Doosan Infracore

65.99897-8115A

Operation & Maintenance Manual

GENERATOR DIESEL ENGINE

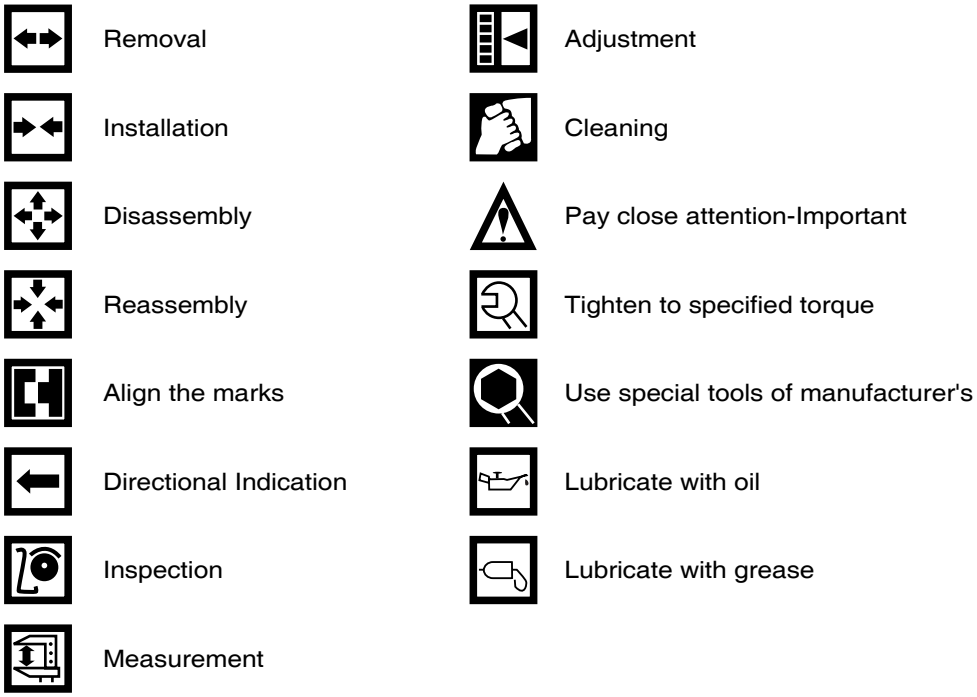
P158FE
P180FE
P222FE

FOREWORD

This content is the maintenance instruction for Diesel generator Engine of DOOSAN Series (P158FE, P180FE and P222FE). P158FE (8 cylinder), P180FE (10 cylinder), P222FE (12 cylinder) engines are 4 strokes, 4 valves per cylinder, V-type, and direct injection mode and thus, are also satisfying with various features required as generator 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.



During engine maintenance, please observe following instructions to prevent environmental damage;

- Take old oil to an old oil disposal point only.
- Ensure without fail that oil and diesel fuel will not get into the sea or rivers and canals or the ground.
- Treat undiluted anti-corrosion agents, antifreeze agents, filter element and cartridges as special waste.
- The regulations of the relevant local authorities are to be observed for the disposal of spent coolants and special waste.

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.

For the last, the content of this maintenance instruction may be changed without notice for some quality improvement and please feel free to contact to our agents near by your location for any services. Thank you.

Doosan Infracore Co., Ltd.
Nov. 2007

CONTENTS

1. Safety Regulations & Engine Specifications

1.1. Safety Regulations

1.1.1. General notes

- Day-to-day use of power engines and the service products necessary for running them presents no problems if the persons occupied with their operation, maintenance and care are given suitable training and think as they work.
- 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.

MPORTANT:
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. To prevent accidents with injury to persons

1) During commissioning, starting and operation

- This is the safety alert symbol. When you see this symbol in this manual, be alert to the potential for personal injury.

- Carefully read all safety message in this manual and on your vehicle safety signs. Be sure new equipment components and repair parts include the current safety signs.

- Avoid possible injury or death from vehicle runaway. Do not start engine by shorting across starter terminals. Vehicle will start in gear if normal circuitry is bypassed. Start engine only from operator's seat with transmission in neutral or park.

- Prevent fires by keeping machine clean of accumulated trash, grease, fuel and debris.
- When the engine is running, do not get too close to the rotating parts.

- Do not touch the engine with bare hands when it is warm from operation risk of bums.

- Exhaust gases are toxic. If it is necessary to run an engine in an enclosed area, remove the exhaust gases from the area with an exhaust pipe extension. If you do not have an exhaust pipe extension, open the doors and get outside air into the area.

- Keep vicinity of engine 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 rise 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. 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 DOOSAN.
2) If faults occur, find the cause immediately and have it eliminated in order to prevent more serious of damage.
3) Use only genuine DOOSAN spare parts. DOOSAN 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 DOOSAN-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.

1.1.4. 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.

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 DOOSAN 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 property.

1.2. Engine Specifications

Items \ Engine model		P158FE	P180FE	P222FE
Engine type		Water-cooled, 4 cycle, 4 valves per cylinder, V-type, turbo charged & intercooled		
Combustion chamber type		Direct injection type		
Cylinder liner type		Wet type		
Timing gear system		Gear driven type		
No. of piston ring		2 compression ring, 1 oil ring		
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		14.3 : 1		
Engine dimension (length × width × height) (mm)		1,492 × 1,388 × 1,240	1,577 × 1,388 × 1,248	1,719 × 1,388 × 1,305
Engine weight (kg)		997	1,188	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		Bosch in-line “P” type		
Governor type		Electrical governor (GHANA control)		
Engine stop system		Fuel cut lever of injection pump side		
Injection nozzle type		Multi-hole type (8 hole)		
Fuel injection pressure (kg/cm^2)		280		
Compression pressure (kg/cm^2)		28 (at 200 rpm)		
Intake and exhaust valve clearance (at cold) (mm)		0.4 / 0.5		
Intake valve	Open at	24° (B.T.D.C)		
	Close at	30° (A.B.D.C)		
Exhaust valve	Open at	59° (B.B.D.C)		
	Close at	21° (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)		28 / 26	35 / 28	40 / 33
Oil cooler type		Water cooled		
Water pump		Belt driven centrifugal type		
Cooling method		Pressurized circulation		
Cooling water capacity (engine only) (lit)		20	21	23
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		

1.3. Engine Power

Production tolerance : ±5%

Engine model				Power condition		Remark
Model	Suffix	Timing (BTDC)	Hz	Prime	Stand by	
P158FE	EUZOA	10°	50 HZ (1,500 rpm)	546 PS (402 kW)	600 PS (441 kW)	TIER-2
	EUZOB	12°	60 HZ (1,800 rpm)	600 PS (441 kW)	669 PS (492 kW)	TIER-2
P180FE	EUSOA	8°	50 HZ (1,500 rpm)	615 PS (452 kW)	675 PS (496 kW)	TIER-2
	EUSOB	12°	60 HZ (1,800 rpm)	–	770 PS (566 kW)	TIER-2
P222FE	EUYOA	9°	50 HZ (1,500 rpm)	774 PS (569 kW)	832 PS (612 kW)	TIER-2
	EUYOB	12°	60 HZ (1,800 rpm)	896 PS (659 kW)	967 PS (711 kW)	TIER-2

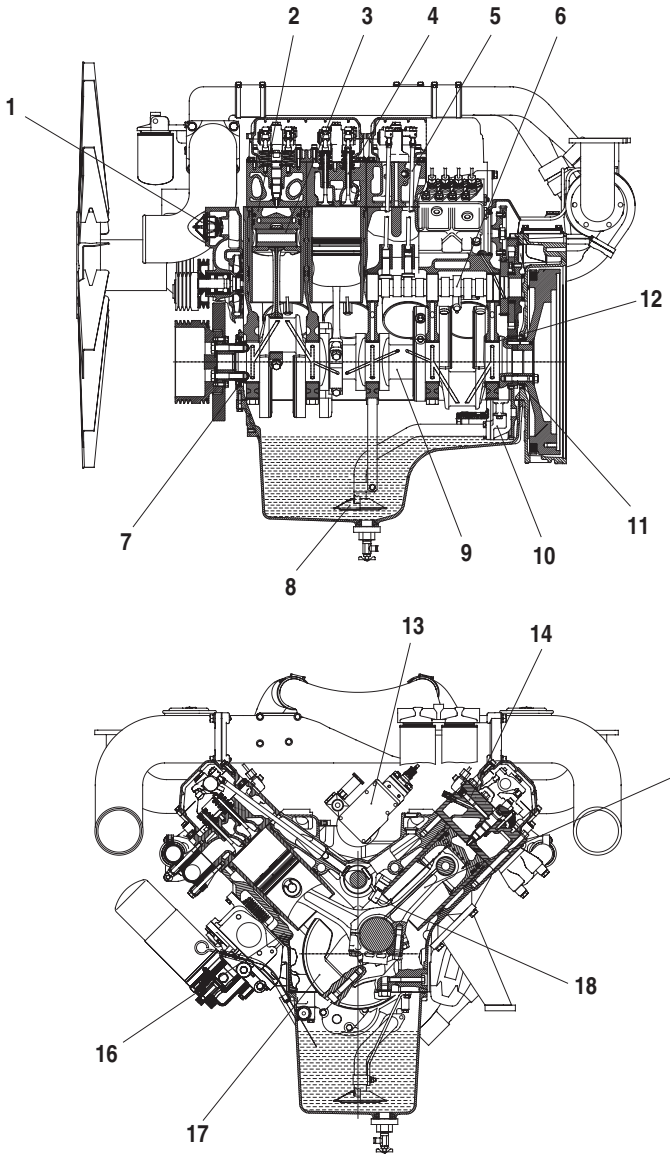
* Note : 1) All data are based on operation without cooling fan at ISO 3046.

2) Rating are based on ISO 8528

- **Prime power** available at variable load. The permissible average power output (during 24h period) shell not exceed 70 % of the prime power rating.
- **Standard power** available in the event of a main power network failure. No overload is permitted.

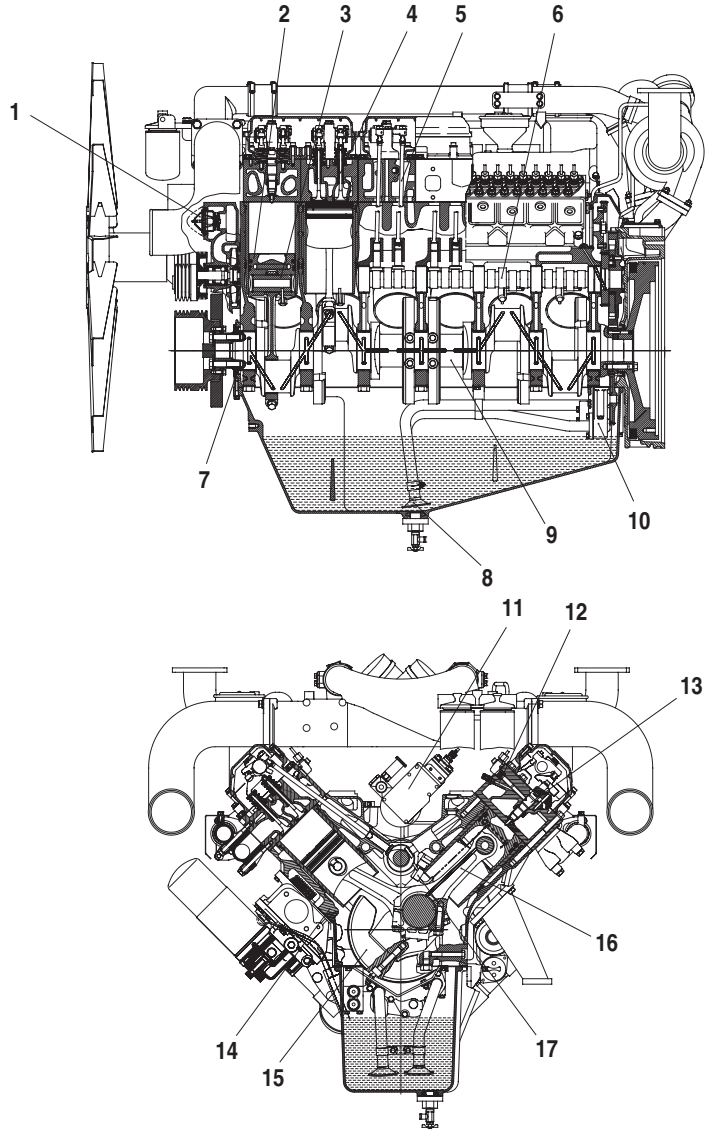
1.4. Engine Assembly

1.4.1. Engine sectional views – P158FE



1. Thermostat
2. Piston
3. Piston pin
4. Valve
5. Push rod
6. Cam shaft
7. Front oil seal
8. Oil suction pipe
9. Crank shaft
10. Oil pump
11. Rear oil seal
12. Thrust bearing
13. Fuel injection pump
14. Fuel high pressure connector
15. Connecting rod
16. Cylinder block
17. Counter weight
18. Oil spray nozzle

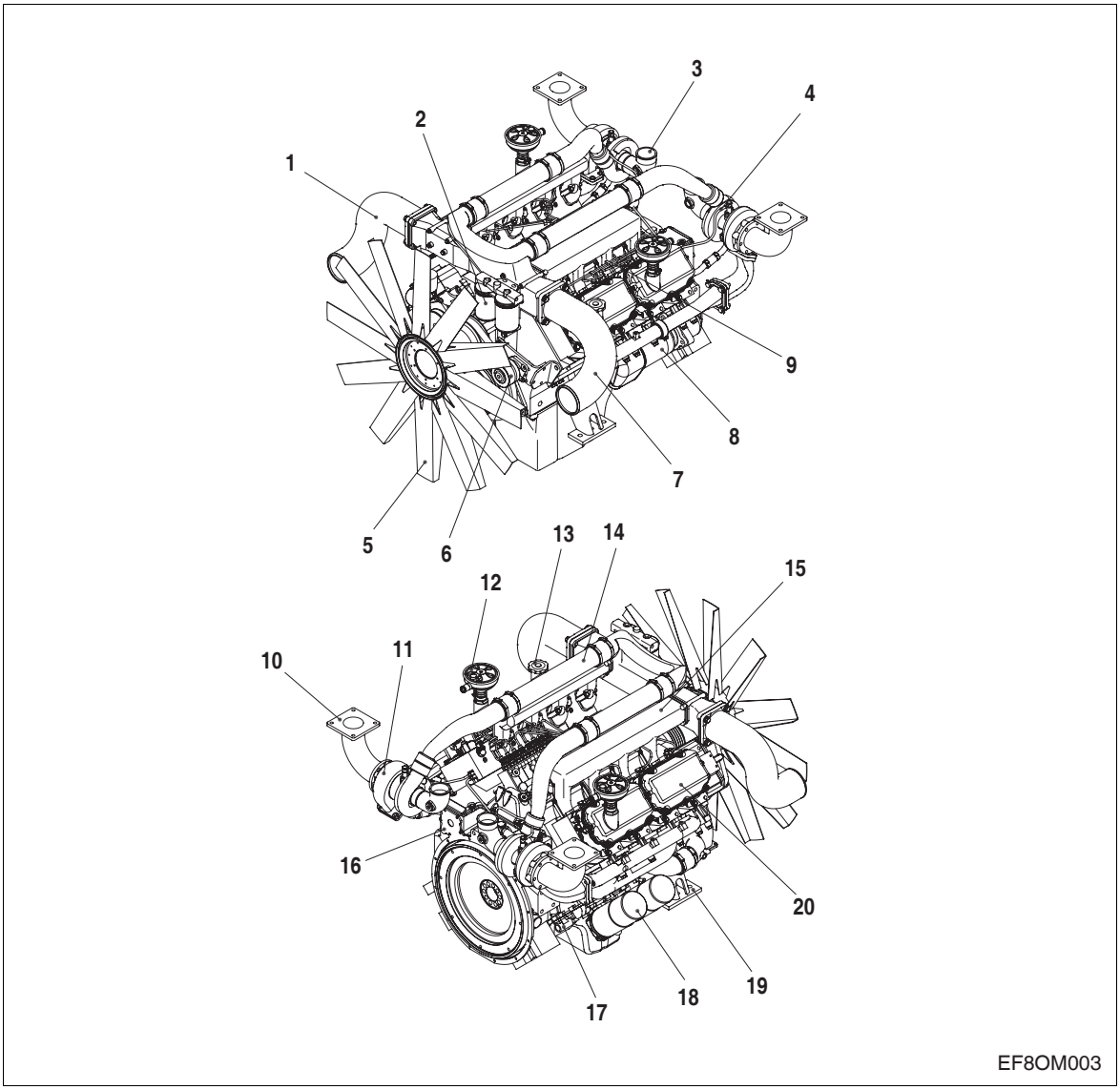
1.4.2. Engine sectional views – P222FE



1. Thermostat
2. Piston
3. Piston pin
4. Valve
5. Push rod
6. Cam shaft
7. Front oil seal
8. Oil suction pipe
9. Crank shaft
10. Oil pump
11. Fuel injection pump
12. High pressure connector
13. Injector
14. Cylinder block
15. Balance weight
16. Connecting rod
17. Oil spray nozzle

