulic test :

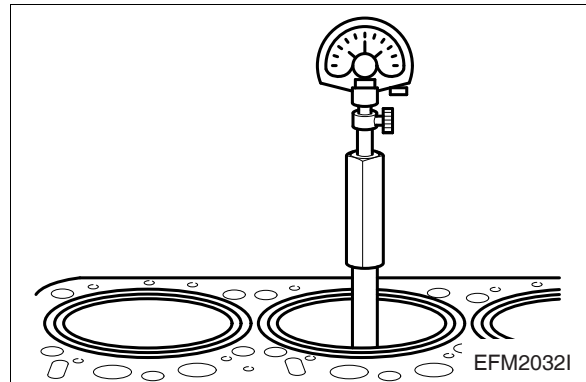
Stop up each outlet port of water and oil passages in the cylinder block, apply air pressure of about 5 kg/cm² against the inlet ports, then immerse the cylinder block in water for about 1 minute to check any leaks. (Water temperature : 70 °C)

3.2.2. Cylinder liner measurement



- Assemble the cylinder liner at the cylinder block and measure inner diameter at upper, middle, lower that is, 3 steps by 45° interval and calculate the average values after eliminating the maximum and minimum values.
- If the measured values are very close to the limit value or beyond, replace it

Liner inner diameter	Standard	Limit
	∅ 127.990 ~ ∅ 128.010 mm	∅ 128.16 mm



3.2.3. Cylinder head



- Carefully remove carbon from the lower face of the cylinder head using nonmetallic material to prevent scratching of the valve seat faces.
- Check the entire cylinder head for very fine cracks or damage invisible to ordinary sight using a hydraulic tester or a magnetic flaw detector.

1) Cylinder head disassembly

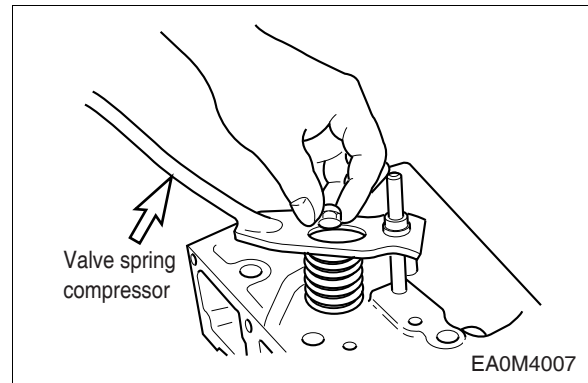


NOTE :

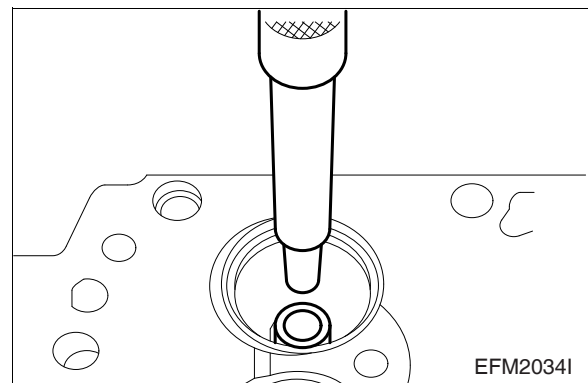
Be careful for the cylinder head gasket contacting surface of cylinder head not to be damaged.



- Remove the cotter pin pressing the valve spring by means of a special tool.



- Take out the valve stem seal.
- Pull out the intake and exhaust valves.
- Remove the valve guides from the combustion room side of cylinder head by means of a special tool.



2) Inspection and measurement of cylinder head

a) Inspection of cracks and damage

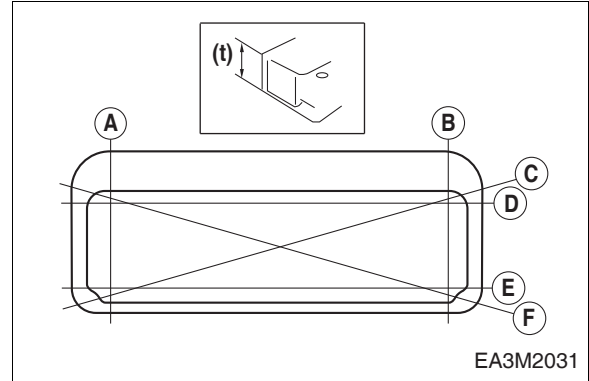


- Eliminate the carbon residue and gasket piece from the cylinder head lower face thoroughly. Then be careful for the valve seat not to be damaged.
- For cracks or damages to search difficult may be inspected by a hydraulic test or a magnetic powder test. (Hydraulic test is same as for cylinder block.)

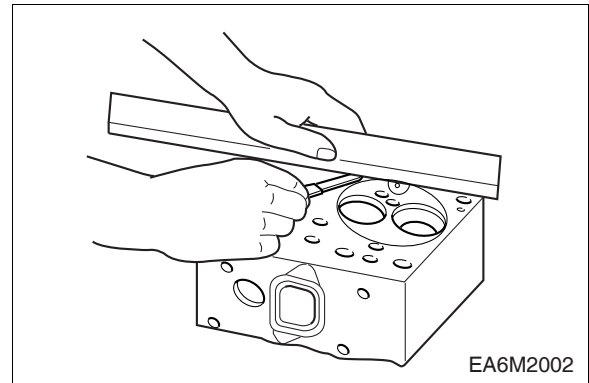


b) Distortion at the lower face

- Measure the amount of distortion using a straight edge and a feeler gauge at six positions as shown in the right figure.



- If the measured value exceeds the standard value, retrace the head with grinding paper of fine grain size to correct such defects.
- If the measured value exceeds the maximum allowable limit, replace the cylinder head.



<Lower face warp and height>

Warpage	Standard	Limit
	0.05 mm or less	0.2 mm
Thickness : t (reference)	113.9 ~ 114.0 mm	112.9 mm

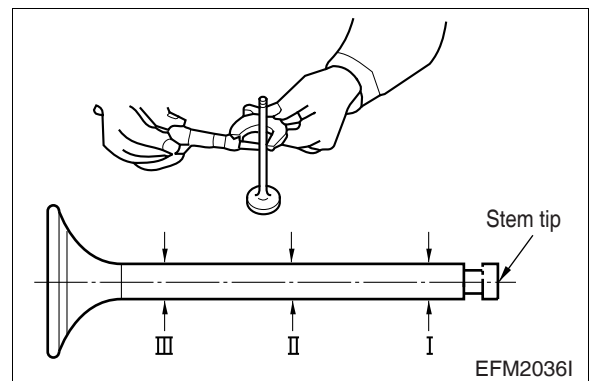
3) Inspection and measurement of valve and valve guide

a) Valve



- After cleaning the valves with clean diesel oil, measure the valve as follow.
Measure the valve stem's outside diameter at upper, middle, and lower to determine the wears and when the wear limit is more than limit, replace the valves.

Valve	Standard	Limit
Intake	$\phi 11.969 \sim \phi 11.980$ mm	$\phi 11.949$ mm
Exhaust	$\phi 11.944 \sim \phi 11.955$ mm	$\phi 11.914$ mm



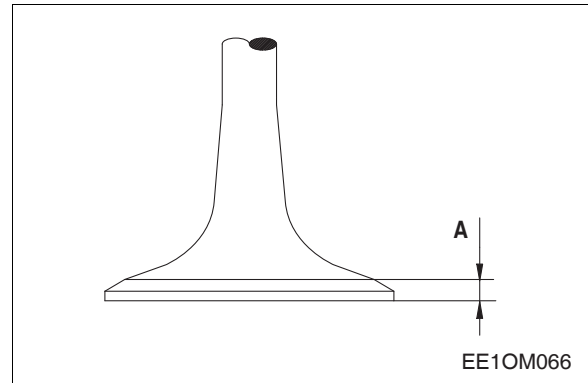


- inspect the scratch and wear of valve stem seal contacting face, and if necessary correct with the grinding paper but if severe replace it.



- If valve head thickness becomes less than limit, replace the valve.

Valve	Standard	Limit
Intake	4.6 ~ 5.0 mm	4.1 mm
Exhaust	4.33 ~ 4.83 mm	3.83 mm



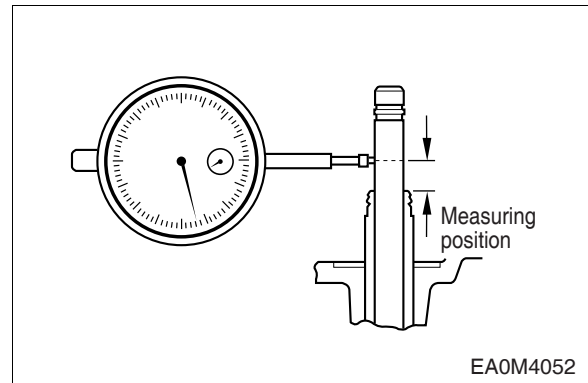
b) Check of valve guide



- Insert the valve into valve guide and measure the clearance between valve and valve guide by the shaking degree of valve. If the clearance is bigger, measure the valve and then replace the more worn valve guide.



- If the valve guide has already been replaced, measure the center with valve seat if it deviates or not and if abnormal it must be corrected.



NOTE :
Simultaneously be processed when in guide reamer process.

Valve	Standard	Limit
Intake	0.020 ~ 0.049 mm	0.10 mm
Exhaust	0.045 ~ 0.074 mm	0.15 mm

c) Valve seat



- Visual inspection

Check if the exterior of the valve spring is damaged with the naked eye. Replace it with a new one if required.



- Valve seat thickness and angle

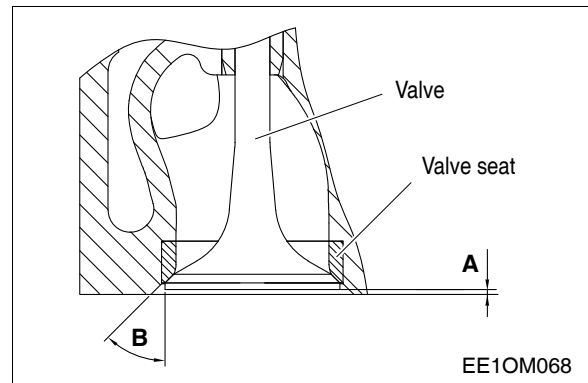
Assemble the valves at the cylinder head and using the measuring instrument from the lower face, measure the projection amount of valve. If the measured wear is excessive, replace the valve seat.

<Valve projecting amount>

Items	Standard
Intake (A)	0.65 ~ 0.95 mm
Exhaust (B)	0.65 ~ 0.95 mm

<Valve seat angle>

Items	Standard
Intake (A)	60°
Exhaust (B)	45°



- The disassembly of valve seat can be pulled out by means of a special tool with the arc welding done at two points of valve seat rotating tool or valve seat.



- Regarding the valve seat assembling, shrink the valve seat by putting it in the dry ices for about 1 hour or so, and then press it into the cylinder head by means of a special tool.
- After coating the grinding powder paste on valve head contacting face of valve seat, and after executing a sufficient lapping operation with the rotating and grinding motion of valve, wipe off the grinding agent thoroughly.

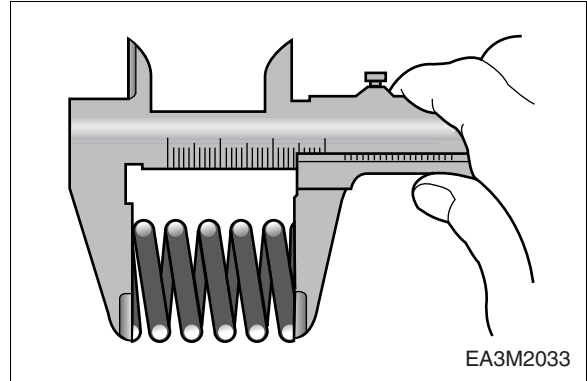
d) Valve spring



- Visual inspection
Check if the exterior of the valve spring is damaged with the naked eye. Replace it with a new one if required.



- By means of spring tester, measure the tension and free length.
- Measure the perpendicularity of valve spring.
- In case that the measured value exceeds the limit value, replace it.



<Dual spring perpendicularity regular>

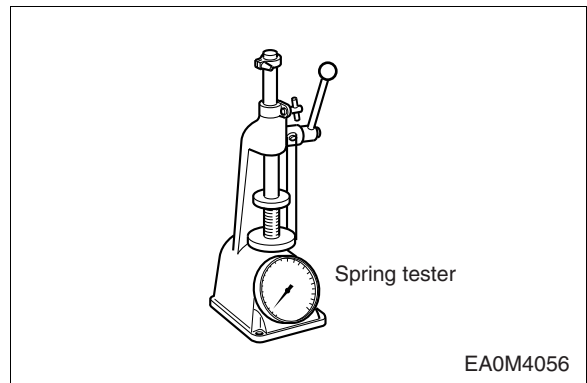
Items		Free Length
Spring	Inside	65.5 mm
	Outside	64 mm

<Single spring perpendicularity regular>

Items		Free Length
Intake / exhaust	Outside	61.9 mm

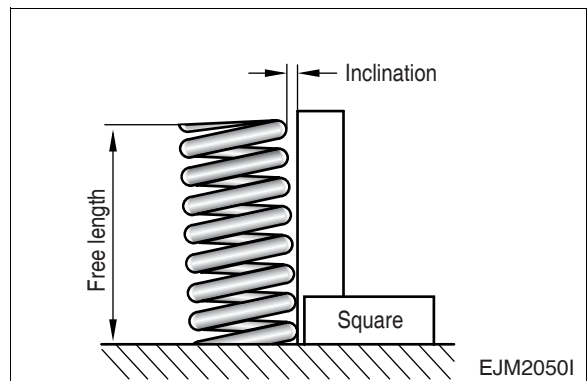
<Valve spring tension standard>

Items		Length P1/P2 (mm)	Spring tension P1/P2 (kg)	Limit P1/P2 (kg)
Intake / exhaust	Out	46.8/	47.0/	±2.5/
	side	32.8	90.5	±4.5



- Squareness of valve spring:
Measure the squareness of the valve spring with the surface plate and the right-angle square. If the reading exceeds the tolerance limit, replace the valve spring.

Items		Standard	Limit
Intake / exhaust	Outside	1.2 mm	2.0 mm



e) Assembling cylinder head



- Clean the cylinder head thoroughly.



- Coat the valve stems and valve guides with engine oil and assemble the valves.
- Replace the valve stem seals with new ones and insert the stem seals to the valve guides of cylinder head with a special tool. (Be careful for the valve stem seals not to be damaged)

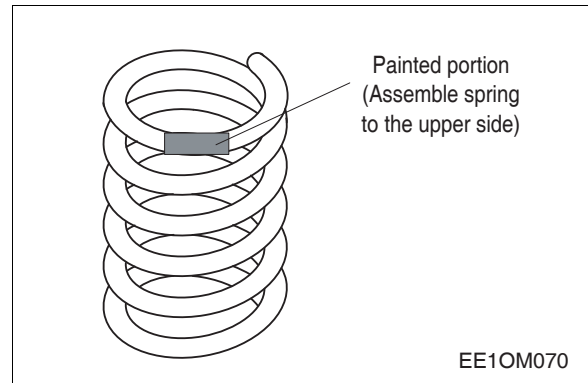


- Install the valve spring washer to valve guide.
- Put in the valve spring and then attach the valve spring plate on the springs.

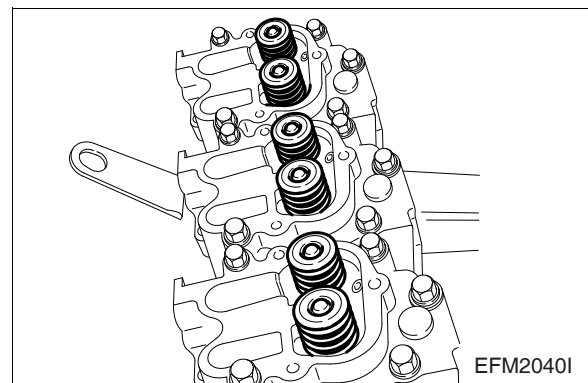


NOTE :

Install the valve spring seat with “TOP” (painted in Dual Spring - Yellow / Single Spring - Red) side up.



- Pressing the spring down with a special tool, assemble by inserting the valve cotter.
- After the valve is assembled, inspect the valve tapping it lightly with an urethane hammer if accurate assembling was done.



3.2.4. Rocker arm

1) Cylinder head disassembly



- Remove the snap rings in both ends of rocker arm with a pair of pliers.
- Tear down washer, rocker arm.
- Disassemble the rocker arm bush by means of a press.

2) Inspection and measurement

a) Rocker arm bracket

(Single unit type with a shaft)



- Measure the outer diameter of rocker arm bracket with outside micrometer at the position that the rocker arm is installed, and in case that it exceeds the limit value, replace.

Items	Standard	Limit
Bush Inner Dia.	$\phi 25.005 \sim \phi 25.035$ mm	$\phi 25.083$ mm
Shaft Outer Dia.	$\phi 24.967 \sim \phi 24.990$ mm	$\phi 24.930$ mm
Clearance	0.015 ~ 0.068 mm	0.14 mm

b) Rocker arm

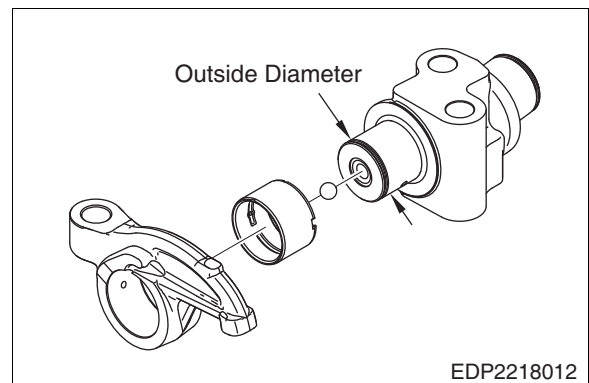
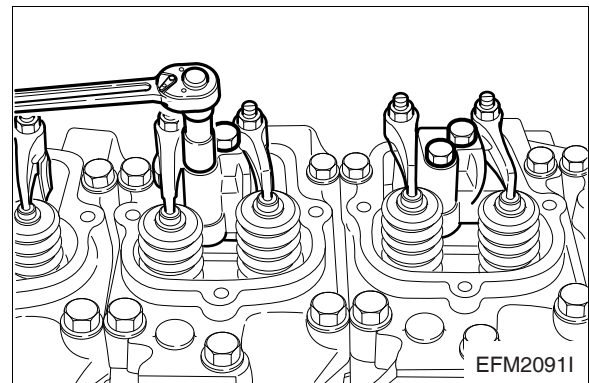


- Inspect the rocker arm surface that contacts with the valve stem for any scratch, step wear and correct the minor degree of wear with an oil stone or the fine grinding paper and replace if they are severe.



NOTE :

If the wear is severe, replace new one.



c) Tappet and push rod



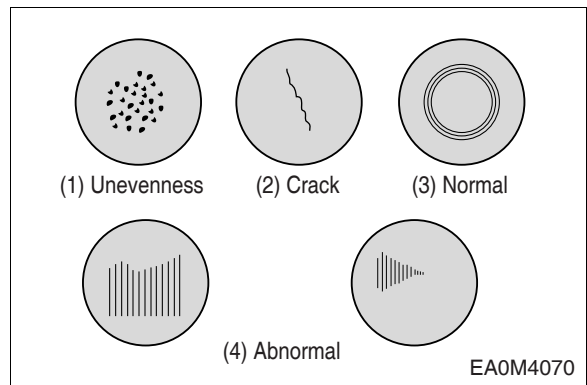
- Tappet clearance

Measure the outer diameter of a tappet and the inner diameter of the tappet bore. If the reading exceeds the tolerance limit, replace the tappet

Items	Standard	Limit
Tappet clearance	0.035 ~ 0.077 mm	0.15 mm



- Inspection if the tappet surface which contacts the camshaft has damage like crack or scratch. If the damage is small, correct it with oil stone or fine grinding paper, if excessive, replace it.

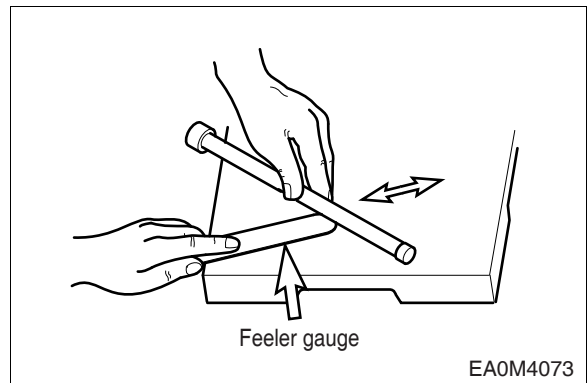


- Warpage of push rod

Put the push rod on a surface plate, and measure the warpage with a feeler gauge while spinning it. If the reading exceeds the tolerance limit, replace it.

<Run-out>

Limit	0.3 mm or less
-------	----------------



d) Rocker arm reassembling



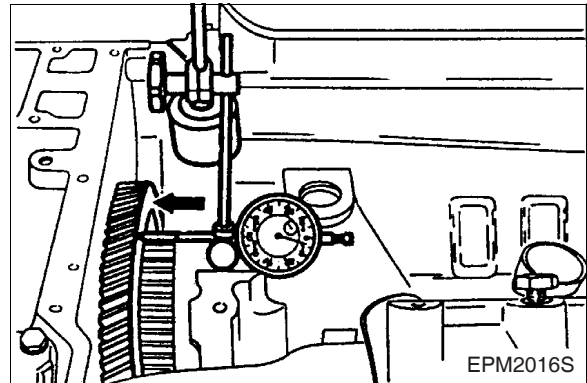
- Inspect the oil passages of rocker arm and rocker arm bracket for any clogs and reassemble them in the reverse order of disassembling after thorough cleaning.

3.2.5. Camshaft

1) Axial end play

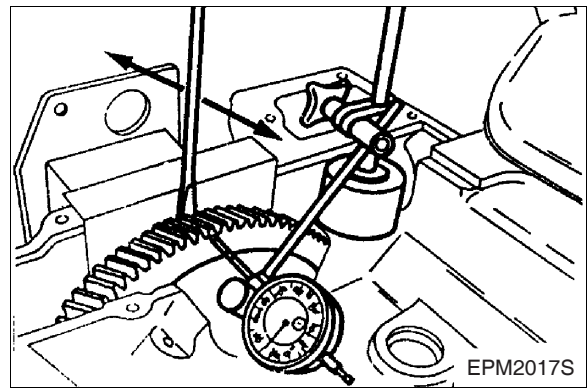


- Push the camshaft toward the pulley side.
- Place a dial gauge onto the camshaft gear.



- Measure the camshaft's axial end play, moving the camshaft gear by means of a driver.

Items	Standard	Limit
End Play	0.24 ~ 0.86 mm	0.9 mm



- If excessive end play, assemble it by means of other thrust washer.

2) Inspection and measurement

● Visual check



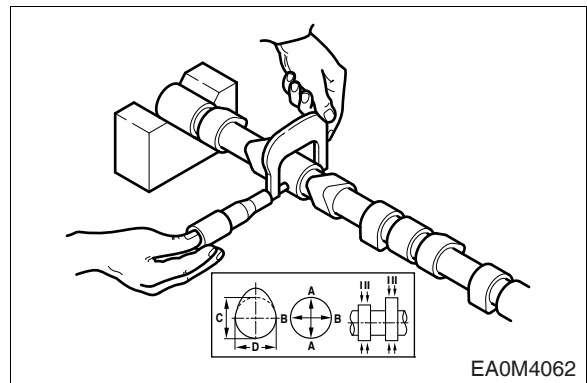
With inspecting the cam surface for any damage with naked eyes and correct any minor scratches by means of an oil stone grinding and if severe, replace it.

● Cam lobe height



Use a micrometer to measure the cam lobe height and journal diameter. If the measured number is less than the specified limit, the camshaft must be replaced.

Items		Standard	Limit
Cam lobe height (C)	Intake	56.370 mm	56.032 mm
	Exhaust	56.430 mm	56.091 mm
Cam journal diameter (A,B)		$\phi 69.91 \sim \phi 69.94$ mm	$\phi 69.560$ mm

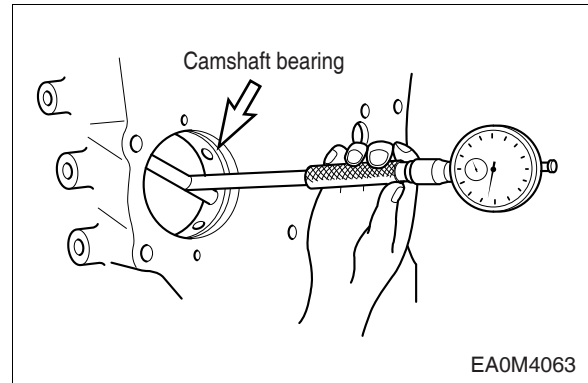




- **Cam bearing diameter**

Measure the camshaft bush inside diameter with a cylinder gauge and by comparing the inside and outside diameters, replace if abnormal.

Items	Standard	Limit
Thust	∅70.070 ~ ∅70.090 mm	∅69.464 mm
Middle	∅70.000 ~ ∅70.030 mm	∅69.192 mm



- **Clearance**

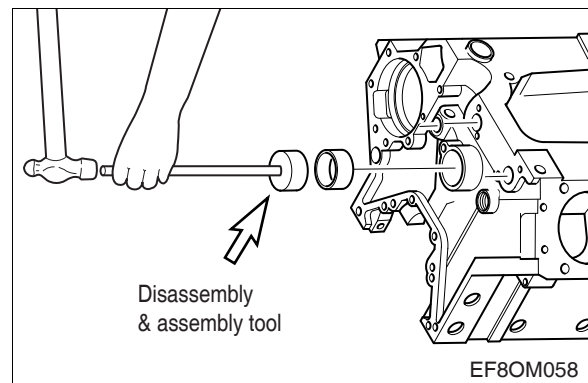
Between camshaft journal and body.

Items	Standard	Limit
Thust	0.060 ~ 0.120 mm	0.240 mm
Middle	0.130 ~ 0.180 mm	0.240 mm



- **Camshaft bearing replacement**

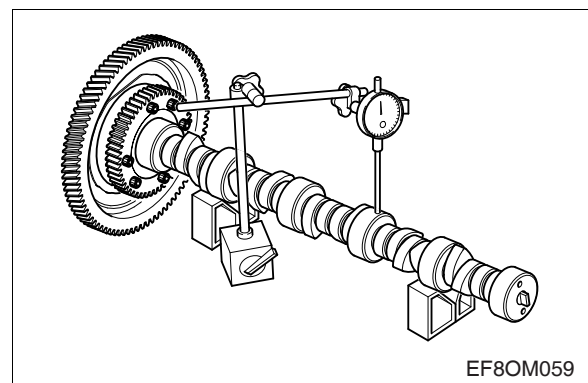
Replace the camshaft bearing with a special tool.



- **Camshaft run-out**

With placing the camshaft on the 2 ea of V-blocks, and inspect the run-out of the camshaft, adjust or replace the severe one.

Standard	Limit
0.05 mm	0.15 mm



- **Cam lobe height**

Use a micrometer to measure the cam lobe height and journal diameter.

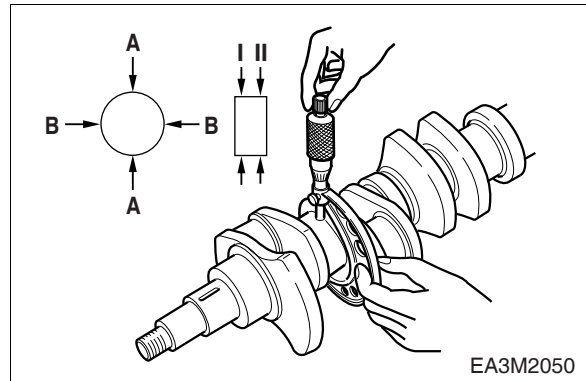
If the measured number is less than the specified limit, the camshaft must be replaced.

3.2.6. Crankshaft

1) Inspection and measurement



- Inspect for any scratch or damage with naked eyes, and grind to the undersize according to the damaged degree and use the undersized bearing.
- Inspect for any crack by means of magnetic powder and color check, and replace the cracked ones.



a) Journal and pin diameter



- With outside micrometer, measure the outside diameter of crank journal and crank pin at the direction and position of the figure shown and take the wear.

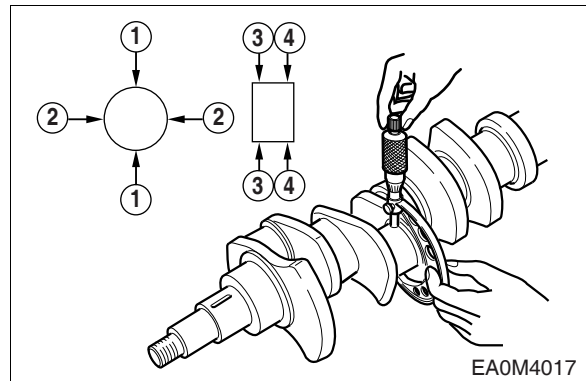
<Crankshaft journal outside diameter>

Standard	$\phi 103.98 \sim \phi 104.00 \text{ mm}$
----------	---

<Crankshaft pin outside diameter>

Standard	$\phi 89.98 \sim \phi 90.00 \text{ mm}$
----------	---

- In case that the lopsided wear is more than the limit value, grind to the undersize, and use the undersized bearing.



<Main bearings>

- Standard
- 0.10 (Inside diameter 0.10 mm less than standard)
- 0.25 (Inside diameter 0.25 mm less than standard)
- 0.50 (Inside diameter 0.50 mm less than standard)
- 0.75 (Inside diameter 0.75 mm less than standard)
- 1.00 (Inside diameter 1.00 mm less than standard)

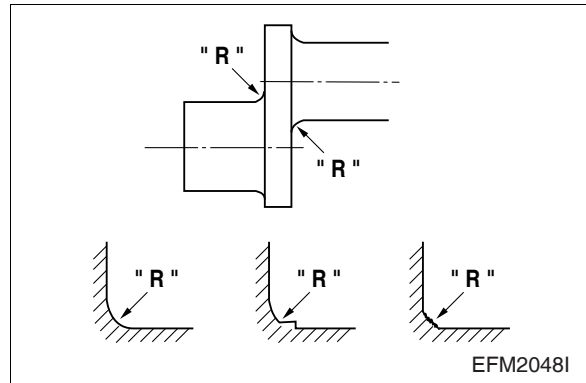
<Connecting rod bearings>

- Standard
- 0.25 (Inside diameter 0.25 mm less than standard)
- 0.50 (Inside diameter 0.50 mm less than standard)

- There are kinds as above, and the crankshaft also can be used by regrinding as above.

<“R part” standard value>

- ① Crank pin 'R' : $4.0^{0}_{-0.5}$
- ② Crank journal 'R' : $4.0^{0}_{-0.5}$



NOTE :

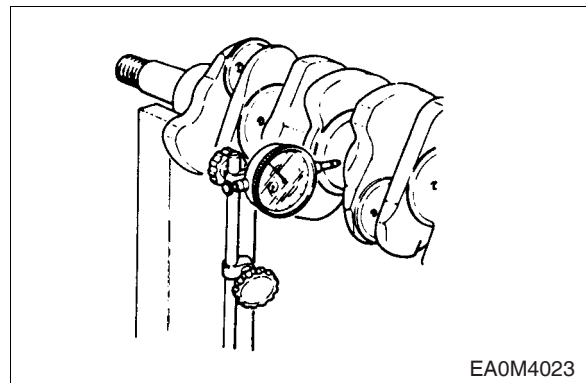
In case of crankshaft regrinding, the “R part” at the end of bearing must accurately be ground without fail and should avoid any processed jaw or coarse surface

b) Run out of crankshaft



- Place the crankshaft on the V-block.
- Place the dial gauge on the surface plate and measure the run out of crankshaft rotating the crankshaft

Standard	Limit
0.06 mm	0.4 mm



2) Inspection on crankshaft bearing and connecting rod bearing Inspection



- Inspect the crankshaft bearing and connecting rod bearing for any damages such as lopsided wear, scratch etc. and if abnormal, replace it.
- Inspect the oil clearance between the crankshaft and bearing.

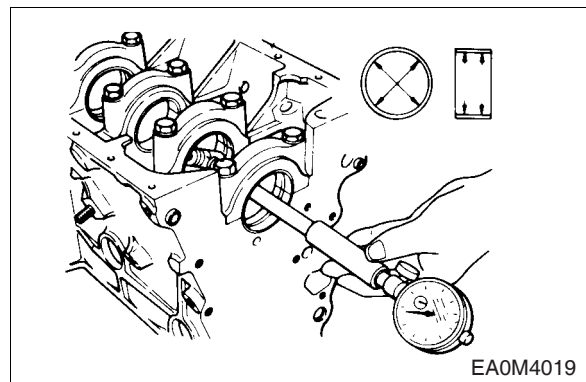
a) How to utilize the cylinder gauge

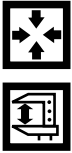


- Assemble the main bearing at the cylinder block and after tightening the bearing cap at the specified torque, measure the inside diameter.

Journal bearing nominal diameter	$\phi 104.066 \sim \phi 104.115$ mm
----------------------------------	-------------------------------------

Bearing cap Bolt torque	Initial 30 kg-m + angle 90°
-------------------------	-----------------------------

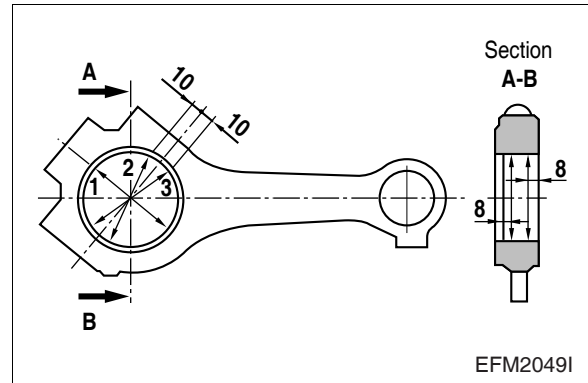




- Assemble the bearing at the bigger end of connecting rod, and after tightening the bearing cap at the specified torque, measure the diameter.

Connecting rod bearing journal diameter	$\phi 90.056 \sim \phi 90.098 \text{ mm}$
---	---

Connecting rod Bolt torque	Initial 10 kg·m + angle 90°
----------------------------	-----------------------------



- Crankshaft pin and bearing clearance In case that this clearance value exceeds the limit value, grind the crankshaft journal and pin and then use the undersized bearing.

Standard	Limit
$\phi 90.056 \sim \phi 90.098 \text{ mm}$	0.143 mm

b) How to utilize plastic gauge

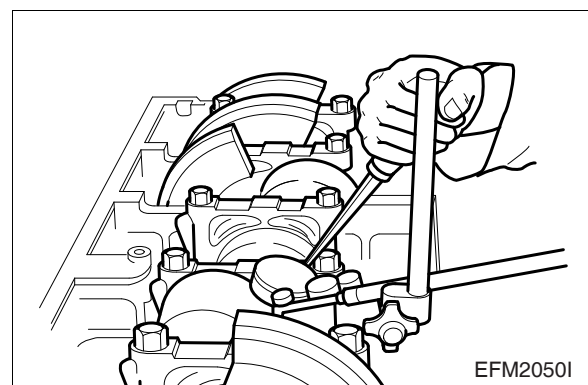
- Install the crankshaft in the cylinder block and place the plastic gauge on the crankshaft journal and pin at axial direction and then after tightening the bearing cap at the specified torque and again after tearing apart the bearing cap, measure the flatten plastic gauge thickness by pick it up. This is the oil clearance.
- With the same points, the oil clearance of connecting rod also can be measured.

c) End play



- Assemble the crankshaft in the cylinder block.
- Install the dial gauge, and measure the end play of crankshaft by pushing the crankshaft to axial direction.