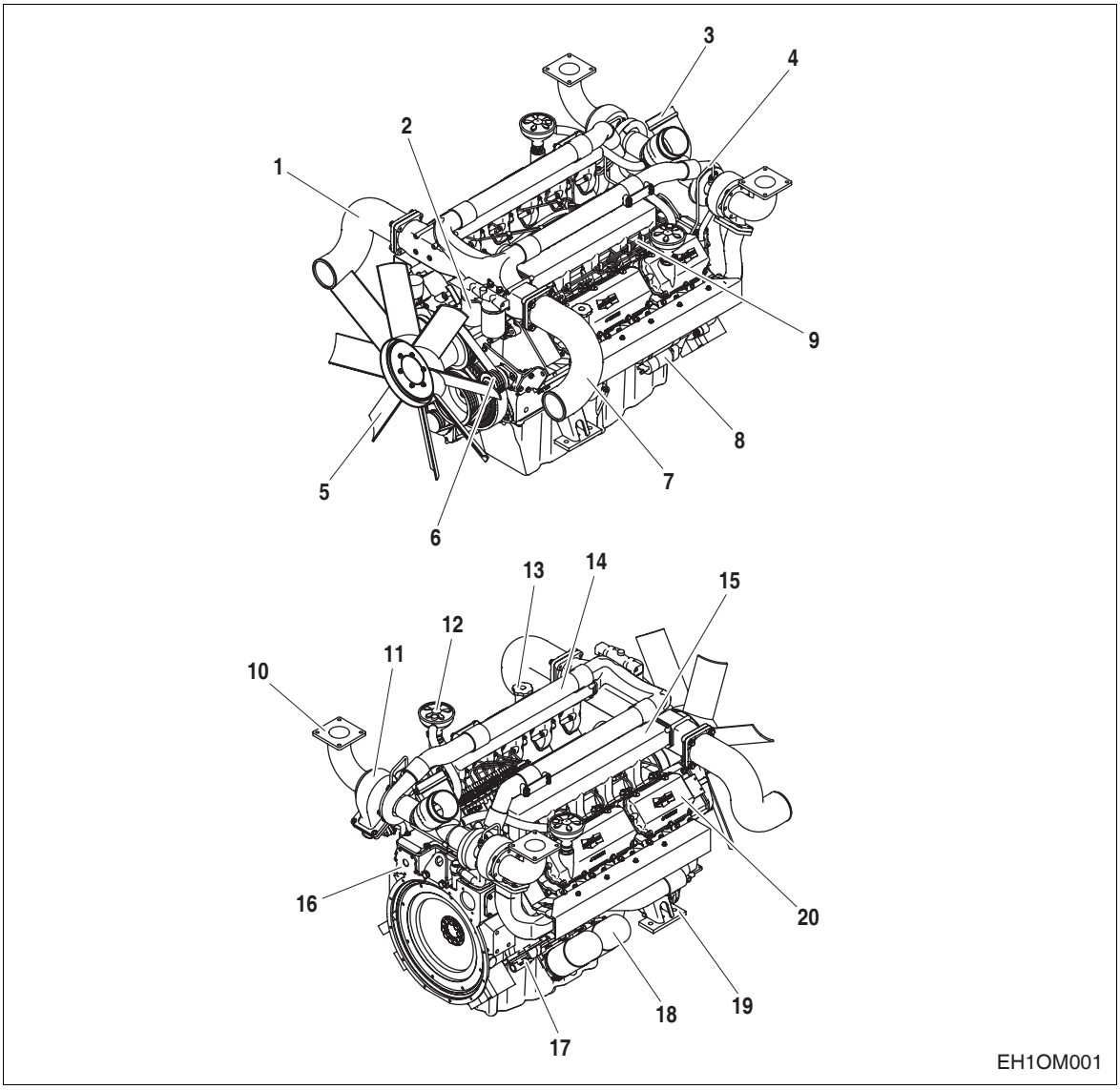
1.4.3. Engine assembly views

1) P158FE



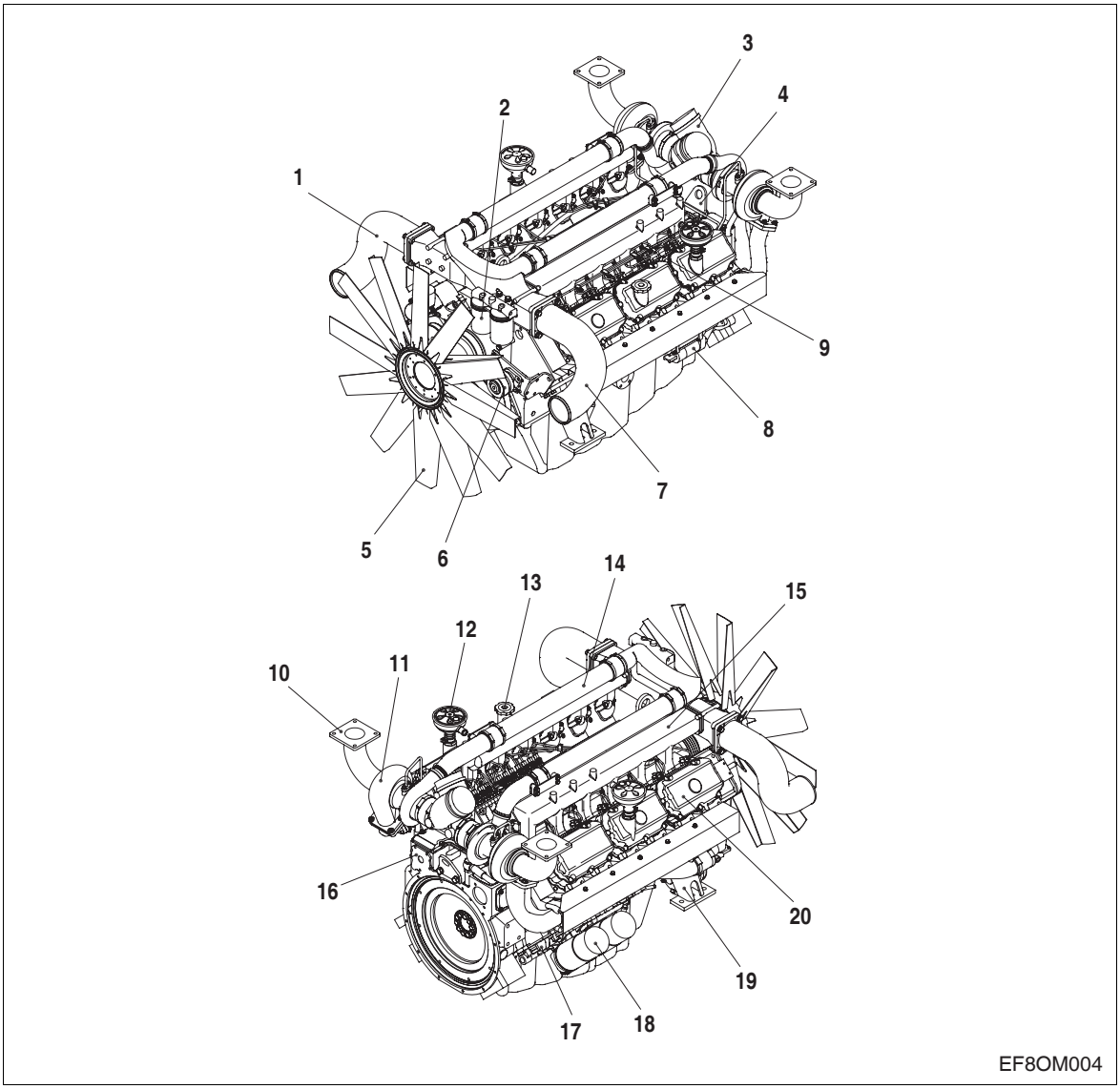
1. Air pipe (Intercooler to intake manifold)
2. Fuel filter
3. Air pipe (Air cleaner to turbocharger)
4. Oil delivery pipe
5. Cooling fan
6. Idle pulley
7. Air pipe (Turbocharger to intercooler)
8. Starter
9. Fuel injection pipe
10. Exhaust elbow
11. Turbo charger
12. Breather
13. Oil filler cap
14. Air pipe
15. Intake manifold
16. Flywheel housing
17. Oil cooler
18. Oil filter
19. Mounting bracket
20. Cylinder head cover

2) P180FE



1. Air pipe (Intercooler to intake manifold)
2. Fuel filter
3. Air pipe (Air cleaner to turbocharger)
4. Oil delivery pipe
5. Cooling fan
6. Idle pulley
7. Air pipe (Turbocharger to intercooler)
8. Starter
9. Fuel injection pipe
10. Exhaust elbow
11. Turbo charger
12. Breather
13. Oil filler cap
14. Air pipe
15. Intake manifold
16. Flywheel housing
17. Oil cooler
18. Oil filter
19. Mounting bracket
20. Cylinder head cover

3) P222FE

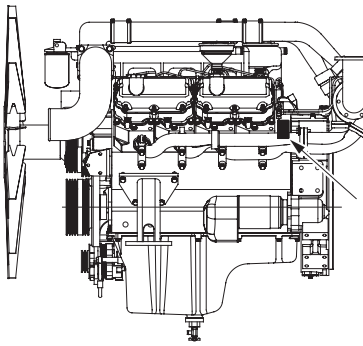


1. Air pipe (Intercooler to intake manifold)
2. Fuel filter
3. Air pipe (Air cleaner to turbocharger)
4. Lifting hook
5. Cooling fan
6. Idle pulley
7. Air pipe (Turbocharger to intercooler)
8. Starter
9. Fuel injection pipe
10. Exhaust elbow
11. Turbo charger
12. Breather
13. Oil filler cap
14. Air pipe
15. Intake manifold
16. Flywheel housing
17. Oil cooler
18. Oil filter
19. Mounting bracket
20. Cylinder head cover

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.

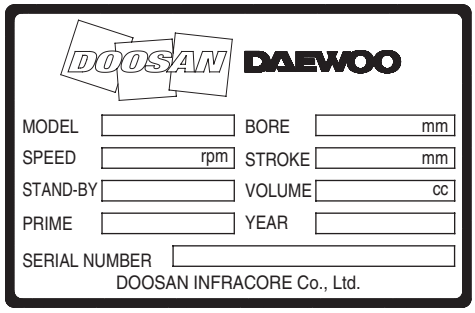


EF8OM005

- **Engine serial No. (example 1 : P158FE)**

EUZOA 7 00001

- Serial no.
- Production years(2007)
- Engine model suffix

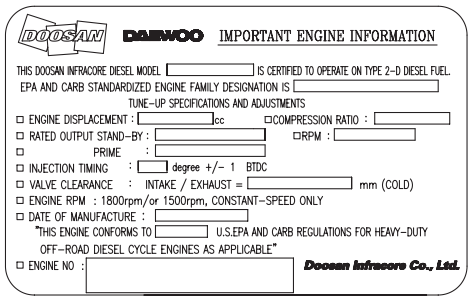


EF8OM006

- **Engine serial No. (example 2 : P180FE)**

EUSOA 7 00001

- Serial no.
- Production years(2007)
- Engine model suffix



EF8OM007

- **Engine serial No. (example 3 : P222FE)**

EUYOB 7 00001

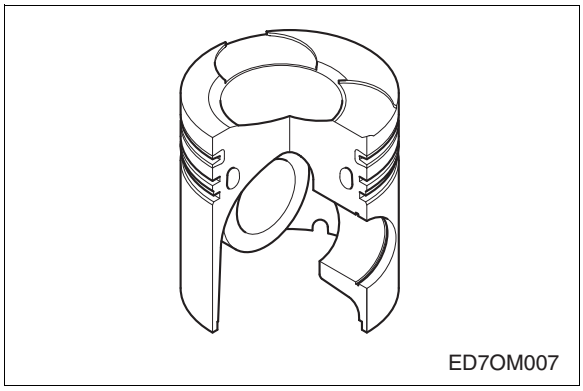
- Serial no.
- Production years(2007)
- Engine model suffix

2.2. Engines Characteristic

The engines **P158FE, P180FE, P222FE** are V-type liquid-cooled 8/10/12-cylinder four-stroke, overhead 4-valves, direct injection engines with turbo-charged and inter-cooler.

2.2.1. OMEGA combustion bowl

- The OMEGA combustion bowl is a unit designed to perform high efficiency, low emission combustion. As the rim around the combustion bowl port of the upper of the piston has been machined in a smaller size than the interior of the combustion bowl, strong swirl is produced in the combustion bowl and strong squish flow makes the fuel be mixed more sufficiently with air.
- Due to the application of **OMEGA** combustion system and optimal utilization of intake and exhaust port configuration within the cylinder head, the **P158FE, P180FE, P222FE** diesel engines discharge very low level of hazardous exhaust gases such as smoke, nitrogen oxide, hydrocarbon, or carbon monoxide and thus ensure high performance and low fuel consumption.


ED7OM007

2.2.2. Engine block

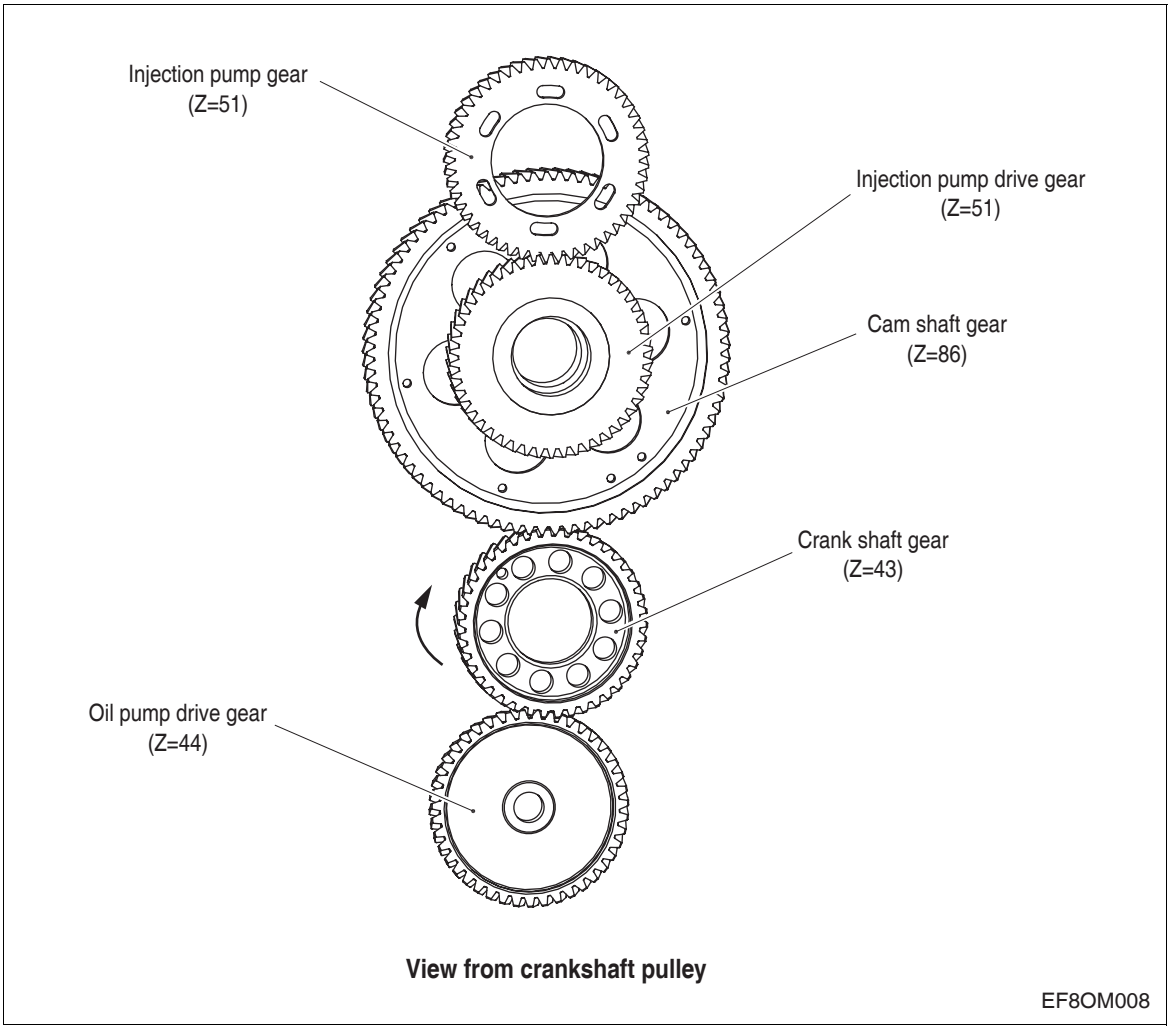
- The cylinder block is a single piece of alloy cast iron. To increase its stiffness, it is extended to a level below the crankshaft center line. The engine has replaceable wet cylinder liners and individual cylinder heads.

2.2.3. Piston / Connecting rod / Crank assembly

- The forged crankshaft has screwed-on the balance weights. Radial seals with replaceable wearing rings on crankshaft and flywheel are provided to 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 steel-backed lead bronze ready-to fit type bearings.

2.2.4. Engine timing

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

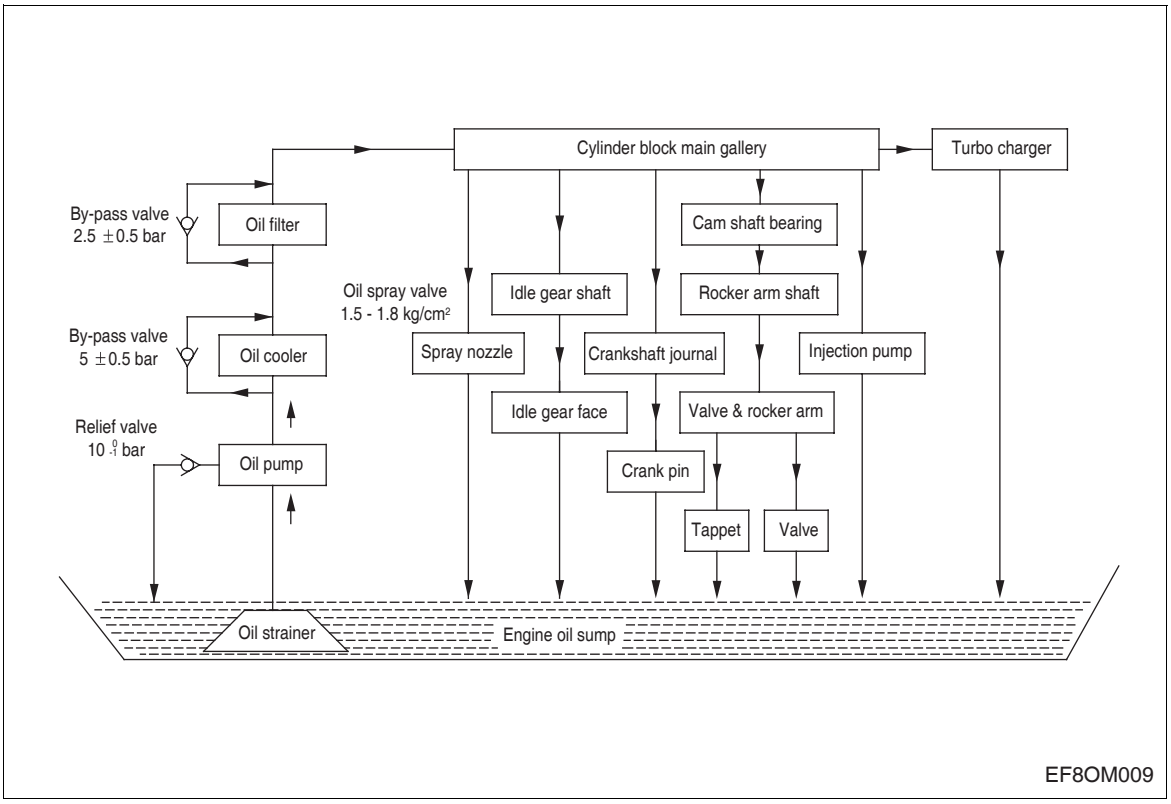


2.2.5. Valves

- The overhead valves are actuated via chilled cast iron tappets, 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. 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.