Standard	Limit
0.140 ~ 0.361 mm	0.4 mm

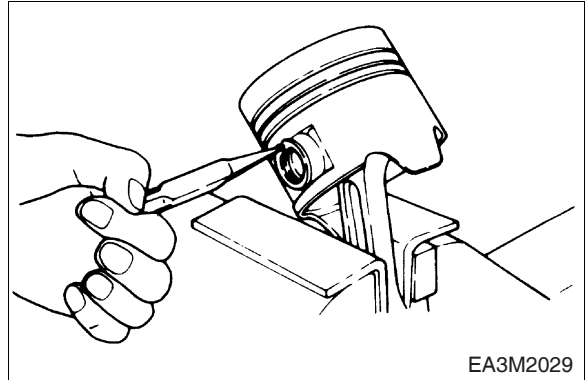


3.2.7. Piston

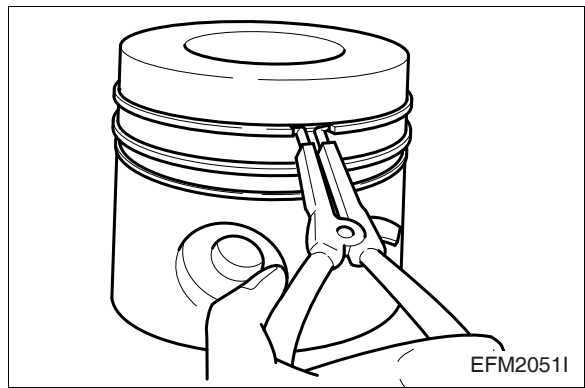
1) Piston disassembling



- Pull out the snap ring for piston pin and with a pair of snap ring pliers.
- With a round bar, remove the piston pin.



- With a pair of pliers, remove the piston rings.
- Clean the piston thoroughly.



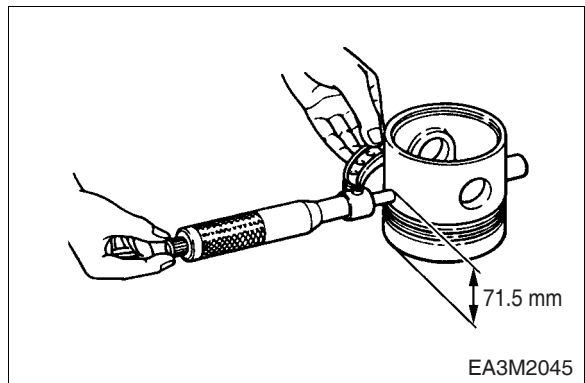
2) Inspection & measurement of the piston



- With naked eyes, inspect the piston for any wear, crack and scratch and particularly inspect carefully at the ring grooves for any wear.



- With the outside micrometer, measure the piston's outside diameter the measuring position is 71.5 mm from the piston lower end, and the direction of measurement must be perpendicular to the piston pin direction.



Standard	$\phi 127.739 \sim \phi 127.757 \text{ mm}$
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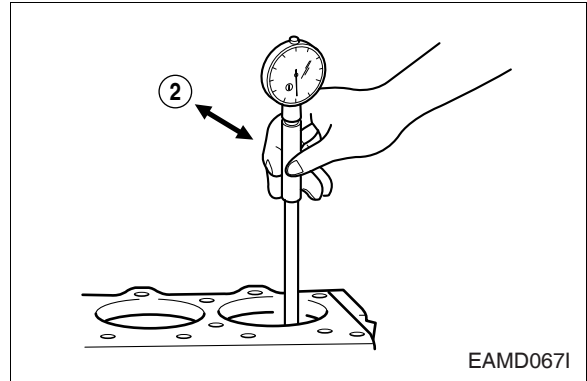
- By comparing the measured value of the piston outside diameter with the cylinder liner inside diameter, the bigger clearance is replaced.



- **Measurement of cylinder bore**

Assemble the cylinder liner at the cylinder block and measure inner diameter at upper, middle, lower that is, 3 steps by 45° interval and calculate the average values after eliminating the maximum and minimum values.

Standard	$\phi 127.739 \sim \phi 127.757 \text{ mm}$
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EAMD067I

- Measure the clearance between the cylinder liner bore and the piston outer diameter, if it is more than the use limit value, replace either one that is more severe.

Standard	0.233 ~ 0.271 mm
----------	------------------

3) Piston ring and ring groove

a) Inspection

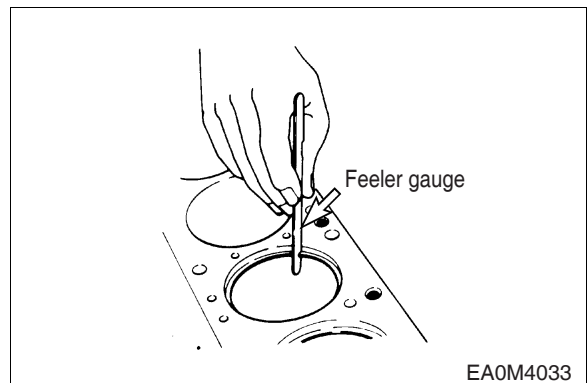


- In case of piston ring's wear, damage or engine overhaul, replace piston rings.

b) Gap clearance



- Measure the piston ring cut part.
- Insert the piston ring at the cylinder liner's upper part perpendicularly.
- With a feeler gauge, measure the gap clearance of piston ring.
- If the measured value exceeds the limit value, replace it.



EA0M4033

<Piston ring gap>

Division	Standard	Limit
Top ring	0.35 ~ 0.50 mm	1.5 mm
2nd ring	0.40 ~ 0.60 mm	1.5 mm
Oil ring	0.40 ~ 0.70 mm	1.5 mm

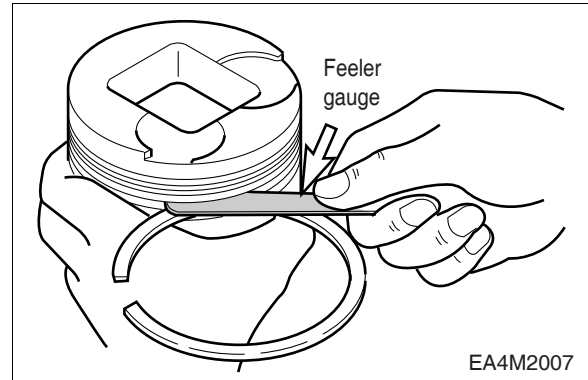
c) Piston side clearance



- Assemble the piston ring at the piston.
- Measure the each ring's side clearance and if the measured value exceeds the limit value, replace rings or piston.

<Piston side clearance>

Division	Specified value	Limit value
Top ring	0.105 ~ 0.150 mm	0.3 mm
2nd ring	0.050 ~ 0.082 mm	1.5 mm
Oil ring	0.030 ~ 0.062 mm	1.5 mm



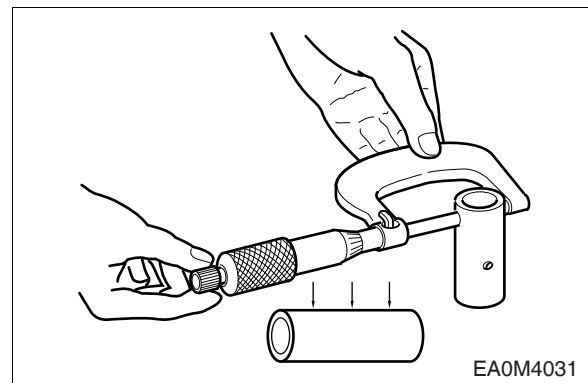
4) Piston pin

a) Outside diameter



- With the outside micrometer, measure the piston pin's outside diameter and if the value is same as the use limit value or less, replace it.

Standard	Limit
0.055 ~ 0.071 mm	∅45.979 mm or less

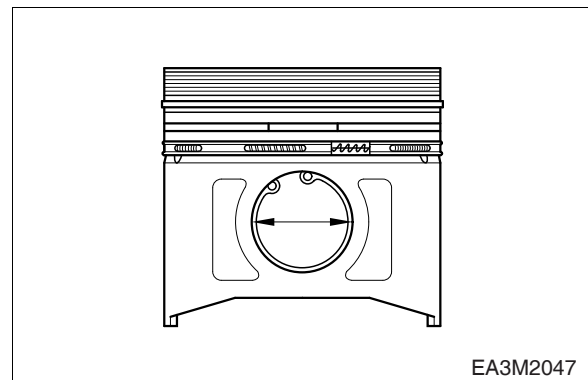


b) Piston pin and connecting rod bush clearance



- Inspect the clearance between the piston pin and the connecting rod bush, if it is more than the use limit value, replace either one that is more severe.

Standard	Limit
0.055 ~ 0.071 mm	0.1 mm



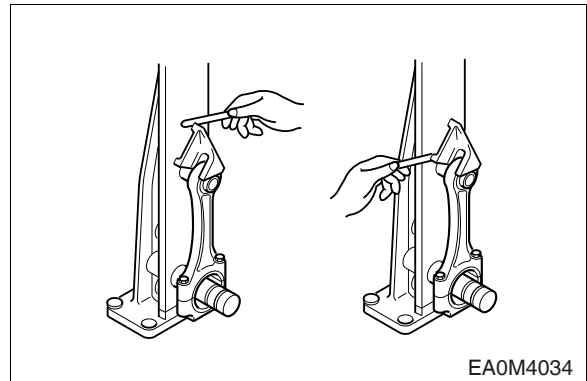
5) Connecting rod

a) Distortion and parallel



- Install the measurement tester as figure.
- Measure the distortion of the bigger and smaller end bearing holes after that do as regard parallel of both holes and if abnormal, replace the connecting rod.

Standard	Limit
0.02 mm	0.2 mm



b) Amounts of wear



- After assembling the connecting rod in the crankshaft measure the clearance between connecting rod bigger hole and crank pin diameter using filler gauge.
- Assemble the connecting rod in the piston and then measure the clearance of these parts.
- If it is more than the use limit value, replace the connecting rod.

Standard	Limit
0.02 mm	0.2 mm

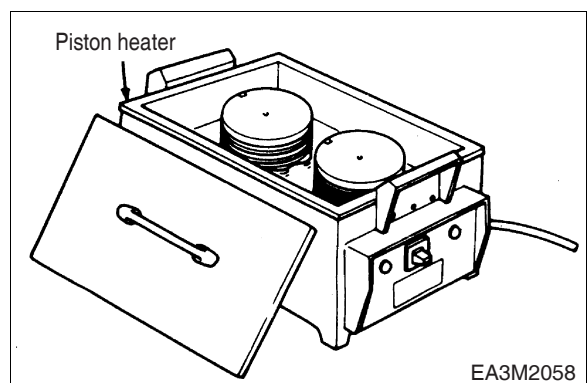
6) Piston reassembling



- After heating the piston at the piston heater for about 5 min (120 ~ 150 °C), by aligning the piston pin hole with the pin hole of connecting rod's smaller end, insert the oil coated piston pin.



NOTE :
Confirm the direction of connecting rod and assemble.



- With the snap ring plier, insert the snap rings of the piston pin.
- With confirming the upper side indication of piston ring, after assembling the ring in the piston ring groove, inspect if the movement of ring is smooth.
- Arrange the assembled piston in order as the cylinder number.

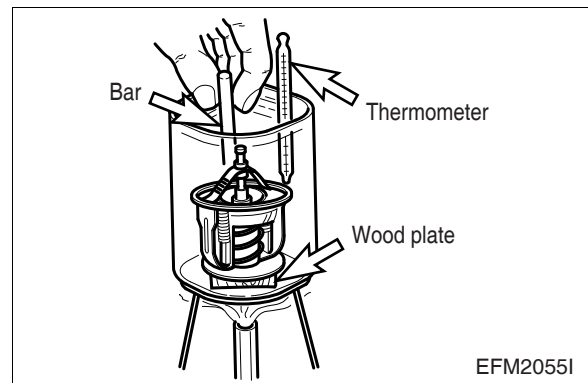
7) Water temperature inspection



- Inspect the wax case and spring for any damage.
- With putting the water temperature gauge into water and heating the water at the indirect method, when the water temp reaches to 71 °C, the valve begin to open and fully open when it reaches to 85 °C.



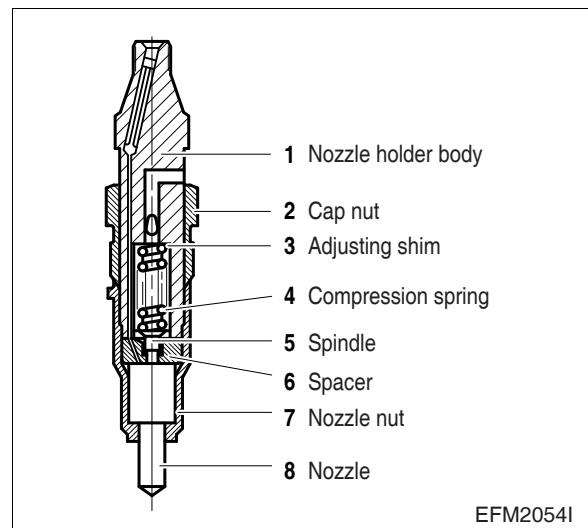
- Measure the valve opening temperature and the valve full opening temperature and inspect if the valve lift is more than 8 mm and if abnormal, replace it



8) Injection nozzle

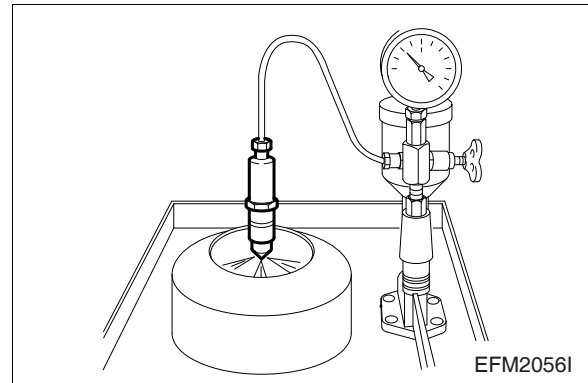


- Set the nozzle assembly between the vise holder and disassemble it.
- Remove the nozzle nuts and disassemble the inner parts.





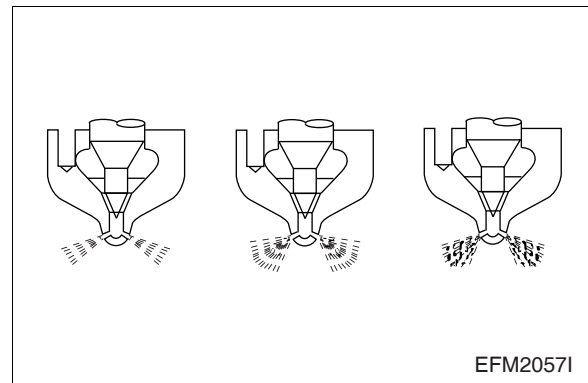
- Inspect the disassembled parts if there is any damage, replace it.
- Assembling can be done in the reverse order of disassembling.
- After assembling the nozzle, set it in the injection pressure measuring tester.
- By manipulating the tester handle, inspect the injection pressure and atomizing state.



<Operating pressure>

New nozzle holder	$300 + 8 \text{ kg/cm}^2$
Used nozzle holder	$285 + 8 \text{ kg/cm}^2$

- In case of low or high injection pressure, adjust by adding or reducing the spring tension adjusting shims.
- In case that atomizing state is not good, it should be replaced.



3.3. Engine Reassembly

3.3.1. General preparation

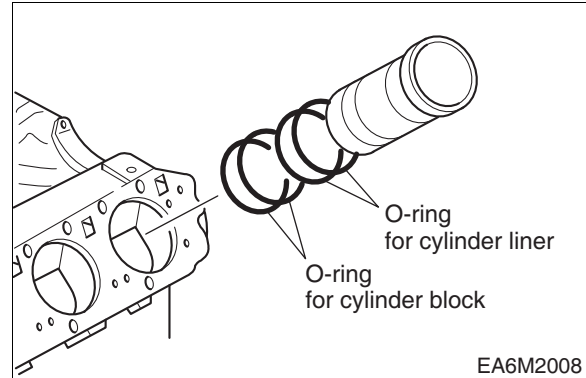
- Clean all the disassembled parts, particularly oil and water ports, using compressed air, then check that they are free from restrictions.
- Arrange the general and special tools in order for engine assembly operation.
- To wet each sliding part, prepare the clean engine oil.
- Prepare service materials such as sealant, gaskets, etc.
- Discard used gaskets, seal rings, and consumable parts, and replace with new ones.
- Apply only the specified torque for bolts in the specified tightening order and avoid over-tightening.
- Be sure to check that all the engine parts operate smoothly after being reassembled.
- Check the bolts for looseness after preliminary re-assembly.
- After completing the engine re-assembly operation, check if there is missing parts or shortage of parts.
- Keep your hands clean during the working.

3.3.2. Cylinder block

- Cover the floor of the workshop with wood plate or thick paper to prevent damage to the cylinder head and place the head face of the cylinder block towards downward.

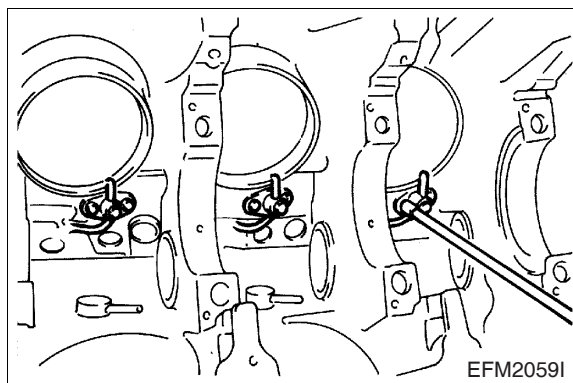
3.3.3. Cylinder liner

- Replace the used O-rings with new one and insert two O-ring in the cylinder liner upper side, but the other two in the cylinder block lower side separately.
- Coat the joint parts where O-ring contacts with oil.
- After slipping the cylinder liner smoothly into the cylinder block, press it in being careful for O-ring not to damage.
- After completion of assembling the cylinder liner, confirm no leaks with 4 kg/cm² hydraulic test.



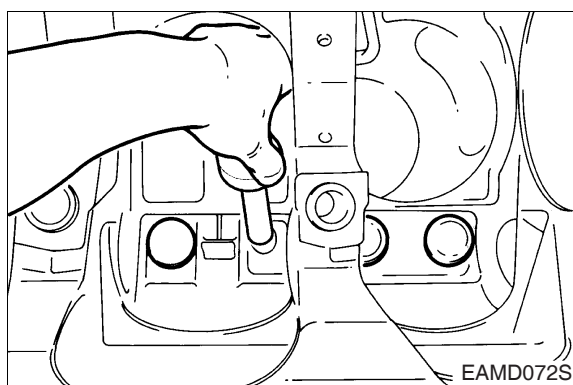
3.3.4. Oil spray nozzle

- Assemble the oil spray nozzle.
- Tighten the fixing bolts.



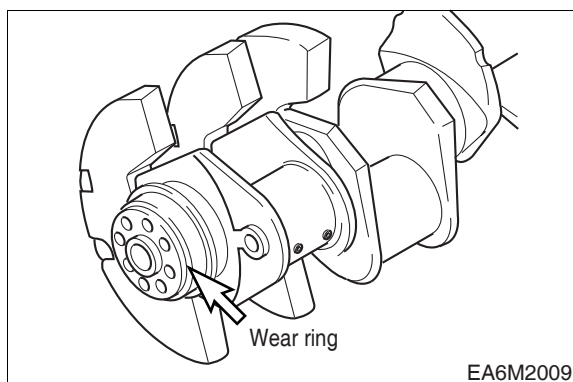
3.3.5. Tappet

- Coat the tappet wholly with clean oil and push in the tappet hole of the cylinder block.

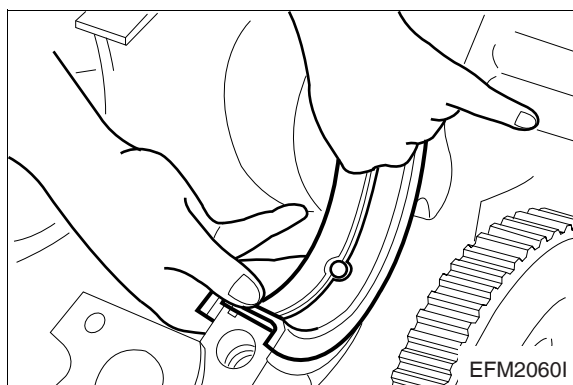


3.3.6. Crankshaft

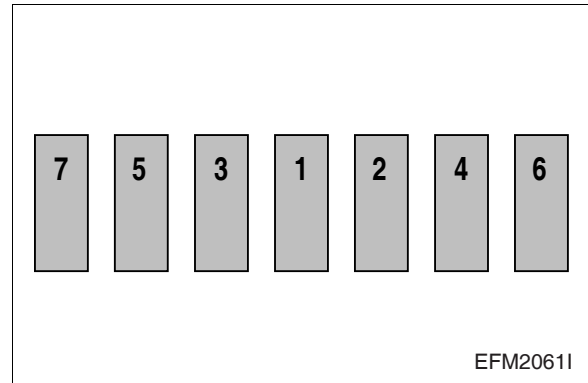
- Put the wear ring into the heater to heat it up to 150 ~ 200 °C level, push it over the crankshaft by means of a jig.



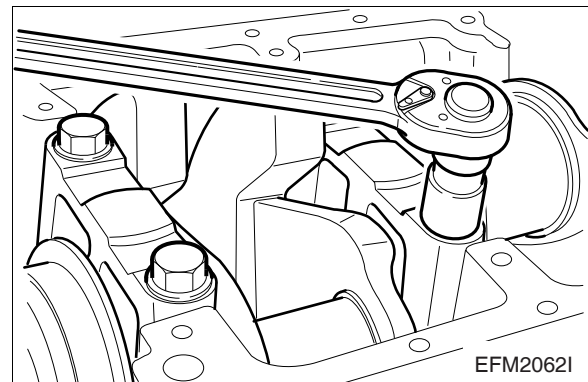
- Assemble the main bearing to the cylinder block and coat it with engine oil. Then assemble the bearing that has a hole to the cylinder block side and one that has no hole to the bearing cap and be careful not to change.



- Assemble temporarily one bolt each at both bolt holes and by connecting the wire to the bolts, lift it with crane or chain block and put down on the cylinder block carefully.
- Coat the crankshaft journal and pin parts with clean engine oil, and after fitting the main bearing into the bearing cap and assemble it to the cylinder block making sure of the number in order not to change the bearing cap.



- Coat the bearing cap bolt and its bolt seat part with engine oil necessarily and according to the tightening order, tighten them with 30 kg·m and with rotating angle method ($90^\circ +10^\circ$) and tightening order is as follows.



<Bearing cap bolt's Tightening Order>

- (1) First step : Coat the bolts with engine oil.
- (2) Second step : Screw down 1 ~ 2 threads.
- (3) Third step : Tighten with about 15 kg·m by wrench.
- (4) Fourth step : Tighten with about 25 kg·m by torque wrench.
- (5) Fifth step : Tighten with 30 kg·m by torque wrench.
- (6) Sixth step : Tighten with final rotating angle method $90^\circ +10^\circ$.

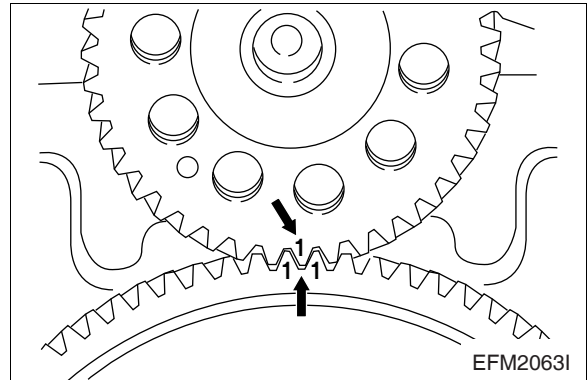
However, according to above tightening order, tighten step by step.



- Inspect if the crankshaft's rotation is smooth.
- Assemble the crankshaft gear on the crankshaft and coat a white paint mark on "1" part in order to find easily.

3.3.7. Camshaft

- Coat the cam bush of cylinder block and camshaft with engine oil.
- Assemble the cam bush and camshaft for them not to be damaged.
- Assemble the crankshaft gear and the camshaft gear making sure that the gear marks on both gears are aligned together as right figure.

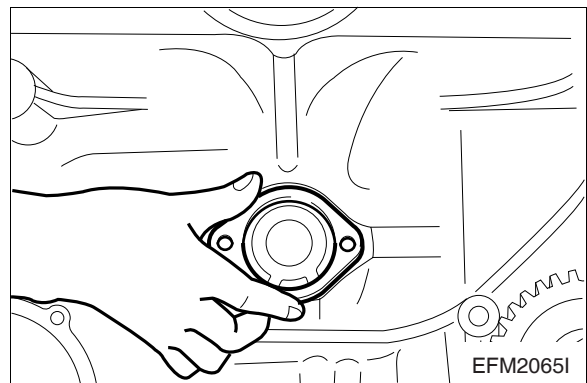


3.3.8. Flywheel housing



- Coat the thrust washer fixing bolt with an adhesive and tighten it with specified torque.

Torque	3.1 kg-m
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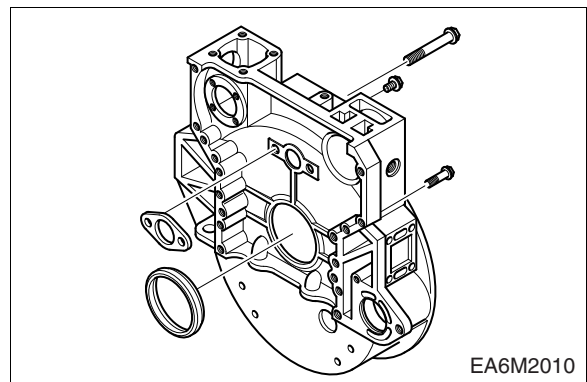


- Coat the oil seal with lubricating oil and assemble it carefully not to be deviated or damaged by means of special tool. (Mandrel for assembling).
- Attach the gasket on the surface of cylinder block where the flywheel housing is to be installed. (In order to prevent the gasket slip down, coat a grease on the cylinder block surface.)
- Temporarily assemble 2ea of guide bolts for installing the flywheel housing to the cylinder block.



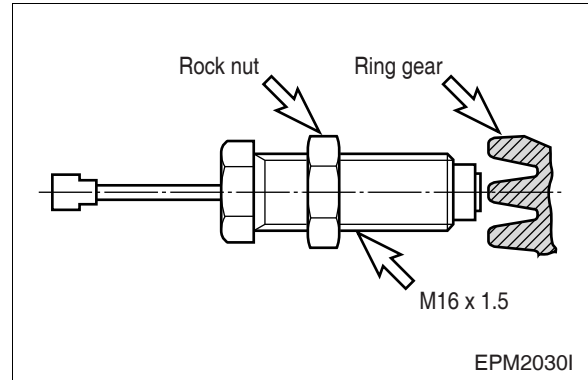
- After fitting the flywheel housing holes to the guide pins and engage temporarily 2 ~ 3 threads of fixing bolts, and according to the tightening order (zigzag method) tighten them in the specified torque.

Torque	4 kg-m
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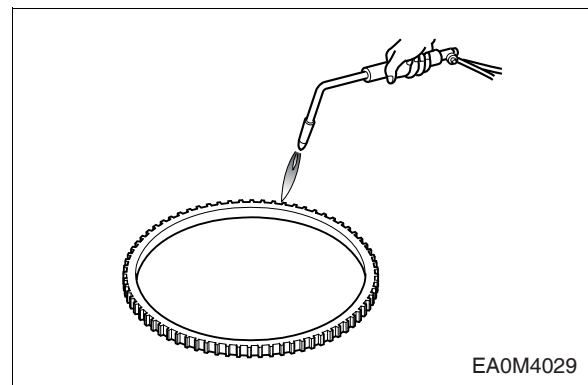
3.3.9. Tacho sensor

- Loosen the lock nut to hexagonal side of sensor.
- Rotate (CW) the tacho-sensor on fly wheel housing, until the end of it reach on fly wheel ring gear as figure.
- Rotate (CCW) the tacho-sensor for 270° (gap : about 1.0 mm) and fix the lock nut.
- Tolerance limit is 27°. (gap \pm 0.1 mm)

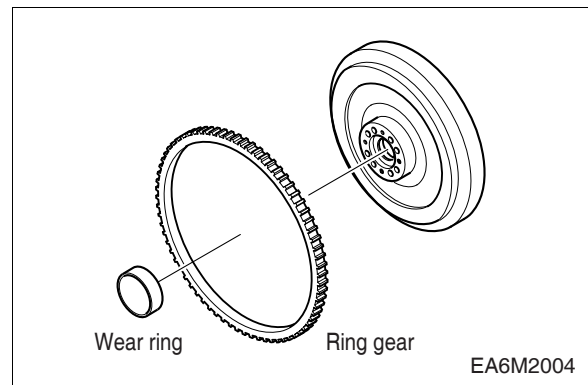


3.3.10. Flywheel

- Installation of flywheel ring gear With a gas burner, heat the ring gear evenly until heat expansion takes place, then install it using a hammer.
- Do not allow the temperature of the ring gear to exceed 200 °C (390 °F)



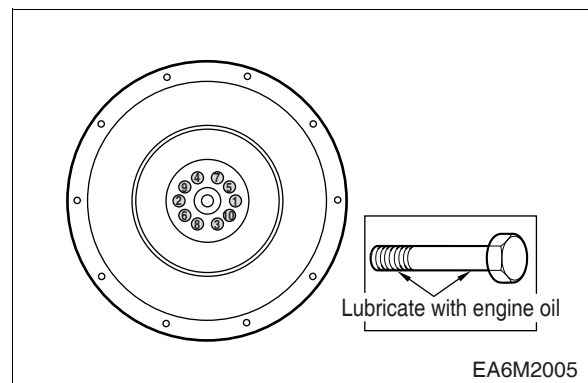
- By means of mandrel, press in the wear ring at the backward face.



- Install two guide bolts for installing the flywheel to the crankshaft.
- After letting the guide pin insert through the flywheel holes and engaging the fixing bolts by 2 ~ 3 threads temporarily, tighten them to the specified torque according to lightening order. (Zigzag order)



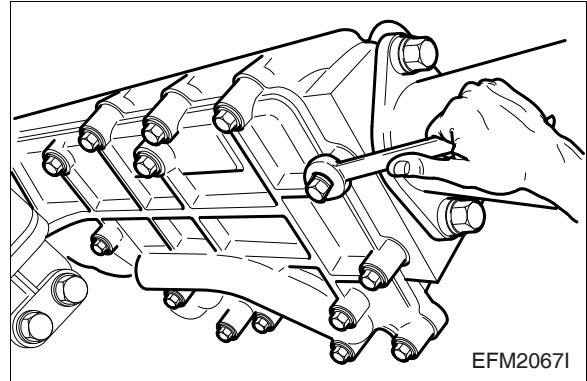
Torque	26 kg-m
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3.3.11. Oil cooler

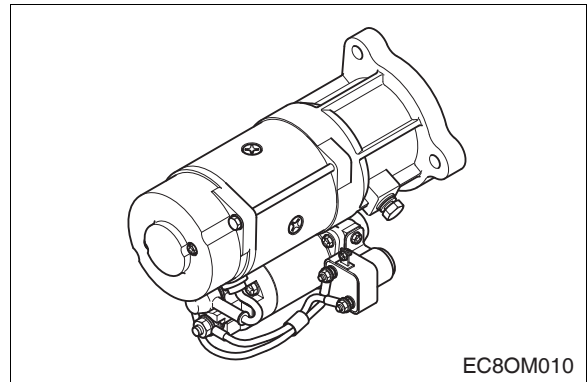
- Attach a gasket on the surface in the oil cooler housing where the oil cooler is installed.
- Tighten the oil cooler with fixing bolts.
- Install the oil cooler assembly by tightening the fixing bolts in the zigzag order.

Torque	M8	3.1 kg·m
	M10	5.5 kg·m



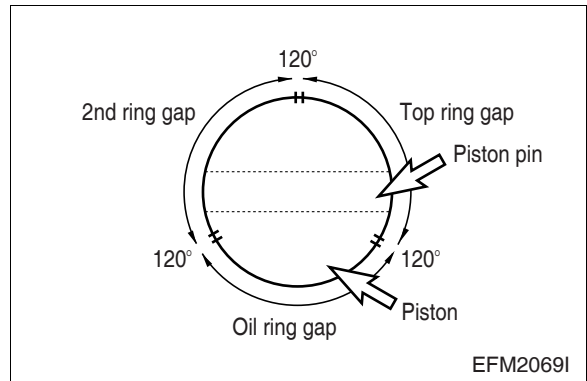
3.3.12. Starting motor

- Install stud bolts at the bolt holes on the flywheel housing for installing the starter.
- Insert the starter into the flywheel housing and tighten the fixing bolts.



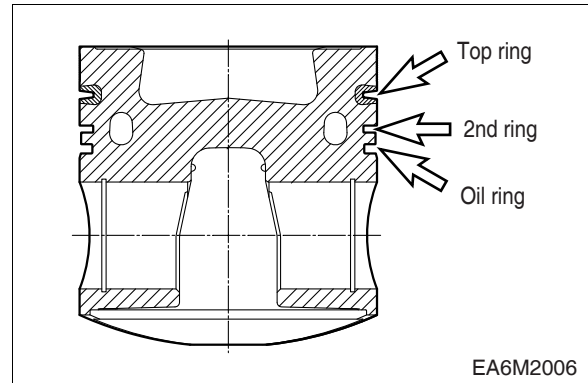
3.3.13. Piston

- Line up the piston assembly in the order of cylinder number and fit the bearings to the connecting rods and bearing caps. However, take care not to swap between the connecting rods and bearing caps.
- Coat the pistons and connecting rod bearings sufficiently with clean engine oil.
- By means of a special tool, insert the piston rings and adjust the angles between the ring gaps at 120° as right figure.
- Push in the piston with hands or wooden bar into cylinder. (Be careful for piston and rings not to be damaged.)





- Pushing the piston down, rotate the crankshaft about 180° and fit the bearing cap to the connecting rod.
- Coat the tap parts of connecting rod bolts and their seats with engine oil, and after engaging 2 ~ 3 threads of bolts primarily rind then tighten them to the specified torque. (10 kg·m + 90° +10°)



<Connecting rod bolt Tightening Order>

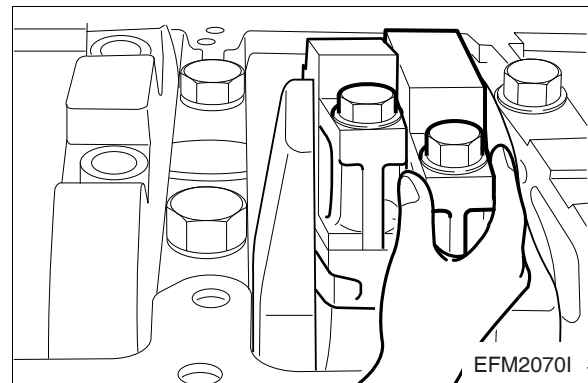
- (1) **First step : Coat the bolts with engine oil.**
- (2) **Second step : Engage 2 ~ 3 threads by hands.**
- (3) **Third step : Tighten to about 7 kg·m with wrench.**
- (4) **Fourth step : By means of torque wrench tighten to 10 kg·m.**
- (5) **Fifth step : Finally assemble by means of rotation angle method 90°+10°.**

However, according to above tightening order, tighten them step by step.

* **Standard length of bolt and use limit :**
(from head seat to bolt tip)

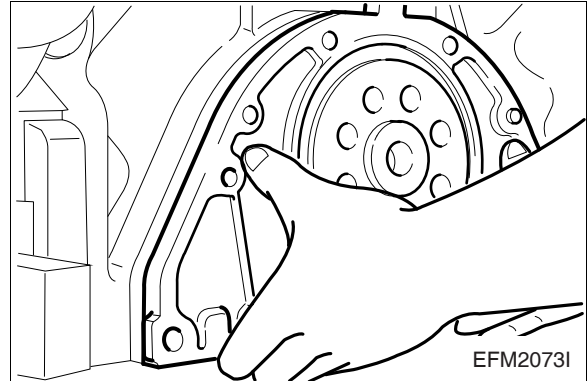
Standard length	Use limit
67.5 ^{-0.3} mm	69 mm

- By moving the connecting rod bearing cap by hands, make sure if there is any play in left and right.
- With same ways as above, assemble in each cylinder rotating the crankshaft.



3.3.14. Front oil seal holder

- After placing the oil seal in the oil holder hole properly, press it in with a mandrel. (Be careful for oil seal not be damaged.)
- Attach the gasket at oil seal holder.
- Align the dowel pin with the oil seal holder dowel hole and assemble them by tapping lightly the dowel pin part with an urethane hammer. When in assembling, take care not to hurt the oil seal by the crankshaft.



NOTE :

Without coating the oil seal with oil or lubricant, assemble it in the dry state.

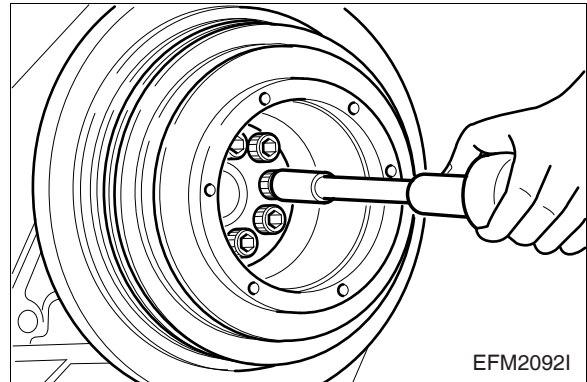
- Tighten the fixing bolts in the zigzag method.

3.3.15. Vibration damper

- Assemble the vibration damper tightening firstly by the crankshaft pulley and the fixing bolts.
- Insert the crankshaft pulley assembly to the crankshaft and tighten the fixing bolts in the method of zigzag to the specified torque.

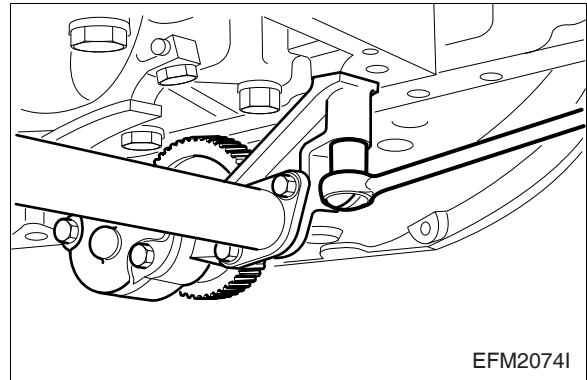


Torque	21 kg·m
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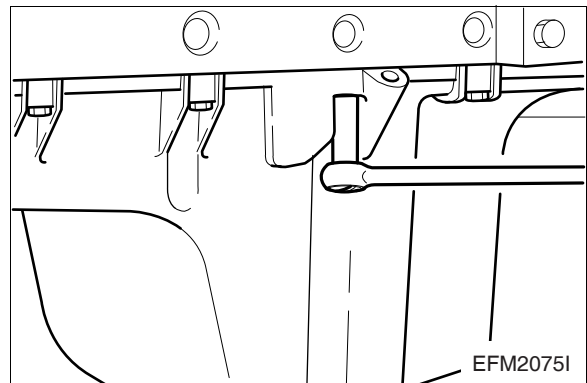
3.3.16. Oil pump

- Put the oil pump at the place to be installed on the cylinder block.
- Attach the gasket at the surface of oil pump where the pressure regulating valve is to be installed and place the regulating valve on the gasket.
- Assemble the oil pump by tightening the fixing bolts.
- Attach the gasket at the surface of the oil pump where the oil suction pipe is to be installed, and install the oil suction pipe by tightening the fixing bolts.
- Assemble the pipe bracket on the cylinder block side with bolts.



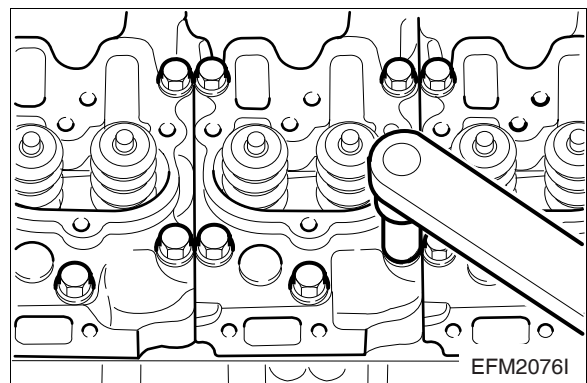
3.3.17. Oil pan

- Clean thoroughly the gasket that is projecting at the junction parts of front oil seal holder and flywheel housing of cylinder block's lower face with a scraper. In the process of gasket removal, be careful for the gasket pieces not to get into the engine inside.
- Attach the gasket to the cylinder block.
- Install the oil pan and tighten the fixing bolts. Then take care not to squeeze out the gasket.
- Install the guide tube and insert the oil level gauge.

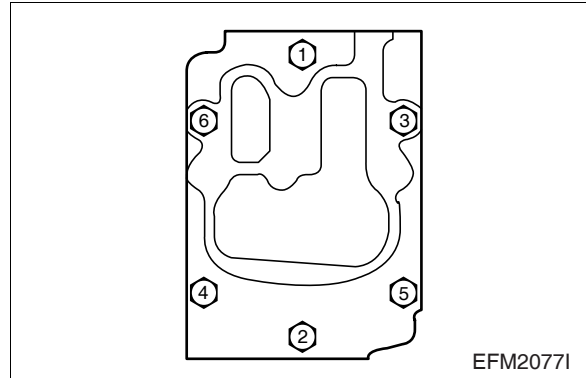


3.3.18. Cylinder head

- Blow the cylinder head bolt holes with compressed air to remove the foreign material cleanly.
- Wipe off cleanly the junction part of cylinder block's head gasket.
- After confirming whether there is foreign material or not necessarily, if there is, remove it.
- Assemble the gasket fitting with the fixing pin of the cylinder block.



- Fit the cylinder head assembly on the cylinder block aligning with its dowel pin. (Take care not to damage the head gasket.)
- Tighten them to the specified torque according to step by step. However, prior to tightening the bolts, with a long steel rule, the parallel between the cylinder heads must be adjusted.



EFM20771

<Cylinder head bolts tightening order>

- (1) First step : Tighten temporarily 1 ~ 2 threads by hands.
- (2) Second step : Tighten to about 8 kg·m with a wrench.
- (3) Third step : Tighten to 15 kg·m with a torque wrench.
- (4) Fourth step : Rotate 90° twice by rotation angle method.

* Standard length of bolt and use limit :
(from the head seat face to tip)

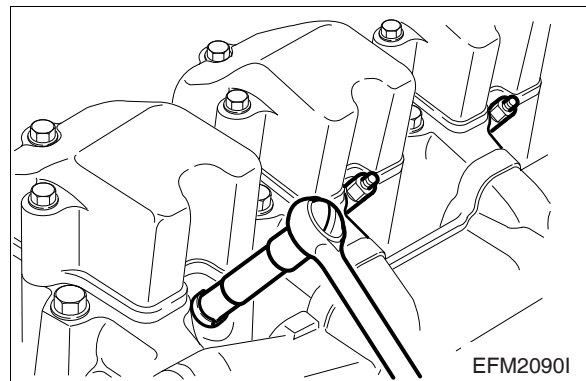
Bolt No.	Standard length	Use limit
3, 6	168 mm	171 mm
2, 4, 5	144 mm	147 mm
1	109 mm	112 mm



Take care for the foreign material not to get into the cylinder head suction passages.

3.3.19. Nozzle

- Put the new seal ring in nozzle hole of the cylinder head and after inserting the nozzle assembly, tighten it to assemble. However, coat the nozzle outer part with the stuck preventing agents and assemble it.



EFM20901

3.3.20. Rocker arm

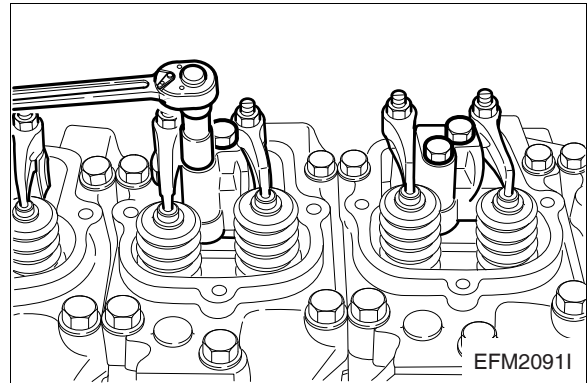
- Coat the push rod with engine oil and put it into the push rod hole.
- Make a position the rocker arm assembly on the cylinder head and tighten the fixing bolts to the specified tightening torque.



Torque	6.2 kg-m
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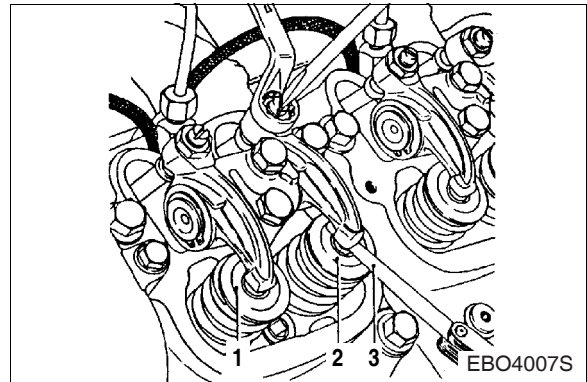


- Adjust the valve clearance. Regarding the adjustment, refer to the regular maintenance part.



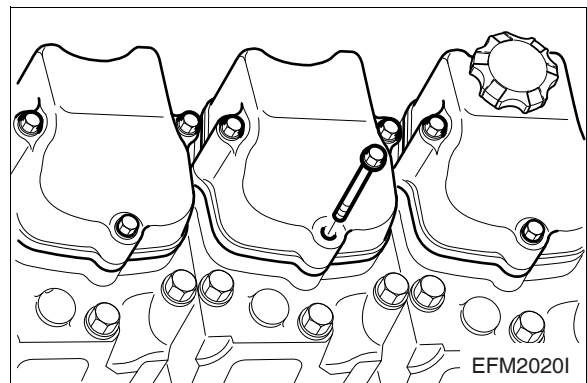
3.3.21. Checking and adjusting valve clearance

- After removing the head cover loosen the lock nuts of rocker arm adjusting screws using a spanner and push the filler gauge of specified value between rocker arm and valve stem.
- Tighten the adjusting screw using a driver until the inserted feeler gauge can be taken a slight resistance between the valve stem and the rocker arm. Then tighten the lock nut simultaneously on not moving the adjusting screw.
- After checking the clearance once more if necessary re-adjust it.



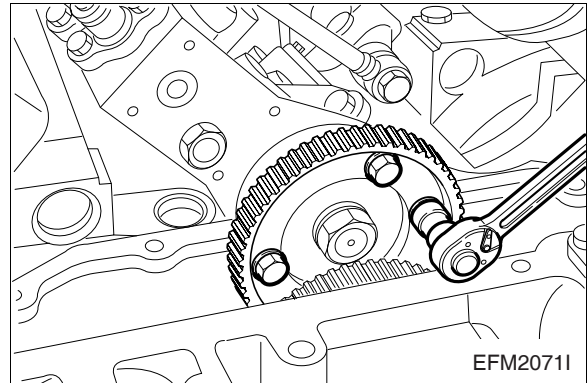
3.3.22. Cylinder head cover

- Attach the new gasket on the surface of cylinder head where the cover is to be installed.
- Assemble the cylinder head cover by tightening the fixing bolts.
- Insert the oil filler cap.

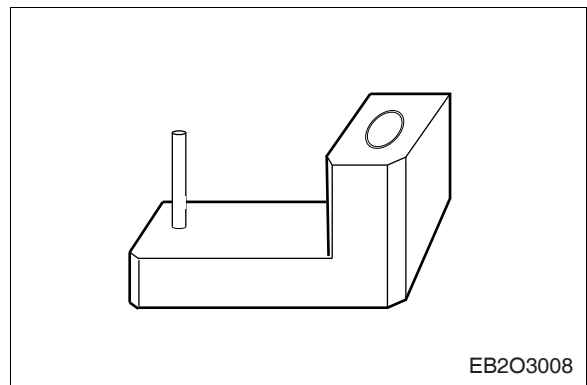


3.3.23. Fuel injection pump

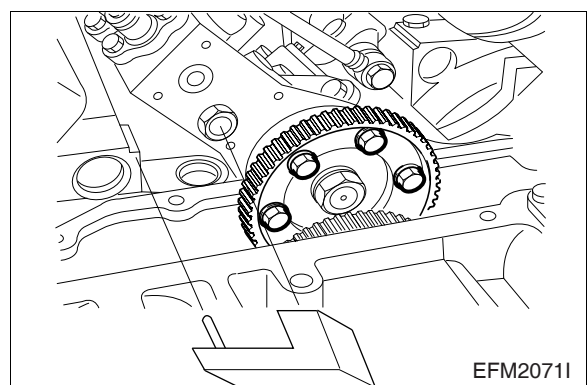
- Turn the crank shaft so as to let the cylinder No.6 for P158LE, PU158TI, P222LE, PU222TI engines and the cylinder No.7 for P180LE, PU180TI come to the overlap TDC (Top Dead Center).
- Rotate the crankshaft to reverse about 30° (in order to remove a backlash), and then rotate it to engine rotating direction to set the fuel injection timing angle.



- Coat the O-ring with grease and insert it at the lower part of fuel injection pump. (Be careful O-ring not to be removed).
- Prior to install the fuel pump drive gear, fit the rubber gasket first.
- Tighten temporarily the fuel injection pump drive gear with aligning the pointer on drive gear with injection pump pointer.
- Fit the injection pump in the appropriate position using a special tool. (Special tool no. : EF120-189).



- After fixing the jig hole on the limit cap of the injection pump rotate the jig counterclockwise and align the jig pin to the machined corner of the cylinder block, then assemble the injection pump.
- After completing the preparation for injection pump assembling, install the injection pump and tighten the bolts in the zigzag method.



- After assembling the injection pump, find out whether the injection pump pointer and drive gear's pointer is aligned, and if aligned, tighten the fixing bolts that were temporarily tightened. However, if not aligned, loosen the fixing bolts and turn the fuel pump so as to align the pointers then tighten the fixing bolts.



In case of exchange the injection pump, should fill the engine oil in the governor of the injection pump before the engine running.

<Oil quantity of the injection pump>

P158LE / PU158TI	P180LE / PU180TI	P222LE / PU222TI
0.95 liter	1.1 liter	1.3 liter

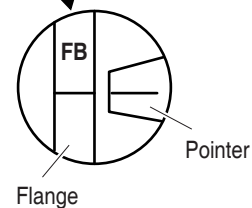
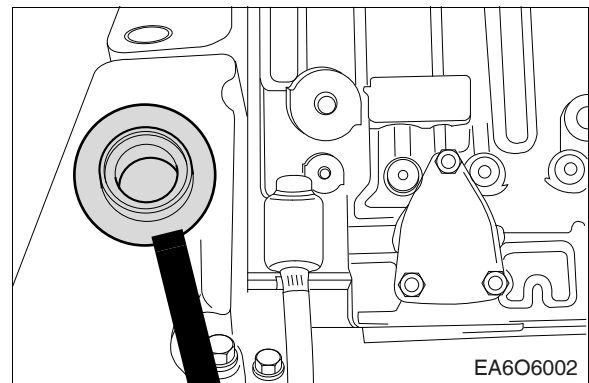
3.3.24. Injection timing

● How to check the injection timing

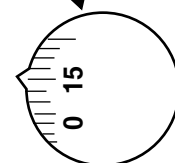
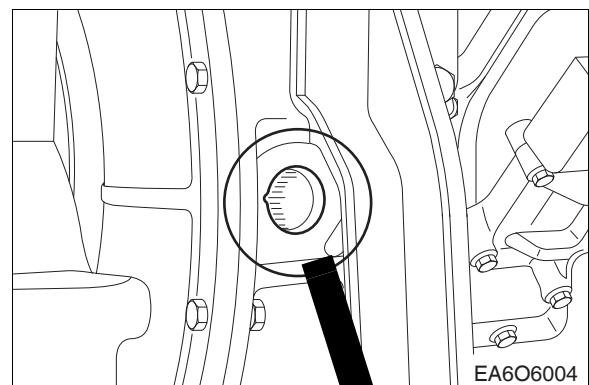
Check the current injection timing of the engine as follows before adjusting it but if the injection timing is wrong should do it.

- (1) Remove the plug screw assembled in case cover on the injection pump drive gear. (Some cases are needed to remove cover assembly)

And turn the crank pulley so that the mark on pointer provided on injection pump coincides with matching mark (FB) on the flange surface of the drive gear.



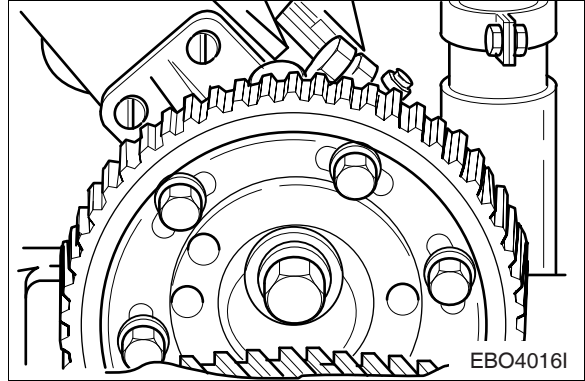
- (2) Check the injection timing degree whether the V-type edge of the flywheel housing sight hole coincides with the engine injection timing degree marked on the flywheel corresponding to fuel delivery position.



- **How to adjust injection timing**

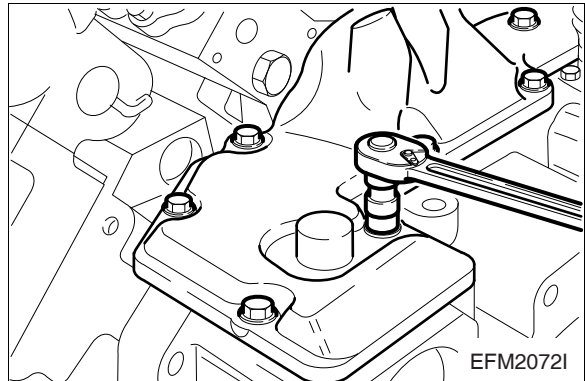
If upper pre-checked injection timing degree is wrong, follow as below.

- (1) Loosen the fixing bolts(M8) of the injection pump driving gear in order to adjust the injection timing slightly.
- (2) Turn the crank pulley clockwise until V-groove of the flywheel housing sight hole is aligned with the injection timing degree of the engine.
- (3) Coincide the mark on pointer provided in injection pump with the matching mark (FB) on the flange surface of the drive gear by turning the flange in the oblong holes of the drive gear.
- (4) Tighten the bolt (M8) to specified torque. (3.1 kg-m) not to move the drive gear.
- (5) After confirmation that fastening bolts are completely tightened check the start point (injection timing degree) of fuel delivery setting once more if not right repeat it again as same as upper way.



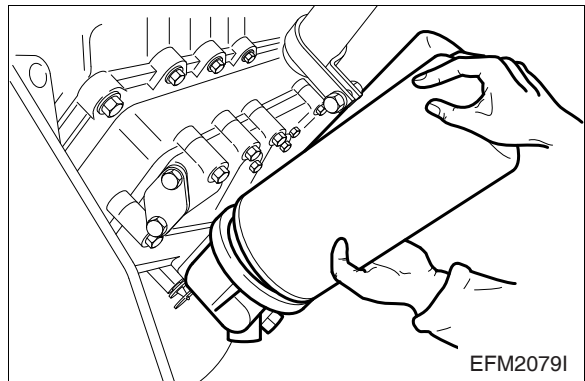
3.3.25. Flywheel housing cover

- Attach the gasket to the flywheel housing cover.
- Install the flywheel housing cover and tighten the fixing bolts by zigzag method.



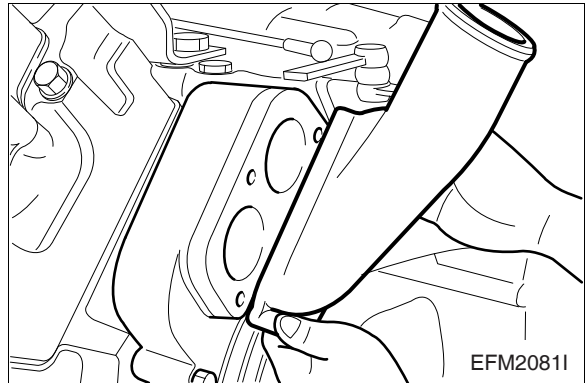
3.3.26. Oil filter

- Install the oil filter cartridge.



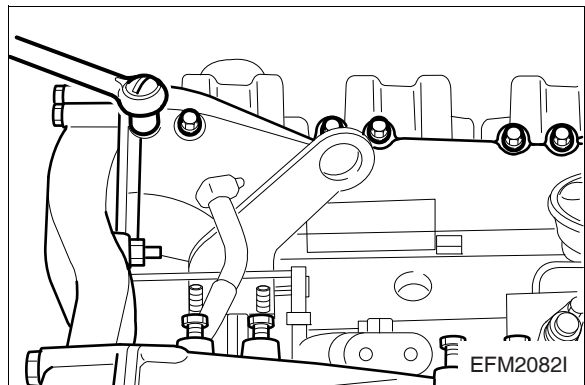
3.3.27. Cooling water pump

- Attach the gasket of the fresh water pump. (at cylinder block side)
- Assemble the fresh water pump by tightening the fixing bolts. (zigzag method)
- Insert the thermostat of fresh water pump.
- Insert the O-ring to the thermostat and assemble the cooling water pipes by tightening the fixing bolts.



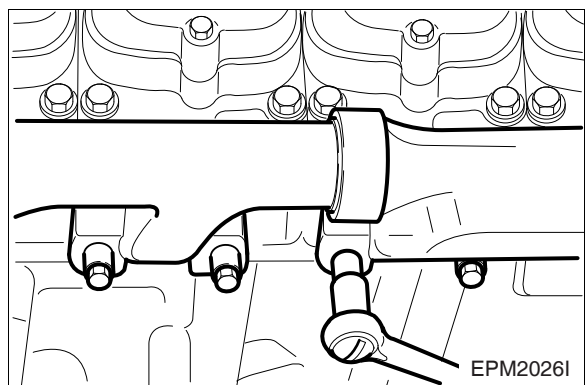
3.3.28. Intake manifold

- Attach the new gasket to the cylinder head side.
- Assemble the intake manifold by tightening the fixing bolts.
- Attach the gasket to the inlet flange and assemble by tightening the fixing bolts.
- Assemble both sides by the above method.
- Attach the gasket to the equalizing pipe that connects the intake manifolds of both sides and assemble both manifolds by tightening the fixing bolts.



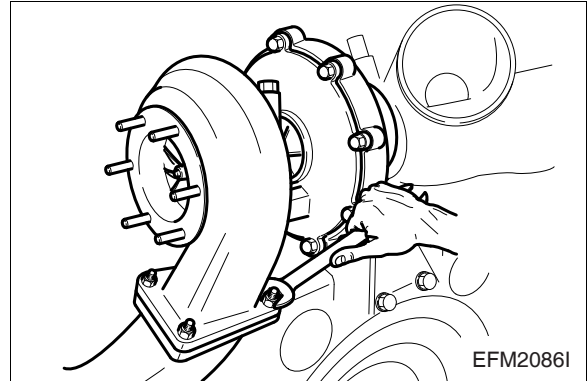
3.3.29. Exhaust manifold

- Connect the exhaust manifold that consists of two sets after inserting the exhaust gas ring between them.
- Attach a new gasket to the exhaust manifold.
- Attach a gasket to the exhaust elbow that is connected to the exhaust manifold, and assemble the elbow by tightening the nuts for connection.
- Assemble both sides in the same method as above.



3.3.30. Turbo charger

- Attach a gasket to the exhaust elbow and assemble the turbocharger with fixing bolts.
- Install the connecting pipes and an O-ring between the inlet flange and turbocharger. Then, it is assembled with the O-ring that was coated with engine oil.
- Attach a gasket on the oil supply pipe and assemble the pipe with the fixing bolts.
- Attach a gasket on the oil discharge pipe and assemble the pipe by tightening the bolts.
- At the same method as above, both sides are assembled.

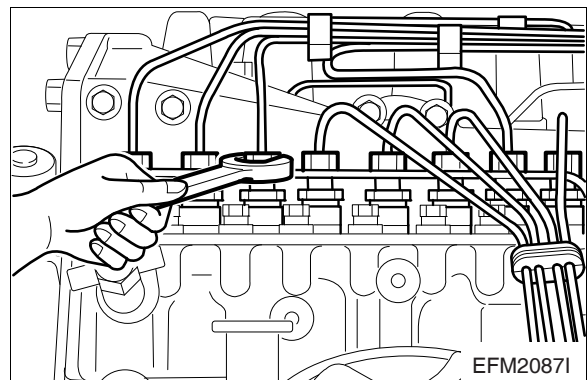


3.3.31. Intake stake

- Connect rubber hoses between the intake stake and turbocharger and assemble by tightening clamps.

3.3.32. Fuel injection pipe

- Connect the fuel injection pipes to the fuel injection pump and the nozzle respectively and then assemble them by tightening nuts.
- Assemble the fuel return pipes by tightening fixing nuts.



3.3.33. Fuel filter

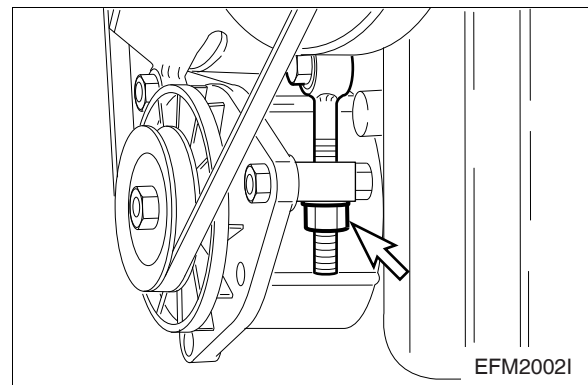
- Assemble the fuel filter to the intake stake by tightening bolts.
- As for the replacement method of fuel filter element, loosen the fixing bolts of upper parts, and assemble the element with O-ring that must necessarily be a new one.

3.3.34. Alternator

- Assemble the alternator bracket to the lower part of cylinder block by tightening the fixing bolts.
- Install the alternator supporting plate.
- Connect the crankshaft and the alternator and water pump pulleys with V-belts by inserting them into the respective pulleys.

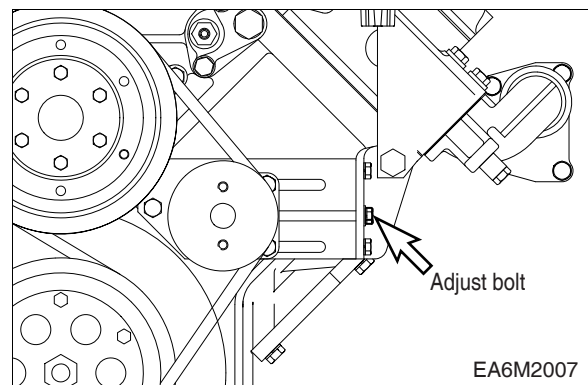


- Adjust the alternator support nut until the belt tension can be 10 mm ~ 15 mm by pushing with thumb.



3.3.35. Idle pulley

- Install the idle pulley.
- Connect the water pump, the crank and the idle pulleys with driving V-belts.
- Tighten eye bolt and nut. (10 mm ~ 15 mm or so pushing with a thumb)



3.4. Breaking-In

3.4.1. Operation of a new engine (Break-In)

Because the sliding surfaces of a new engine are not lapped enough, the oil film can be destroyed easily by overload or overspeed and the engine life-time may be shortened.

Therefore the following things must be obeyed by all means.

Up to the first 50 hours

- Engine should be run at fast idling until the temperature of the engine becomes normal operating condition.
- Overload or continuous high speed operation should be avoided.
- High speed operation with no load should be prevented.
- Abrupt start and stop of the engine should be avoided.
- Engine speed must be under 70 % of its maximum speed.
- Maintenance and inspection must be accomplished thoroughly.

3.4.2. Check points for break-in

During the break-in (the initial running of the engine) period, be particularly observant as follows :

- 1) Check engine oil level frequently. Maintain oil level in the safe range, between the “min.” and “max.” marks on dipstick.



NOTE :

If you have a problem getting a good oil level reading on dipstick, rotate dipstick 180° and re-insert for check.

- 2) Watch the oil pressure warning lamp. If the lamp blinks, it may be the oil pick-up screen is not covered with oil. Check oil dipstick. Add oil to the oil pan, if required. Do not overfill. If level is correct and the status still exists, see your DEALER for possible switch or oil pump and line malfunction.



NOTE :

Oil pressure will rise as RPM increases, and fall as RPM decreases. In addition, cold oil will generally show higher oil pressure for any specific RPM than hot oil. Both of these conditions reflect normal engine operation.

- 3) Watch the engine water temperature gauge and be sure there is proper water circulation. The water temperature gauge needle will fluctuate if water level in expansion tank is too low.

At the end of the break-in period, remove break-in oil and replace the oil filter. Fill oil pan with recommended engine oil. Refer to following table.

<Engine Oil capacity>

	Oil pan (only)
P158LE / PU158TI	21 liter
P180LE / PU180TI	35 liter
P222LE / PU222TI	40 liter

4. Commissioning and Operation

4.1. Preparations

- Before daily starting the engine, check fuel level, coolant level and engine oil level and replenish, if necessary.
- The notches in the dipstick indicate the highest and lowest permissible oil levels.



CAUTION :

Do not add so much engine oil that the oil level rises above the max. marking on the dipstick. Overfilling will result in damage to the engine.

- The oil required in the sump is specified in the “Engine Specification” at the head of these instructions.



NOTE :

The oil required to fill the oil filters and pipes depends upon the engine equipment and use and must be determined individually at the time of initial commissioning. (Make a note of the determined quantity).

- Ensure outpost cleanliness when handling fuels, lubricants and coolants.
- Use approved fuels, lubricants and coolants only, as otherwise the manufacturer’s guarantee will be null and void.

4.2. Starting

- Insert key in starting lock.
- Moving control lever to “Idle speed”.
- Key switch rotate clockwise.
- Do not operate for longer than 10 seconds at a time.
- After ignition of the engine, take-off the hands in key switch.
- And adjust control lever for desired speed.
- If engine fails to start, release the key, wait about 1 minute, then operate starter again.
- Avoid running the cold engine for any length of time since in any internal combustion engine this is liable to cause increased wear due to corrosion. Prolonged idling is harmful to the environment.



NOTE :

On initial start of an overhauled engine or after long periods without use, press shut-down lever in “stop” position and operate starter motor for a few seconds (max. 10) until oil pressure is indicated.

Only then the engine should be started in the normal way

4.3. Running In

- It is recommended that new or overhauled engines should not be operated at a load higher than about 75 % maximum load during the first few hours of operation. Initial run-in should be at varying speeds. After this initial run-in, the engine should be brought up to fuel output gradually.

4.4. During Operation

Do not overload the engine. Do not exceed the maximum permissible engine tilt. If faults occur, find their cause immediately and have them eliminated in order to prevent more serious damage!

During operation the oil pressure in the engine lubrication system must be monitored. If the monitoring devices register a drop in the lube oil pressure, switch off the engine immediately.

The coolant temperature should be approx. 80 to 95 °C.

The charge warning light of the alternator should go out when the engine is running.

1) Alternator

In order to avoid damage to the alternator, observe the following instructions ;

While the engine is running

- Do not de-energize the main battery switch!
- Do not disconnect the battery or pole terminals or the cables!
- If during operation, the battery charge lamp suddenly lights up, stop the engine immediately and remedy the fault in the electrical system!
- Do not short-circuit the connections of the alternator with those of the regulator or said connection with ground, not even by briefly bringing the connections into contact!
- Do not operate the alternator without battery connection! of the alternator with those of the regulator or said connections with ground, not even by briefly bringing the connections into contact!
- Do not operate the alternator without battery connection!

4.5. Shutting Down

- Cut off the main circuit breaker of the generator control panel to “stop” After the engine has been running at a high load level, do not shut it down immediately but allow it to idle about 5 minutes so that temperatures may equalize.

Remove key from starting lock



CAUTION :

Ensure that the engine can not be started by unauthorized persons.

4.6. Maintenance and Care

4.6.1. Oil level

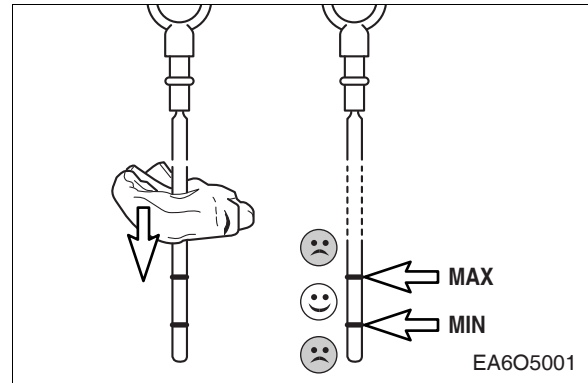
- Check the oil level in the engine sump daily with a dipstick. The level should be between the two notches cut into the dipstick and should never be allowed to drop below the lower notch.



CAUTION :

Do not add so much engine oil that the oil level rises above the max. marking on the dipstick. Over filling will result in damage to the engine.

- The oil level should be checked with the engine horizontal and only after it has been shut down for about 5 minutes.



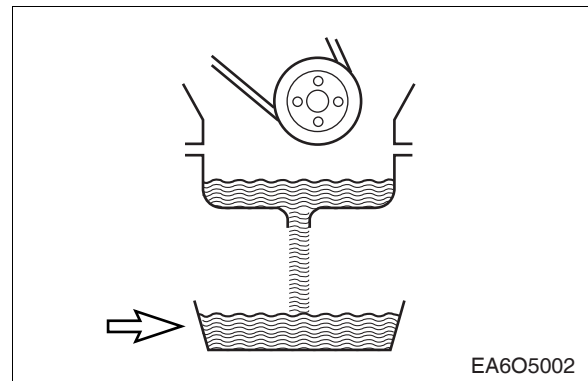
4.6.2. Oil drainage

- With the engine at operating temperature, remove the oil drain valve on the oil sump and the oil cartridge bowl and allow the old oil to drain off completely. Use a vessel of sufficient size to ensure that the oil does not overflow. Refit the oil drain valve.



CAUTION :

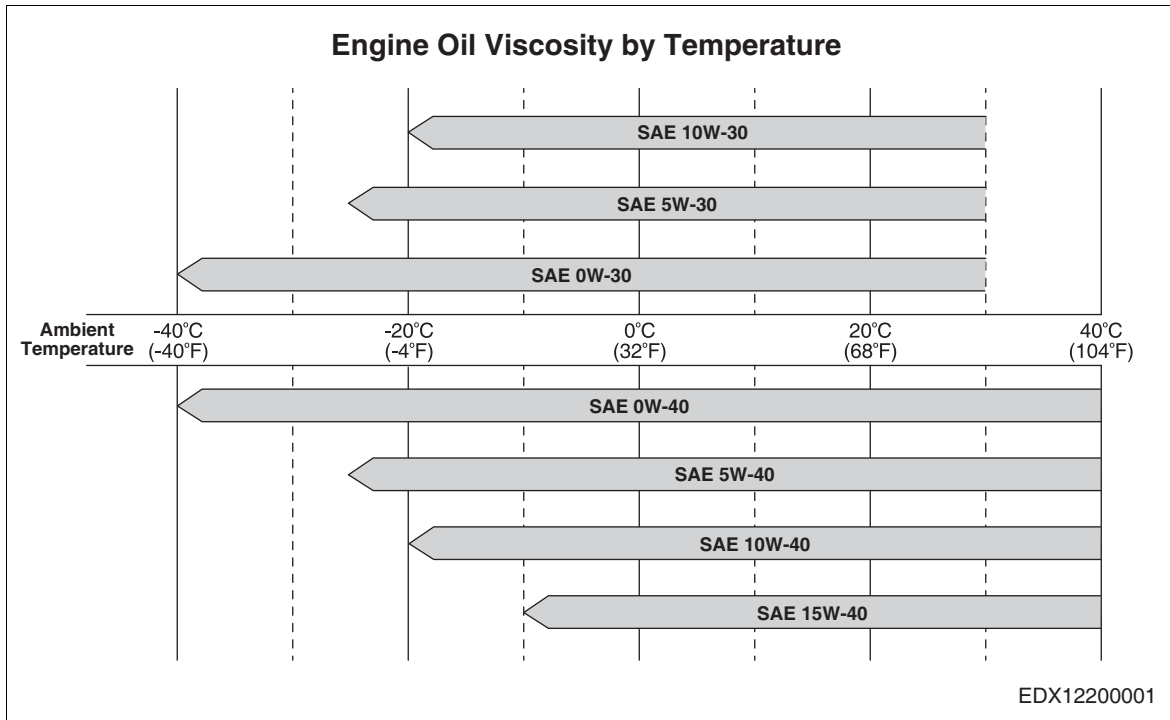
The oil is hot-risk of scalding. Do not touch the oil drain plug with bare fingers. Oil is an environmental hazard. Handle it with care!