2.2.7. Recommend of lubricating oil

- Initial factory fill is high quality break-in oil for API service. During the break-in period 50 hours, 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. marks on the dipstick. The safe range between the marks represents approximately 3 liters. To obtain the best engine performance and engine life, grade of engine oil is recommended. Engine oils are specified by API service, letter designations and SAE viscosity numbers.

- Engine oil should be changed at the specified intervals. Elements in the oil filter should be changed simultaneously.

First oil change	After 50hr operation
P158FE P180FE P222FE	every 250 hours

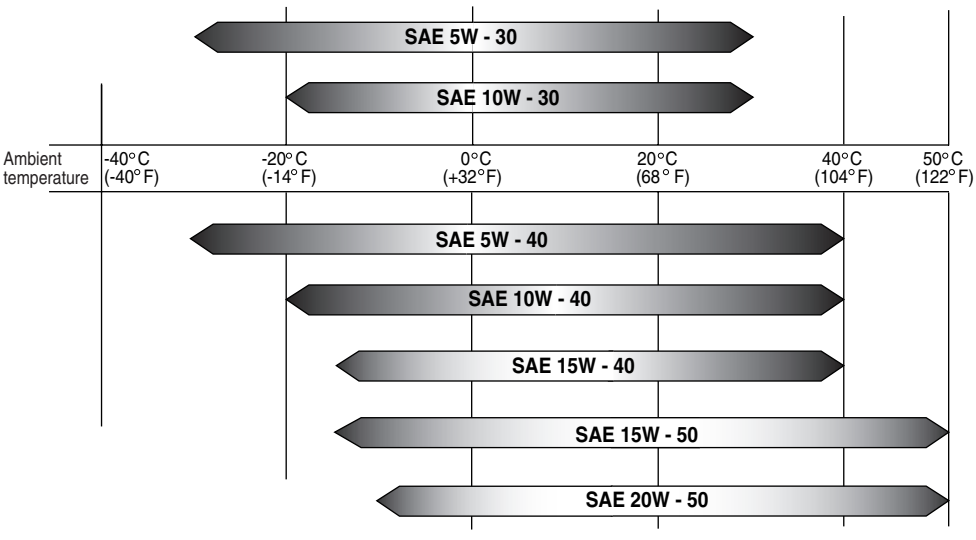
- The following oils are also recommended

Engine model	Recommend oil	
	SAE No.	API No.
P158FE P180FE P222FE	SAE15W40 SAE10W40	ACEA-E2 or ACEA-E3 (API CH-4)

* If long oil change intervals are to be used, ACEA-E3 oil must be used.

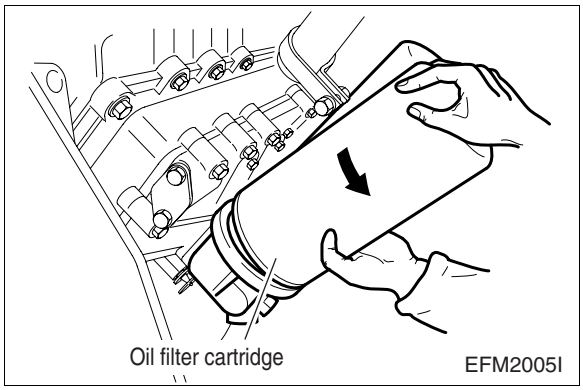
- Engine oil capacity

Engine oil capacity			
Engine model	in Oil pan		Total (lit)
	Max. (lit)	Min. (lit)	
P158FE	28	26	31
P180FE	35	28	38
P222FE	40	33	43



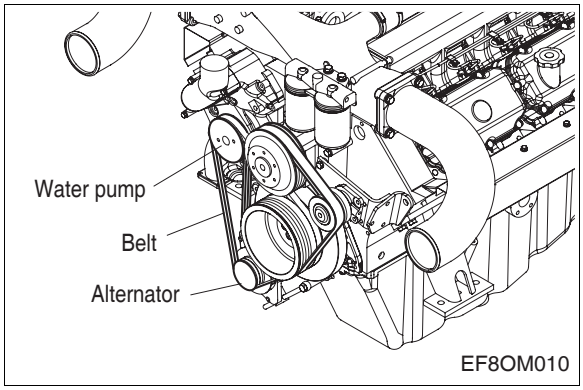
2.2.8. Oil filter

- 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.

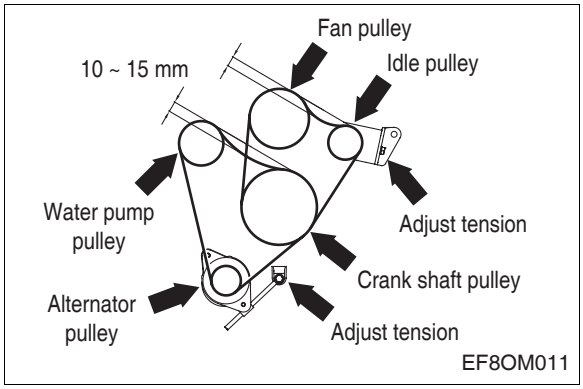


2.2.9. Check and adjust of V-belt tension

- Use a fan belt of genuine part and replace if damaged, frayed or deteriorated.
- Check the fan belt for belt tension, inspect suitability for specified for dimensions.

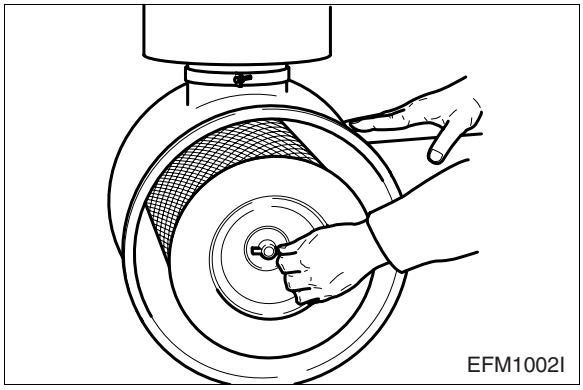


- By the finger-pressure the belt is pressed by 10 mm ~ 15 mm between the fan pulley and the alternator pulley in normal condition.



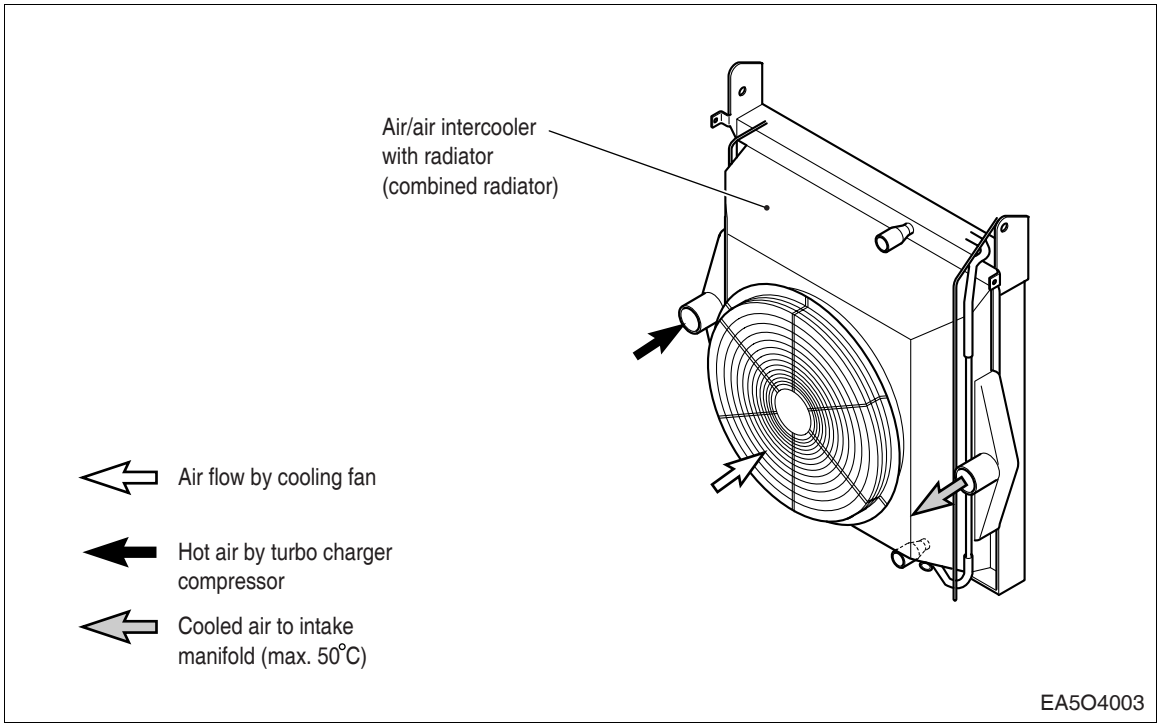
2.2.10. Air cleaner

- 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.



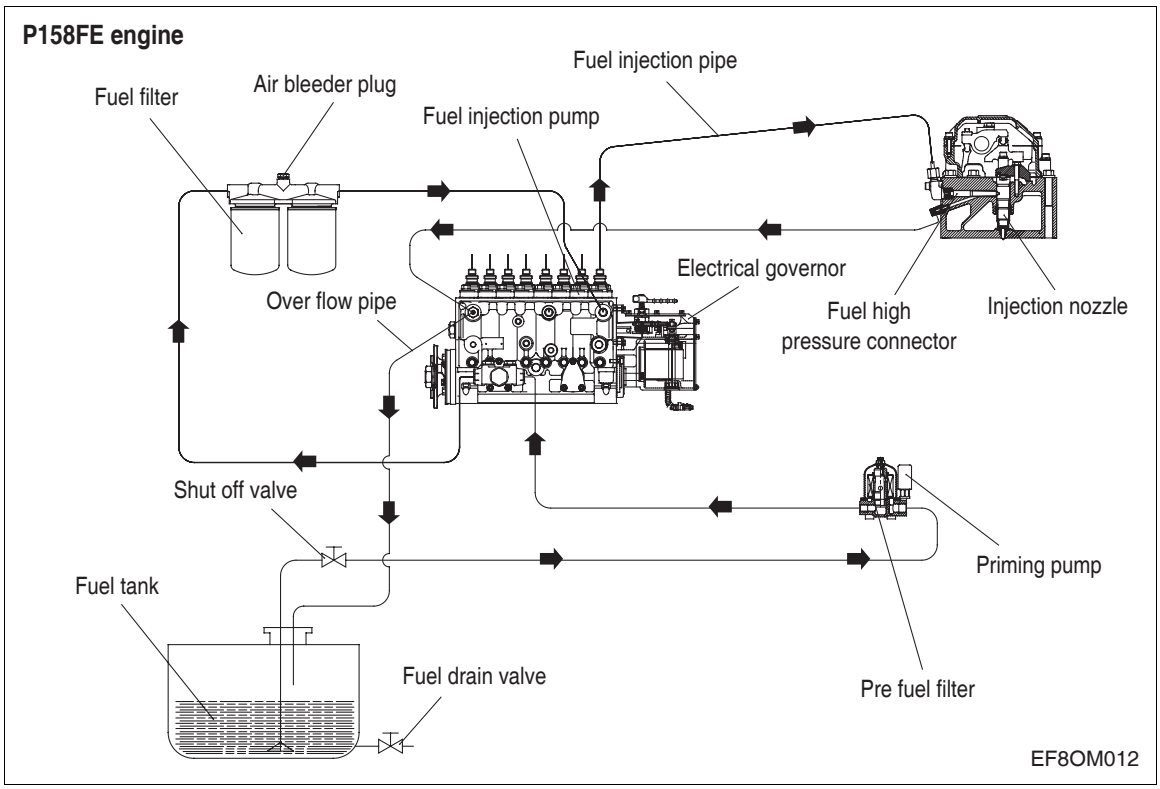
2.2.11. Intercooler

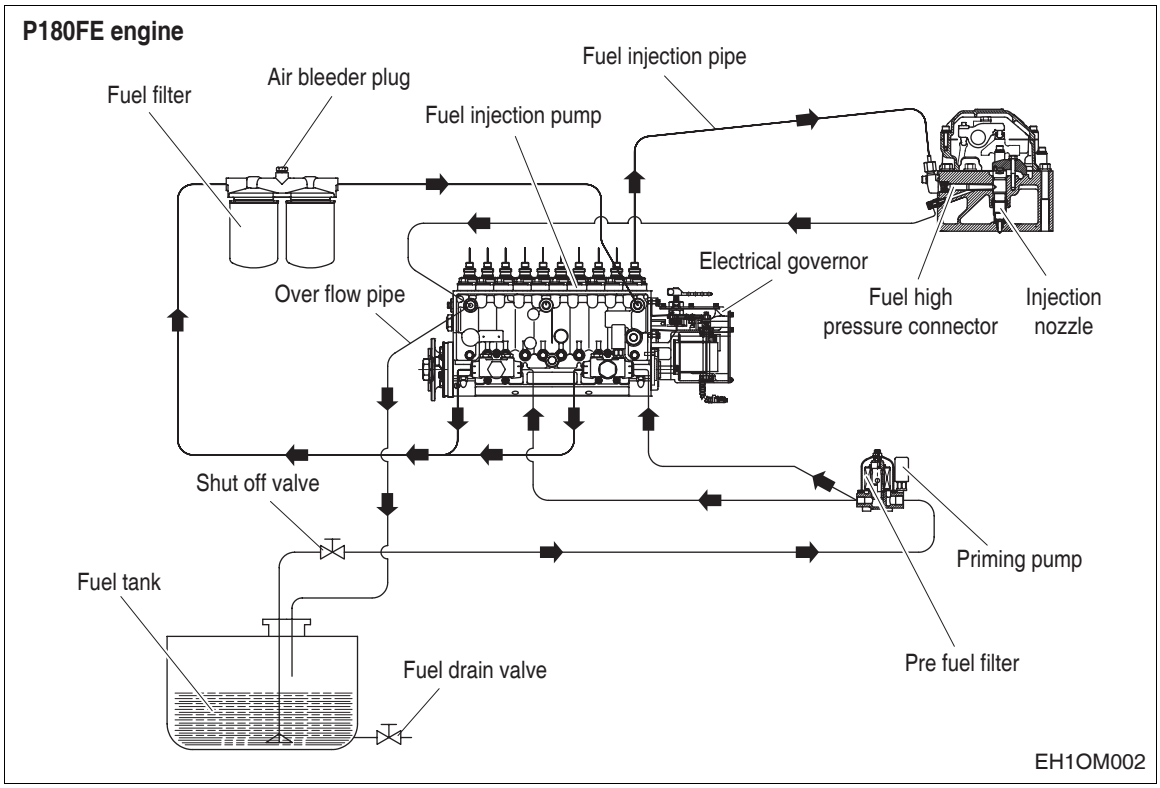
- The intercooler is air to air type and has a large cooling fan capacity. The intercooler life and performance depends on the intake air condition greatly. Fouled air pollutes and clogs the air fins of intercooler. As a result of this, the engine output is decreased and engine malfunction is occurred.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

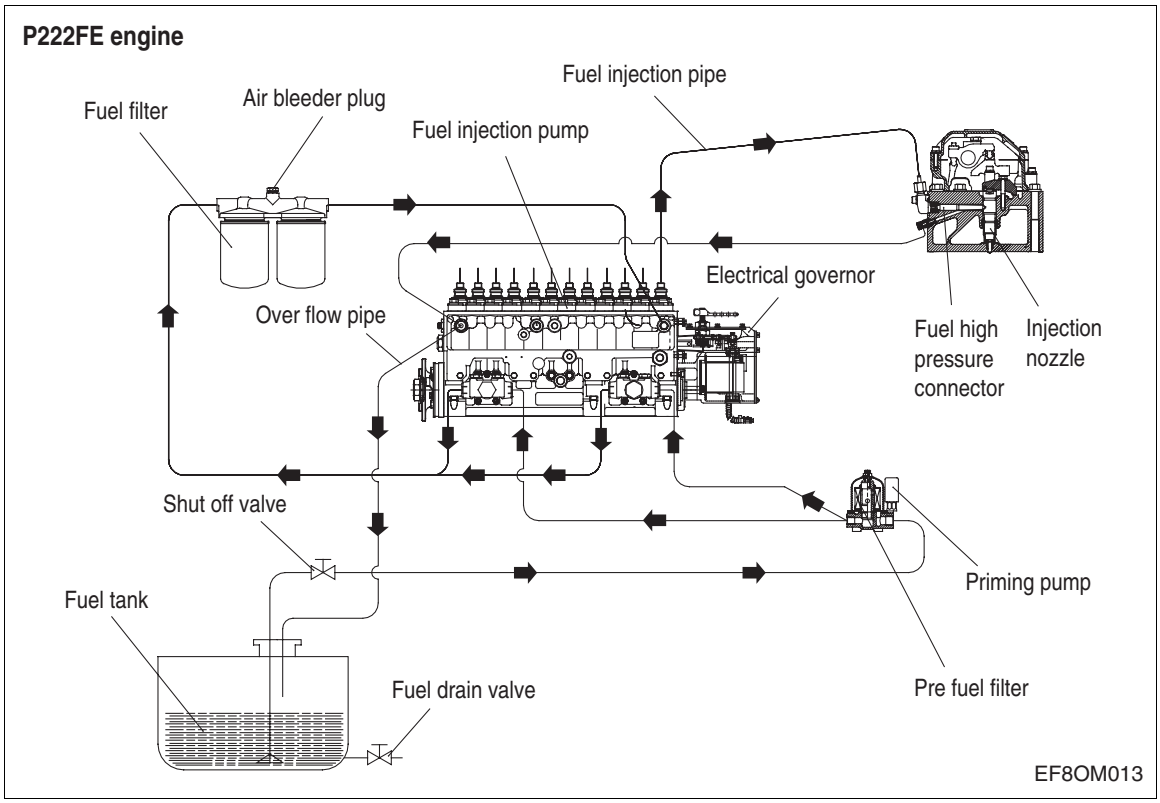


2.2.12. Fuel system

- 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.