- **Recommend of lubricating oil**



Initial factory fill is high quality break-in oil for API Service CI-4 grade. During the break-in period, frequently check the oil level. Somewhat higher oil consumption is normal until piston rings are seated. The oil level should be maintained in the safe range between the Min. and Max. mark on the dipstick. To obtain the best engine performance and engine life, Engine oil is specified by API service, lettered designations and SAE viscosity numbers. If the specified engine oil is not available, use a reputable brand of engine oil labeled for API Service CI-4 and SAE viscosity 10W40. Refer to oil identification symbol on the container

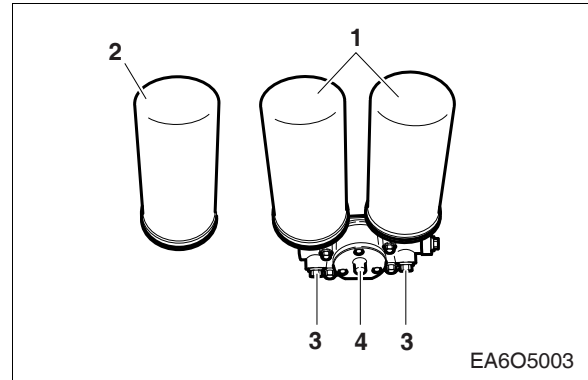


4.6.3. Refilling with oil

- Refill with fresh engine oil at the oil filler neck.
- After refilling with oil, rotate the engine with the starter and move the shut-down lever to “stop” at the same time until the oil pressure warning light goes out and the oil pressure gauge shows a pressure.
- Then start the engine and allow it to run at medium speed for a few minutes. Check oil pressure and tightness of system.
- Then shut down the engine. After about 5 minutes, check the oil level. The oil level should now be at the upper notch of the dipstick, but not higher.
- Add any necessary oil to the upper dipstick mark.

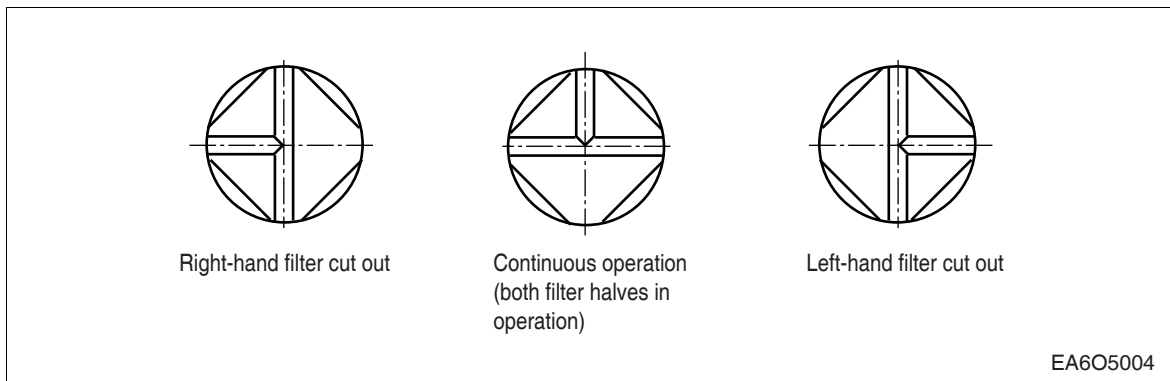
4.6.4. Lubricating oil filter

- Cleaning of the lubricating oil is effected in a full-flow oil filter with paper cartridges. A bypass valve ensures continuity of oil supply if the filter elements should be clogged.
- After draining off the oil release tie screw. Remove filter bowl. Renew filter cartridge. Thoroughly clean all other parts in cleaning fluid. Use new gaskets for re-assembly.



1. Oil filter(Change over-type)
2. Element
3. Oil drain plug
4. Selector cock

- During continuous operation the selector lever that both filter halves are in operation.
- Observe positions of selector level.



CAUTION :

Do not leave selector lever in any intermediate position because this would be liable to interfere with oil supply.

4.6.5. Renewal of filter cartridges

- Allow the filter content to run off along drain plugs. Hold a suitable vessel under hole.



CAUTION :

Oil is hot and under pressure!

- After releasing the clamping bolts remove filter bowls.
- Renew filter cartridges. Thoroughly clean all other parts in cleaning fluid. (do not allow cleaning fluid to enter the oil circuit)



NOTE :

To prevent the seal from twisting hold the filter bowl firmly when tightening the tensioning screw.

- Every time an oil change is made, the two oil filter cartridges should be renewed!



CAUTION :

Use oil filters are classed as dangerous waste and must be disposed of accordingly.

5. Maintenance of Major Components

5.1. Fuel Injection System

5.1.1. Injection pump calibration

1) P158LE series engine (BOSCH)

- (1) Injection pump : 400912-00026C
 - Model : PE8P120A500/4LS7935 (0 412 628 937)
 - Governor : Ghana control(DWA-2000)
 - Plunger & barrel : 2 418 455 545
 - Delivery valve : 2 418 559 045
 - Feed pump : FP/KD22P78-2 (0 440 008 152)
 - Prestroke : 4.5 ± 0.05 mm at 13 ± 1.5 mm
- (2) Nozzle holder assembly : 65.10101-7051 (0 432 131 667)/65.10101-7053(0 432 131 669)
- (3) Nozzle : 65.10102-6047 (0 433 171 174)/65.10102-6070(0 433 171 169)
- (4) Injection pipe : 420208-00907, 420208-00906
- (5) Injection order : 1 – 5 – 7 – 2 – 6 – 3 – 4 – 8
- (6) Fuel injection timing : BTDC 16°

(A) Test condition for injection pump	Nozzle & holder ass'y	1 688 901 105	Opening pressure : 208.5 ± 1.5 bar			
	Injection pipe (ID ,OD ,L)	–	$\phi 3.0 \times \phi 8.0 - 600$ mm			
	Test oil	ISO4113	Temperature : 40 ± 5 °C			
(B) Engine standard parts	Nozzle & holder ass'y	65.10101-7051	Nozzle ($4 \times \phi 0.40$)			
			285 kg/cm ²			
	Injection pipe(ID, OD ,L)	420208-00907, 420208-00906	$\phi 2 \times \phi 6 - 650$ mm			
Rack diagram and setting valve at each point						
Standby power	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q'ty on RIG (mm ³ / 1,000 st)		Press. (mmHg)
				(A) Test condition for inj. pump	(B) Engine standard parts	
	A	12.6	700	304 ± 3	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
Boost pressure : zero boost						

2) P158LE series engine (WEIFU)

- (1) Injection pump : 400912-00734
 – Model : PW2000
 – Governor : 300701-00133 (Electric governor)
 – Plunger & barrel : 05U817-00
 – Delivery valve : 05F238-00
 – Feed pump : -
 – Prestroke : 4.1 ± 0.05 mm
- (2) Nozzle holder assembly : 65.10101-7051
- (3) Nozzle : 65.10102-6047
- (4) Injection pipe : 420208-00907, 420208-00906
- (5) Injection order : 1 - 5 - 7 - 2 - 6 - 3 - 4 - 8
- (6) Fuel injection timing : BTDC 16°

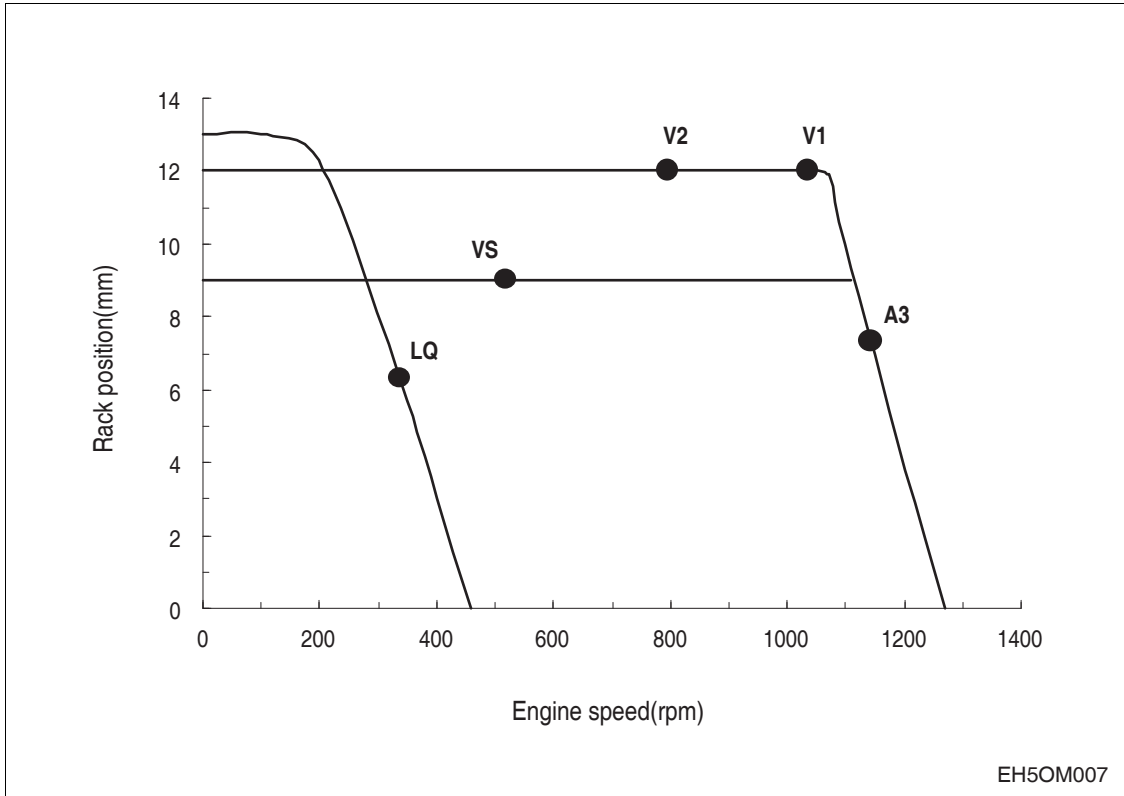
(A) Test condition for injection pump	Nozzle & holder ass'y	1 688 901 105	Opening pressure : 175 bar			
	Injection pipe (ID ,OD ,L)	–	∅2.0 × ∅6.0 – 600 mm			
	Test oil	ISO4113	Temperature : 40 ± 5 °C			
(B) Engine standard parts	Nozzle & holder ass'y	65.10101-7051	Nozzle (4 × ∅0.40)			
			285 kg/cm ²			
	Injection pipe(ID, OD ,L)	420208-00907, 420208-00906	∅2.0 × ∅6.35 – 650 mm			
Rack diagram and setting valve at each point						
Standby power	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q'ty on RIG (mm ³ / 1,000 st)		Press. (mmHg)
				(A) Test condition for inj. pump	(B) Engine standard parts	
	A	16	750	350	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
Boost pressure : zero boost						

5) PU158TI engine

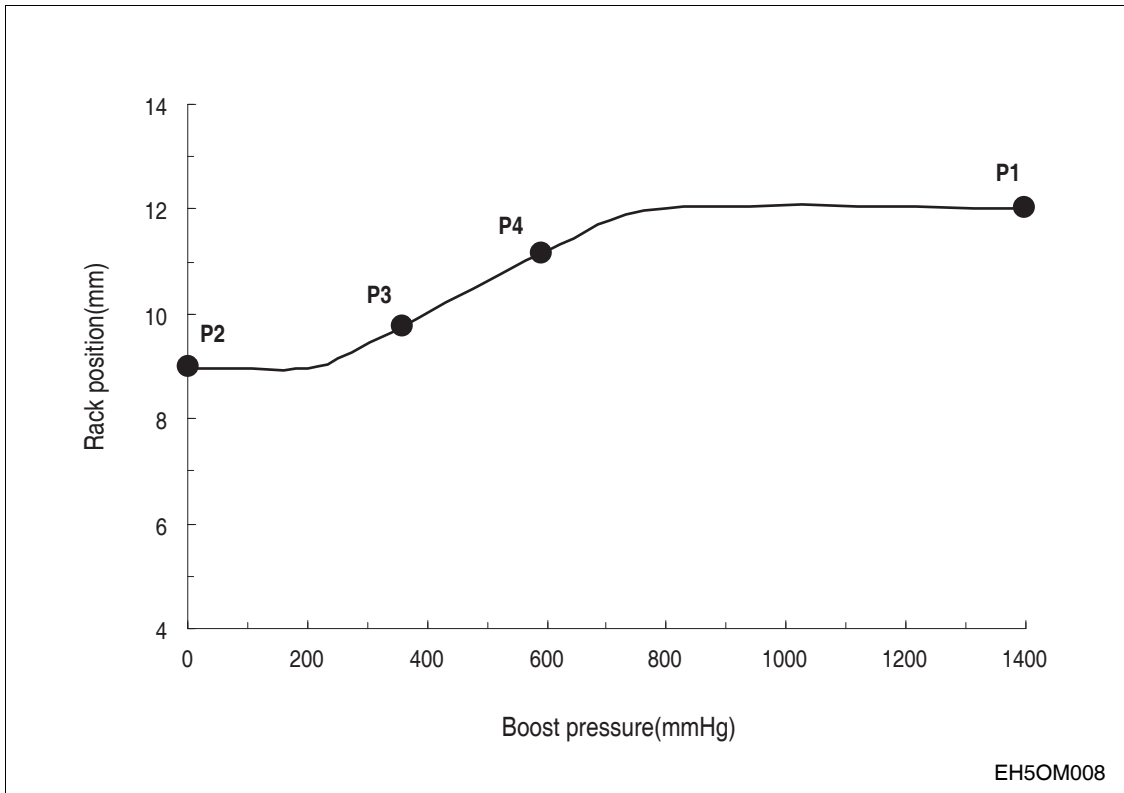
- (1) Injection pump : 65.11101-7680 (A 401 881 102 BOSCH)
 – Model : PE8P120A520/4LS7947 (0 412 628 942)
 – Governor : RQV250...900PA1434(0 440 008 152)
 – Plunger & barrel : 2 418 455 188
 – Delivery valve : 2 418 552 039
 – Feed pump : FP/KD22P78-2 (0 440 008 152)
 – Prestroke : 4.5 ± 0.05 mm
- (2) Nozzle holder assembly : 65.10101-7053 (0 432 131 669)
- (3) Nozzle : 65.10102-6070 (0 433 171 169)
- (4) Injection pipe : 65.10301-6053A, 65.10301-6054A
- (5) Injection order : 1 – 5 – 7 – 2 – 6 – 3 – 4 – 8

(A) Test condition for injection pump	Nozzle & Holder Ass'y	1 688 901 019	Opening pressure : 212.6 bar			
	Injection pipe(OD ,ID ,L)	1 680 750 075	∅8.0 x ∅3.0 – 1,000 mm			
	Test oil	ISO4113	Temperature :40 ± 2 °C			
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7053	Nozzle (5 x ∅0.418)			
		0 432 131 669	Spec. : 285.5 bar			
	Injection pipe (OD, ID, L)		∅6 x ∅2 – 750 mm			
Rack diagram and setting valve at each point						
Refer to (3) Rack Diagram	Check Point	Rack position (mm)	Pump Speed (rpm)	Injection Q'ty on RIG (mm ³ / 1,000st)		Press. (mmHg)
				(A) Test condition for inj. Pump	(B) Engine standard parts	
	V1	12.00 ± 0.05	1,050	266.0 ± 3.0	Max. power	1,500
	V2	12.00 ± 0.10	800	266.0 ± 3.0	–	1,500
	VS	8.96 ± 0.20	500	159.8 ± 1.0	–	0
	LQ	6.15 ± 0.20	350	53.7 ± 15.0	Only 2/3/4/8	0
	A3	7.10 ± 0.50	1,150	109.4 ± 15.0	Only 2/3/4/8	0
ST	with Cap	100	127.5 ± 10.0	Only 2/3/4/8	0	
Boost pressure dependent full –load stop (boost compensator spring operation point)						
Refer to (4) Boost pressure	Check point	Rack Position (mm)	Pump speed (rpm)	Injection Q'ty on RIG (mm ³ / 1,000st)		Press. (mmHg)
				(A) Test condition for inj. Pump	(B) Engine standard parts	
	P1	12.00 ± 0.05	500	–	–	1,500
	P2	8.96 ± 0.05	500	–	–	0
	P3	9.25 ± 0.10	500	–	–	275
P4	11.20 ± 0.05	500	–	–	600	
Weight	Weight =630 g		Lever ratio(min/max)		Not fixed	
Idle spring	k=14.03 N/mm		Plunger		∅12	
Middle spring	k=57.14 N/mm		Delivery valve retraction volume		90 mm ³ /st	
Inner spring	k=21.98 N/mm		Delivery valve opening pressure		–	
LDA spring	k=30.5 N/mm		Delivery valve spring		k = 7.2 N/mm	
Feed Pump	Double action		Timer		None	

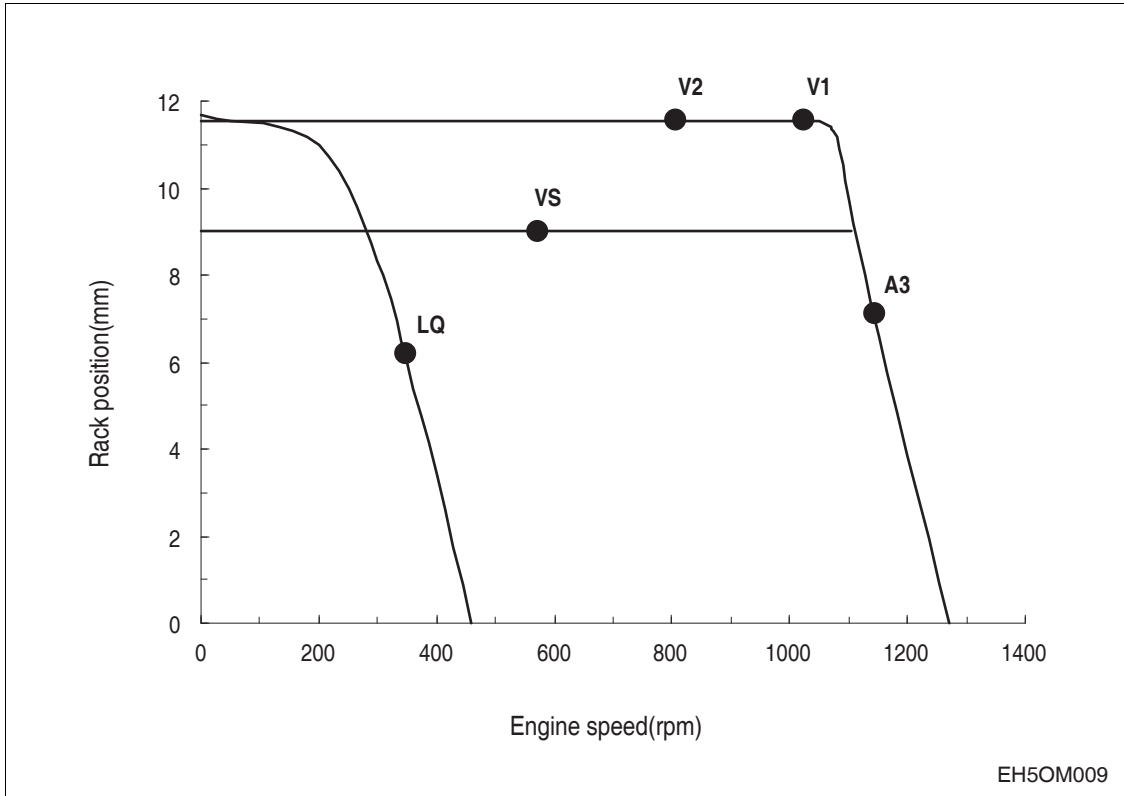
- **Rack diagram**



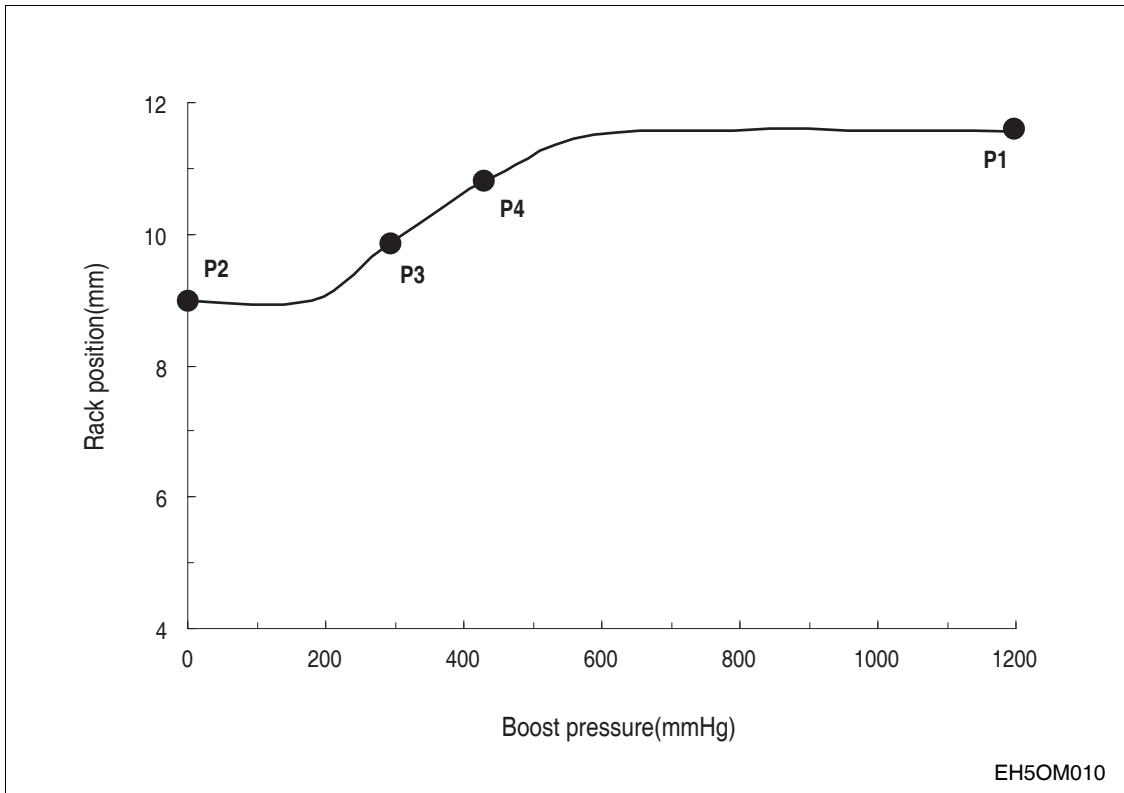
- **Boost compensator pressure**



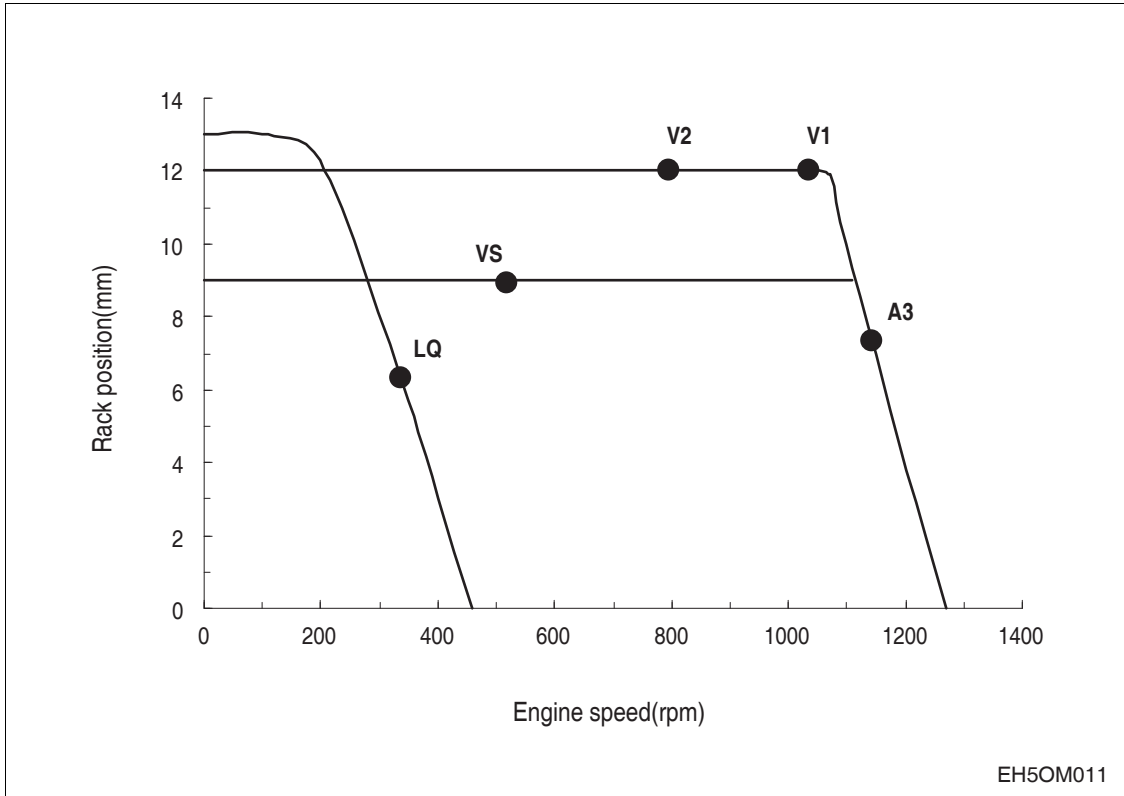
- **Rack diagram**



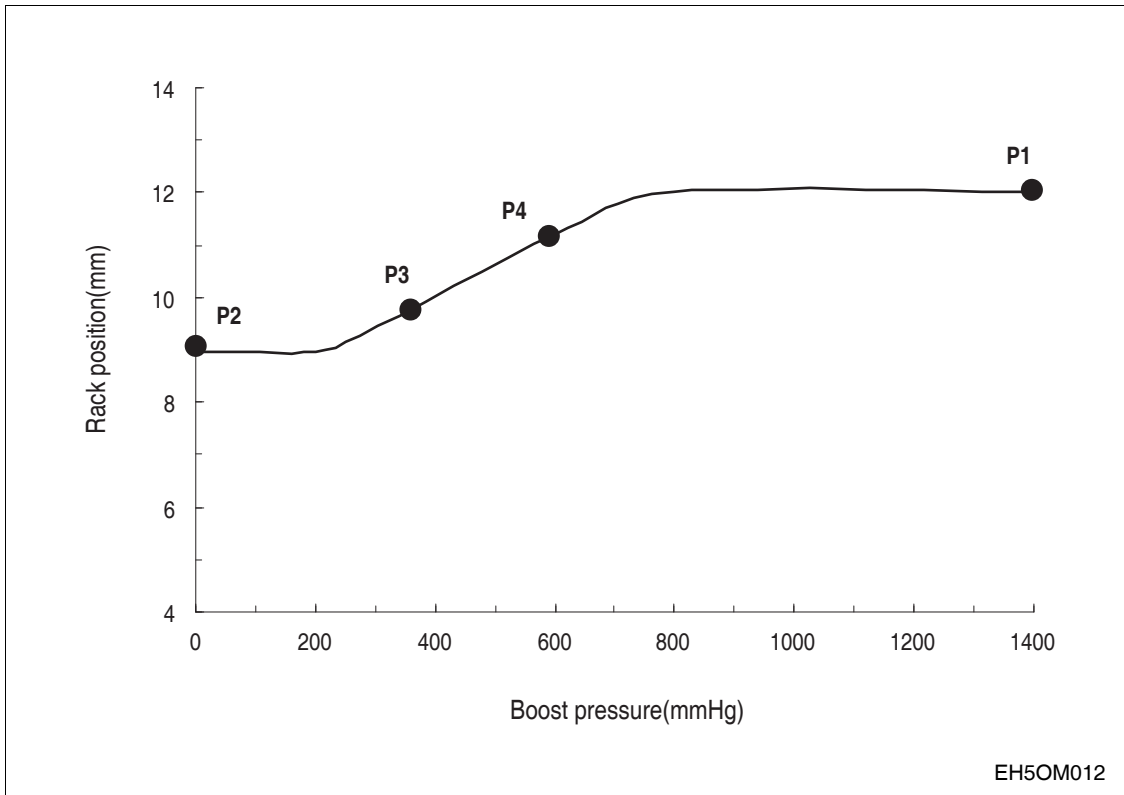
- **Boost compensator pressure**



- **Rack diagram**



- **Boost compensator pressure**



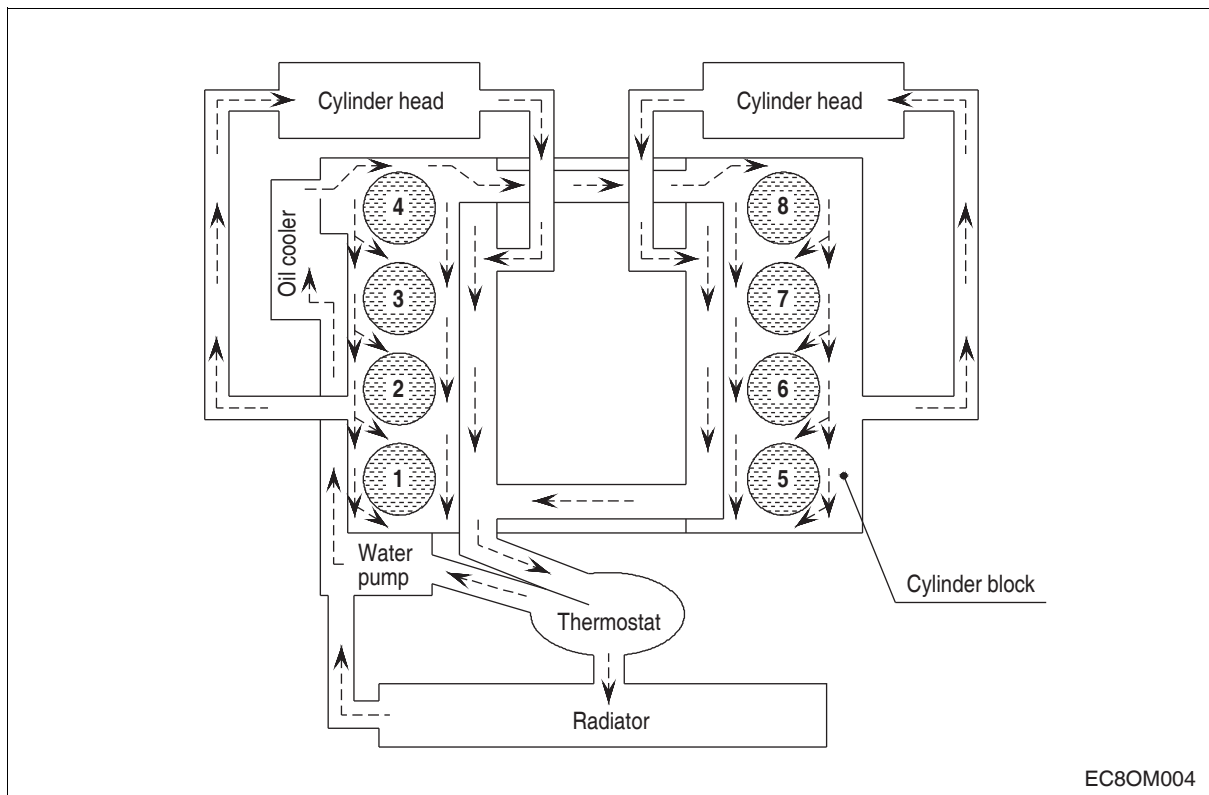
5.2. Cooling System

5.2.1. General information

This engine is water-cooling type. Heat from the combustion chamber and engine oil heat are cooled down by coolant and radiated to the outside, resulting in the normal operation of the engine.

Looking into the cooling system, the water pumped up by the water pump circulates around the oil cooler through the water pipe to absorb the oil heat, and then flows through the water jacket of the cylinder block and water passage of the cylinder head to absorb the heat of the combustion chamber.

The water absorbing the oil heat and combustion chamber heat goes on to the thermostat through the water pipe, and circulates to the water pump if water temperature is lower than the valve opening temperature on the thermostat, while circulating to the radiator at water temperature higher than the valve opening temperature. At the radiator, the heat absorbed in the coolant is radiated to cool down and the coolant recirculates to the water pump.



● Specification

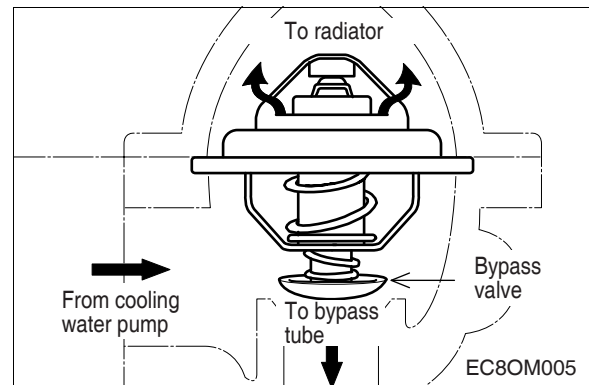
Item	Specification
1. Water pump Type Delivery Pumping speed Pumping back pressure	Centrifugal type About 650 liter/min 3,060 rpm 760 mmHg
2. Thermostat Operating temperature	71 ~ 85°C
3. Cooling fan and belt Fan diameter – Number of blades Fan belt tension	∅915 mm – 7 15 mm / deflection by thumb

5.2.2. Thermostat

● General descriptions and main data

The thermostat maintains a constant temperature of coolant (71 ~ 85 °C) and improves thermal efficiency of the engine by preventing heat loss.

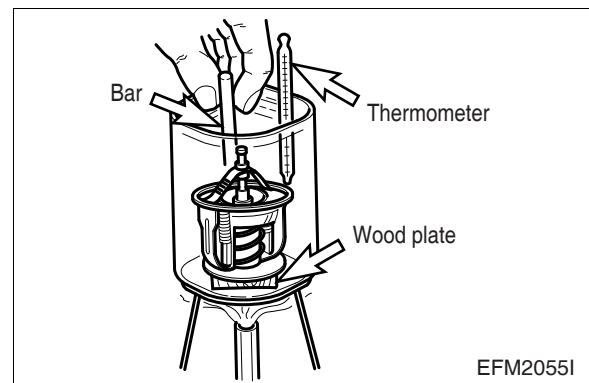
Namely, when the temperature of coolant is low, the thermostat valve is closed to make the coolant bypass to directly enter the water pump; when the coolant temperature rises to open wide the thermostat valve, the bypass circuit is closed and the water passage to the radiator is opened so that the coolant is forced to flow into the radiator.



Item	Specifications
	In moderate climates
	Generator
Type	Wax-pallet type
Open at	71 °C
Open wide at	85 °C
Valve lift	8 mm or more

● Inspecting

- (1) Check the wax pallet and spring for damage.
- (2) Put the thermostat in a container of water, then heat the water slowly and check temperature with a thermometer.
If the valve lift is 0.1 mm (starting to open) at temperature of 71 °C and 8 mm or more (opening wide) at temperature of 85 °C, the thermostat is normal.



● **Replacing thermostat and precautions for handling**

(1) Precautions for handling

The wax pallet type thermostat does not react as quickly as bellows type one to a variation of temperature of coolant. Such relatively slow reaction is mainly due to the large heat capacity of the wax pellet type thermostat. Therefore, to avoid a sharp rise of coolant temperature, it is essential to idle the engine sufficiently before running it. In cold weather, do not run the engine at overload or over-speed it immediately after engine starting

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

(3) Replacing thermostat

If the thermostat is detected defective, retrace with a new one.

5.2.3. Diagnostics and troubleshooting

Complaints	Possible causes	Corrections
1. Engine overheating	<ul style="list-style-type: none"> ● Lack of coolant ● Radiator cap pressure valve spring weakened ● Fan belt loosened or broken ● Fan belt fouled with oil ● Thermostat inoperative ● Water pump defective ● Restrictions in water passages due to deposit of scales ● Injection timing incorrect ● Restriction in radiator core ● Gases leaking into water jacket due to broken cylinder head gasket 	<ul style="list-style-type: none"> ● Replenish coolant ● Replace cap ● Adjust or replace fan belt ● Replace fan belt ● Replace thermostat ● Repair or replace ● Clean radiator and water passages ● Adjust injection timing correctly ● Clean exterior of radiator ● Replace cylinder head gasket
2. Engine overcooling	<ul style="list-style-type: none"> ● Thermostat inoperative ● Ambient temperature too low 	<ul style="list-style-type: none"> ● Replace thermostat ● Install radiator curtain
3. Lack of coolant	<ul style="list-style-type: none"> ● Radiator leaky ● Radiator hoses loosely connected or damaged ● Radiator cap valve spring weakened ● Water pump leaky ● Heater hoses loosely connected or broken ● Cylinder head gasket leaky ● Cylinder head or cylinder block cracked 	<ul style="list-style-type: none"> ● Correct or replace ● Retighten clamps or replace hoses ● Replace cap ● Repair or replace ● Tighten or replace hoses ● Replace cylinder head gasket ● Replace cylinder head block
4. Cooling system noisy	<ul style="list-style-type: none"> ● Water pump bearing defective ● Fan loosely fitted or bent ● Fan out of balance ● Fan belt defective 	<ul style="list-style-type: none"> ● Replace bearing ● Retighten or replace fan ● Replace fan ● Replace fan belt

5.3. Lubricating System

5.3.1. General descriptions and main data

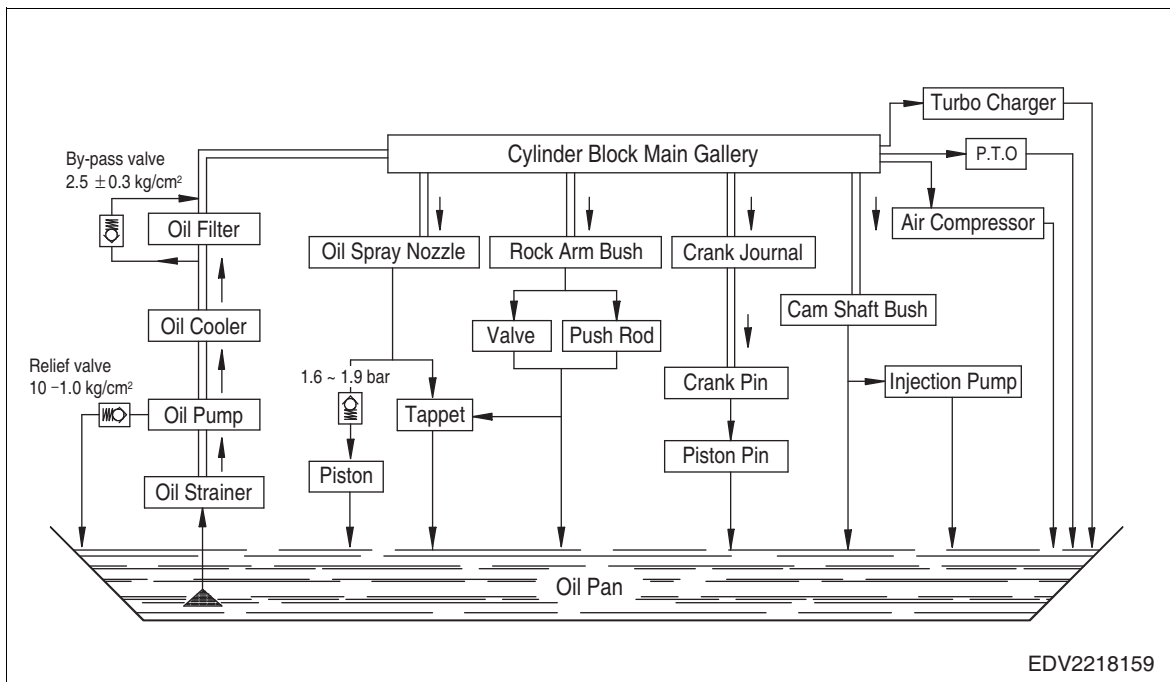
- **General descriptions**

All the engine oil pumped up from the oil pan by the gear type oil pump is filtrated through the oil cooler and oil filter, and this filtrated oil is forced through the main oil gallery in the cylinder block from where it is distributed to lubricate the various sliding parts, and fuel injection pump in order to ensure normal engine performance.

- **Specifications**

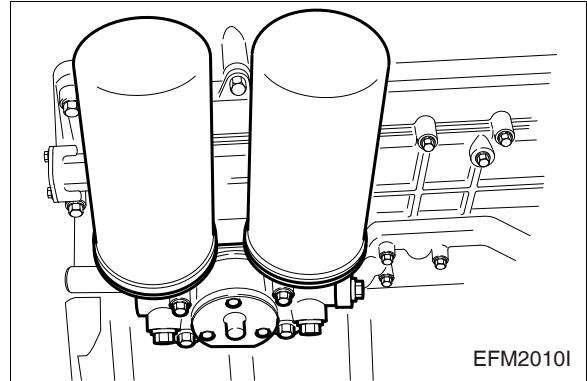
Item	Specifications	Item	Specifications
Lubricating system	Forced pressure circulation	Oil filter type	Full flow
Oil pump type	Gear type	Bypass for filter element	
Relief valve opening pressure	1.0 -1.0 kg/cm ²	Valve opening pressure	2.5 ±0.3 kg/cm ²
Adjusting valve for spray nozzle			
Opening pressure	1.6 ~ 1.9 kg/cm ²		

- **Diagram of lubricating system**



5.3.2. Oil filter

- This oil filter mounted in this engine is a full flow type, so it is necessary to replace it with a new one at the specified intervals.



5.3.3. Diagnostics and troubleshooting

Complaints	Possible causes	Corrections
1. Oil consumption excessive	<ul style="list-style-type: none"> ● Poor oil ● Oil seal or packing leaky ● Pistons or piston rings worn ● Cylinder liner worn ● Piston rings sticking ● Valve guide oil seals or valve guides, or valve stem worn 	<ul style="list-style-type: none"> ● Use suggested oil ● Replace ● Replace pistons and/or piston rings ● Replace cylinder liner ● Replace pistons and/or piston rings ● Replace
2. Oil pressure too low	<ul style="list-style-type: none"> ● Poor oil ● Relief valve sticking ● Restrictions in oil pump strainer ● Oil pump gear worn ● Oil pump feed pipe cracked ● Oil pump defective ● Oil pressure gauge defective ● Various bearings worn 	<ul style="list-style-type: none"> ● Use suggested oil ● Replace ● Clean strainer ● Replace ● Replace ● Correct or replace ● Correct or replace ● Replace
3. Oil deteriorates quickly	<ul style="list-style-type: none"> ● Restriction in oil filter ● Gases leaking 	<ul style="list-style-type: none"> ● Replace filter element ● Replace piston rings and cylinder liner

5.4. Turbo Charger

5.4.1. Data and structure

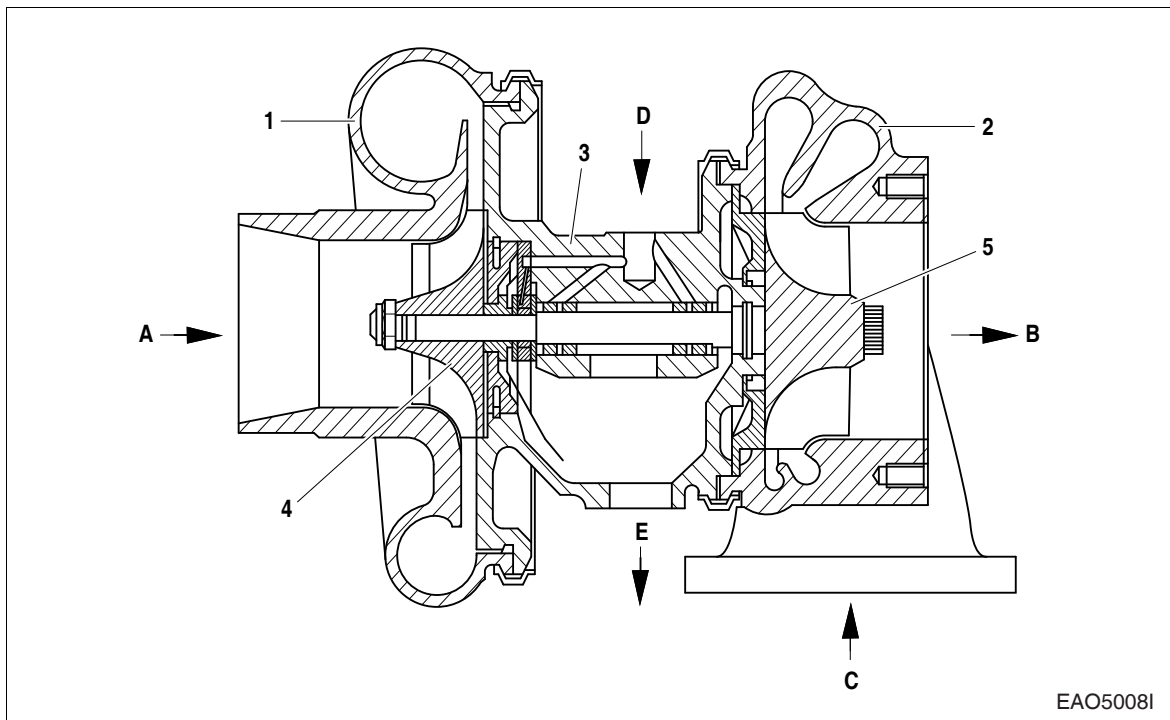
1) Technical data of generator engine

Generator Engine	P158LE	P180LE	P222LE
Turbocharger Model	T04E	T45	T45
Engine Output	690 PS (508 kW) @60 Hz	827 PS (608 kW) @60 Hz	1,000 PS (736 kW) @60 Hz
Intake Air Quantity (m ³ /sec)	0.26	0.32	0.40

2) Technical data of power unit engine

Generator Engine	PU158TI	PU180TI	PU222TI
Turbocharger Model	T04E	T45	T45
Engine Output	540 PS (397 kW)/ 2,100 rpm	650 PS (478 kW)/ 2,100 rpm	800 PS (588 kW)/ 2,100 rpm
Intake Air Quantity (m ³ /sec)	0.26	0.32	0.40

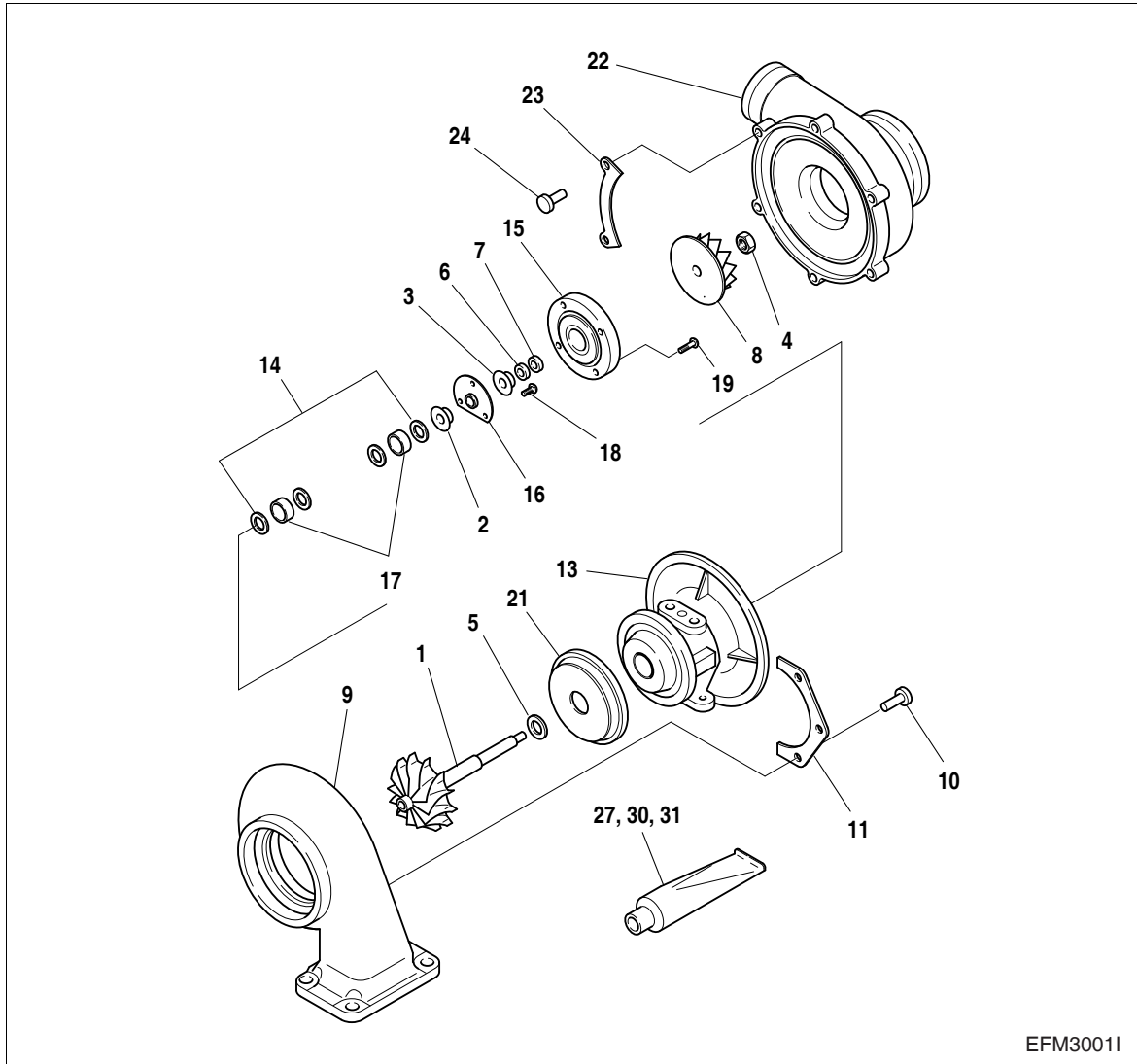
3) Structure



- | | |
|--------------------|---------------|
| 1. Impeller casing | A. Air inlet |
| 2. Turbine casing | B. Gas outlet |
| 3. Bearing casing | C. Gas inlet |
| 4. Impeller | D. Oil supply |
| 5. Turbine | E. Oil return |

5.4.2. Construction

- Make sure that serving should be performed at the professional maintenance shop as authorized by allied signal Company.



EFM3001I

- | | |
|--------------------------|-----------------------------|
| 1. Turbine shaft | 15. Seal plate |
| 2. Thrust bush | 16. Thrust bearing |
| 3. Oil shut off | 17. Journal bearing |
| 4. Fixing nut | 18. Screw |
| 5. Seal ring | 19. Screw |
| 6. Seal ring | 21. Heat dissipator |
| 7. Seal ring | 22. Compressor housing |
| 8. Compressor wing wheel | 23. Clamp |
| 9. Turbine housing | 24. Bolt |
| 10. Bolt | 27. Liquid gasket |
| 11. Clamp | 30. Loctite |
| 13. Bearing housing | 31. Liquid anti-burn agents |
| 14. Retainer ring | |

5.4.3. Summary

- The engine output depends upon the supplied fuel quantity and the engine efficiency. In order to transform into the effective work of engine by burning the supplied fuel fully, the sufficient air to burn the fuel should be supplied to the cylinder. Therefore, the engine output is essentially determined by the size of the cylinder, and for if the air is supplied to the given volume of cylinder with the air being compressed, the air quantity in the cylinder will increase as much to result in that it may burn more fuel. the output will also be able to increase, Supplying the air by compressing like this into the engine cylinder is called as super charging, and super charging by means of exhaust gas energy that discharges to the atmosphere is called as the turbo charging.

5.4.4. Function

1) Turbine

The exhaust gas that is discharged from combustion chamber passes through turbine housing conveying an energy to turbine wings to give the rotating power, This is called as the turbine and in order not to influence a bad effect at bearing part, there are the seal ring and heat dissipator.

2) Compressor

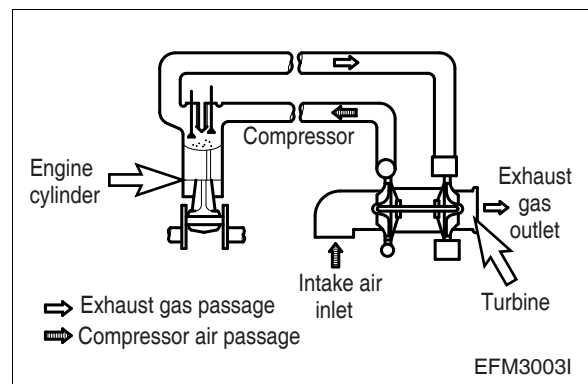
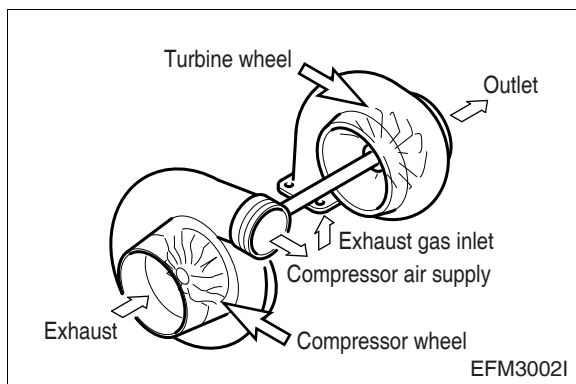
It is connected to the same shaft with the turbine to make a revolving assembly, and receive the revolving force of turbine, and sends air to the suction manifold by suctioning and compressing it. This is called as the compressor.

3) Bearing

- Thrust bearing force is applied to the turbine wheel and an arrangement is made for the shaft not to shift.
- Journal bearing (floating bearing) is adopted and it forms the double oil films at the in out surfaces in comparison to the general stationary type so that the bearing may be able to rotate independently and consequently the double layers of films act as the damper to make the slipping speed on the bearing surface less than the rotating speed of shaft so that the dynamic stability may be obtained.

4) Sealing at compressor shaft

In order for the compressed intake air and lubricating oil not to leak, a seal plate and a seal ring are made to the double structures.



5.4.5. Maintenance

The turbochargers do not call for any specific maintenance.

The only points to be observed are the oil pipes which should be checked at every oil change for leakage and restrictions.

The air cleaners should be carefully serviced.

Furthermore, a regular check should be kept on charge air and exhaust gas pipes. Any leakage should be attended to at once because they are liable to cause overheating of the engine.

When operating in highly dust or oil laden atmospheres, cleaning of the air impeller may be necessary from time to time. To do this, remove compressor casing (Caution : Do not skew it!) and clean in non-acid solvent, if necessary using a plastic scraper.

If the air compressor should be badly fouled, it is recommended that the wheel be allowed to soak in a vessel with solvent and to clean it then with a stiff brush. In doing so, take care to see that only the compressor wheel is immersed and that the turbocharger is supported on the bearing casing and not on the wheel.

5.4.6. Handling

1) Precautions at engine

Operation following items must be observed at the starting, operation and stop of engine.

Item	Care	Items
At starting	<ol style="list-style-type: none"> 1) Inspect oil quantity 2) After confirming that oil pressure rises by starting engine with starter (until the pointer of oil pressure gauge moves or pressure indicating lamp operates), the starting must be done. 3) In case that oil, oil filter and lubricating system's part are replaced or engine was stalled for long time (more than a week), and in case of operation under cold weather, loosen the oil pipe connecting parts of turbocharger inlet, and operate the starting motor until oil comes out the connecting parts. Care must be paid that after the confirming above, retighten the pipe connecting parts without fail, and proceed with the normal starting. 	<ol style="list-style-type: none"> 2) If engine is started quickly, of course beginning with every parts of engine, for it revolves without oil that is to reach to the turbocharger, the bearing's abnormal wear or stuck may be caused. 3) In case that engine stalled for long time and of cold weather, the fluidity of oil may be get worse.
Immediately after starting	<ol style="list-style-type: none"> 1) Perform idling operation for about 5 min. immediately after engine starting. 2) Various inspections must insure that there are no leakage of oil, gas and air. 	<ol style="list-style-type: none"> 1) Sudden load at time soon after engine starting and at the state when turbocharger did not yet reach to smooth revolution, if abrupt load is applied to engine, some parts where oil did still not reach may cause a burn to be stuck. 2) If there are the leakage of oil, gas, air, particularly oil, for the oil pressure lowers, it causes a burn of bearing to be stuck.
During operation	<p>Following items must be confirmed.</p> <ol style="list-style-type: none"> 1) Oil pressure at Idling : 90 ~ 300 kPa (0.9 ~ 3.0 bar) at full load : 300 ~ 650 kPa (3.0 ~ 6.5 bar) 2) When abnormal noises and vibration are generated, slow down the revolution and must stop it to investigate the causes. 	<ol style="list-style-type: none"> 1) If the pressure is too low, abnormal wear or stuck may be caused. Or if too high, the oil leak may be generated. 2) If the engine operation were continued with abnormal noises and vibration, it causes the engine trouble that can not be repaired or some other troubles.
At stop	<ol style="list-style-type: none"> 1) At stopping the engine, perform the idling operation for 5 min. and then stop it. 	<ol style="list-style-type: none"> 1) After heavy load operation, if the engine were stopped suddenly, the heat would be conducted to bearing parts from red hot turbine wings that would result in burning the oil to cause the stuck bearing metal and revolving shaft.

5.4.7. Routine inspection and maintenance

Since the state of turbocharger depends largely on the state of engine maintenance, to perform the specified up keep thoroughly is needed.

1) Intake air

System in the intake air system, care must be taken to the air cleaner. In case of oil passing type air cleaner, if the oil level is lower than the specified value, the cleaning efficiency get worse, if higher, the sucked oil pollutes a case. Particularly, for if the rotor were polluted, the balance adjusted precisely would be deviated to cause a vibration that may cause the stuck or abnormal wear by loading large force to the bearing, the perfect air cleaner must always be used. In case of dry type filter, according to the indication of a dust indicator, cleaning must be done to make the intake air resistance as small as possible.

2) Exhaust system

In exhaust system, a care must be taken to the gas leak and the stuck prevention. If exhaust gas leaks from the exhaust pipe and turbocharger etc., for the super charging effect will be lowered, the installed states of various parts must be paid with careful attention. Since the parts that reach to high temperature during operation such as the turbine room use the anti-heat nuts, a care must be paid not to mix with the general nuts and at the same time, bolt stuck preventing paint should be coated on the nut for the designated places.

3) Fuel system

If the full load stopper that restricts the maximum fuel injection quantity of fuel injection pump and the maximum speed stopper that restricts the maximum speed are adjusted without the pump tester, the turbocharger may overrun to be damaged. Also, if the atomizing state of fuel injection nozzle becomes worse or the injection timing gets wrong, for the raised temperature of exhaust gas will influence badly to the turbocharger, the nozzle testing must be done.

4) Lubricating system

In the lubricating system, a care must be paid to the oil quality and oil element replacement cycle. For the oil deterioration of turbocharger equipped engine, needless to speak of engine assembly itself, influences badly to the turbocharger too, the specified engine oil (15W40, CE class) should be used.

5.4.8. Periodic inspection and maintenance

The turbocharger assembly must be inspected periodically.

1) Revolving state and inspection points of rotor

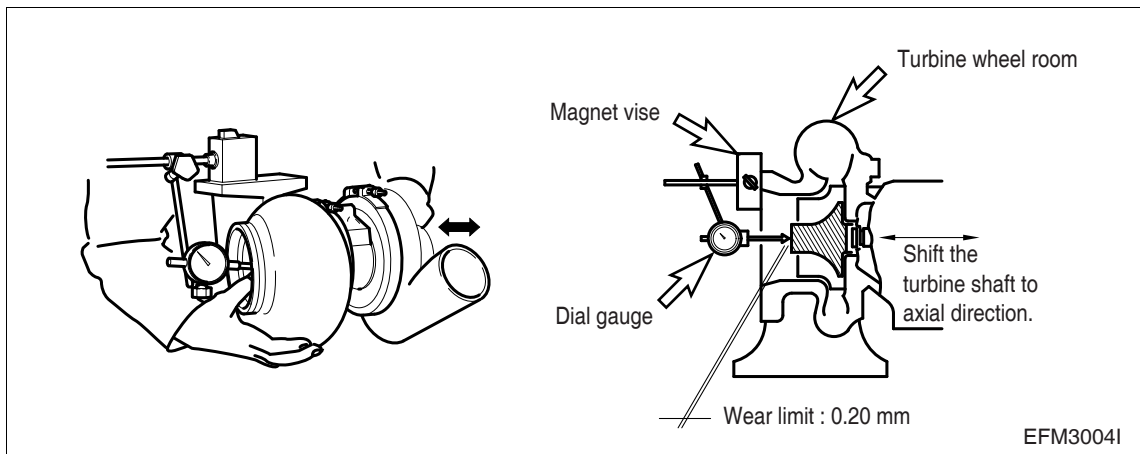
Inspection on the revolving state of rotor is performed according to abnormal noises. In case of using an acoustic bar, touch the turbocharger housing with a tip of bar and raise the engine revolution slowly, Then, in case that high sound is heard by every 2 ~ 3 sec. continuously, for there should be the possibility to be abnormal metal and rotor, replace or repair the turbocharger.

2) End play inspecting points of rotor

Disassemble the turbocharger from the engine and should inspect the end plays in axial and circumference direction. In case of disassembling the turbocharger, the oil inlet and outlet should necessarily be sealed with a tape.

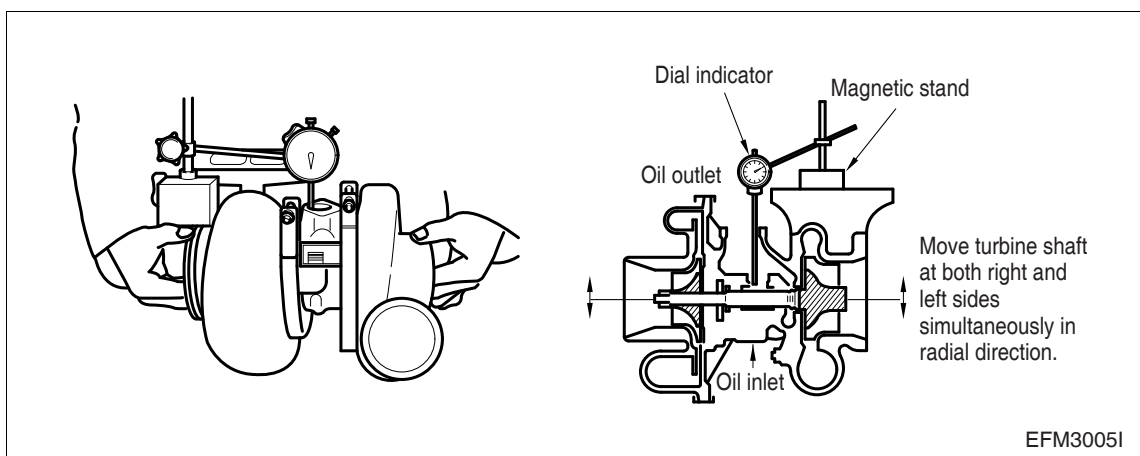
a) Axial direction end play

- Wear limit : 0.20 mm



b) Rotor's circumference direction end play

- Wear limit : 0.65 mm



c) In case that the end plays to axial and circumference directions, replace or repair the turbocharger.

3) Overhaul and cleaning points

Disassemble the turbocharger from engine and perform a cleaning and inspection, and in this case, the oil inlet and outlet should necessarily be sealed with tape etc.

4) Precautions in assembling engine

When in assembling the turbocharger or the handling after assembling should work observing the following precautions necessarily. Particularly, precise care should be taken for foreign material not to get into the turbocharger.

a) Lubricating system

- Prior to assembling it into the engine, fill new oil into oil Inlet and turning turbine shaft with hand, lubricate journal and thrust bearing.
- Clean the pipe and oil outlet pipe between engine and oil inlet, and confirm if there is any pipe damage or foreign material.
- In order for oil not to leak from various connections, assemble securely.

b) Air intake system

- Confirm if there is any foreign material inside the air intake system.
- Assemble securely the air intake duct and air cleaner so that the connections from them may not leak an air.

c) Exhaust system

- Confirm if there is any foreign material in the exhaust system.
- Bolts and nuts must be made of anti-heat steel and in assembling, care should be taken not use the general nuts and coat the bolts and nuts with the anti-stuck agents at the same time.
- Assemble securely for gas not to leak from various connecting parts of exhaust pipes.

5.4.9. Trouble cause diagnosis and remedy

Condition	Causes	Remedies
1. Exhaust gas excessive	1) Air cleaner elements clogged 2) Air Inlet port clogged 3) Air leaks from air intake system 4) Turbocharger impossible to rotate due to stuck 5) Turbine wing's contact 6) Piping deformation or clogging of exhaust system	Replace or clean Inspect or repair Inspect or repair Overhaul and repair or replace Overhaul and repair or replace Inspect and repair
2. White smoke excessive	1) Oil leaks into turbine and compressor. 2) Seal ring's abnormal wear or damage	Overhaul and repair or replace Overhaul and repair or replace
3. Output lowered	1) Gas leak from various parts of exhaust system 2) Air cleaner's elements clogged 3) Turbocharger's pollution or damage 4) Air leaks from discharge part of compressor side	Inspect and repair Replace or clean Overhaul and repair or replace Inspect and repair
4. Abnormal noises or vibrations	1) Revolving part's contact 2) Revolving imbalance of rotor 3) Stuck 4) Various connections loose	Overhaul and repair or replace Overhaul and repair or replace Overhaul and repair or replace Inspect and repair

5.5. Installation

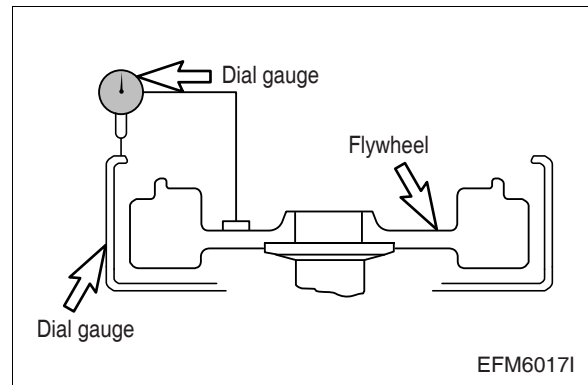
5.5.1. Inspection prior to installation



Measure the correctness of flywheel and flywheel housing. Prior to inspection, clean the flywheel and flywheel housing.

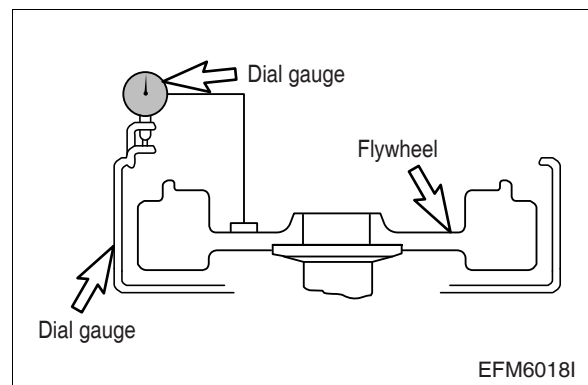
1) Measuring flywheel housing

Measure the flywheel housing surface and install the dial gauge (1/1,000) at the flywheel so as to be vertical to the flywheel housing, and let the gauge stem to contact to the flange. Rotate the flywheel, and measure the surface error of flywheel housing flange. The surface error should not exceed 0.2 mm.



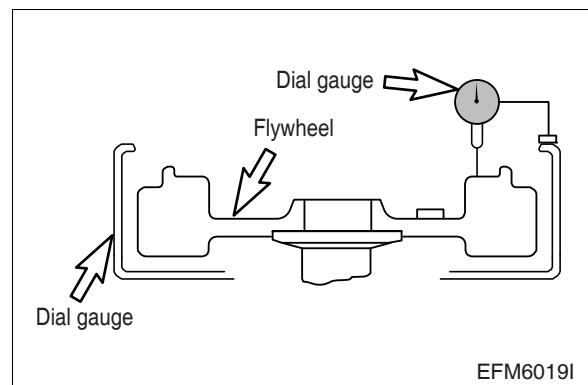
2) Measuring bore of flywheel

Housing Attach the gauge as above so that the gauge stem may contact the flywheel housing bore as the right figure. Measure the eccentrics of flywheel housing bore by rotating the flywheel. The eccentrics should not exceed 0.2 mm.



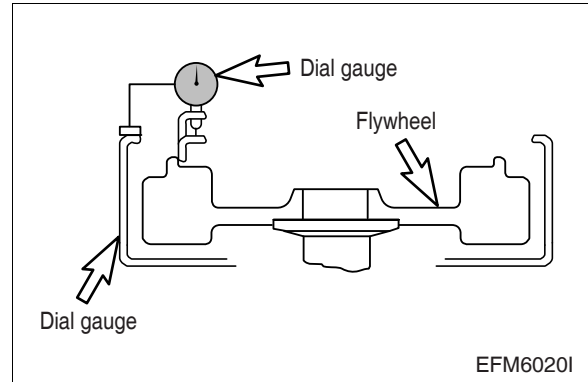
3) Measuring deformation of flywheel installing surface

Fix the dial gauge to the flywheel housing so as for the gauge stem to be vertical to the surface to be installed. The deviation quantity should not exceed 0.127 mm/inch.



4) Measuring pilot bore of flywheel

Install the gauge as below so as for the gauge stem to contact to the pilot bore of the surface to be installed. The eccentrics of the pilot bore of flywheel should not exceed 0.127 mm at maximum.

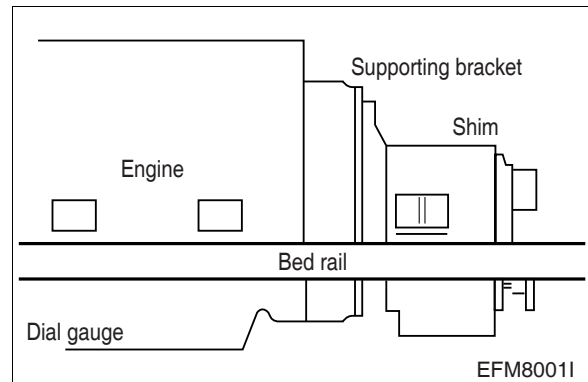


5.5.2. Installing

The center alignment of engine and Generator set is the most important factor for the extension of performance and life. Although aligning the center perfectly and accurately requires only few minutes, it is able to prevent unnecessary mechanical trouble at the future.

1) Bed rail

At the installation of Generator set's bed rail, use steel. If the bed rail is strong enough, the center alignment of engine with Generator gets worse so that the excessive vibration may occur.



2) Supporting

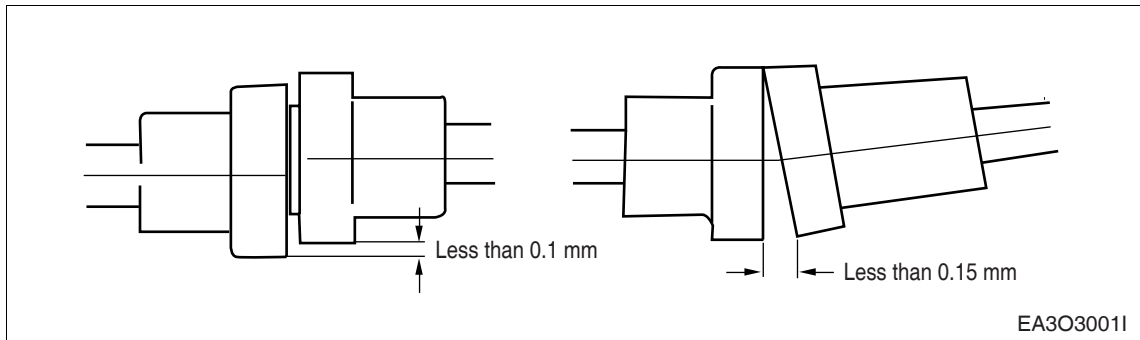
As in the engine installation, the supporting brackets are used even at the installation of Generator. The bracket must be solidly fixed at the Generator installing platform and the bed rail.

3) Aligning center

The center alignment of engine and Generator is the most important factor for the extension of life cycle.

- Output shaft flange and opponent side flange of Generator should be aligned in their centers horizontal and parallel direction.
- The adjustment between flange surfaces at the lower part should maintain less than 0.15 mm when the upper part's surfaces just meet and the deviation around the circumference should be maintained within 0.1 mm as following figure.

Surface (TIR)	Less than 0.15 mm
Center (TIR)	Less than 0.1 mm

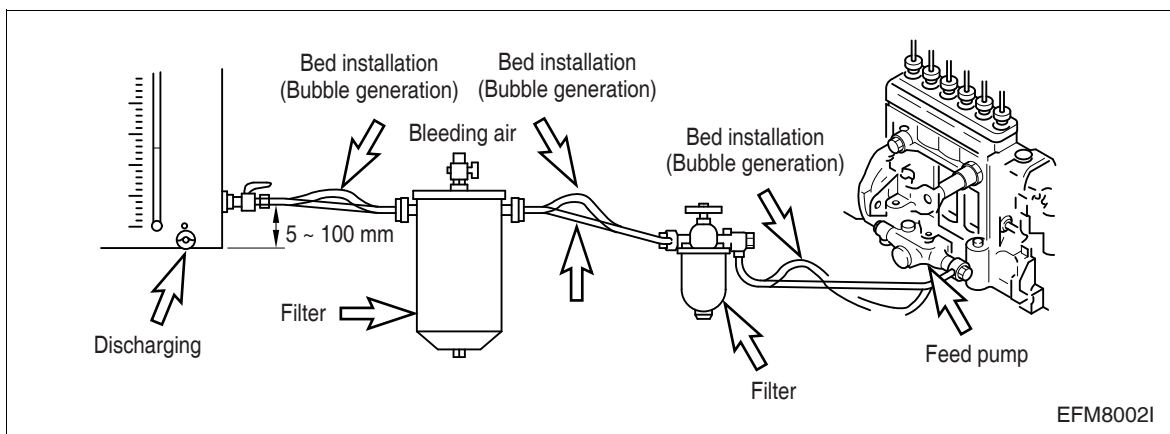


For bed rail is apt to deform for 6 months after initial performance, adjusting the center should be checked after 1 ~ 2 months.