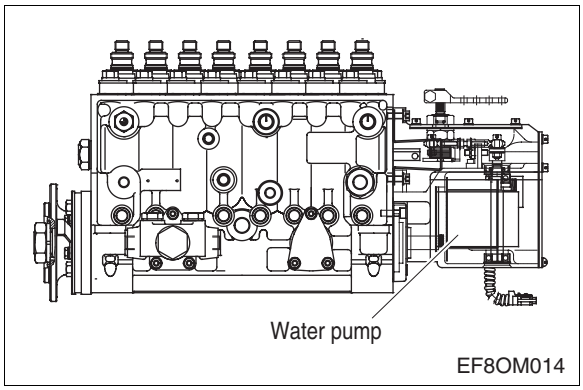






2.2.13. Injection pump

- The in-line injection pump is driven via gears from the crankshaft. It is connected to the force-feed lubricating system of the engine and consequently maintenance-free. The electrical governor flange-mounted on the pump casing is a variable range governor designed to keep the speed set by the control electrical constant under conditions of varying load.
- No alterations must be made to the injection pump. It the lead seal is damage the warranty on the engine will become null and avoid.



- **Faults**

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

- **Bleeding the fuel system**

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

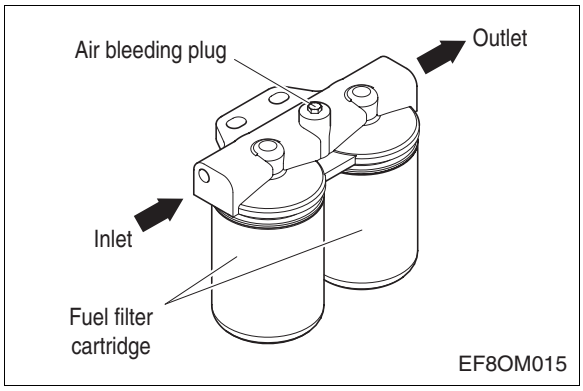
  The suction chamber of the injection pump is continuously bled via the relief valve during operation. If the suction chamber is completely empty, e.g., when fitting a new pump, filling and bleeding it is by actuating the manual primer.

- **Fuel lift pump**

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

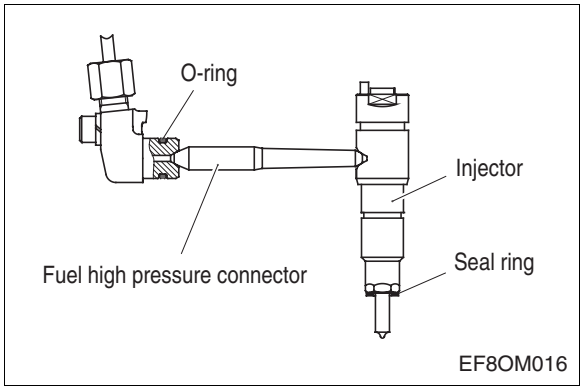
2.2.14. Fuel filters

- Before entering the suction chamber of the injection pump, the fuel is cleaned in a strainer of fuel feed pump and a fuel filter.
- The fuel filter should be replaced at every 1,250 hours.



2.2.15. Injector and high pressure connector

- Be careful to mix the foreign matter into the injector and inside of the connector for connecting the high pressure at disassembly and check.
- O-ring and cupper washer should be changed with new one at reassembly.
- Assemble after coat the oil on the O-ring.



2.2.16. Fuel requirements

- DOOSAN diesel engines were designed to use Number 2-D diesel fuel or equivalent that meets specification ASTM D (Grade Low Sulfur). For maximum fuel economy, Number 2-D fuel whenever possible. When temperatures are below -7 °C, use Number 1-D fuel. If Number 1-D fuel is not available, the mixture of one kerosene to two gallons of Number 2-D fuel can be used. Once kerosene has been added, the engine should be run for several minutes to mix the fuel.

2.2.17. How to select fuel oil

- Fuel quality is an important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. DOOSAN engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D975 (grades 1-D and 2-D : Grade Low Sulfur) have provided satisfactory performance.
- The ASTM 975 specification, however, does not in itself adequately define the fuel characteristics needed for assurance of fuel quality.
- The properties listed in the fuel oil selection chart below have provided optimum engine performance. Grade 2-D fuel is normally available for generator service. Grade 1-D fuel should not be used in pleasure craft engines, except in an emergency.

- **Fuel oil selection chart**

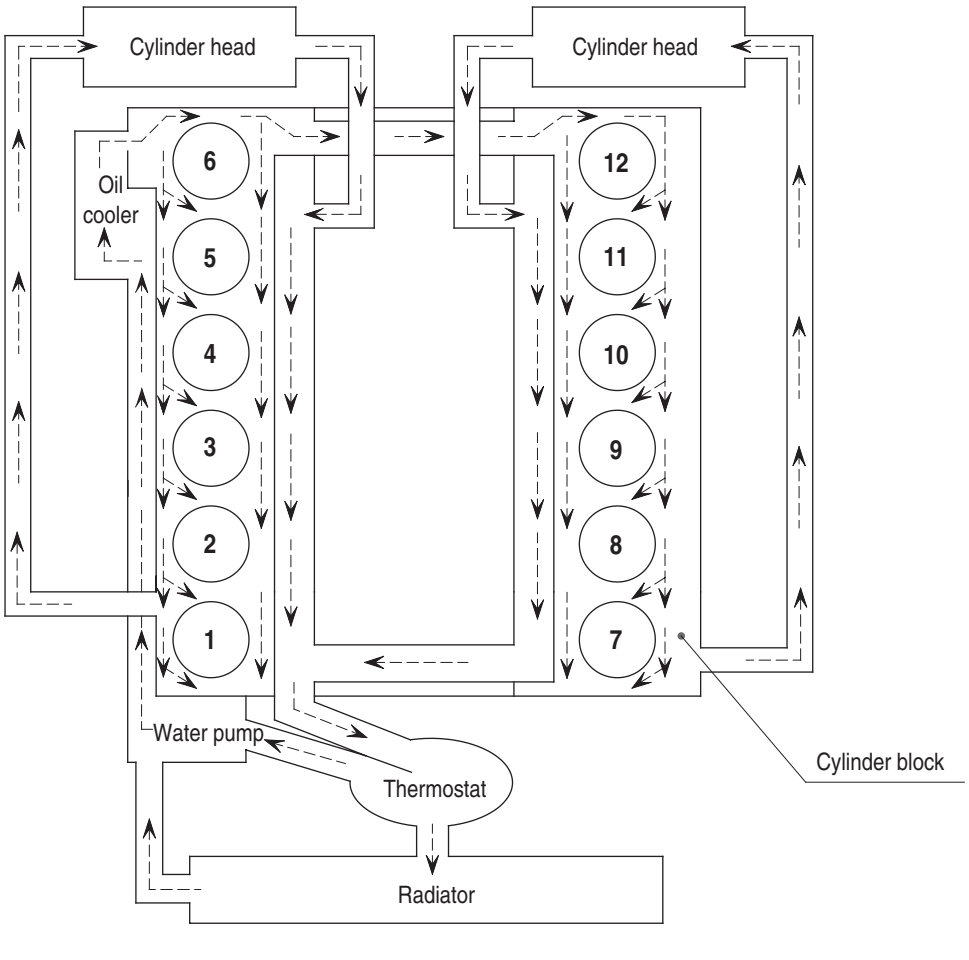
Fuel classification	Unit	DIN EN 590
Cetane number	–	≥ 51
Cetane index	–	≥ 46
Density @ 15 °C	kg/m^3	820 ~ 845
Poly aromatic hydrocarbon	% (m/m)	≤ 11
Sulfur content	mg/kg	≤ 50
Flash point	°C	≥ 55
Ash content	% (m/m)	≤ 0.01
Water content	mg/kg	≤ 200
Particulate matter content	mg/kg	≤ 24
Copper corrosion 50 °C, 3h	grade	1
Oxidation stability	g/m^3	≤ 25
Lubricity (wsd 1.4 @ 60 °C)	g/m^3	≤ 460
Viscosity (40 °C)	mm^2/s	2.0 ~ 4.5
Distillation (95 %)	°C	≤ 360

Note:

The cloud point should be 6 °C below the lowest expected fuel temperature to prevent clogging of fuel fitters by crystals.

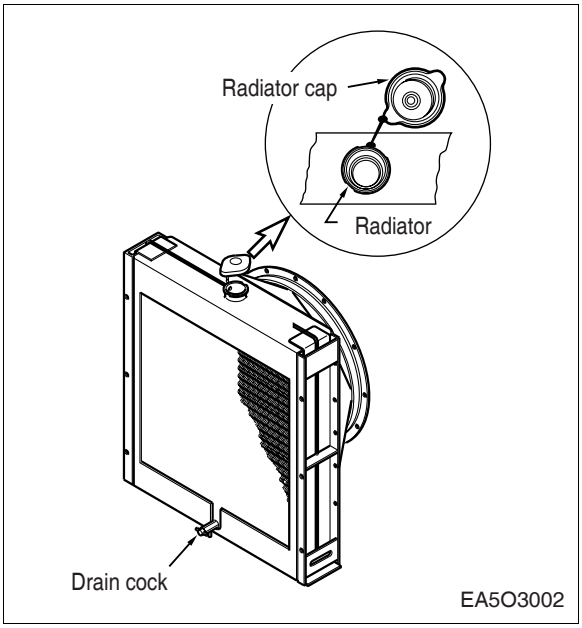
2.2.18. Cooling system

- 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.



2.2.19. Coolant pressure cap

- Check the pressure valve opening pressure using an expansion tank cap tester.
- Replace the filler cap assembly if the measured valve does not reach the specified limit. (pressure valve opening pressure : 0.9 kg/cm^2)

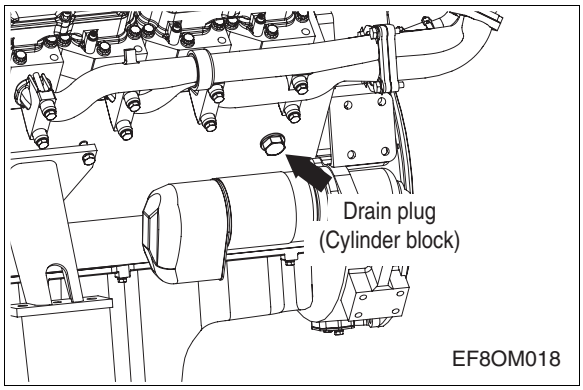


NOTE :

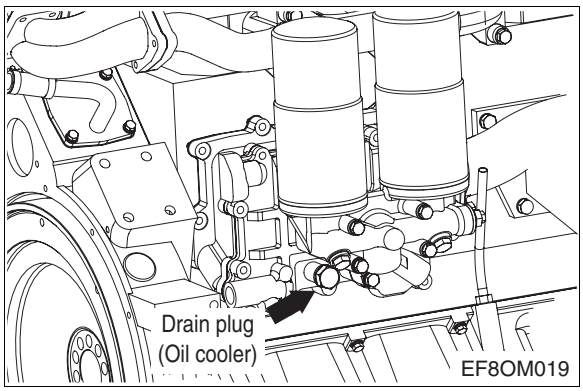
Because it is dangerous to open the pressure cap quickly when coolant is hot, after lowering the inside pressure of the tank by slow-opening at first open it fully.

2.2.20. Drain of cooling water

- Open the radiator cap and discharge the cooling water in radiator through a drain cock.
- The cooling water in engine main body is discharged through the drain plug located at the side of the engine cylinder block.



- Remove the drain plug of oil cooler and discharge the cooling water in the oil cooler. Pay particular attention to the discharge of the cooling water in the oil cooler to prevent the oil cooler from freezing and failure in winter.



2.2.21. Cooling water

- We recommend the coolant for engines should be mixture of fresh water and additional agent (33 ~ 50 % anti-freeze and 3 ~ 5 % anti-corrosion agent).
- Check the quantity of anti-freeze every 600 hours. From time to time, refill the anti-freeze as much as required.

NOTE :

Suitable mixture of anti-freeze and-corrosion agent can protect the engine corrosion from deteriorating and raises a boiling point, but by using unsuitable mixture engine components like water pump impeller and water jacket of cylinder block may be occurred a malfunction by any bad corrosion damage or cavitation.

- You can check the quantity of anti-freeze and anti-corrosion agent by using a FLEETGUARD test kit simply as follow.
  (Fleetguard CC2602M or DOOSAN 60.99901-0038)

- How to use the cooling water test kit
  (1) When the cooling water temperature 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) Shake the bottle filled with sample coolant to mix well and take out one strip from bottle of the test kit. Then dip the strip into coolant sample for 3 ~ 5 seconds, take it out and shake it briskly to remove excess liquid.

NOTE:

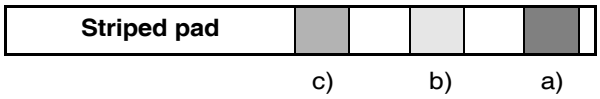
Do not touch the pads on the end of the strip. Discard the kit if unused strips have turned brown for the nitrite test pad.

(3) Wait for 45 seconds until color of the dipping striped pad is turned into any colors and then compare and record the compared results with the color figure as following order.

NOTE:

All three readings must be completed no later than 75 seconds after dipping striped pad rapidly. Do not touch the striped pad with fingers.

- **How to judge the strip**



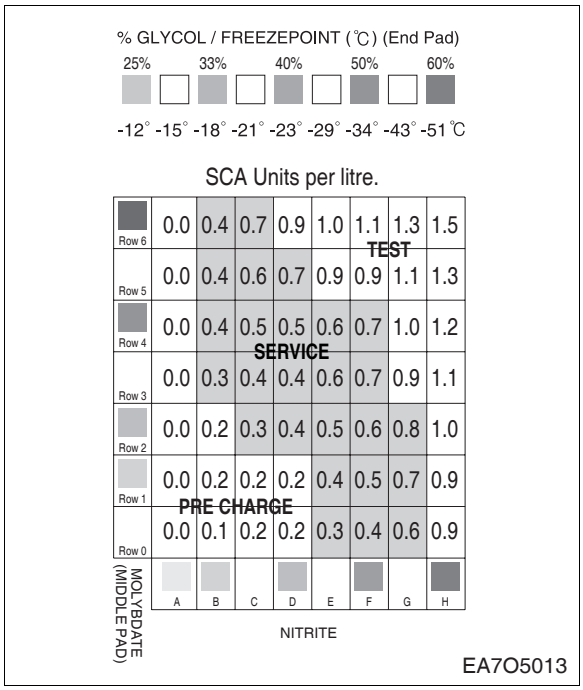
a) Compare FREEZEPOINT (end pad) to chart and record result.

b) Next compare MOLYBDATE (middle pad) to chart and record result.

c) Finally compare NITRITE test to chart and record result.

(4) Compare the end pad “a)” color of the strip with color block of a row at the upper part of the standard color chart (bellow of the letter “GLYCOL/ FREEZEPOINT”). Same color in the block of the row means the content of anti-freeze in the coolant. (Normal range is between 33 % and 50%)

(5) Compare the middle pad “b)” color of the strip with the color that the column block color of MOLYBDATE at the left side of the table intersects the row block color of NITRITE at the bottom (pad “c)” color of the strip) on the table “SCA Units per Litre”.
(Normal range of “SCA Units per Litre” is between 0.3 and 0.8 : “green color area”)



NOTE:
During the comparison, if uncertain about color match, pick the lower numbered block. (example : if the color of NITRITE pad is between standard color “D” and “F”, then use column E)

(6) If the value of “SCA Units per Litre” is less than 0.3, refill the DCA4 liquid (anti-corrosion agent) a little, but larger than 0.8, drain some amount of engine coolant and replenish the fresh water instead. The content of the anti-freeze and anti-corrosion agent can be regulated by this way.

NOTE:
Every year coolant must be replaced. It is essential the coolant should be mixture of fresh water, proper anti-freeze and anti-corrosion agent.

- **Amount of Anti-freeze**

  The anti-freeze, 33 ~ 50 % of the whole coolant, is always to be used to prevent the cooling system from the corrosion. And in the winter the amount of anti-freeze shown in the following table should be used in accordance with the ambient temperature.

  As the individual freezing points corresponding to the proportions of antifreeze in the table are subject to change slightly according to the kind of antifreeze, you must follow the specifications provided by the antifreeze manufacturer.

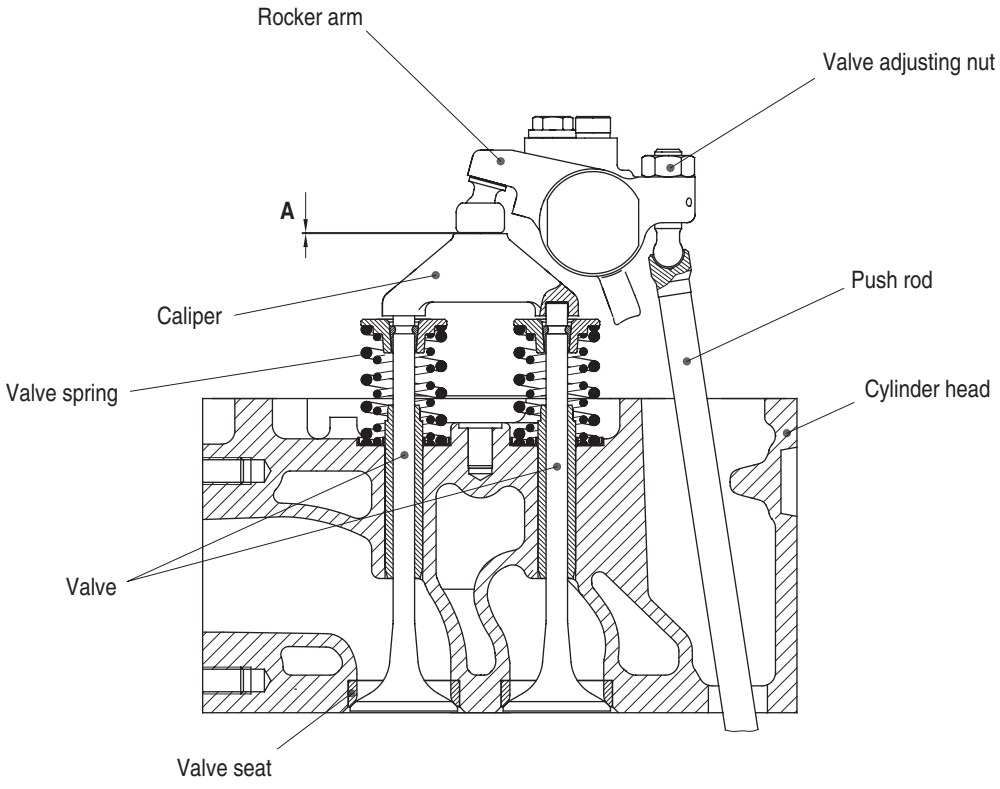
Ambient Temperature (°C)	Cooling water (%)	Anti-freeze (%)
Over –10	85	15
-10	80	20
-15	73	27
-20	67	33
-25	60	40
-30	56	44
-40	50	50

Any coolant loss due to engine operation must be replenished. But adding fresh water for coolant tends to lower the content of anti-freeze. Always replenish the coolant with a mixture of antifreeze and water, and keep the proper the content of anti-freeze (33 ~ 50 %).

2.2.22. Valve clearance adjust procedure

- After letting the #1 cylinder's piston come at the compression top dead center by turning the crankshaft, adjust the valve clearances.
- Loosen the lock nuts of rocker arm adjusting screws and push the feeler gauge of specified value between a rocker arm and a caliper, and then adjust the clearance with adjusting screw respectively and tighten with the lock nut.
- As for the valve clearance, adjust it when in cold, as follows.

Model	Intake valve	Exhaust valve
P158FE P180FE P222FE	0.4 mm	0.5 mm



Intake & exhaust valve adjusting

EF8OM020

- **Adjusting sequence of valve clearance**

  This is a precision method, but it takes more time.

  * 8 Cylinder Engine (P158FE)

Valve overlapping on cylinder (Intake & Exhaust valve)	1	5	7	2	6	3	4	8
Adjusting valves on cylinder (Intake & Exhaust valve)	6	3	4	8	1	5	7	2

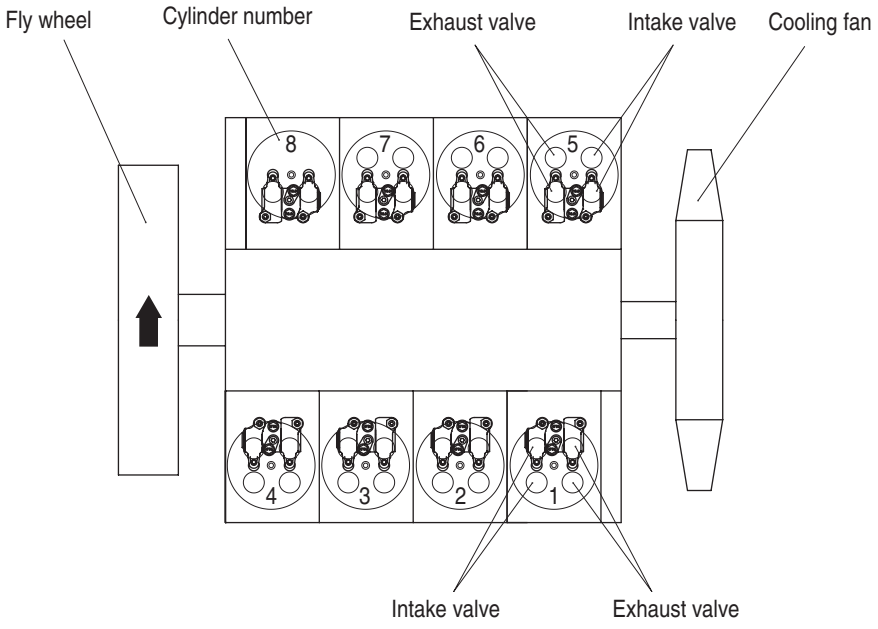
  * 10 Cylinder Engine (P180FE)

Valve overlapping on cylinder (Intake & Exhaust valve)	1	6	5	10	2	7	3	8	4	9
Adjusting valves on cylinder (Intake & Exhaust valve)	7	3	8	4	9	1	6	5	10	2

  * 12 Cylinder Engine (P222FE)

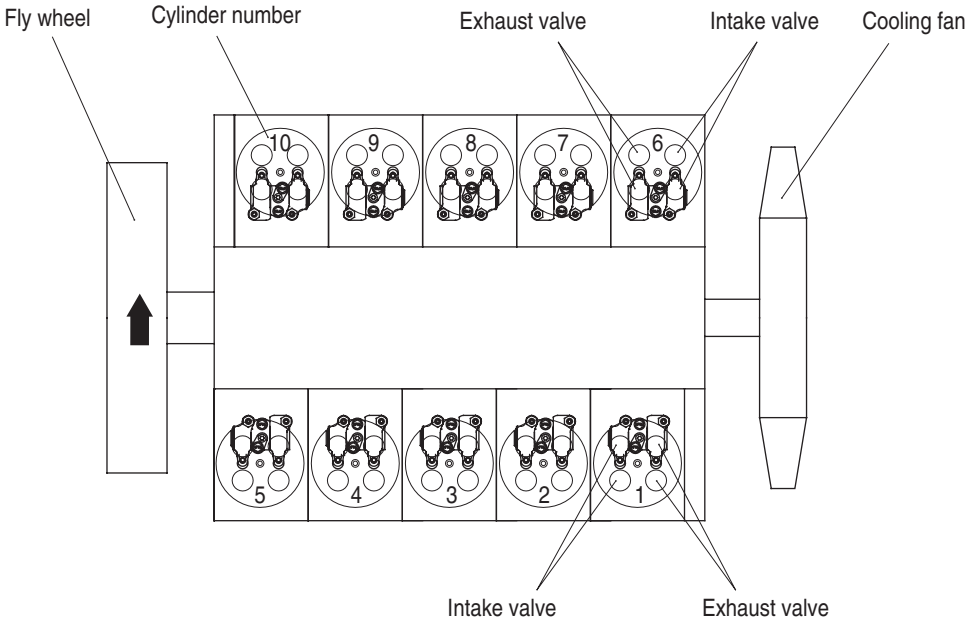
Valve overlapping on cylinder (Intake & Exhaust valve)	1	12	5	8	3	10	6	7	2	11	4	9
Adjusting valves on cylinder (Intake & Exhaust valve)	6	7	2	11	4	9	1	12	5	8	3	10

- No. 1 cylinder is located at the side where cooling water pump was installed.



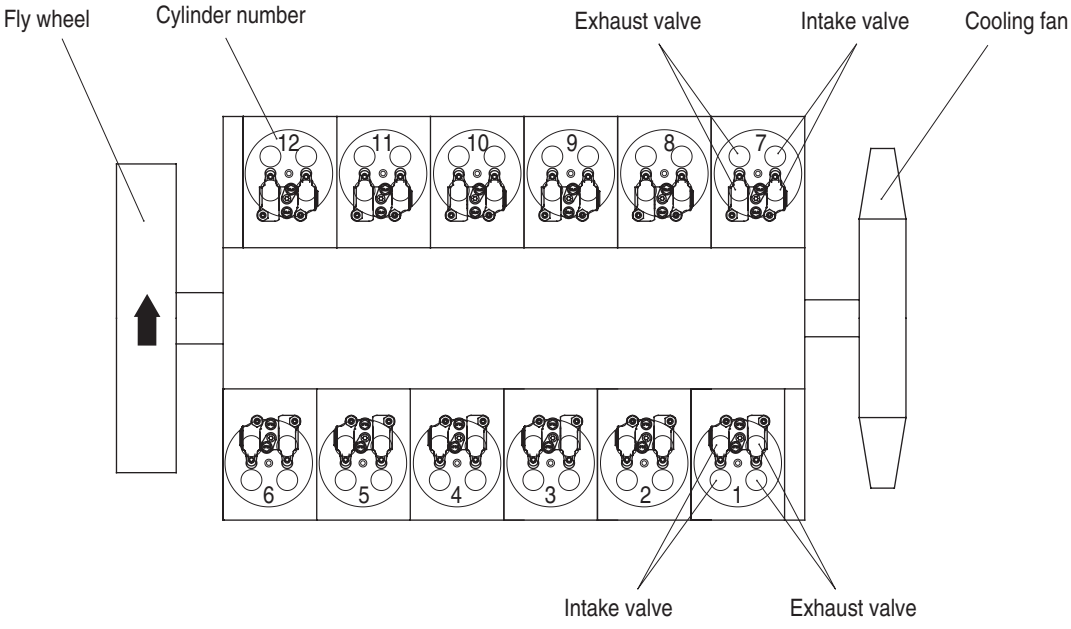
8 Cylinder engine

EF8OM021



10 Cylinder engine

EF8OM022

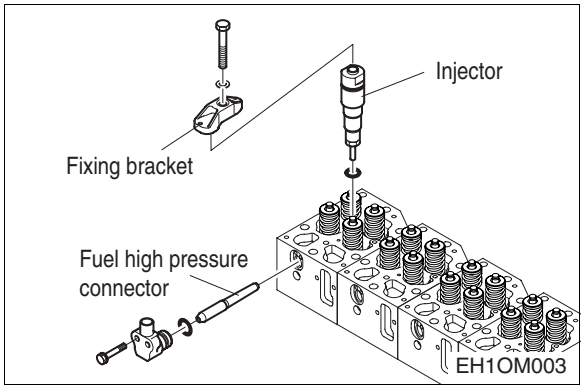


12 Cylinder engine

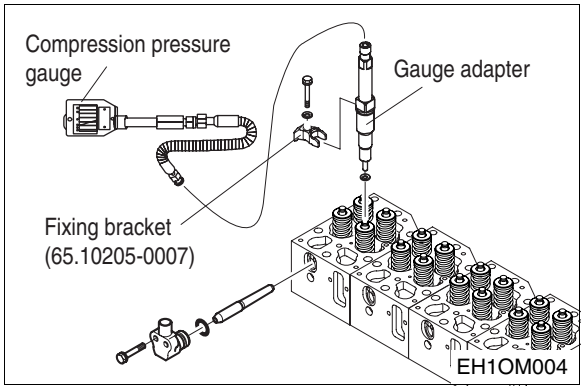
EF8OM023

2.2.23. Cylinder compression pressure

- Stop the engine after warming up.
- Remove injector fixing bracket and high pressure connector flange and then take out the fuel high pressure connector and injector.
- Install the special tool (compression gauge adapter) at the injector hole, and connect the compression pressure gauge there.



- Compression pressure gauge adapter : EF.110-119
- Fixing bracket : 65.10205-0007
- Measure the compression pressure by the starting motor.

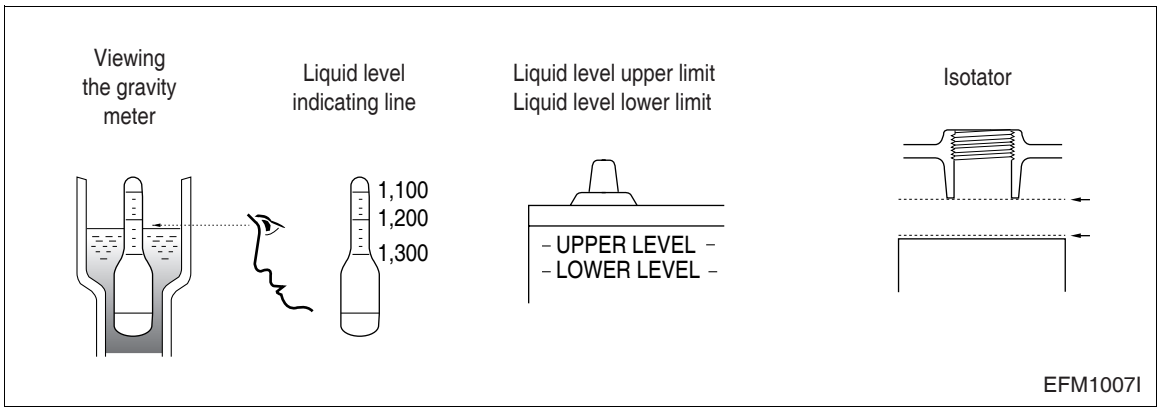


Standard value	28 kg/cm^2 over
Limit value	24 kg/cm^2
Difference between each cylinder	Within ± 10 %

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

2.2.24. Battery

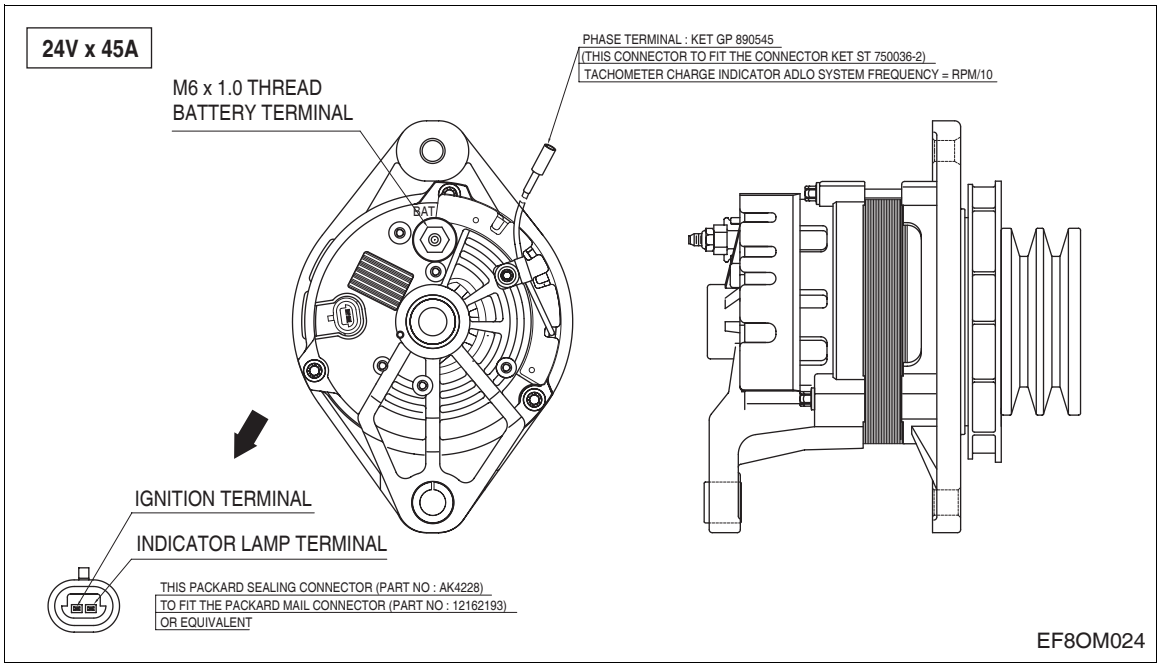
- Inspect for any leakage of electrolytic solution owing to battery crack, and replace the battery in case of poor condition.
- Inspect for amount of electrolytic solution, and replenish if insufficient.
- Measure the gravity of electrolytic solution, if less than specified value (1.12 ~ 1.28), replenish.



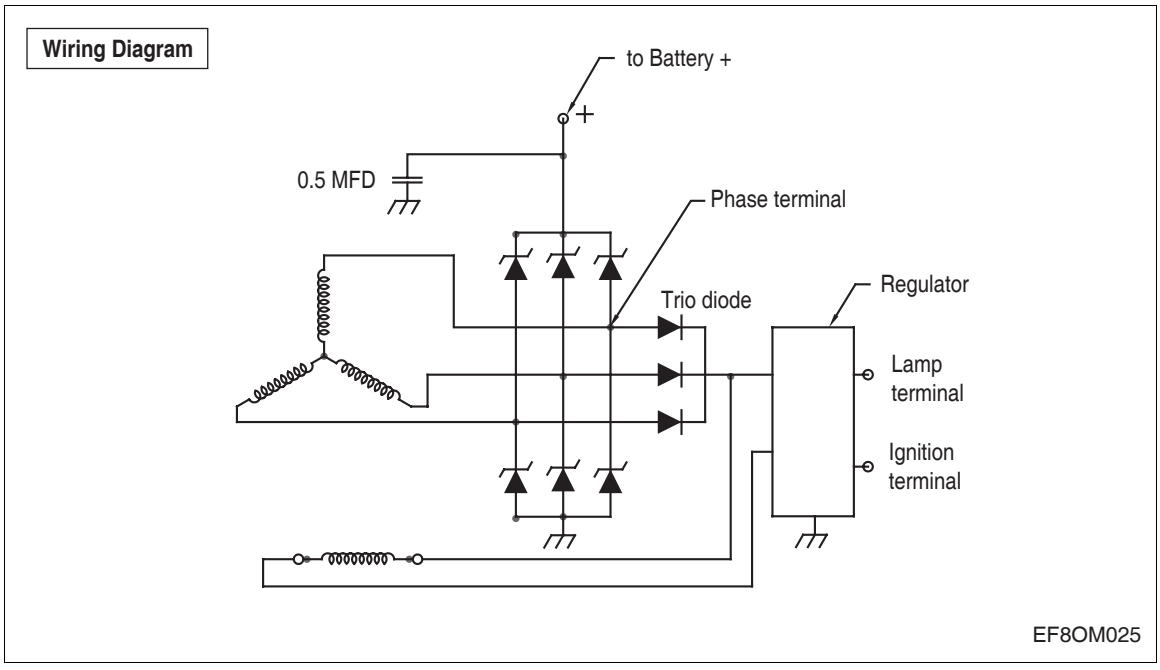
2.2.25. Alternator

- **Alternator (24V x 45A)**

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.