5.5.3. Installing fuel system

Oil purifier should be installed between fuel tank and engine. For tank is always surrounded with humidity, water part often infiltrates into fuel and then engine to result in the nozzle stuck and engine efficiency drop etc.

● Example of fuel system installation



The position of fuel tank should be high than the engine fuel pump but when it is compelled to install at lower position, its lift should be within 1 m, and the fuel pipe be straight in order to prevent air bubble generation.

5.6. Air Cleaner

5.6.1. Maintenance

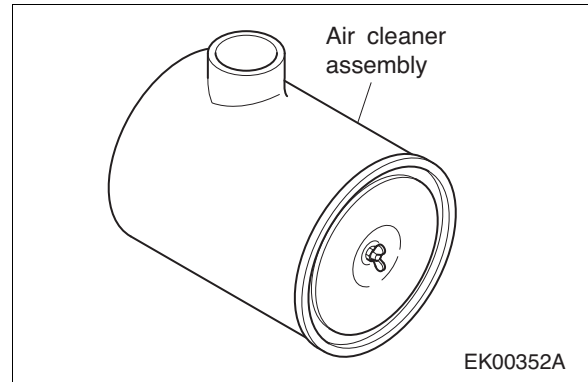
(only when engine is switched off)

Empty the dust bowl regularly. The bowl should never be filled more than halfway with dust.

On slipping off the two clamps, the dust bowl can be removed. Take off the cover of the dust bowl and empty.

Be careful to assemble cover and bowl correctly.

There is a recess in the cover rim and a lug on the collector which should register. Where the filter is installed horizontally, watch for "top" mark on cleaner bowl.



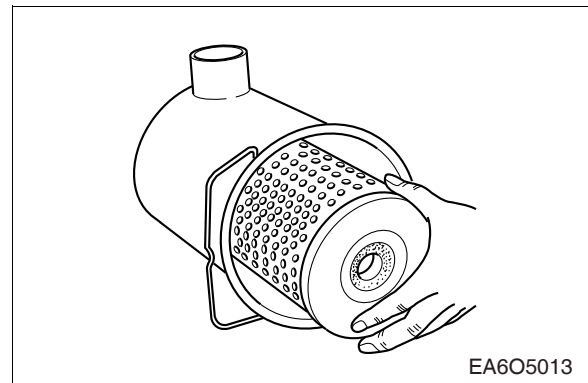
5.6.2. Changing filter element



CAUTION :

Do not allow dirt to get into the clean air end.

- On removing the hexagon nut, take out the dirty cartridge and renew or clean.
- Wipe the cleaner housing with a damp cloth, in particular the sealing surface for the element.



NOTE :

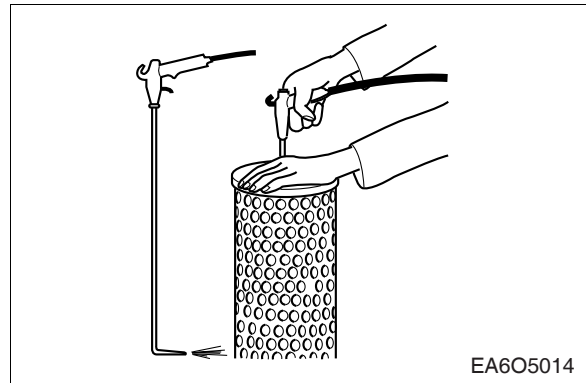
Unless the maximum number of cleanings (up to 5 x) have been done, the filter cartridge should be renewed every two years or 4,000 hours operation.

5.6.3. Cleaning filter elements

- **By compressed air**
(wear goggles)

For the purpose, the air gun should be fitted with a nozzle extension which is bent 90° at the discharge end and which is long enough to reach down inside to the bottom of the element.

Moving the air gun up and down, blow out the element from the inside (maximum 500 kPa - 5 bar) until no more dust comes out of the filter pleats.



- **By washing**

Before washing, the element should be precleaned by means of compressed air, as described above.

Then allow the element to soak in lukewarm washing solvent for 10 minutes, and then move it to and for in the solvent for about 5 minutes.

Rinse thoroughly in clean water, shake out and allow drying at room temperature. The cartridge must be dry before it is reinstalled. Never use steam sprayers, petrol (gasoline), alkalis or hot liquids etc. to clean the filter elements.



- **Knocking out dirt by hand**

In emergencies, when no compressed air or cleaning agent is available, it is possible to clean the filter cartridge provisionally by hitting the end disk of the cartridge with the ball of one's thumb.

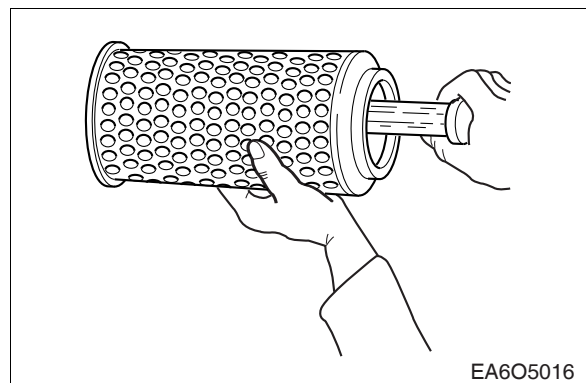
Under no circumstances should the element be hit with a hard object or knocked against a hard surface to loosen dirt deposits.

- **Checking the filter cartridge**

Before reinstalling the cartridge, it must be checked for damage e.g. to the paper pleats and rubber gaskets, or for bulges and dents etc. in the metal jacket.

Cracks and holes in the paper pleating can be established by inspecting the cartridge with a flashlight.

Damaged cartridges should not be reused under any circumstances. In cases of doubt, discard the cartridge and install a new one.



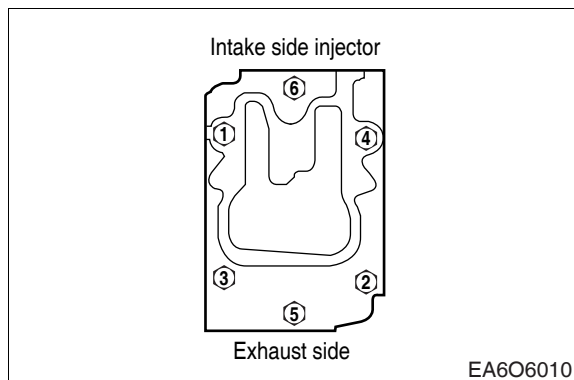
5.7. Tightening Cylinder Head Bolts

1) Tightening cylinder head bolts after a repair by authorized specialist personnel (engine cold)

Before inserting the cylinder head bolts oil them with engine oil on the thread (not to the bore) and coat the contact face of the bolt head with “Optimoly White T” assembly paste. Do not use any oils or oil additives that contain MoS₂.

The bolts must be tightened by the angle-of-rotation method as shown in right figure.

- 1st pretightening step = to 10 N·m
- 2nd pretightening step = to 80 N·m
- 3rd pretightening step = to 150 N·m
- 4th pretightening step = turn by 90°
- Final tightening = turn by 90°



NOTE :

When a cylinder head has been removed the cylinder head gasket must always be changed.

5.8. V-belts

The tension of the V-belts should be checked after every 2,000 hours of operation.

1) Change the V-belts if necessary

If in the case of a multiple belt drive, wear or differing tensions are found, always replace the complete set of belts.

2) Checking condition

Check V-belts for cracks, oil, overheating and wear.

3) Testing by hand

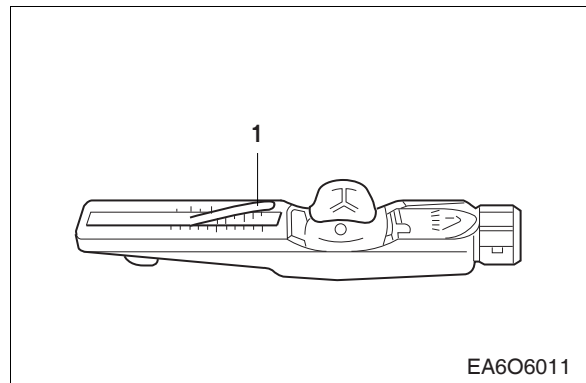
The tension is correct if the V-belts can be pressed in by about the thickness of the V-belt. (no more midway between the belt pulleys)

A more precise check of the V-belt tension is possible only by using a V-belt tension tester.

4) Measuring tension

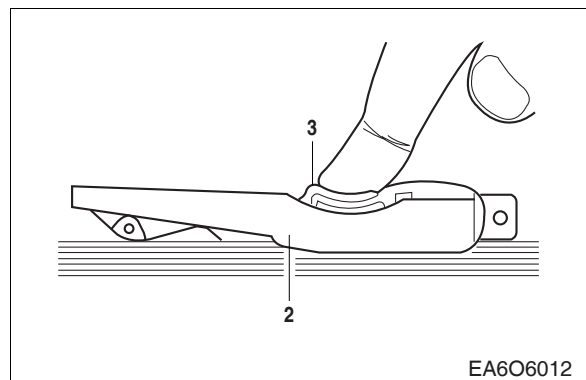
① Lower indicator arm (1) into the scale.

- Apply tester to belt at a point midway between two pulleys so that edge of contact surface (2) is flush with the V-belt.
- Slowly depress pad (3) until the spring can be heard to disengage. This will cause the indicator to move upwards. If pressure is maintained after the spring has disengaged a false reading will be obtained!



② Reading of tension

- Read of the tensioning force of the belt at the point where the top surface of the indicator arm (1) intersects with the scale.
- Before taking readings make ensure that the indicator arm remains in its position.



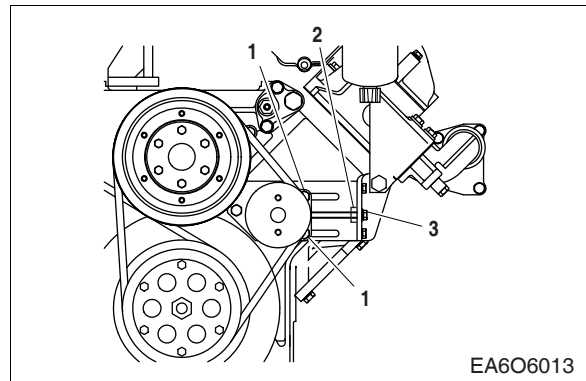
Type	Drive belt width	Tensioning forces on the tester		
		new installation		When servicing after long running time
		Installation	After 10 min. running time	
M	9.5 mm	50 kg	45 kg	40 kg
A *	11.8 mm	55 kg	50 kg	45 kg
B	15.5 mm	75 kg	70 kg	60 kg
C	20.2 mm	75 kg	70 kg	60 kg
3V-4	39.4 mm	180 ~ 200 kg	140 ~ 160 kg	120 kg
3V-6	60.0 mm	270 ~ 300 kg	210 ~ 240 kg	180 kg

* : Adopted in P158LE, PU158TI, P180LE, PU180TI, P222LE, PU222TI

5) Tensioning and changing V-belt

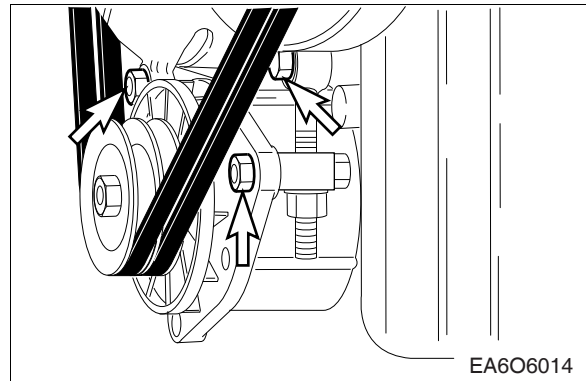
- Remove fixing bolts. (1)
- Remove lock nut. (2)
- Adjust bolt (3) until V-belts have correct tensions.
- Retighten lock nut and fixing bolts.

To change the V-belts loosen mounting bolts (1) and lock nut (2) and push tension pulley inwards by turning adjusting bolt (3).



- Remove fixing bolts.
- Remove lock nut.
- Adjust nut until V-belts have correct tensions.
- Retighten lock nut and fixing bolts.

To replace the V-belts loosen lock nut and swing alternator inwards.



Appendix

● Standard table of tightening torque

Specification	Screw	Strength	Tightening Torque kg·m	
Cylinder block bearing cap				
– main bolt	M18 × 2	12.9	Initial 30 kg·m + rotating angle 90° 8	
– side bolt	M12 × 1.5	10.9		
Flywheel housing				
– tightening bolt	M12 × 1.5	10.9	10	
	M10	12.9	7.5	
– cover bolt	M8	8.8	2.2	
Counter weight	M16 × 1.5	10.9	Initial 14 kg·m + rotating angle 90° 21	
Crank pulley	M16 × 1.5	10.9		
Vibration damper	M10	10.9	6	
Flywheel	M16 × 1.5	12.9	26	
Cooling fan	M8	8.8	2.2	
Connecting rod cap	M16 × 1.5	10.9	Initial 10 kg·m + rotating angle 90°	
Cylinder head	M15 × 2	12.9	8 kg·m + 15 kg·m + angle 90° + angle 90° 2.2	
Cylinder head cover	M8	8.8		
Fuel injection nozzle holder	M28	CK60		7 ± 0.5
Fuel injection pipe	M14 × 1.5			2.5
Cam shaft timer	M10	10.9	6.2	
Rocker arm bracket	M10	10.9	6.2	
Lock nut (adjusting screw)	M12 × 1	8.8	5.0 ± 0.5	
Oil pump cover	M8	8.8	2.2	
Oil pump	M8	8.8	2.2	
Oil cooler	M12	10.9	5	
Oil pan	M8	8.8	2.2	
Oil pan plug	M26 × 1.5		8	
Exhaust manifold	M10	10.9	5.0	
Intake manifold	M8	8.8	2.2	
Fuel injection pump(cylinder block)	M10	10.9	6.5	
Fuel filter	M12 × 1.5	8.8	8	
Starting motor	M12 × 1.5	8	8	
Alternator bracket	M14	8.8	12	
Oil pressure switch	PT1/8		2	
Water temperature switch	M14	8.8	2	
Plug screw	M12 × 1.5		5	
	M14 × 1.5		8	
	M16 × 1.5		8	
	M18 × 1.5		10	
	M22 × 1.5		10	
	M24 × 1.5		12	
	M26 × 1.5		12	
	M30 × 1.5		15	
	AM10 × 1.0		5	
AM14 × 1.5		8		

● **Standard bolt tightening torque table**

Refer to the following table for bolts other then 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
Tightening torque (kg-m)											
M5	0.15	0.16	0.25	0.22	0.31	0.28	0.43	0.48	0.5	0.75	0.9
M6	0.28	0.30	0.45	0.4	0.55	0.47	0.77	0.85	0.9	1.25	1.5
M7	0.43	0.46	0.7	0.63	0.83	0.78	1.2	1.3	1.4	1.95	2.35
M8	0.7	0.75	1.1	1	1.4	1.25	1.9	2.1	2.2	3.1	3.8
M8 × 1	0.73	0.8	1.2	1.1	1.5	1.34	2.1	2.3	2.4	3.35	4.1
M10	1.35	1.4	2.2	1.9	2.7	2.35	3.7	4.2	4.4	6.2	7.4
M10 × 1	1.5	1.6	2.5	2.1	3.1	2.8	4.3	4.9	5	7	8.4
M12	2.4	2.5	3.7	3.3	4.7	4.2	6.3	7.2	7.5	10.5	12.5
M12 × 1.5	2.55	2.7	4	3.5	5	4.6	6.8	7.7	8	11.2	13.4
M14	3.7	3.9	6	5.2	7.5	7	10	11.5	12	17	20
M14 × 1.5	4.1	4.3	6.6	5.7	8.3	7.5	11.1	12.5	13	18.5	22
M16	5.6	6	9	8	11.5	10.5	17.9	18.5	18	26	31
M16 × 1.5	6.2	6.5	9.7	8.6	12.5	11.3	17	19.5	20	28	33
M18	7.8	8.3	12.5	11	16	14.5	21	24.2	25	36	43
M18 × 1.5	9.1	9.5	14.5	12.5	18.5	16.7	24.5	27.5	28	41	49
M20	11.5	12	18	16	22	19	31.5	35	36	51	60
M20 × 1.5	12.8	13.5	20.5	18	25	22.5	35	39.5	41	58	68
M22	15.5	16	24.5	21	30	26	42	46	49	67	75
M22 × 1.5	17	18.5	28	24	34	29	47	52	56	75	85
M24	20.5	21.5	33	27	40	34	55	58	63	82	92
M24 × 1.5	23	25	37	31	45	38	61	67	74	93	103

Others :

1. The above torque rating 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.

● Maintenance specification table

(unit: mm)

Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark	
Cylinder block	Cylinder block & liner	Inside diameter of cylinder liner	ø127.99 ~ ø128.01	ø128.122	Replace liner	Measure unworn portion beneath the rim of the upper side	
		Liner's roundness & columnness (upper)	0.005	–		From top up to 168 mm	
		Liner's roundness & columnness (lower)	0.008	–		From bottom up to 85 mm	
		Amount of liner projection	0.04 ~ 0.09	–		Measure at upper side of cylinder block	
		The flatness of upper surface of cylinder block	0.03	–	Correct with a surface grinder	0.015 for a length of 150 mm	
		Hydraulic test for 1 minute (kg/cm ²)	4	–	Replace if leaky	Temperature 70°C	
	Cylinder head & valve	Valve seat depression	Intake	0.65 ~ 0.95	2.5	Replace valve seat	0.25↓ @250 hr valve clearance inspection interval
			Exhaust	0.65 ~ 0.95	2.5		
		Cylinder head height		113.9 ~ 114	113.35	Replace cylinder head	
		The flatness of lower surface of cylinder head		0.015	0.1		
		Inner diameter of valve guide	Intake	ø8.015 ~ ø8.030	–		
			Exhaust	ø8.015 ~ ø8.030	–		
		Thick of cylinder head gasket (at assembly status)		1.215 ~ 1.285	–		
		Hydraulic test for 1 minute (kg/cm ²)		4	–	Replace if leaky	Room temperature
Major moving parts	Piston	Outer diameter of piston	ø127.739 ~ ø127.757	–	Replace piston	Measure at 56.8 mm away from piston head (long diameter)	
		Clearance between piston and liner		0.233 ~ 0.271	0.35	Replace one worn more	
		Inner diameter of piston pin		ø46.010 ~ ø46.016	–		Standard diameter
		Width of piston ring grooves	Top ring	3.20 ~ 3.23	–	Replace piston if groove width is beyond specified value	Measure at 125 mm of top ring groove
			2nd ring	3.040 ~ 3.060	–		
			Oil ring	4.020 ~ 4.040	–		
		Piston projection from cylinder block upper surface		0.18 ~ 0.47	–		Measure unworn portion beneath the rim of the upper side
Permissible weight difference of each piston		50 g	50 g ↓	Replace piston			

(unit: mm)

Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark		
Major moving parts	Piston ring	Width of piston ring	Top ring	3.075 ~ 3.095	—	Replace ring		
			2nd ring	2.975 ~ 2.990	—			
			Oil ring	3.97 ~ 3.99	—			
		Piston ring gap	Top ring	0.30 ~ 0.45	0.70	Replace ring		Standard gauge inside diameter: ϕ 128
			2nd ring	1.10 ~ 1.30	1.45			
			Oil ring	0.40 ~ 0.70	0.95			
		Piston ring side clearance	Top ring	0.105 ~ 0.150	0.30	Replace ring or piston		Limit for use is if for standard clearance
			2nd ring	0.05 ~ 0.082	0.15			
			Oil ring	0.030 ~ 0.070	0.15			
		Direction of ring gap			—	—		Cross Install by 120°
	Piston pin	Outer diameter of piston pin		ϕ 45.994 ~ ϕ 46.000	ϕ 45.94	Replace piston pin		
		Clearance between piston pin and its bush		0.010 ~ 0.022	0.08	Replace one worn more		
	Radial run-out of journal and pin		0.02	—	Correct with a grinder	Measure in horizontal and vertical directions		
	Outside diameter of journal		ϕ 103.98 ~ ϕ 104.00	ϕ 102.98	Use under sized bearings respectively (0.10, 0.25, 0.5, 0.75, 1.0)			
	Outside diameter of pin		ϕ 89.980 ~ ϕ 90.000	ϕ 88.980				
	Width of thrust journal		38.000 ~ 38.062	37.000				
	Ellipticity of journal and pin		0.01	0.025				
	Taper of journal and pin		0.02	0.03				
	Clearance between crankshaft and bearing		0.066 ~ 0.134	0.166	Replace bearings	Measure at crown part not parting line		
	End play of crankshaft		0.140 ~ 0.361	0.452	Replace thrust bearing			
	Balance of crankshaft (g·cm)		60 ↓	60 or less	Check dynamic balance	Measure at 400 rpm		
	Torque of journal bearing cap bolt		30 kg·m + 90°	—	Coat the bolt with engine oil	Clean out foreign objects on joining surface.		
	Crush height of Journal bearing cap	Main	0.3 ~ 1.2	—		Measure after tightening metal cap and releasing one bolt		
		Thrust	0.3 ~ 1.2	—				
	Out diameter of wear ring after assembled		ϕ 104.86 ~ ϕ 105.00	—		5 minutes or more at 220°C		
	Oil seal for wear (crank shaft rear)		—	—	Replace oil seal if oil leaking			

(unit: mm)

Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark	
Major moving parts	Connecting rod	Width of connecting rod	Small end	38.7 ~ 39.0	—		
			Big end	35.38 ~ 35.341	—		
			Cap	32.8 ~ 33.1	—		
		Inner diameter of small end with bush		ø50.6 ~ ø50.9	—		
		Outer diameter of big end with bearing		ø94.97 ~ ø94.99	—		
		End play of connecting rod	Big end	0.15 ~ 0.351	0.50	Replace connecting rod	
			Small end	1.5	—		
		Clearance between connecting rod bearing and crank pin		0.056 ~ 0.118	0.154	Replace bearing	
		Clearance between small end bush & piston pin		0.055 ~ 0.071	0.12		
		Crush height of connecting rod bearing cap		0.125 ~ 0.155	—		Measure after installing the bearing and releasing one bolt
		Perpendicularity of big end inner diameter		0.035	0.08	Replace connecting rod	
		Roundness of big end inner diameter		0.005	0.01		
		Parallelness of small end side and big end		0.02	0.1		
		Allowable weight difference per con-rods		50g ↓	—		
	Torque value of connecting rod bearing cap bolt (kg·m)		10kg·m + 90°	—	Coat the bolt with engine oil	Clean out foreign objects on joining surface	
	Cam shaft	Diameter (bearing) of cam shaft side of cylinder block	Inner diameter of thrust bush	ø70.07 ~ ø70.09	—		
			Inner diameter of cam bush	ø70.00 ~ ø70.03	—		
		Diameter of cam shaft journal		ø69.910 ~ ø69.940	ø69.560		
		Clearance between camshaft and thrust bushing		0.130 ~ 0.180	0.24	Replace cam bush	
		Clearance between cam shaft and cam bush		0.060 ~ 0.120	0.24	Replace cam bush	
		End play of camshaft		0.24 ~ 0.86	0.9	Replace thrust washer	
		Run-out of camshaft		0.05	0.15	Correct or replace the cam shaft	

(unit: mm)

Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark
Major moving parts	Fly wheel	Ring gear assembly part's outer diameter	ø432.590 ~ ø432.700	-		Heating temperature at ring gear assembly (200 ~ 230°C)
		Ring gear inner diameter	ø432.000 ~ ø432.200	-		
		Overlap	0.390 ~ 0.700	-		
		Allowable shaking amount after assembly	0.5	-		
		Outer diameter after assembly wear ring	ø119.860 ~ ø120.000	-		
Valve system	Valve and valve guide	Exhaust valve	Stem O.D.	ø11.945 ~ ø11.955	-	
			Radial clearance	0.045 ~ 0.073	-	
			Seat angle	45°	-	
			Head diameter	ø50.9 ~ ø51.1	-	
			Valve head thickness ("H")	1.9 ~ 2.3	-	
			Valve seat head diameter	ø53.00 ~ ø53.03	-	
			Valve seat O.D.	ø53.10 ~ ø53.11	-	
		Intake valve	Stem O.D.	ø11.969 ~ ø11.980	-	
			Radial clearance	0.020 ~ 0.049	-	
			Seat angle	30°	-	
			Head diameter	ø57.85 ~ ø58.15	-	
			Valve head thickness ("H")	2.6 ~ 3.0	-	
			Valve seat head diameter	ø61.00 ~ ø61.03	-	
			Valve seat O.D.	ø61.10 ~ ø61.11	-	
	Head valve seat assembly part's depth	12.5 ~ 12.6	-			
	Valve guide I.D.	ø12.000 ~ ø12.018	-			
	Head valve guide I.D.	ø18.000 ~ ø18.018	-			
	Valve guide O.D.	ø18.028 ~ ø18.046	-			
	Valve guide mounting clamp	0.010 ~ 0.046	-			
	Valve guide play	0.04	-			
	Valve spring	Valve lift	14.1	-		
		Valve guide protrusion	17.1 ~ 17.5	-		
		Free length of inner spring	72.43	-		
Load on inner spring		15 ~ 17 kg	-			
Load on inner spring		27 ~ 32 kg	-			
Free length of outer spring		68.17	-			
Load on outer spring		37 ~ 41 kg	-			
Load on outer spring	66.5 ~ 76.5 kg	-				

(unit: mm)

Group	Part	Inspection item		Stand value for assembly	Limit for use	Correction	Remark	
Valve system	Valve and valve guide	Intake and exhaust valve spring (inner)	Free length		59.5	—	Replace valve spring	
			Tension force (kg)	41 mm	14.8	13.3 or less		
				28.6 mm	25	23 or less		
			Inclination (free length)		1.5 mm	2.0 or less		
		Intake and exhaust valve spring (outer)	Free length		57.0	—	Replace valve spring	
			Tension force (kg)	44 mm	25.5	23.5 or less		
				31.6 mm	52.3	49.8 or less		
			Inclination (free length)		1.5 mm	2.0 or less		
	Rocker arm & push rod	Joining surface of valve stem and rocker arm bush			—	—	Grind or replace if severely pitted on tip of rocker arm and stem	
		Inner diameter of rocker arm bush			ø24.991 ~ ø25.012	—		
		Diameter of rocker arm shaft			ø24.953 ~ ø24.976	ø24.916		
		Clearance between rocker arm shaft & rocker arm bush			0.015 ~ 0.059	0.12	Replace bush or shaft	
		Run-out of push rod			0.3	0.3 or less	Replace or correct	
	Tappet	Tappet assembly part's inner diameter of cylinder head			ø20.000 ~ ø20.021	—		
Diameter of tappet			ø19.944 ~ ø19.965	—	Replace tappet			
Clearance between tappet & tappet hole of cylinder block			0.035 ~ 0.077	0.15	Replace tappet			
Tappet face in contact with cam			—	—	Replace if severely worn or deformed			

(unit: mm)

Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark
Lubricating system	Engine oil	Oil pressure (kg/cm ²) (at rated speed)	3.0 ~ 6.5	–	Check oil leakage and clearance between each part	
		Oil pressure (kg/cm ²) (at idle speed)	1.0 ~ 3.0	0.8 or more	Use recommended oil	
		Oil temperature (°C)	110 or less	–		Must not exceed this value
		Permissible oil temperature in short time (°C)	Max. 120	–		
	Oil spray nozzle	Operating pressure	1.5 ~ 1.9		Replace valve	
	Oil pump	Delivery volume lit/min – Pump rpm: 2,440 rpm – Oil temperature: 50°C	275 or more	–	Replace gear or cover	
		Oil pump pressure control valve (kg/cm ²)	9 ~ 10	–	Replace valve	
	Oil filter and oil cooler	Damage of oil filter element	–	–	Clean or replace	
		By-pass valve pressure of oil filter (kg/cm ²)	2.2 ~ 2.5			
		By-pass valve pressure of oil cooler (kg/cm ²)	4.5 ~ 5.5			
Cooling system	Radiator	Radiator & water pump for corrosion, damage & improper connecting	–	–	Correct or replace	
		Test for leakage by air pressure (kg/cm ²)	1.2 ~ 1.3	–	Submerge in water and replace if air bubbles found	
		Pressure valve for opening pressure (kg/cm ²)	0.9	–		
		Pressure valve for vacuum (kg/cm ²)	0.05			
	Water pump	Delivery volume lit/min – Pump speed: 3,500 rpm – Water temp.: 25°C – Pressure: 1.8 kg/cm ²	700 or more	–	Check the water passage	
		Fan belt depression	Refer to adjust table	–	Adjust	

(unit: mm)

Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark	
Cooling system	Cooling water temperature	Operating temperature (°C)	79 ~ 95	–	Must not exceed this value		
		Permissible temperature in a short time (°C)	–	105			
	Thermostat	Operating temperature (°C)	2V TIL	71	–	Replace	
			2V TIM/TIH	79	–		
		Full opening temperature (°C)	2V TIL	85	–	Replace if defective Stroke: min. 8 mm	
2V TIM/TIH	94		–				
Fuel system	Fuel injection pump maker		Bosch	–			
	Fuel piping & others	Fuel pipe, injection pipe & injector for damage, cracks, improper O-ring	–	–	Replace		
		Damage of fuel filter cartridge	–	–	Replace cartridge		
	Injector opening pressure (kg/cm ²)		285.5 ~ 297.8	–			
	Operating pressure of overflow valve (kg/cm ²)		1.33 ~ 1.84	–	Replace valve		
	Diameter of injector nozzle		–	–	Differs for each suffix		
	Projection height of nozzle from the cylinder head surface (mm)		3.0	–	Replace sealing		
Drive system	Gear back lash	Between crank gear & oil pump drive gear	0.099 ~ 0.451	–	Adjust back lash		
		Between crank gear & cam shaft gear	0.143 ~ 0.292	0.3			
		Between drive gear & fuel pump gear	0.102 ~ 0.338	0.45			

Paper Size : 120mmx165mm

Diesel Engine for Generators (Land/Marine) Digital Speed Controller User Manual

Ver_1.07

300611-01127A(Land)

300611-01440(Marine)



HYUNDAI

HD Construction Equipment

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1. Product Overview and General Specification

1.1 Product Information

Digital Speed Controller (300611-01127A/01440) is applicable to generator (vehicles and vessels) engines as a high performance embedded electronic control system designed based on PID control for fast and precise control of engine speed with an enhanced micro controller unit (MCU) that minimizes analog circuits vulnerable to user environments.

This product features PID auto setting functions along with battery voltage, pick-up sensors and actuator condition checking. It also has a black box function that manages engine operation records when faults are detected for users to have more convenience in operating this precise digital speed controller.

[Product Features]

- Rigid and stable case structure and easily recognizable front design
- Readily understandable GUI (graphic user interface) with graphic LCD displays
- Easy and simple setup with 8 button keys without manual controls by users
- Fast setting available by migrating initial settings depending on types of the engines
- Listing fault messages (over speed, pick-up error, etc.) and recording messages
- RS232 and CAN ports available for communication
- Digital inputs and PID auto setup functions for PID control parameters
- Application of digital clock for fault timing and engine operating hours

1.2 Product Appearance

Digital Speed Controller is made of a rigid aluminum case taking into account anti-shock, electromagnetic resistance and environmental protection. An embedded system containing graphic LCD and high performance MCU is inside the controller and a heat sink is located on the outside of the case for protection and precise control of actuator operating elements.

A terminal block is located on the bottom and right of the front side for easy connection to external devices. Over speed, run and crank signals are displayed on the front LED and contact points (a or b) are also available for outputs on external controllers or indicators.

RS232 and CAN communication is available and DSUB-9 connector enables universal use of RS232 communication.

Users can easily input and adjust values for parameter inputs using 8 button keys. In addition, graphic LCD shows graphic displays, bar graphs and design symbols so that users can readily identify the control information while external LED displays important conditions of the engine.

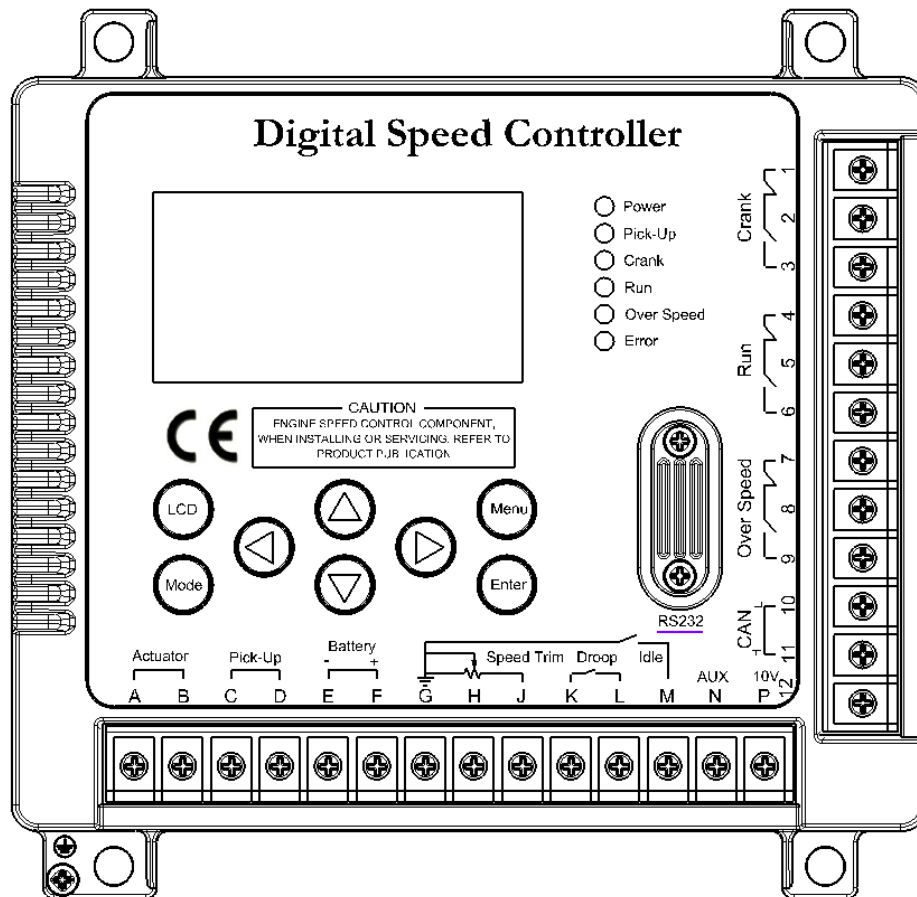


Figure 1: Product Front View

1.3 Product Specification

No.	Item	Description
1	MCU	16-bit DSC dsPIC33FJ256
2	Display	Graphic LCD 128*64
		LED: 6 EA
3	Keypad	8 Button Keys
4	Output	3 Contact Points (a and b)
5	Input	RMS 3V (Min)
6	Memory	128Mb
7	Communication	RS232 57600bps
		CAN (J1939) / 250kbps
8	Rated Power	DC 24V (12V to 32V)
9	Current Consumption	120mA
10	Operating Temperature	-20 to +70°C
11	Storing Temperature	-30 to +80°C
12	Operating Humidity	0 to 95%

1.4 Product System Diagram

Cautions on wiring

- The total length of the Actuator(15AWG), Pick-up(24AWG_Shield Cable), and Battery(15AWG) connections shall be limited to 10m or less.
- Refer to the system diagram (Figure 2) to wire the circuit and check the cable type.
- Wiring assembly must be checked before use as it will cause fatal damage to the controller.
- The fuse 10A for circuit protection is always provided at the front end of the battery input terminal "F".
- RS232 communication cable should use designated dedicated cable.
- It does not guarantee the fault of the product caused by not following the system diagram and wiring connection precautions.