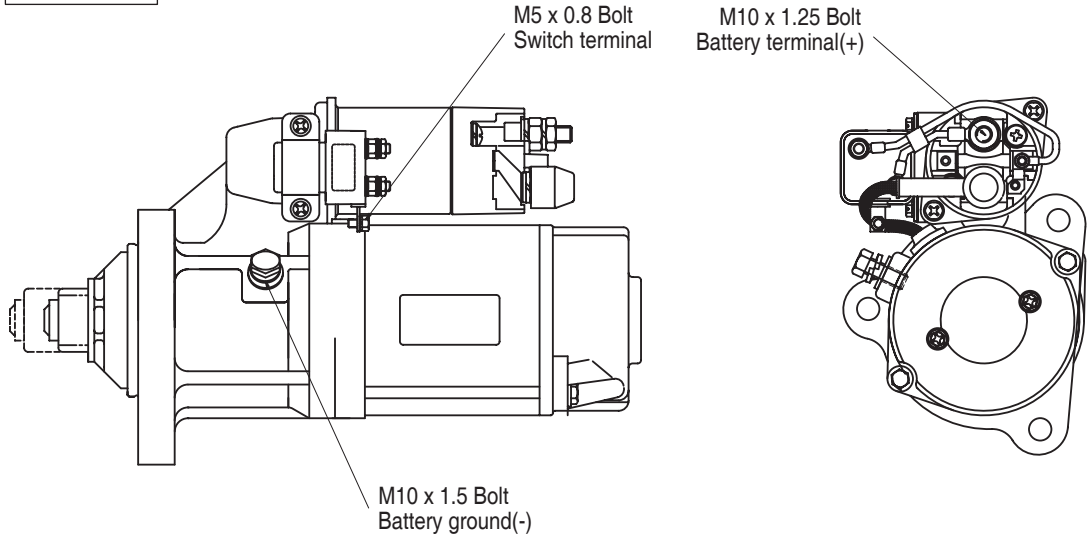
- The alternator is maintenance-free, nevertheless, it must be protected against dust and, above all, against moisture and water.



Operate the alternator according to the instructions given in the chapter.

2.2.26. Starting motor

- The sliding-gear starter motor is flanged to the rear of the flywheel housing on the left-hand side. As parts 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.



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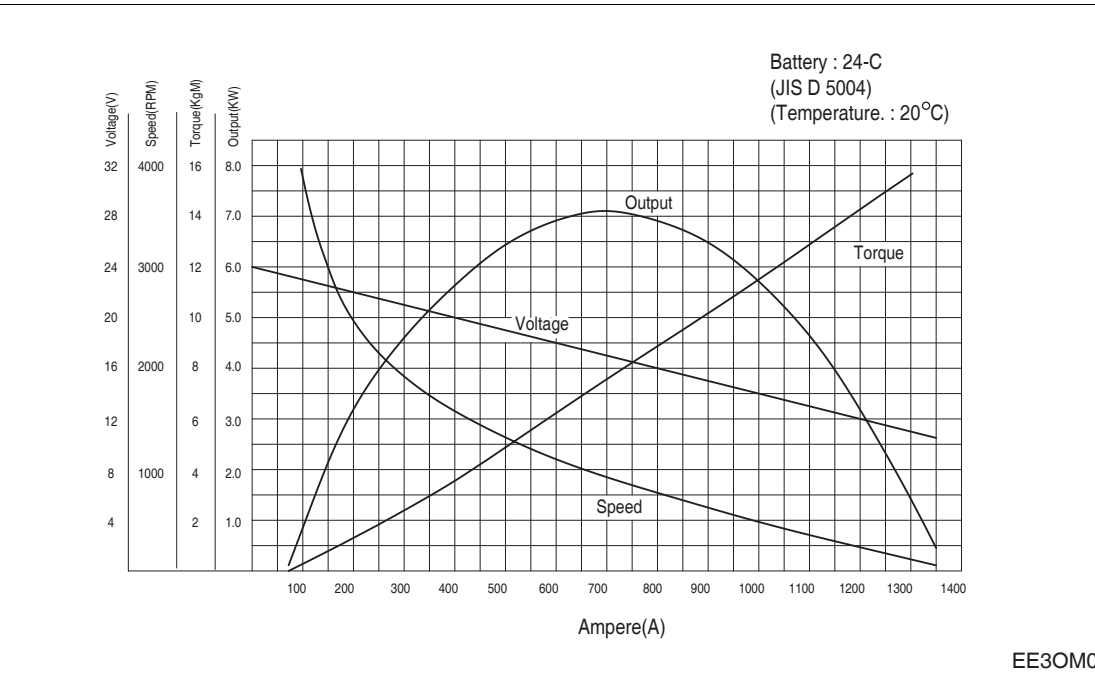
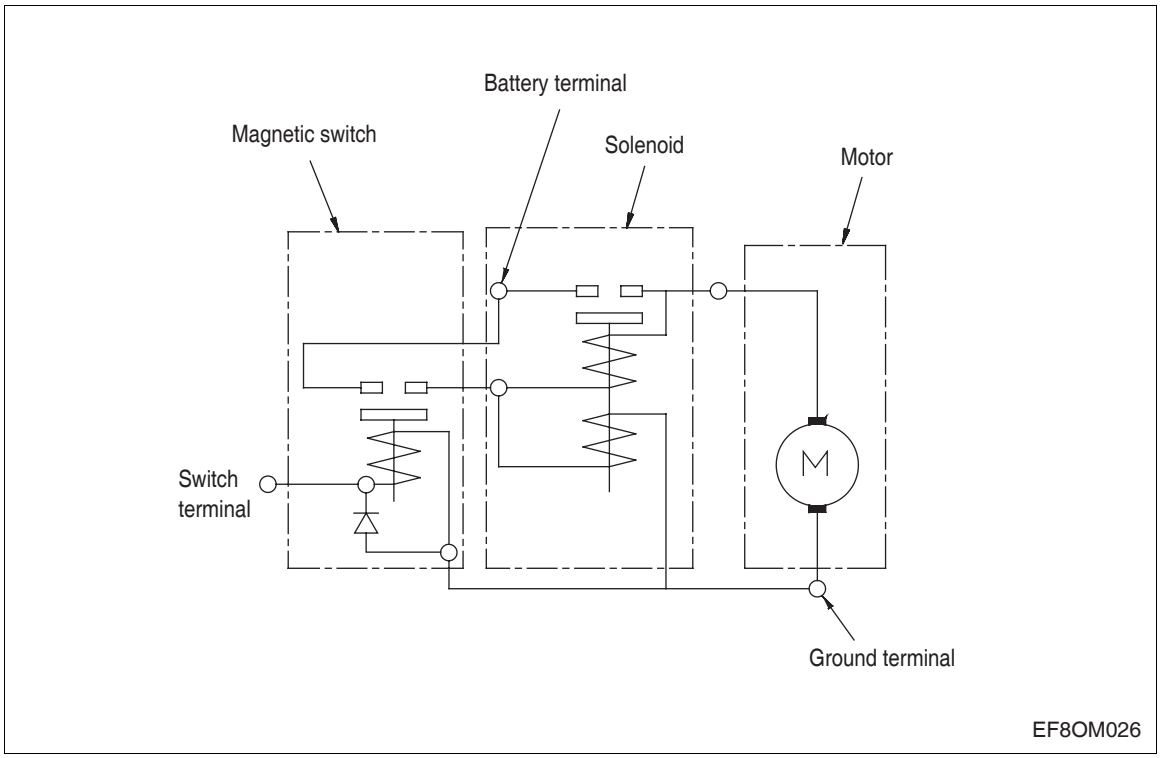


EE3OM022

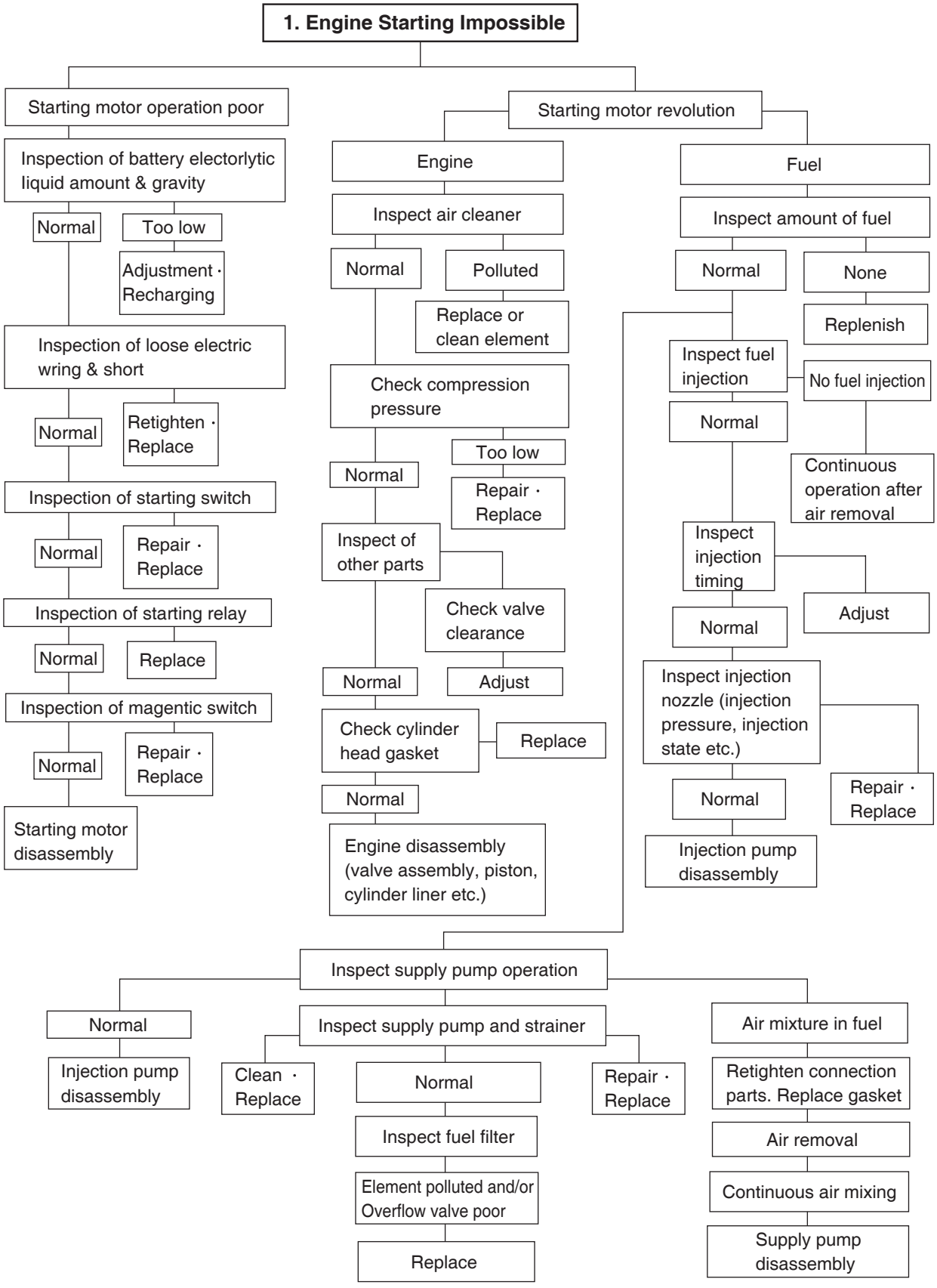
IMPORTANT :

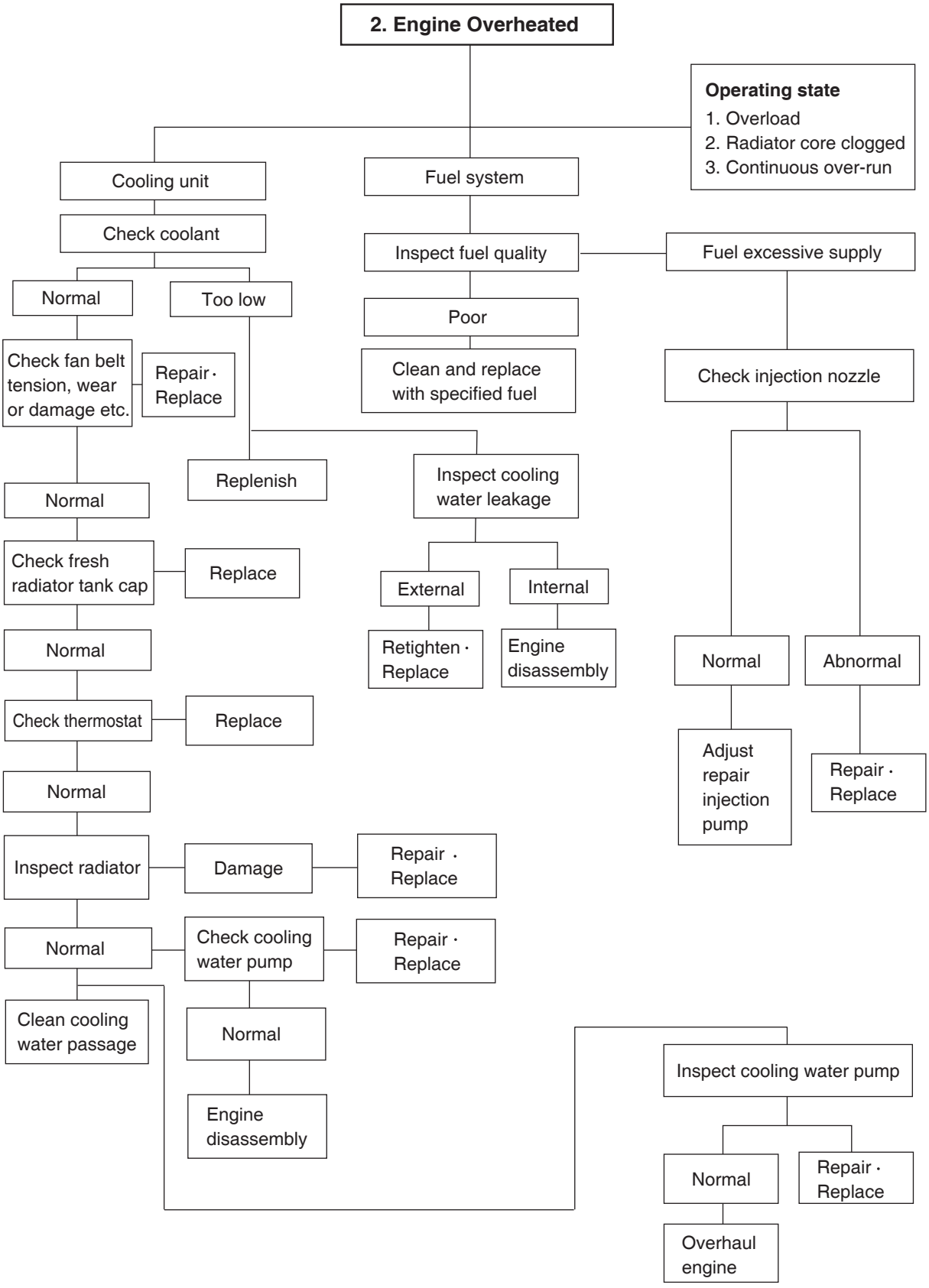
Always disconnect the battery earth cable before starting work on the electrical system. Connect up the earth cable last, as there is otherwise a risk of short-circuits.

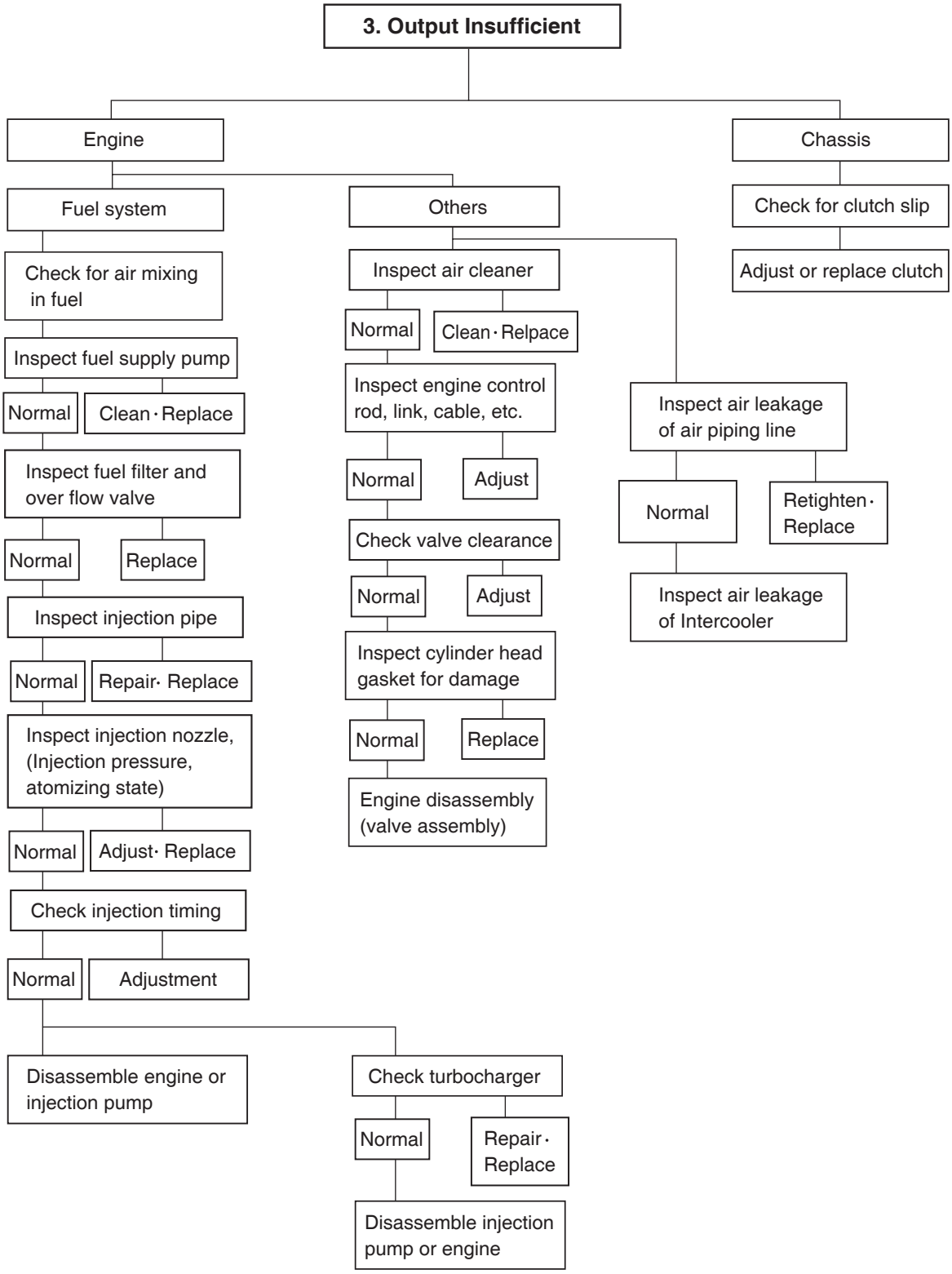

Battery terminal
Magnetic switch
Solenoid
Motor
Switch
terminal
M
Ground terminal
EF8OM026

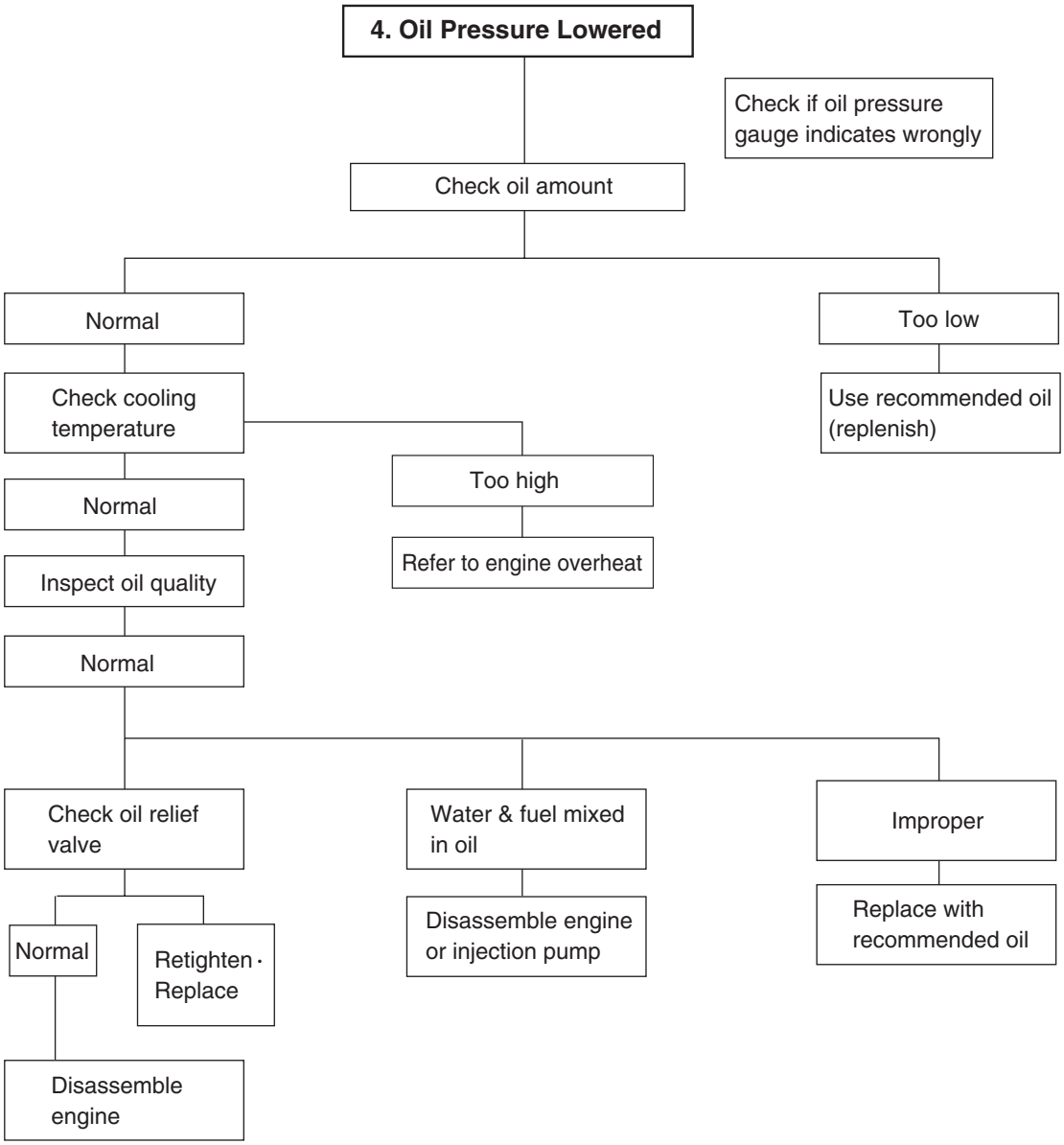
2.3. Diagnosis and Remedy

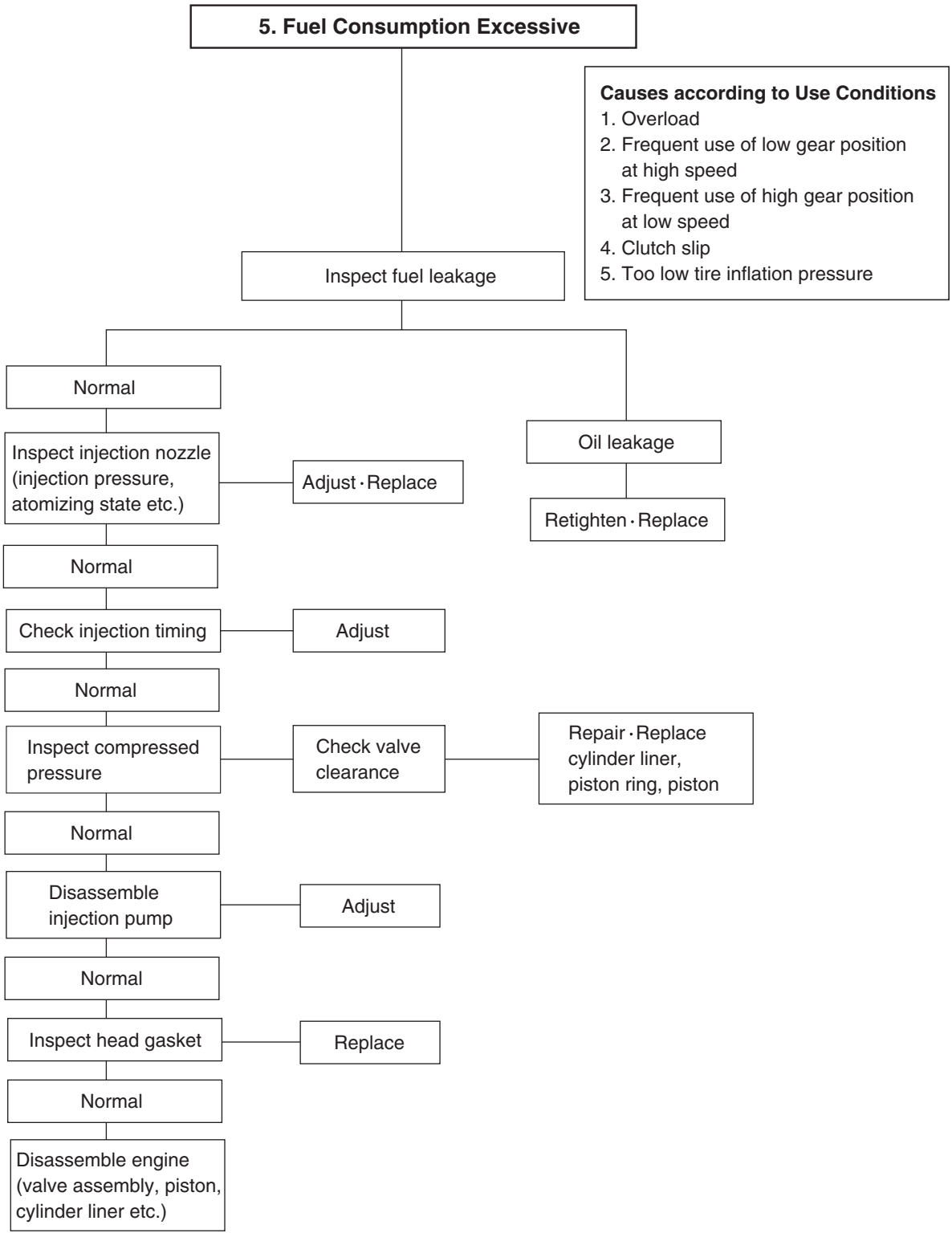
- The following description summarizes the probable cause of and remedy for general failure by item.
- Immediate countermeasures should be taken before a failure is inflamed if any symptom is detected.

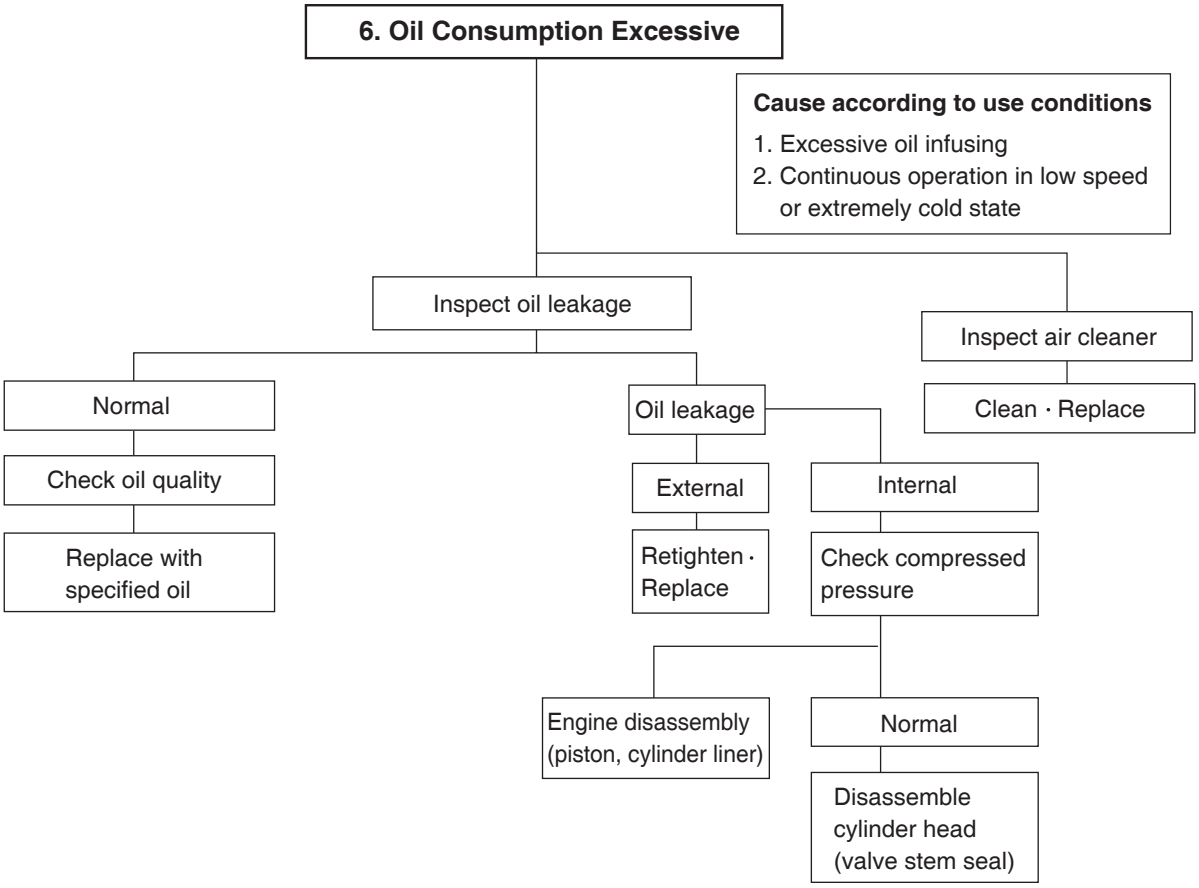


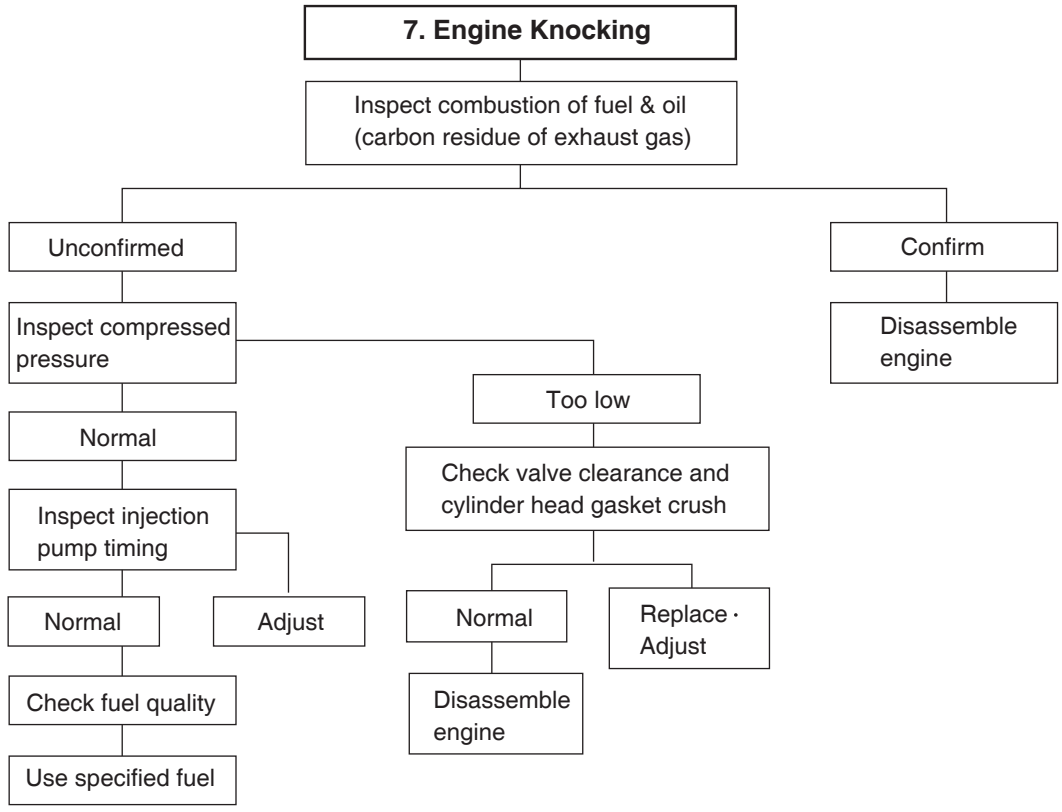

2. Engine Overheated
Operating state
1. Overload
2. Radiator core clogged
3. Continuous over-run
Cooling unit
Fuel system
Check coolant
Inspect fuel quality
Fuel excessive supply
Normal
Too low
Poor
Check fan belt tension, wear or damage etc.
Repair · Replace
Clean and replace with specified fuel
Check injection nozzle
Replenish
Inspect cooling water leakage
Normal
Check fresh radiator tank cap
Replace
External
Internal
Normal
Retighten · Replace
Engine disassembly
Normal
Abnormal
Check thermostat
Replace
Adjust repair injection pump
Repair · Replace
Normal
Inspect radiator
Damage
Repair · Replace
Normal
Check cooling water pump
Repair · Replace
Clean cooling water passage
Normal
Inspect cooling water pump
Engine disassembly
Normal
Repair · Replace
Overhaul engine

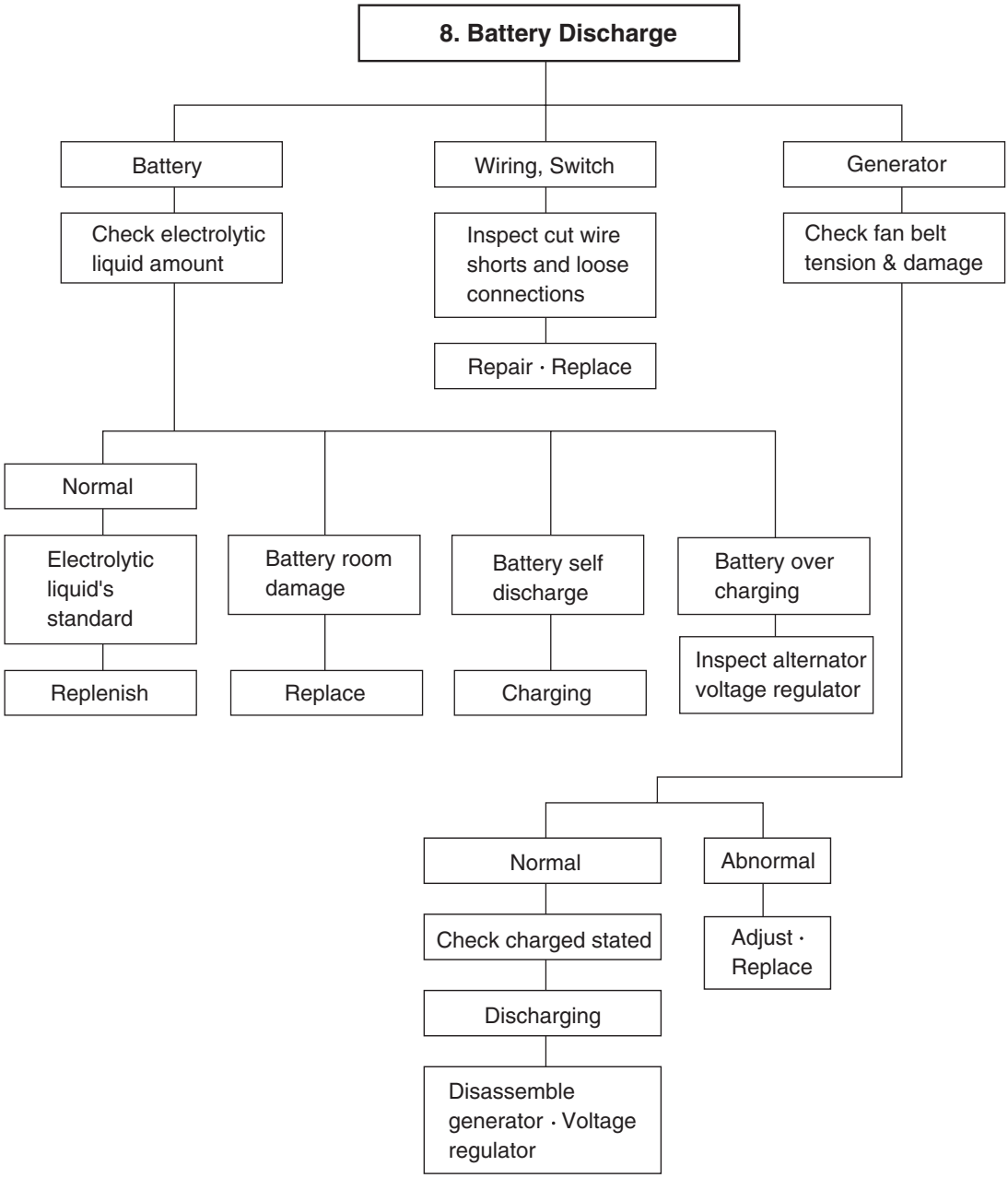

3. Output Insufficient
Engine
Chassis
Fuel system
Others
Check for clutch slip
Adjust or replace clutch
Check for air mixing in fuel
Inspect air cleaner
Inspect fuel supply pump
Normal
Clean · Relpace
Normal
Clean · Replace
Inspect engine control rod, link, cable, etc.
Inspect air leakage of air piping line
Inspect fuel filter and over flow valve
Normal
Adjust
Normal
Retighten · Replace
Normal
Replace
Check valve clearance
Inspect injection pipe
Normal
Adjust
Inspect air leakage of Intercooler
Normal
Repair· Replace
Inspect cylinder head gasket for damage
Inspect injection nozzle, (Injection pressure, atomizing state)
Normal
Replace
Normal
Adjust· Replace
Engine disassembly (valve assembly)
Check injection timing
Normal
Adjustment
Disassemble engine or injection pump
Check turbocharger
Normal
Repair · Replace
Disassemble injection pump or engine


4. Oil Pressure Lowered
Check if oil pressure gauge indicates wrongly
Check oil amount
Normal
Too low
Check cooling temperature
Use recommended oil (replenish)
Too high
Normal
Refer to engine overheat
Inspect oil quality
Normal
Check oil relief valve
Water & fuel mixed in oil
Improper
Normal
Retighten · Replace
Disassemble engine or injection pump
Replace with recommended oil
Disassemble engine


5. Fuel Consumption Excessive
Causes according to Use Conditions
1. Overload
2. Frequent use of low gear position at high speed
3. Frequent use of high gear position at low speed
4. Clutch slip
5. Too low tire inflation pressure
Inspect fuel leakage
Normal
Oil leakage
Inspect injection nozzle (injection pressure, atomizing state etc.)
Adjust · Replace
Retighten · Replace
Normal
Check injection timing
Adjust
Normal
Inspect compressed pressure
Check valve clearance
Repair · Replace cylinder liner, piston ring, piston
Normal
Disassemble injection pump
Adjust
Normal
Inspect head gasket
Replace
Normal
Disassemble engine (valve assembly, piston, cylinder liner etc.)