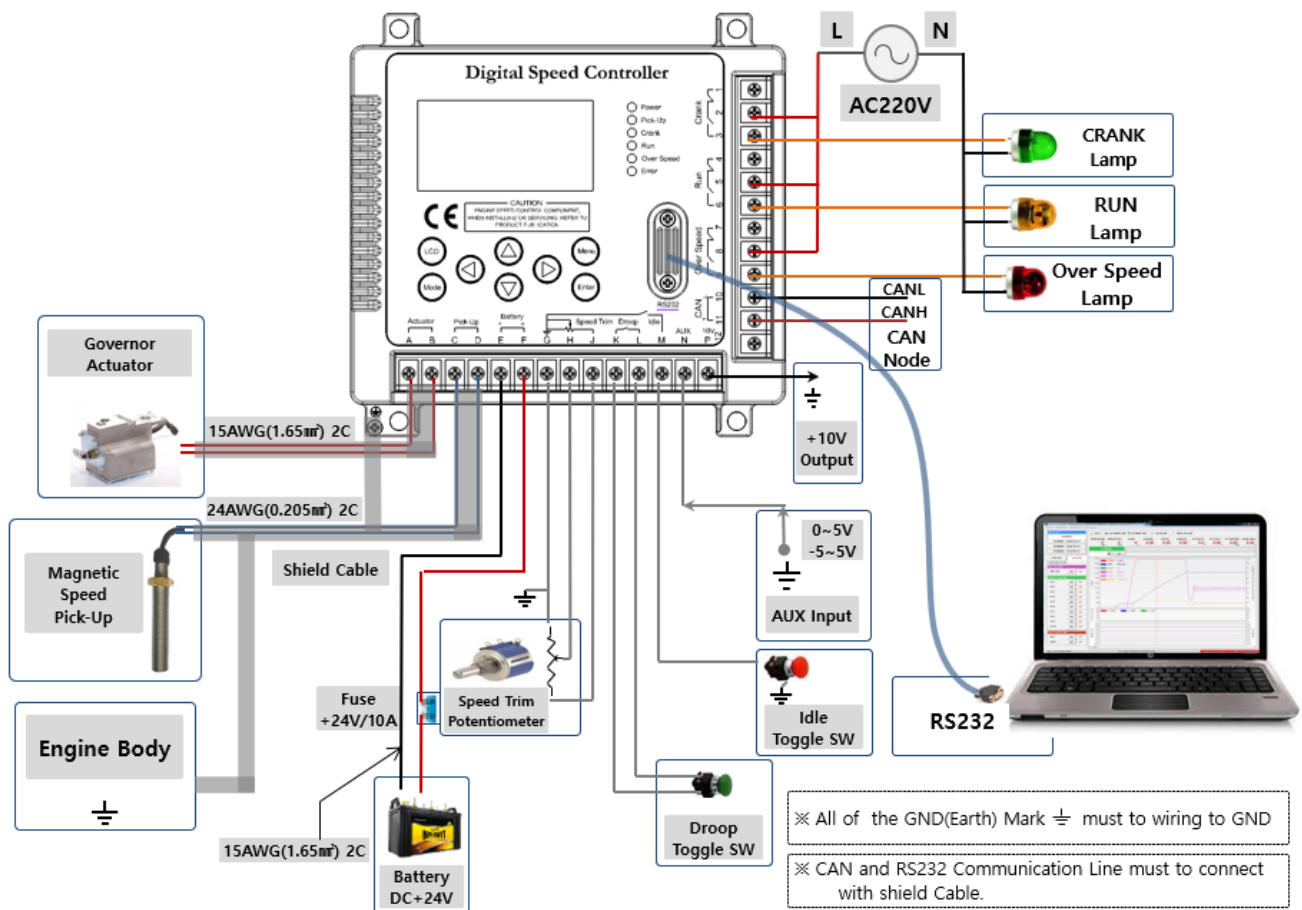


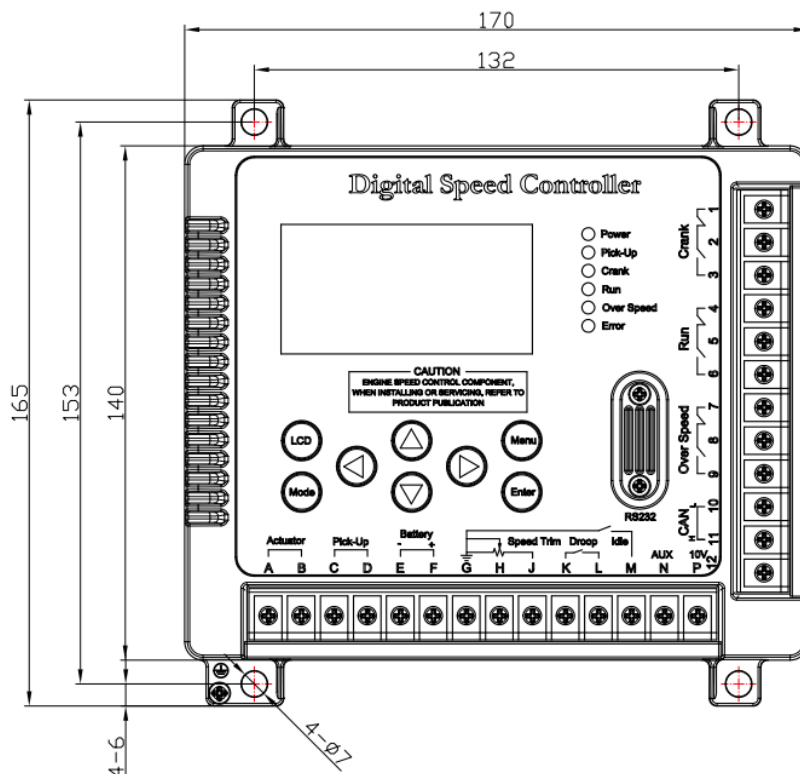
Figure 2: System Diagram for Digital Speed Controller

1.5 Product I/O Signals

No	Terminal	I/O type	Terminal Functions
1	Actuator (A, B)	Output	Outputs are actuator control signals. Wiring should be 15AWG (105°C) or better. (However, terminals A and B can be used regardless of their polarities. Actuator's shield cable terminal should be connected to Ground(Engine body). (Voltage measuring terminals are A and E.)
2	Pick-Up (C, D)	Input	Inputs are RPM sensor signals. Terminal D should be connected to the ground(Engine body) in connection with the shield cable. Gap between the RPM sensor and the gear tooth should be adjusted between 0.9 and 1.1mm (sensor inputs should be at least 3V AC RMS). Pick-up voltage shown on System monitor menu is Peak value
3	Battery Voltage (-E, +F)	Input	It is a power input terminal for the controller and inputs are DC +24V/10A. The positive pole of the battery should be connected to the terminal F. (Back voltage protection circuit is built in.)
4	Speed Trim (G, H, J)	Input (G)	It has a ground signal and is connected to the ground of the potentiometer.
5		Input (H)	Inputs are RPM trim signal values and the voltage level is between 0 and 5V. It is connected to the output of the potentiometer.
6		Input (J)	Outputs are DC +5V and it is connected to VCC of the potentiometer.
7	Droop (K, L)	Input	Terminal K receives droop function selecting information. Terminal L has a ground signal and the switch is connected to terminals K and L. Once the terminal K is connected to the ground, droop starts to operate.
8	Idle (M)	Input	Terminal M receives idle function selection signals. Once it is connected to the ground, idle operation starts.
9	AUX (N)	Input	Terminal N receive load sharing and synchronization signal for parallel operation. The signal level is an input between DC -5 and +5V.
10	10V (P)	Output	Outputs are +10V/20mA ratings and it can be used for various purposes including power to external auxiliary devices.
11	Crank Contact Point (1, 2, 3)	Output	The second crank contact point is a shared terminal while terminals 1 and 2 are for the contract point b and terminals 2 and 3 for the contact point a. The contact point a starts to operate when the digital speed controller reaches at the RPM delivering control signals to the actuator after the engine is activated.
12	Run Contact Point (4, 5, 6)	Output	The fifth run contact point is a shared terminal while terminals 4 and 5 are for the contact point b and terminals 5 and 6 for the contact point a. The contact point a starts to operate when the engine reaches its designated normal speed RPM.
13	Over Speed Contact Point (7, 8, 9)	Output	The eighth over speed contact point is a shared terminal while terminals 7 and 8 are for the contact point b and terminals 8 and 9 for the contact point a. The contact point a starts to operate when the engine reaches its designated over speed RPM.
14	CAN (10, 11)	I/O	Terminal 10 is for CAN-L communication and 11 is for CAN-H communication. CAN-H and CAN-L are used for CAN communication.

15	Power LED	Output	When DC+24V power is supplied to the controller, the LED turns on in red on the power level.
16	Pick-Up LED	Output	When the controller receives normal input signals from the pick-up sensor, the LED turns on in green on the pick-up level.
17	Crank LED	Output	The 2- and 3-terminal contact point a starts to operate and the LED turns on in yellow on the crank level when the digital speed controller reaches at the RPM delivering control signals to the actuator after the engine is activated. When Cranking Rpm is exceeded, Crank LED turns off.
18	Run LED	Output	The LED turns on in green on the run level when the engine reaches its designated normal speed RPM with 5- and 6-terminal contact point a starting to operate.
19	Over Speed LED	Output	The LED turns on in red on the over speed level when the engine reaches its designated over speed RPM with 8- and 9-terminal contact point a starting to operate..
20	Error LED	Output	The LED turns on in red on the error level when abnormal events of the controller occur.
21	RS232	I/O	D-SUB 9PIN (male) is connected to the host through RS232 communication port. The specified dedicated line should be used and only terminals 2, 3, 5 shall be connected, and the other terminals shall not be connected.
22	Ground	Ground	GND part and earthing should be jointly connected before being earthed to generator's engine body.

1.6 Product Dimension



2. Installation

Cautions for installing the digital speed controller

- Mount the controller unit vertically to the surface of a control cabinet to protect from water and high humidity, and do not expose the controller unit to the radiant heat.
- Do not rely solely on the electronic governor's actuator function to prevent overspeed, and use an independent fuel cut-off solenoid auxiliary device.
- When welding around the controller and charging the battery, the controller battery terminal is disconnected.
- We can not guarantee the failure of the product caused by installation neglect.

Digital Speed Controller should be connected to the pick-up sensor attached on the engine and the actuator. Speed trim, droop, idle and aux terminals can be used for additional functions in connection with surrounding circuits. Contact points a or b can also be used to operate external devices using crank, run and over speed functions. RS232 and CAN port allow communication with PCs or external host computers for data transfer and monitoring functions.

2.1 Connecting to the Engine

2.1.1 Battery, Pick-Up and Actuator Connection Diagram

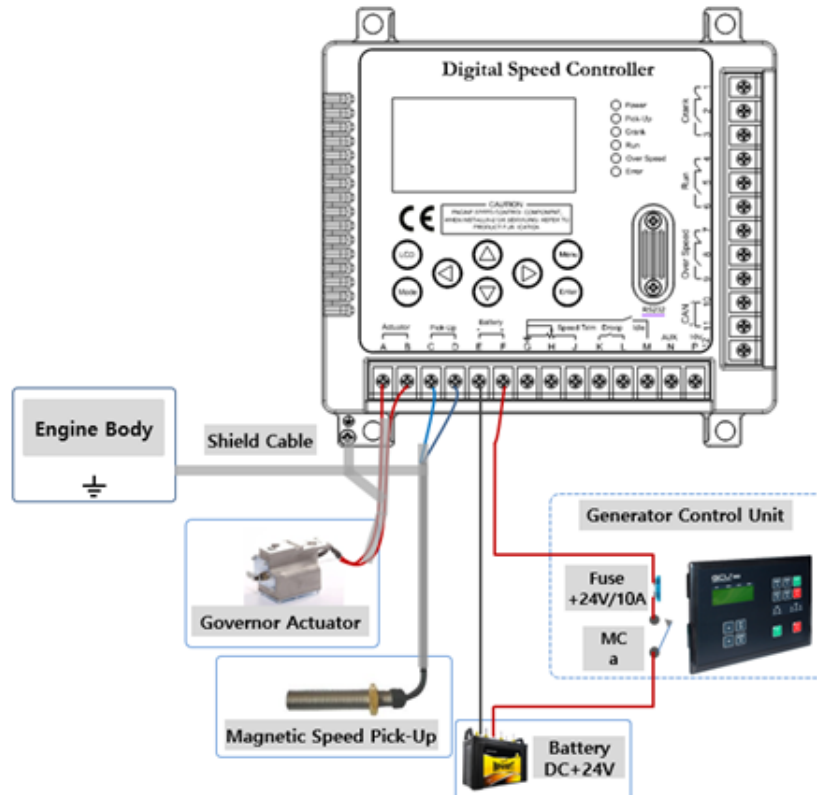


Figure 3: Battery, Pick-Up and Actuator Connection Diagram

2.1.2 Connecting to Batteries

Battery voltage is DC +24V and the battery is connected to the controller matching **E (-)** and **F (+)** with the respective polarities of the battery. **E (-)** is connected to **(-)** of the battery and **F (+)** to **(+)** of the battery. The circuit protection fuse 10A must be formed between the F (+) and the battery. Depending on cases, wiring can be done in a serial connection to the contact point a of MC and the fuse (DC +24V/10A) when connecting to system panels or generator control devices.

2.1.3 Connecting to Actuators

The actuator is also called governor and controls the amount of the fuel spray to the engine cylinder. The controller is connected to the actuator attached on the engine by connecting two wires of the controller terminal to A and B of the actuator regardless of their polarities. Use more than 15AWG(105°C) for the connection wire, and when using a shielded cable, the shield terminal should be connected to Ground(Engine body).

2.1.4 Connecting to Pick-Up Sensors

The pick-up sensor lets users know the engine speed and is connected to terminals **C** and **D** that can receive signals of AC RMS 3V or higher. Gap between the pick-up sensor and the gear tooth should be adjusted between 0.9 and 1.1mm. the shield terminal should be connected to Ground(Engine body).

2.1.5 Operating Sequence for Digital Speed Controller

- **Power On/Off:** It means that DC +24V power is either supplied or terminated through **E (-)** and **F (+)** of the battery matching with their respective polarities.
- **LCD On/Off:** It means to turn **on** or **off** the LCD display alone while DC +24V power is supplied through **E (-)** and **F (+)** of the battery matching with their respective polarities and the controller is in operation.

[Operating Sequence for the Controller]

- Step1)** When DC +24V power is supplied to the controller, the controller starts to operate. It indicates that power LED turns on and the power is being normally supplied.
- Step2)** Inputs for speed trim, droop and idle functions are received.
- Step3)** The controller checks the signals of the speed pick-up sensor.
- Step4)** Actuator control signals are output together with designated values of other information for crank, run and over speed functions according to the PID control values.
- Step5)** The controller checks the operation condition and displays LED outputs and fault messages according to the detected information.

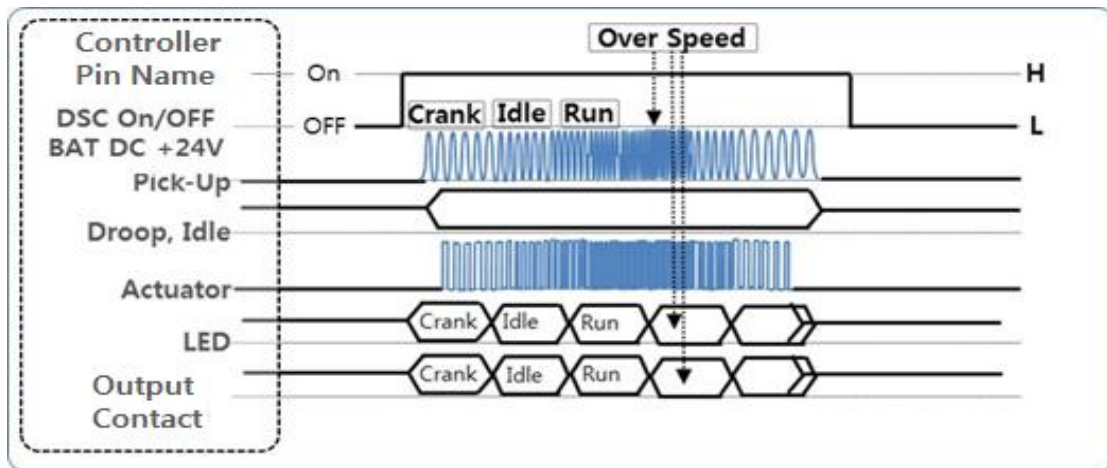


Figure 4: Time Chart for Operation of the Controller

2.2 Connecting to Speed Trim, Droop, Idle and Other Inputs

2.2.1 Speed Trim, Droop, Idle and Other Inputs Diagram

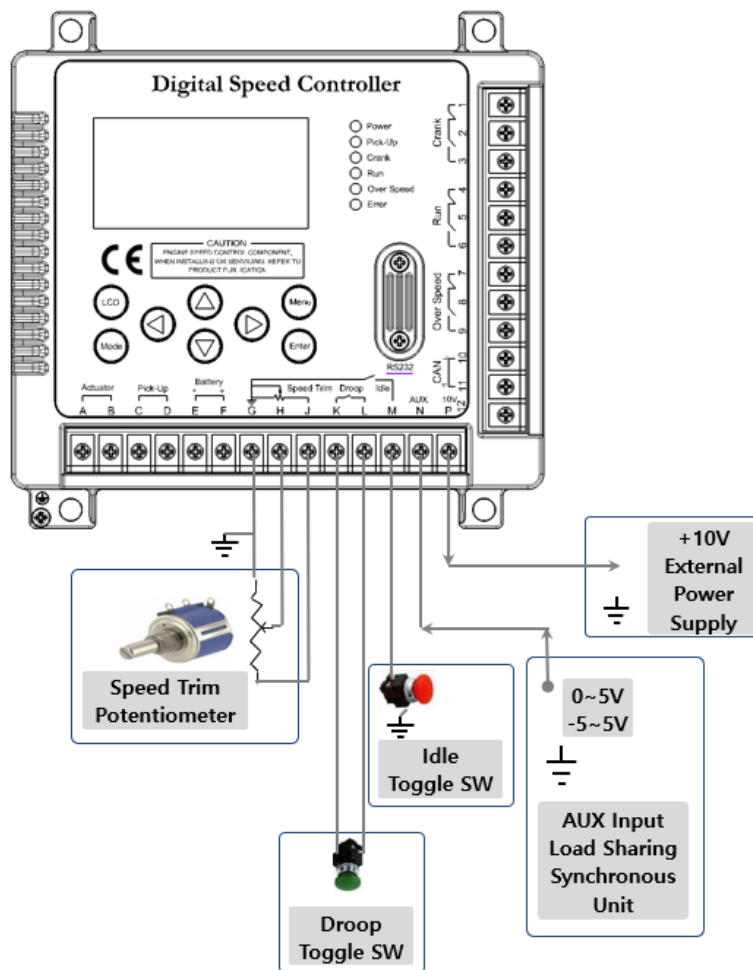


Figure 5: Speed Trim, Droop, Idle and Other Inputs Diagram

2.2.2 Connecting to Speed Trim

Speed trim is an analog voltage signal port for input to fine-tune the engine speed. A potentiometer is used for precise adjustment of the resistance values. The potentiometer needs to be connected to terminals **G**, **H** and **J**. Terminal **G** should be connected to the ground and it is recommended to use shielded cables. Terminal H is the terminal to which the fine adjustment voltage value (0 ~ 5V) is input. Terminal J is a terminal that is connected to VCC of the potentiometer with DC + 5V output.

2.2.3 Connecting to Droop

The switch is connected to terminals **K** and **L**. Signals indicating whether **droop** function works or not serve as inputs to the controller by keeping K and L either **open** or **close**. Inputs can be done by toggle or converting switches.

2.2.4 Connecting to Idle

The port on one side of the switch is connected to terminal **M** and the port on the other side to the **ground**. Connection between terminal **M** and the **ground** becomes either **open** or **close** by keeping the switch **open** or **close**. When connection between the terminal and the **ground** becomes **close**, the controller will have **idle** function. Inputs can be done by toggle or converting switches.

2.2.5 Connecting to AUX

AUX is a terminal for control signal inputs from load sharing devices or synchronization devices through terminal **N**. It shares load from the generator in parallel operation and receives signal inputs from synchronization devices for the controller to control changes to load. Input signal level is between **DC -5** and **5V** and it is recommended to use shielded cables for signal wires.

2.2.6 Connecting Power to External Devices

It can supply power output of **10V/20mA** to external devices through terminal **P**. Users can easily use this terminal when external auxiliary devices need power supply.

However, power supply of **20mA** or higher should not be used and care should be given to prevent short circuits.

2.3 Connecting to Crank, Run, Over Speed and Communication

2.3.1 Crank, Run, Over Speed and Communication Connection Diagram

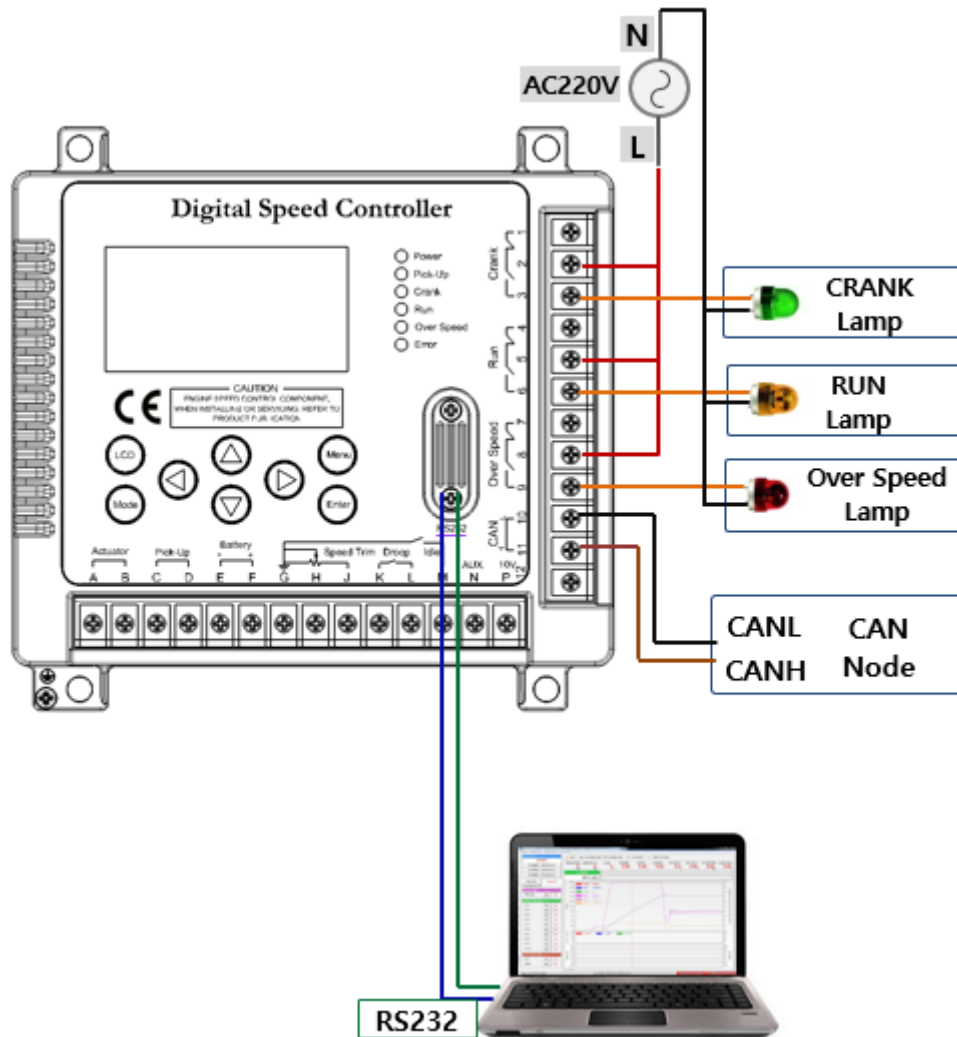


Figure 6: Crank, Run, Over Speed and Communication Connection Diagram

It is used to deliver operation information to external devices by activating contact point (a or b) when activating crank, run or over speed functions.

RS232 and CAN communication is connected to external PCs or hosts so that the controller can transmit system settings or operation information.

2.3.2 Connecting to Crank Terminals

Terminals **1**, **2** and **3** are the ones for **crank** output contact point and the contact point will be in operation when the controller activates the crank function. The second crank contact point is a shared terminal while terminals **1** and **2** are for the contact point **b** and terminals **2** and **3** for the contact point **a**.

Contact points **a** and **b** start to operate when the controller reaches at the RPM delivering control signals to the actuator after the engine is activated. The diagram shows wiring to operate AC220V lamp. The shared terminal is for 220V inputs and the **crank** lamp turns **on** when the contact point a starts to operate.

2.3.3 Connecting to Run Terminals

Terminals **4**, **5** and **6** are the ones for **run** output contact point and the contact point will be in operation when the controller activates the **run** function. The fifth crank contact point is a shared terminal while terminals **4** and **5** are for the contact point **b** and terminals **5** and **6** for the contact point **a**.

Contact points **a** and **b** start to operate when the engine reaches its designated normal speed RPM. The diagram shows wiring to operate AC220V lamp. The shared terminal is for 220V inputs the **run** lamp turns **on** when the contact point **a** starts to operate.

2.3.4 Connecting to Over Speed

Terminals **7**, **8** and **9** are the ones for **over speed** output contact point and the contact point will be in operation when the controller activates the **over speed** function. The eighth **over speed** contact point is a shared terminal while terminals **7** and **8** are for the contact point **b** and terminals **8** and **9** for the contact point **a**.

Contact points **a** and **b** start to operate when the engine reaches its designated over speed RPM. The diagram shows wiring to operate AC220V lamp. The shared terminal is for 220V inputs the **over speed** lamp turns **on** when the contact point **a** starts to operate.

2.3.5 Connecting to CAN Communication

Terminal **10** is for **CAN-L** communication and terminal **11** for **CAN-H** communication. **CAN-H** and **CAN-L** are used for CAN communication with remote control and monitoring of the controller operation. The communication code is based on **J1939**.

2.3.6 Connecting to RS232 Communication

D-SUB 9pin (female) is for RS232 communication for connection to external PCs or hosts. The specified dedicated line should be used and only terminals 2, 3, 5 shall be connected, and the other terminals shall not be connected. It can configure system parameters of the controller or communicate with analytic applications.









3. Configuration and Operation

The controller can be configured and operated by input keys according to the menus on the LCD display by selecting proper ones and assigning values in the selected menu to input control information to the system. Input information should immediately apply to the controller system once updated.

3.1 Input Keys

The controller has 8 input keys including LCD, Mode, Menu, Enter, Up, Down, Left and Right.

Each key as respective functions as follows:

-  **LCD** LCD key turns on and off the display.
-  **Mode** Mode key switches the display to either operation mode or wave form display.
-  **Menu** Menu key lets users change the menu display and go back to the previous menu.
-  **Enter** Enter key applies designated values on the LCD display to the system.
-  Up key lets users go up or increase values in the selected menu on the LCD display.
-  Down key lets users go down or decrease values in the selected menu on the display.
-  Left key lets users move to the left in the selected menu.
-  Right key lets users move to the right in the selected menu.

3.2.1 LCD Displays After Powered On

When DC +24V power is supplied to the battery terminal (E (-), F (+)) of the controller, the **power** LED in the front side of the controller turns on in **red** and the **error** LED turns on in **red** where there are fault conditions. At this moment, the LCD display is not activated and **HYUNDAI** logo will appear for 1 second followed by the operation display after pressing the **LCD** button.

The controller will start control based on information from pick-up sensor and other input devices and designated parameter values. At this moment, where breakdowns of the surrounding devices or system errors occur, the LCD display will show such errors and processing messages.

Step 1) DC +24V power supply to the terminals E (-) and F (+)

When DC +24V power is supplied to the terminals E (-) and F (+), the controller will start to operate with the LCD display off. After pressing the **LCD** button, **HYUNDAI** logo will appear for 1 second as shown below followed by the controller operation display. Then, the LCD display will switch between on and off by pressing the **LCD** button.



Figure 8: **HYUNDAI** Logo

Step 2) The operation display will show 1 second after the logo appears.

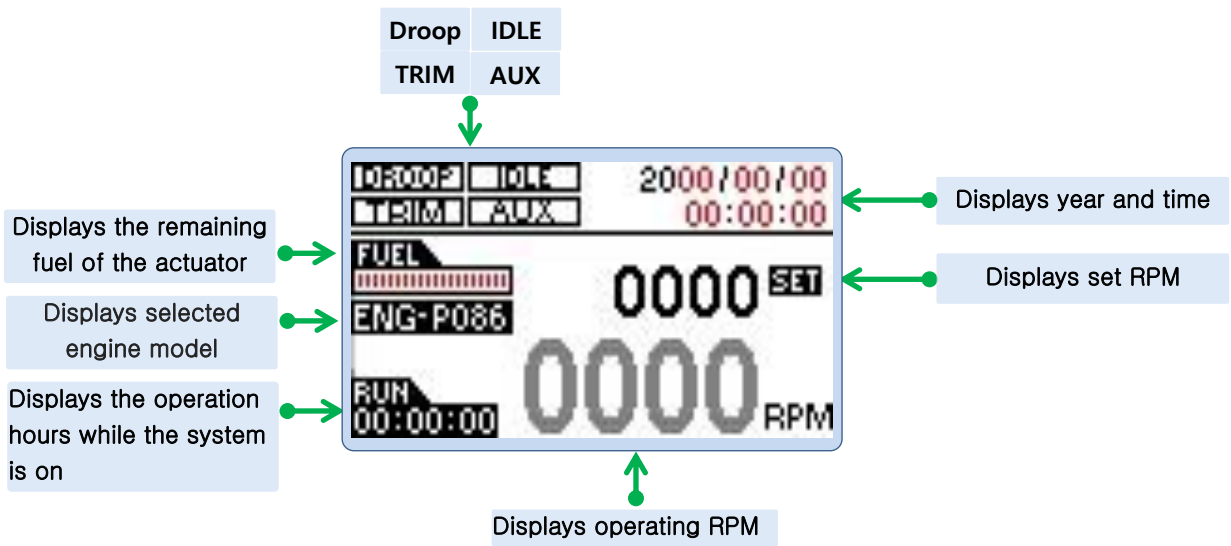
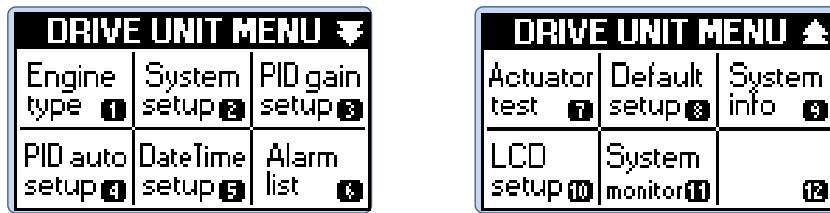


Figure 9: Operation Display

3.2.2 LCD Main Menu Display

Displays main menu screen of the controller

The main menu of the controller has 10 sub-menus.



Menu 1: Main Menu of the Controller - 1 to 2

1) Engine type

The controller can start operation once the initial system values are configured. Users can load preset values depending on types of the engines by selecting the type.

2) System setup

It consists of sub-menus related to system settings including RUN/IDLE/OVERSPEED/CRANK/GEARNUMBER.

3) PID gain setup

It consists of sub-menus to designate Kp, Ki and Kd parameter values related to the engine PID control.

4) PID auto setup

It offers function for automatic designation of Kp, Ki and Kd parameter values related to the engine PID control.

5) DateTime setup

It offers function for users to move to the screen for designating year, month, day and hour.

6) Alarm list

It offers function for users to move to the alarm display for the alarm list.

7) Actuator Test

It offers menu to test the impedance (X_L) of the actuator and any problems in operating load current. It displays current and voltage according to the duty values.

8) Default setup

It offers menu to apply designated default values to the selected engine.

9) System info

It offers menu that shows information of the controller. Such information includes the serial number, software version, last update date, alarm count and engine runs.

10) LCD setup

It offers menu to configure LCD operating conditions including brightness, auto on/off and off hours.

11) System monitor

It offers menu to monitor the controller operation. It shows values for Engine RPM, Valve Duty, Valve Current, Aux RPM Input, Pickup Voltage and Bat Voltage.

3.2.3 Engine Type Setup Menu

This menu offers function to configure setting values of the controller depending on types of the engines in advance and apply such preset values to the selected engine.

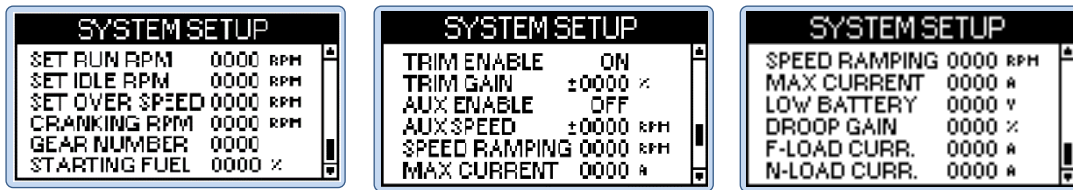


Menu 2: Engine Type Selection Menu

3.2.4 System Setup Menu

System Setup Menu Display of the Controller

It consists of sub-menus for the system configuration items of the controller including the one for configuring RUN/IDLE/OVERSPEED/CRANK/GEAR NUMBER related to RPM setting. Depending on additional functions, users can designate values for STARTING FUEL/SPEED RAMPING/ACTUATOR MAX/LOW BATTERY.



Menu 3: System Setup Menu - 1 to 3

1) SET RUN RPM

Users can designate normal speed (target RPM) of the engine.

Users need to input different normal speed values depending on the specification of the selected engine.

2) SET IDLE RPM

Users can designate the idle speed values of the engine as RPM.

Users need to input values to control the idle operating speed of the engine.

3) SET OVER SPEED

Users can designate RPM values to activate engine protection function when the speed exceeds the normal level (target RPM) and reaches the overspeed range that may cause problems to the engine.

When the engine RPM reaches the over speed RPM range, the engine immediately stops with error messages and alarms.

4) CRANKING RPM

Users can designate RPM values to activate the actuator when the engine starts to operate.

5) GEAR NUMBER

Users can input the number of flywheel teeth in the engine to the controller so that the controller can calculate the accurate RPM depending on the values of the pick-up sensor from the engine.

6) STARTING FUEL

Users can designate the amount of fuels used when the engine starts to operate and the operating current for the controller to activate the actuator changes based on these values.

7) AUX SPEED

Users can adjust values to ensure safe operation of the engine based on the AUX signal values when AUX is enabled.

8) SPEED RAMPING

Users can input ratio values of speed changes when the speed increases or decreases in the idle condition of the engine.

9) MAX CURRENT

Users can designate the maximum operating current for the **actuator** of the engine.

10) LOW BATTERY

It measures the battery voltage supplied to the controller. When the measured values are lower than the present voltage values, it will be alarmed. Usually, the acceptable battery voltage is between 20 and 22V (without load).

11) DROOP GAIN

Users can designate the droop values applicable to maximum load based on the current consumption of the **actuator**.

12) F-LOAD CURR

Users can designate the maximum current values when the generator is in full load.

13) N-LOAD CURR

Users can designate the operating current values of the actuator when the generator has no load.

3.2.5 PID Gain Setup Menu

Users can input Kp, Ki and Kd values as inputs to the PID control of the engine. Kp means proportional values while Ki means integral of the proportional values and Kd means differential of the proportional values.



Menu 4: PID Gain Setup Menu

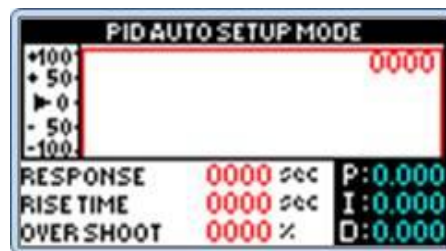
3.2.6 PID Auto Setup Menu

The menu offers function for automatic designation of the P, I and D parameter values related to the engine PID control.

After starting the engine, select **DRIVE UNIT MENU** in the main menu while the engine has no load and then **PID auto setup** menu, press Enter. Then, the system message shows "Auto Setup Mode PID setting?" with YES or NO option. If you select YES, the controller will repeatedly change the RPM to automatically calculate the optimized P, I and D values.

If the controller identifies the optimized P, I and D values within 30 cycles, it will display "PID Auto Setup Complete, OK". When you press Enter, it will apply tuned P, I and D values and close the menu.

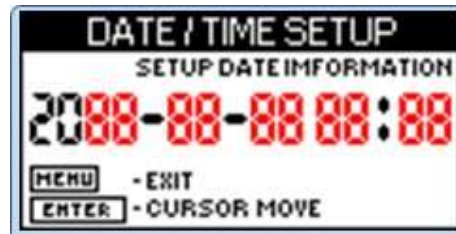
If the controller fails to identify the optimized P, I and D values within 30 cycles, it will display "PID No Successful, OK". When you press Enter, it will apply the final P, I and D values and close the menu.



Menu 5: PID auto setup menu

3.2.7 Date/Time Setup Menu

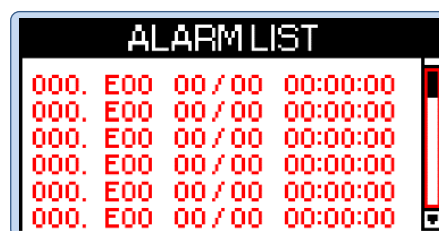
Users can designate year, month, day, hour and minute for the controller and the designated time will be used to monitor the system and manage fault messages.



Menu 6: DATE/TIME SETUP Menu

3.2.8 Alarm List Menu

This menu displays year, month, day, hour and minute for the errors in the controller and types of the faults in codes which are used in troubleshooting.



Menu 7: ALARM LIST Menu

3.2.9 Default Setup Menu

When you cannot identify the type of the control engine by the controller, this menu offers the most common parameter setting values. For default setup, select YES and then press Enter button. If you don't want to implement this function, press No button.

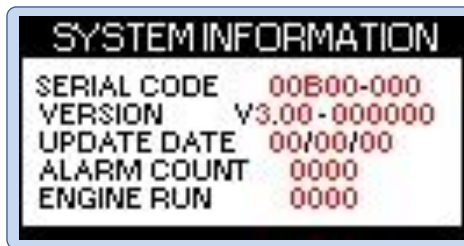
If you press YES, all the configuration values will be changed to the default ones of the engine.



Menu 8: Default Setup Menu

3.2.10 System Info Menu

The controller displays its information including the serial number, software version, last update date, alarm count and engine runs.



Menu 9: System Info Menu

3.3 Engine Configuration

3.3.1 Engine Type Configuration

Users can store control setting information depending on types of the engines in the internal memory of the controller. If you select your engine type, applicable parameters will be automatically configured accordingly. This feature is available for 21 different types of engines.

Designated Parameters by Engine Type (Land use)

No	Menu Name	Run RPM	Over Speed	Gear Teeth	Starting Fuel	PID Value
1	DB58 1500RPM (50Hz) 129T	1500RPM	1725RPM	129	65%	Optimized Value
2	DB58 1800RPM (60Hz) 129T	1800RPM	2070RPM	129	65%	Optimized Value
3	P086 1500RPM (50Hz) 102T	1500RPM	1725RPM	102	65%	Optimized Value
4	P086 1800RPM (60Hz) 102T	1800RPM	2070RPM	102	65%	Optimized Value
5	P086 1500RPM (50Hz) 140T	1500RPM	1725RPM	140	65%	Optimized Value
6	P086 1800RPM (60Hz) 140T	1800RPM	2070RPM	140	65%	Optimized Value
7	P086 1500RPM (50Hz) 146T	1500RPM	1725RPM	146	65%	Optimized Value
8	P086 1800RPM (60Hz) 146T	1800RPM	2070RPM	146	65%	Optimized Value

9	P126 1500RPM (50Hz) 152T	1500RPM	1725RPM	152	65%	Optimized Value
10	P126 1800RPM (60Hz) 152T	1800RPM	2070RPM	152	65%	Optimized Value
11	P126 1500RPM (50Hz) 106T	1500 RPM	1725RPM	106	65%	Optimized Value
12	P126 1800RPM (60Hz) 106T	1800 RPM	2070RPM	106	65%	Optimized Value
13	P158 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	65%	Optimized Value
14	P158 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	65%	Optimized Value
15	P158 2350RPM (60Hz) 160T	2350 RPM	2467RPM	160	65%	Optimized Value
16	P180 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	65%	Optimized Value
17	P180 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	65%	Optimized Value
18	P180 2350RPM (60Hz) 160T	2350 RPM	2467RPM	160	65%	Optimized Value
19	P222 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	65%	Optimized Value
20	P222 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	65%	Optimized Value
21	P222 2350RPM (60Hz) 160T	2350 RPM	2467RPM	160	65%	Optimized Value

Designated Parameters by Engine Type (marine use)

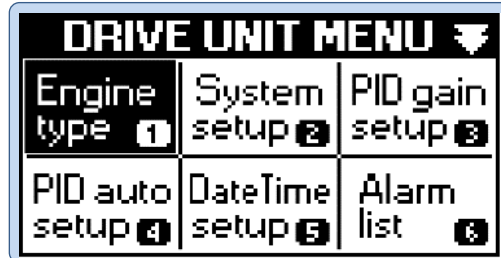
No	Menu Name	Run RPM	Over Speed	Gear Teeth	Starting Fuel	PID Value
1	AD066TI 1500RPM (50Hz) 129T	1500 RPM	1725RPM	129	60%	Optimized Value
2	AD066TI 1800RPM (60Hz) 129T	1800 RPM	2070RPM	129	60%	Optimized Value
3	AD086TI 1500RPM (50Hz) 140T	1500 RPM	1725RPM	140	60%	Optimized Value
4	AD086TI 1800RPM (60Hz) 140T	1800 RPM	2070RPM	140	60%	Optimized Value
5	AD126TI 1500RPM (50Hz) 152T	1500 RPM	1725RPM	152	60%	Optimized Value
6	AD126TI 1800RPM (60Hz) 152T	1800 RPM	2070RPM	152	60%	Optimized Value
7	4AD126TIF 1500RPM (50Hz) 106T	1500 RPM	1725RPM	106	60%	Optimized Value
8	4AD126TIS 1800RPM (60Hz) 106T	1800 RPM	2070RPM	106	60%	Optimized Value
9	AD136 1500RPM (50Hz) 140T	1500 RPM	1725RPM	140	60%	Optimized Value
10	AD136 1800RPM (60Hz) 140T	1800 RPM	2070RPM	140	60%	Optimized Value
11	AD136T 1500RPM (50Hz) 140T	1500 RPM	1725RPM	140	60%	Optimized Value
12	AD136T 1800RPM (60Hz) 140T	1800 RPM	2070RPM	140	60%	Optimized Value
13	AD136TI 1500RPM (50Hz) 140T	1500 RPM	1725RPM	140	60%	Optimized Value
14	AD136TI 1800RPM (60Hz) 140T	1800 RPM	2070RPM	140	60%	Optimized Value
15	AD158TI 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	60%	Optimized Value
16	AD158TI 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	60%	Optimized Value
17	4AD158TI 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	60%	Optimized Value
18	4AD158TI 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	60%	Optimized Value
19	AD180TI 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	60%	Optimized Value
20	AD180TI 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	60%	Optimized Value
21	AD196TI 1500RPM (50Hz) 152T	1500 RPM	1725RPM	152	60%	Optimized Value
22	AD196TI 1800RPM (60Hz) 152T	1800 RPM	2070RPM	152	60%	Optimized Value
23	AD222TI 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	60%	Optimized Value
24	AD222TI 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	60%	Optimized Value
25	4AD222TI 1500RPM (50Hz) 160T	1500 RPM	1725RPM	160	60%	Optimized Value
26	4AD222TI 1800RPM (60Hz) 160T	1800 RPM	2070RPM	160	60%	Optimized Value

Table 1: Configuration Values by Engine Type

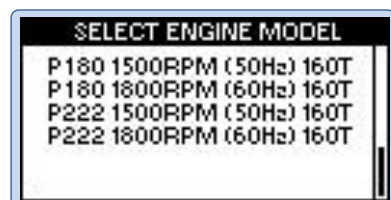
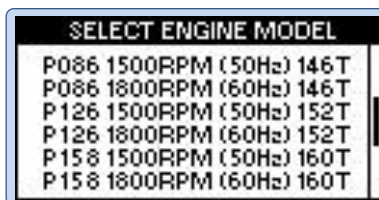
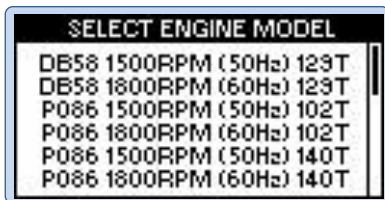
- **Engine Configuration Procedure**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **Engine Type** by using **Up** and **Down** buttons in **DRIVE UNIT MENU** and then press **Enter** button.



Step3) Go to **Engine Type** menu and select your engine type using **Up** and **Down** buttons. Then, press **Enter** button. At this moment, setting values according to the selected type of the engine are designated and will be used as information for the controller to control the actuator.



Menu 10: Selection List by Engine Type

3.3.2 System Setup Configuration

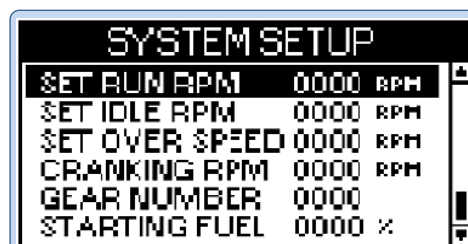
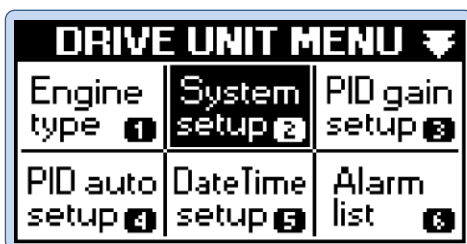
Main setting items of the controller includes **GEAR NUMBER**, **CRANKING RPM** and **SET RUN RPM**. You need to designate setting values to these items. Other system setup items are optional and therefore you can designate values for those items as necessary.

- **Configuring SET RUN RPM**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up**, **Down**, **Left** and **Right** buttons and then press **Enter** button.

Step3) Select **SET RUN RPM** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the normal operating speed of the engine and then press **Enter** button.

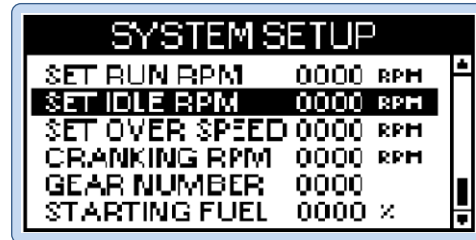
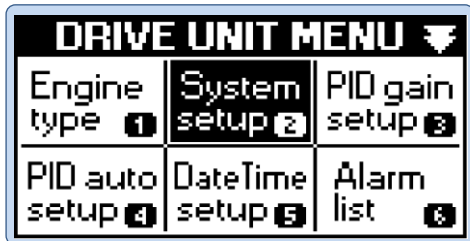


- **Configuring SET IDLE RPM**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **SET IDLE RPM** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the **idle** operating speed of the engine and then press **Enter** button.

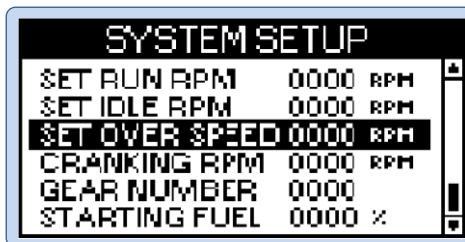
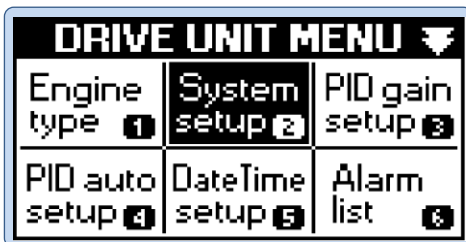


- **Configuring SET OVER SPEED**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **SET OVER SPEED** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the **over speed** values of the engine and then press **Enter** button.

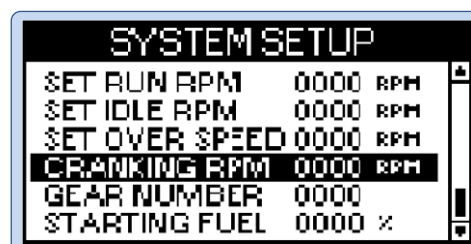
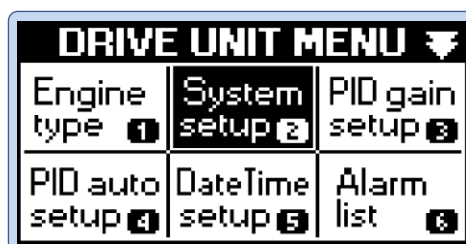


- **Configuring CRANKING RPM**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **CRANKING RPM** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the **RPM** values at which the controller starts to control the **actuator** when the engine starts to operate and then press **Enter** button.

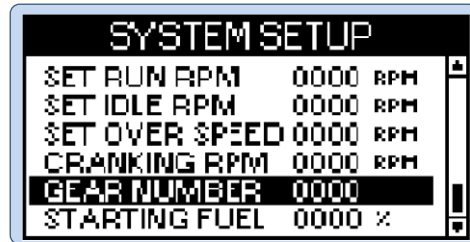
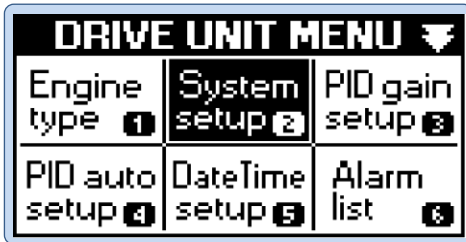


- Configuring **GEAR NUMBER**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **GEAR NUMBER** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the number of gear teeth in the engine and then press **Enter** button.

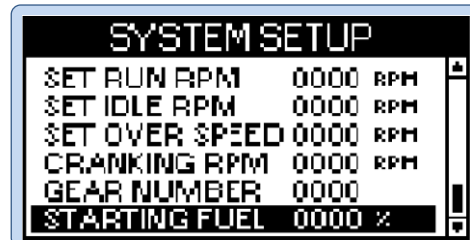
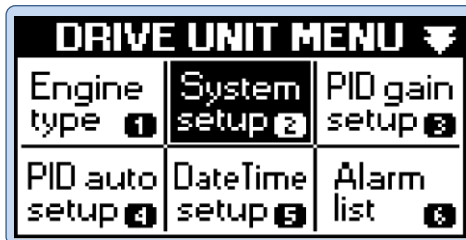


- Configuring **STARTING FUEL**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **STARTING FUEL** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the percentage for the amount of fuel sprayed when the engine starts and then press **Enter** button.

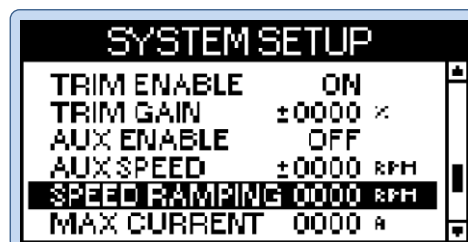
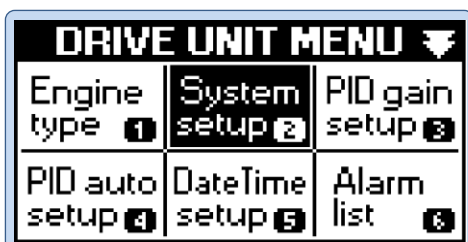


- Configuring **SPEED RAMPING**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **SPEED RAMPING** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the ratio of changes to the speed when increasing from the idle speed or decreasing from the increased speed and then press **Enter** button.

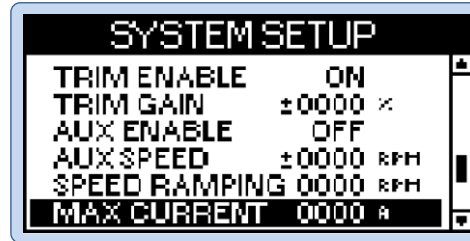
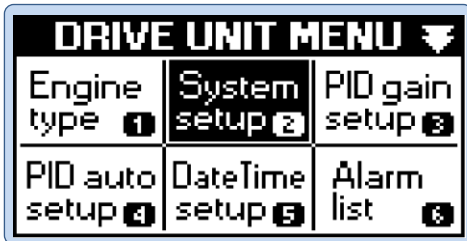


- Configuring **MAX CURRENT**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **MAX CURRENT** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the limit of the maximum current consumption of the **actuator** and then press **Enter** button (Max. 10A).

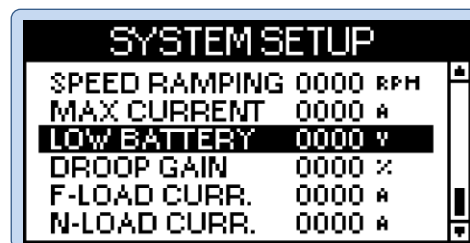
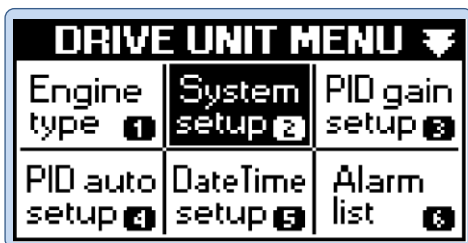


- Configuring **LOW BATTERY**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **LOW BATTERY** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to input voltage values at which low battery alarms are activated and then press **Enter** button.

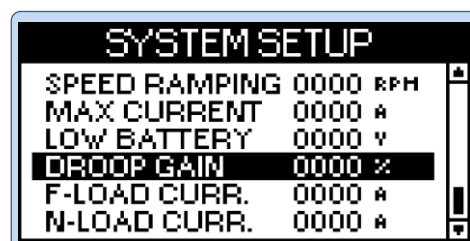
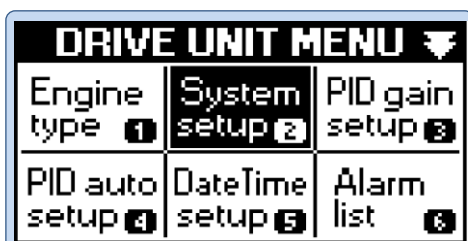


- Configuring **DROOP GAIN**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.

Step2) Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.

Step3) Select **DROOP GAIN** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to increase or decrease the RPM values with adjusted ratio to decrease at the maximum load when the generator is in parallel operation and then press **Enter** button.



DROOP Function

Droop function is indicated in percentages as follows: RPM with no load is subtracted by RPM with maximum load and then divided by RPM with no load.

$$\text{Droop}\% = \frac{\text{RPM with no load} - \text{RPM with maximum load}}{\text{RPM with no load}}$$

(Example for 3% Droop)

Assuming that RPM with no load is 1,800 and RPM with maximum load is 1,854 then the percentage will be 3%. It means that the generator output will be changed by 33.3% as the frequency changes by 1% due to the actuator control.

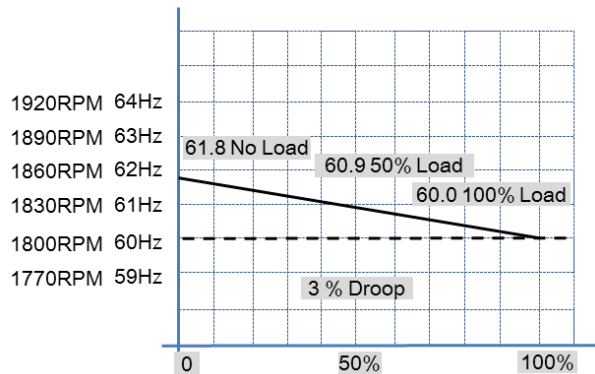


Figure 10: 3% Droop

(Example for 7% Droop)

Assuming that RPM with no load is 1,800 and RPM with maximum load is 1,926 then the percentage will be 7%. It means that the generator output will be changed by 14.3% as the frequency changes by 1% due to the actuator control.

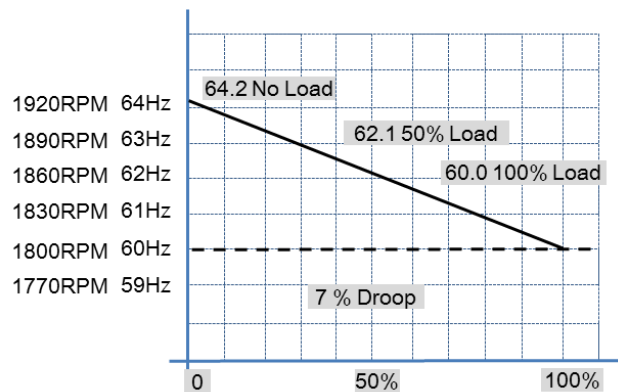
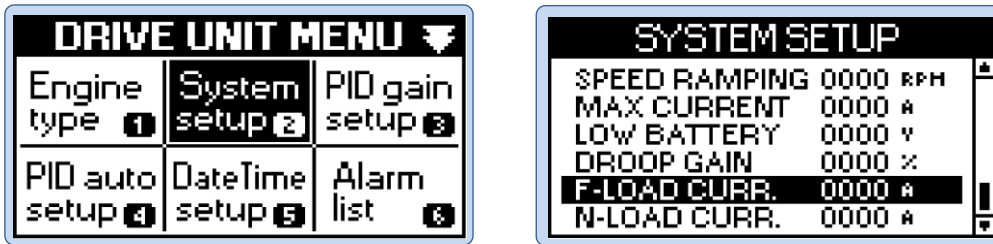


Figure 11: 7% Droop

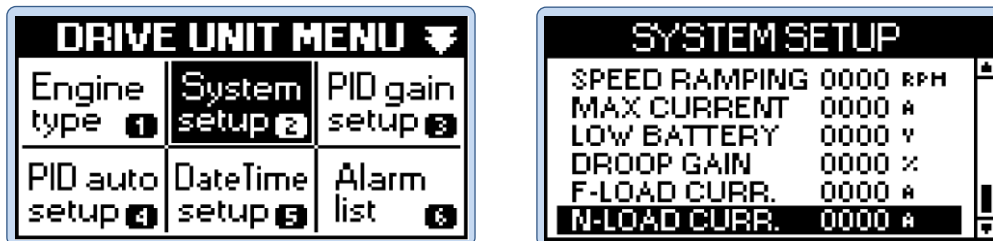
- **F-LOAD CURR.**

- Step1)** Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.
- Step2)** Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.
- Step3)** Select **F-LOAD CURR.** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to input the maximum current values of the **actuator** for the generator with full load and then press **Enter** button.



- **N-LOAD CURR.**

- Step1)** Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**.
- Step2)** Select **System setup** menu in **DRIVE UNIT MENU** using **Up, Down, Left** and **Right** buttons and then press **Enter** button.
- Step3)** Select **N-LOAD CURR.** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to input the operating current values of the **actuator** for the generator with no load and then press **Enter** button.



3.3.3 PID Gain Setup Configuration

- **Configuring PID Gain Kp, Ki and Kd Values**

- Step1)** Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use **Up, Down, Left** and **Right** buttons to select **PID gain setup** menu and then press **Enter** button.
- Step2)** Use **Up** and **Down** buttons in **PID GAIN SETUP** to select **PROPORTIONAL, INTEGRAL** or **DERIVATIVE** and then press **Enter** button.
- In **PID GAIN SETUP**, if a user sets the value over than 100 about each **P, I, D**, we could not the warrant of the product quality.



- Configuring **PID SAMPLING TIME**

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use **Up**, **Down**, **Left** and **Right** buttons to select **PID gain setup** menu and then press **Enter** button.

Step2) Use **Up** and **Down** buttons in **PID GAIN SETUP** to select **SAMPLING TIME** and then press **Enter** button. Use **Up** and **Down** buttons to input **SAMPLING TIME** values and then press **Enter** button.

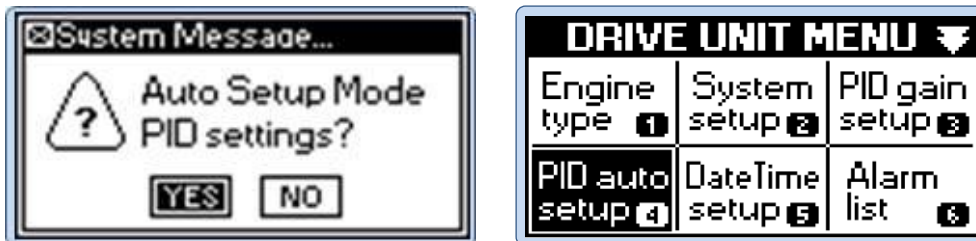


3.3.4 PID Auto Setup Value Configuration

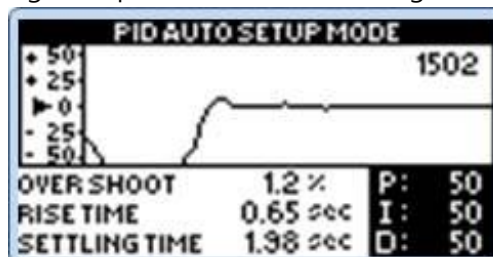
Step1) Select your type in Engine Type menu and then start the engine with the preset configuration values maintaining it with no load.

Step2) During the normal operation, press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use **Up**, **Down**, **Left** and **Right** buttons to select **PID auto setup** menu and then press **Enter** button.

Step3) The menu offers function for automatic designation of the P, I and D parameter values related to the engine PID control. Select PID auto setup menu in **DRIVE UNIT MENU** and then press Enter button to see the system message "Auto Setup Mode PID settings?" with YES or NO options.



Step4) Press YES and then the system message "PID AUTO SETUP MODE" will appear. As PID auto setup was initiated during the operation, PID auto tuning is already in progress.



Step5) PID tuning repeats a process to obtain PID values and a window to indicate whether the process succeeded or failed will appear in several minutes (approx. 4 to 6 minutes). If the process succeeded, the system message window will appear together with OK button. If you press Enter button, you will go back to normal operation window and the auto-tuned values will apply to the normal operation that will be continued.

Step6) If auto-tuning failed to identify optimized P, I and D values within 4 to 6 minutes, the system message window will display failure. If you press Enter button, you will go back to normal operation window. If you want to repeat the process, you need to start with Step1 again.



3.3.5 DATE/TIME Value Configuration

Step1) press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use direction buttons to select **DateTime setup** menu.

Step2) Use **Up, Down, Left** and **Right** buttons to input year, month, day and hour and then press **Enter** button.



3.3.6 ALARM LIST

Step1) press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use direction buttons to select **Alarm List** menu and then press **Enter** button.

Step2) Use **Up, Down, Left** and **Right** buttons in **ALARM LIST** menu to confirm the fault messages.



[Alarm Code Table]

Alarm Code	Alarm Item	Description	Identified Alarm Output
E01	Battery Low	When the battery voltage continues to be lower than Low Battery voltage values for more than 5 seconds	LCD alarm message, Error LED lamp
E02	Battery High	When the battery maintains its voltage exceeding 30VDC for more than 5 seconds	LCD alarm message, Error LED lamp
E03	Pick-up Error	Problems in sensor signals when the engine starts. (Engine RPM lower than 600)	LCD alarm message, Error LED lamp
E04	Pick-up Error	Problems in sensor signals during the engine operation (Engine RPM 600 or higher)	LCD alarm message, Error LED lamp
E05	Actuator Current Short	Disconnection in the actuator or the connecting circuits	LCD alarm message, Error LED lamp
E06	Actuator Current Broken	Short-circuits in the actuator or the connecting circuits	LCD alarm message, Error LED lamp
E07	Over Speed	Engine RPM exceeding the configured over speed values	LCD alarm message, Error LED lamp
E08	FET Drive Error	Damages to components in the actuator output section inside the controller	LCD alarm message, Error LED lamp
E09	Pick-Up Lost	Pick-Up signal lost. (Engine RPM higher than 600rpm)	LCD alarm message, Error LED lamp

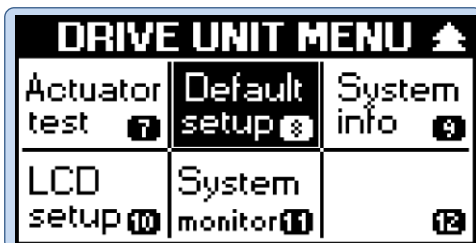
3.3.7 Actuator test

The menu offers function to test whether there is any problem in operating load current of the actuator attached to the engine. It indicates voltage and current for on/off.

3.3.8 Default setup Functions

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use **Up, Down, Left** and **Right** buttons to select **Default setup** menu and then press **Enter** button. At this moment, the system message **“Initialization system settings?”** will appear.

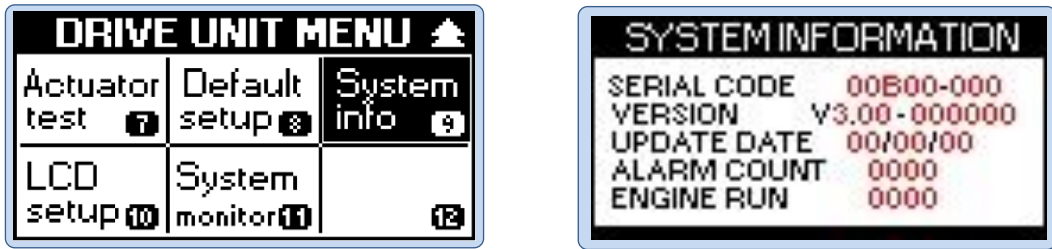
Step2) Use **Left** and **Right** buttons to select either **YES** or **NO** in **System Message** and then press **Enter** button.



Default setup will change the configuration values of the engine to the default values. In order to initiate default setup, you need to select **YES** and then press **Enter** button. Press **No** button if you don't want to.

3.3.9 System info Functions

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use **Up**, **Down**, **Left** and **Right** buttons to select **System info** menu and then press **Enter** button.

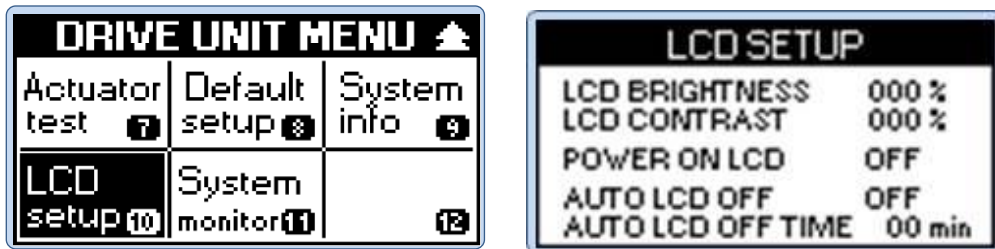


The menu displays information of the controller and the information includes the serial number, software version, last update date, alarm count and engine runs.

3.3.10 LCD setup Functions

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use **Up**, **Down**, **Left** and **Right** buttons to select **LCD setup** menu and then press **Enter** button.

Step2) Use **Up** and **Down** buttons to select menus including **LCD BRIGHTNESS** and **LCD CONTRAST** for adjustment and then press **Enter** button. Use **Up** and **Down** buttons to input setting values and then press **Enter** button.



3.3.11 System monitor Functions

Step1) Press **Menu** button of the controller and then you can see **DRIVE UNIT MENU**. Use **Up**, **Down**, **Left** and **Right** buttons to select **System monitor** menu and then press **Enter** button. It offers menu to monitor the controller operation. It shows values for Engine RPM, Valve Duty, Valve Current, Aux RPM Input, Pickup Voltage(Peak Value) and Bat Voltage.

4. How to Operate

4.1 Operating Sequence for Digital Speed Controller

STEP1) Supply DC +24V power to the battery terminals (E (-), F (+)) of the controller.

STEP2) Configure parameter values required for selection of the engine type and control of the engine.

STEP3) Install the controller on the generator system and complete circuit wiring.

STEP4) The controller will activate the actuator with power supply and pick-up sensor input.

4.2 Detailed Operating Sequence

STEP1) Supply DC +24V power to the battery terminals (E (-), F (+)) of the controller.

Power supply to the controller can be done by direct connection to the battery or power supply controlled by external control devices. Fuses (15A/24V) are required for power supply to the controller through the terminal.

When the controller displays **Low Battery** Fault message, you need to charge the battery or replace it with the one having normal voltage before starting the controller.

STEP2) Configure parameter values required for selection of the engine type and control of the engine.

There are 3 ways to configure parameters required for the controller:

1. Using default setup
2. Designating the engine type in Engine Type menu
3. Configuring each parameter in System setup menu

For more information, see **Chapter 3**. Configuration and Operation.

STEP3) Install the controller on the generator system and complete circuit wiring.

Once the configuration is completed, the controller will be in **Stand By** condition preparing to receive input information from **pick-up** sensor and surrounding terminals and operate.

STEP4) The controller will activate the actuator with power supply and pick-up sensor input.

When the power is supplied and the **pick-up** terminal delivers normal sensor inputs as the **engine** starts, the **controller** activate the **actuator**.

5. Troubleshooting

5.1 Alarm List Check

Where there are problems in the system operation, you need to review the alarm list menu of the controller and then check the engine and the system in reference to the alarm codes.

Land/marine

Alarm Code	Alarm Item	Alarm Condition	Output Control	Measures
E01	Battery Low	When the battery voltage continues to be lower than Low Battery voltage values for more than 5 seconds	1. Alarm message pop-up on LCD 2. Error LED on	1. Check the battery line 2. Replace the battery
E02	Battery High	When the battery maintains its voltage exceeding 30VDC for more than 5 seconds	1. Alarm message pop-up on LCD 2. Error LED on	1. Check the battery line 2. Replace the battery
E03	Pick-up Error	Problems in sensor signals when the engine starts (Engine RPM lower than 600)	1. Alarm message pop-up on LCD 2. Error LED on 3. Actuator control signal off	1. Check the RPM sensor and connecting circuits 2. Replace the RPM sensor
E04	Pick-up Error	Problems in sensor signals during the engine operation (Engine RPM 600 or higher)	1. Alarm message pop-up on LCD 2. Error LED on 3. Actuator control signal off	1. Check the RPM sensor and connecting circuits 2. Replace the RPM sensor
E05	Actuator Current Short	Disconnection in the actuator or the connecting circuits	1. Alarm message pop-up on LCD 2. Error LED on	1. Check the disconnection in the actuator and connecting circuits 2. Replace the actuator
E06	Actuator Current Broken	Short-circuits in the actuator or the connecting circuits	1. Alarm message pop-up on LCD 2. Error LED on	1. Check the disconnection in the actuator and connecting circuits 2. Replace the actuator
E07	Over Speed	Engine RPM exceeding the configured over speed values	1. Alarm message pop-up on LCD 2. Error LED on 3. Actuator control signal off	1. Check the speed setting 2. Adjust PID setting values
E08	FET Drive Error	Damages to components in the actuator output section inside the controller	1. Alarm message pop-up on LCD 2. Error LED on 3. Actuator output power cutoff	1. Check the actuator and connecting circuits 2. Replace the controller
E09	Pick-Up Lost	Pick-Up signal lost. (Engine RPM higher than 600rpm)	1. Alarm message pop-up on LCD 2. Error LED on 3. Actuator output power cutoff	1. Check the RPM sensor and connecting circuits 2. Replace the RPM sensor

- 1) When problems described in alarm codes E03, E04, E07, E08 or E09 occur, the engine is not available for safe operation and therefore the engine will stop as the controller will turn off the actuator for safety.

- 2) When problems described in alarm codes E03, E04, E07 or E08 occur, the engine will not be able to restart as long as the alarm is not released.
- 3) When alarms occur, you can release them by turning off the power of the controller.

5.2 System Checks and Measures

For initial installation, it is recommended for you to check any disconnection in circuits before taking measures described here (see Chapter 2. Installation for how to install the controller).

You can check the controller for failure diagnosis in accordance with the following procedure.

Step1) Check the battery voltage whether it is higher than the Low Voltage setting value. If normal, supply power to the controller and then operate it. If the voltage is lower than the setting value, you need to charge the battery or replace it before operating the system.

Step2) Check the input resistance in the DC +24V input terminals (-E, +F) of the battery whether the resistance is higher than approx. 10K Ohm. If the resistance does not meet this condition, do not supply power to the controller and contact our A/S center for service request.

Step3) Check whether the power LED turns on or not after supplying power to DC +24V input terminals (-E, +F) of the battery. If the LED does not turn on, cut the power off and contact our A/S center for service request.

Step4) Check whether the power LED turns on and **HYUNDAI** logo appears on the LCD display after supplying power to DC +24V input terminals (-E, +F) of the battery. If you cannot see the logo, press LCD key button to check the LCD display once again. If you cannot still see the logo, cut the power off and contact our A/S center for service request.

Step5) Check the controller terminals (C & D) with AC meter or oscilloscope to check whether signal inputs of AC RMS 3V or higher are detected. If no signal detected, check whether the pick-up sensor maintains the gap between 0.9 and 1.1mm and then check whether the pick-up sensor has resistance of 110 Ohms ($\pm 10\%$). If you cannot still detect no signal, replace the pick-up sensor and then operate the controller.

6. Warranty and A/S Service

6.1 Warranty

As this manual contains important contents related to safety, use and maintenance of the product. So please read this manual carefully and then use the product in a proper manner.

Those who are not familiar with the product should keep this manual close to it.

We are not responsible for human injuries or property damages caused by the following reasons:

- Where you use the product for purposes other than the ones described in this manual
- Where you alter the product or its components at discretion
- Where you disassemble the product at discretion to resolve problems
- Where you use accessories or parts not supplied or recommended by us
- ※ Where you use accessories or parts manufactured by other companies, please contact our service center to check their compatibility.

6.2 A/S Service Information

- When you request A/S service, please let us know the model name, breakdown conditions and your contact information.
- Please ask the seller.