6. Oil Consumption Excessive
Cause according to use conditions
1. Excessive oil infusing
2. Continuous operation in low speed or extremely cold state
Inspect oil leakage
Inspect air cleaner
Normal
Oil leakage
Clean · Replace
Check oil quality
External
Internal
Replace with specified oil
Retighten · Replace
Check compressed pressure
Engine disassembly (piston, cylinder liner)
Normal
Disassemble cylinder head (valve stem seal)


7. Engine Knocking
Inspect combustion of fuel & oil (carbon residue of exhaust gas)
Unconfirmed
Confirm
Inspect compressed pressure
Disassemble engine
Too low
Normal
Check valve clearance and cylinder head gasket crush
Inspect injection pump timing
Normal
Adjust
Normal
Replace · Adjust
Check fuel quality
Disassemble engine
Use specified fuel


8. Battery Discharge
Battery
Wiring, Switch
Generator
Check electrolytic liquid amount
Inspect cut wire shorts and loose connections
Check fan belt tension & damage
Repair · Replace
Normal
Electrolytic liquid's standard
Replenish
Battery room damage
Replace
Battery self discharge
Charging
Battery over charging
Inspect alternator voltage regulator
Normal
Check charged stated
Discharging
Disassemble generator · Voltage regulator
Abnormal
Adjust · Replace

Condition	Causes	Remedies
1) Starting difficult		
(1) Starting motor trouble	● Refer to diagnostics	
(2) Fuel system trouble	● Refer to diagnostics	
(3) Compression pressure lack	● Valve's poor shut, stem distortion	Repair or replace
	● Valve spring damage	Replace valve spring
	● Cylinder head gasket's leak	Replace gasket
	● Wear of piston, piston ring or liner	Adjust
2) Idle operation abnormal	● Injection timing incorrect	Adjust
	● Air mixing at injection pump	Remove air
3) Engine output insufficient		
(1) Continuous output insufficient	● Valve clearance incorrect	Adjust
	● Valve tightness poor	Repair
	● Cylinder head gasket's leak	Replace gasket
	● Wear, stick, damage of piston ring	Replace piston ring
	● Injection timing incorrect	Adjust
	● Fuel injection amount insufficient	Adjust injection pump
	● Nozzle injection pressure improper or stuck	Adjust or replace
	● Supply pump's function lowered	Repair or replace
	● Fuel pipe system clogged	Repair
	● Air suction amount insufficient	Clean or replace air cleaner
	● Turbocharger poor	Repair or replace
(2) Output insufficient when in acceleration	● Compression pressure insufficient	Disassemble engine
	● Injection timing incorrect	Adjust
	● Fuel injection amount insufficient	Adjust injection pump
	● Injection pump timer's function insufficient	Repair or replace
	● Nozzle infection pressure, infection angle improper	Repair, replace
	● Supply pump's function lowered	Repair or replace
	● Air intake amount insufficient	Clean or replace air cleaner
4) Overheating	● Engine oil insufficient or poor	Replenish or replace
	● Cooling water insufficient	Replenish or replace
	● Fan belt loosened, worn, damaged	Adjust or replace
	● Cooling water pump's function lowered	Repair or replace
	● Water temp. regulator's operation poor	Replace
	● Valve clearance incorrect	Adjust
	● Exhaust system's resistance increased	Clean or replace

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	● As the wear of bearing or crankshaft progress, the oil clearances increase.	Replace bearing & grind crankshaft
	● Lopsided wear of crankshaft	Grind or replace
	● Oil supply insufficient due to oil passage clogging	Clean oil passage
	● Stuck bearing	Replace bearing & Grind
(2) Con.-rod and Con.-rod bearing	● Lopsided wear of con rod bearing	Replace bearing
	● Lopsided wear of crank pin	Grind crankshaft
	● Connecting rod distortion	Repair or replace
	● Stuck bearing	Replace & grind crankshaft
	● Oil supply insufficiency as clogging at oil passage progresses	Clean oil passage
(3) Piston, piston pin & Piston ring	● Piston clearance increase as the wear of piston and piston ring progresses	Replace piston & piston ring
	● Wear of piston or piston pin	Replace
	● Piston stuck	Replace piston
	● Piston insertion poor	Replace piston
	● Piston ring damaged	Replace piston
(4) Others	● Wear of crankshaft, thrust bearing	Replace thrust bearing
	● Camshaft end play increased	Replace thrust plate
	● Idle gear end play increased	Replace thrust washer
	● Timing gear backlash excessive	Repair or replace
	● Valve clearance excessive	Adjust valve clearance
	● Abnormal wear of tappet, cam	Replace tappet, cam
	● Turbocharger inner part damaged	Repair or replace
6) Fuel Consumption Excessive	● Injection timing incorrect	Adjust
	● Fuel injection amount excessive	Adjust injection pump

Condition	Causes	Remedies
7) Oil Consumption Excessive		
(1) Oil level elevated	● Clearance between cylinder liner & piston	Replace
	● Wear of piston ring, ring groove	Replace piston, piston ring
	● Piston ring's damage, stick, wear	Replace piston ring
	● Piston ring opening's disposition improper	Correct position
	● Piston skirt part damaged or abnormal wear	Replace piston
	● Oil ring's oil return hole clogged	Replace piston ring
	● Oil ring's contact poor	Replace piston ring
(2) Oil level lowered	● Looseness of valve stem & guide	Replace in set
	● Wear of valve stem seal	Replace seal
	● Cylinder head gasket’s leak	Replace gasket
(3) Oil leak	● Looseness of connection parts	Replace gasket, repair
	● Various parts' packing poor	Replace packing
	● Oil seal poor	Replace oil seal

2.4. Engine Inspection

2.4.1. Stopping engine

After checking the engine for any unusual condition at the idling speed, then turn the key switch to stop the engine.

- Daily inspections in bellow figure should be checked every day.
- The maintenance should be executed thoroughly at regular intervals.

2.4.2. General engine inspection cycle

○ : Check & adjust ● : Replace

Inspection		Daily	Inspection time (hours)					Remark
			50	250	500	750	1,250	
Cooling System	Check for leakage (hoses, clamp)	○						
	Check the water level	○						
	Check the V-belt tension	○						
	Adjust the V-belt tension							Every 2,000 hrs
	Change the coolant water						●	
	Check radiator pressure cap	○						
Lubrication System	Check for leakage	○						
	Check the oil level gauge	○						
	Change the lubricating oil		● 1st	●				
	Replace the oil filter cartridge		● 1st	●				
	Insert grease at fan idle pulley						○	
Intake & Exhaust System	Check the leakage for intercooler (hoses, clamp)	○						
	Clean and change the air cleaner element			○ clean	●			
	Clean the inter-cooler air fins				○			
	Clean the turbo charger							Every 2,000 hrs
Fuel System	Check the leakage fuel line	○						
	Clean the pre fuel strainer						○ clean	
	Check the fuel injection timing							When necessary
	Replace the fuel filter cartridge						●	
	Check the injection nozzles							When necessary
Engine Adjust	Check the exhaust gas state	○						
	Check the battery charging	○						
	Check the compression pressure							When necessary
	Adjust the intake/exhaust valve clearance			○ 1st				When necessary

* (●) The engine oil change interval is determined by engine using condition and oil grade.

2.4.3. Use of original parts for repair and replacement

- For engine is being mechanically harmonized with many parts, only when the original parts that the manufacture recommends to use is used, the engine trouble would be preventively maintained and capable to keep up the maximum performances.
- For the analogous parts not the original parts are poor in qualities and gives ill performances, it may rather bring early engine failure.

3. Disassembly and Reassembly of Major Components

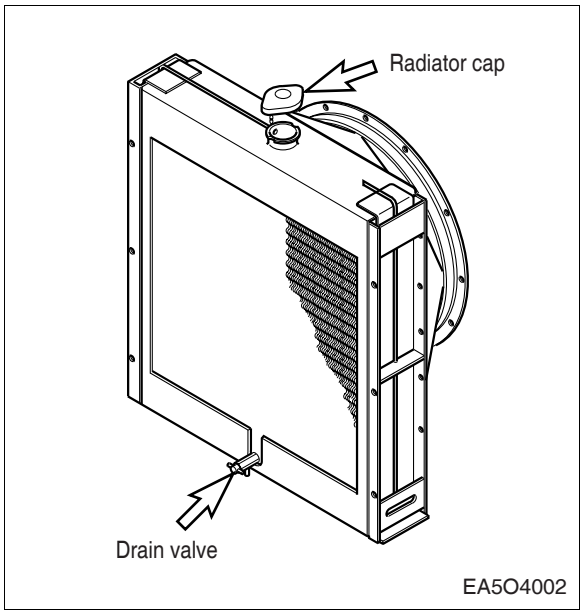
3.1. Engine Disassembly

3.1.1. General precautions

- 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 collision each other.
- In disassembling, torn parts should be laid in disassembled order.
- Before performing service operation, disconnect the grounding cable from the battery for reducing the chance of cable damage and burning due to short-circuiting.

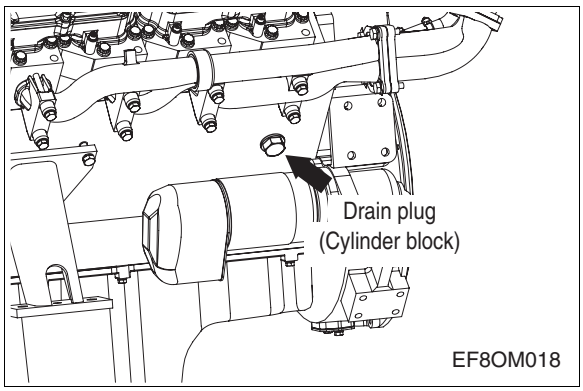
3.1.2. Cooling water

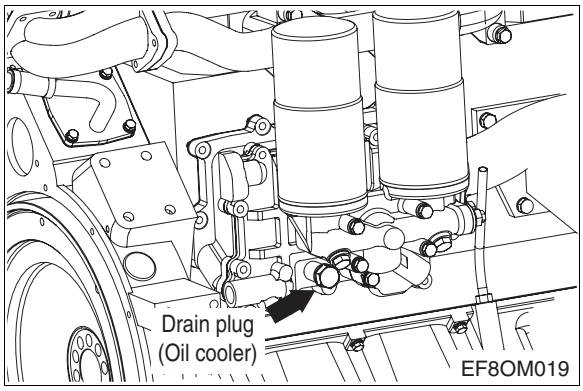
- Remove the radiator cap. Open the drain valve at the radiator lower part to drain the coolant as the right figure.



CAUTION:
When removing radiator filler cap while the engine is still hot, cover the cap with a rag, then turn it slowly to release the internal steam pressure This will prevent a person from scalding with hot steam spouted out from the filler port.

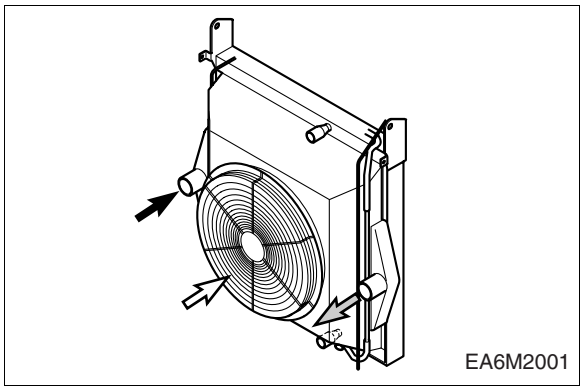
- Remove the cooling water drain plug from the cylinder block and oil cooler, various pipes, etc. and let the cooling water discharge into the prepared vessel.





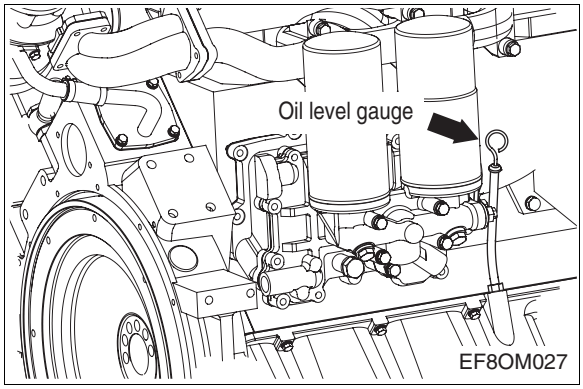
3.1.3. Intercooler

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



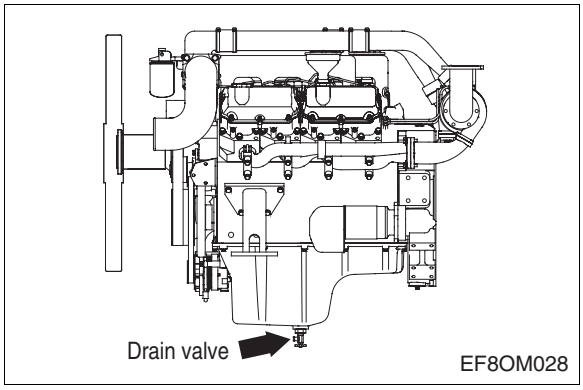
3.1.4. Oil level gauge

- Take out the oil level gauge from the guide tube.



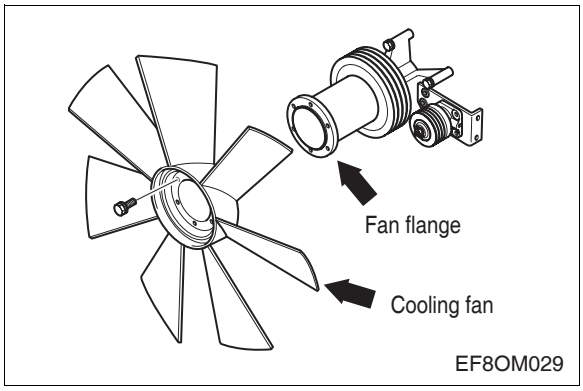
3.1.5. Engine oil

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



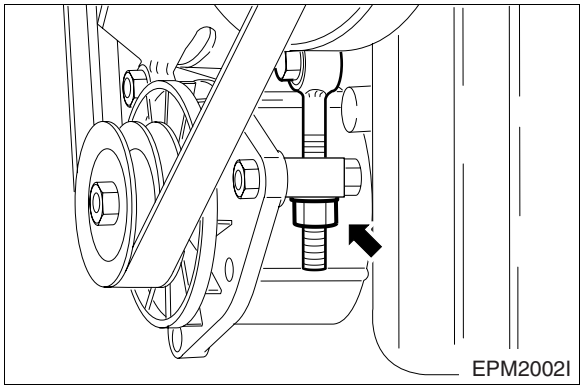
3.1.6. Cooling fan

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



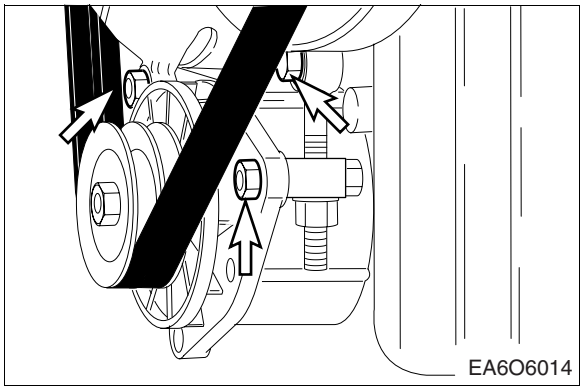
3.1.7. V-belt

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



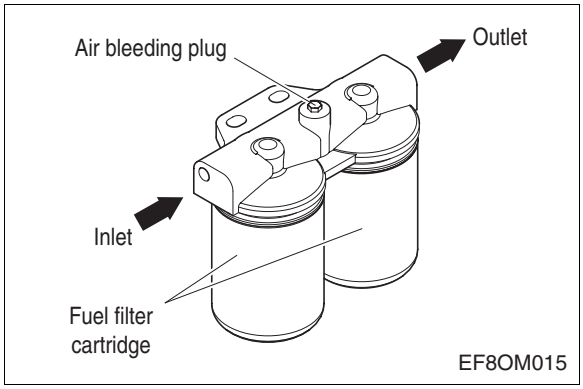
3.1.8. Alternator

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



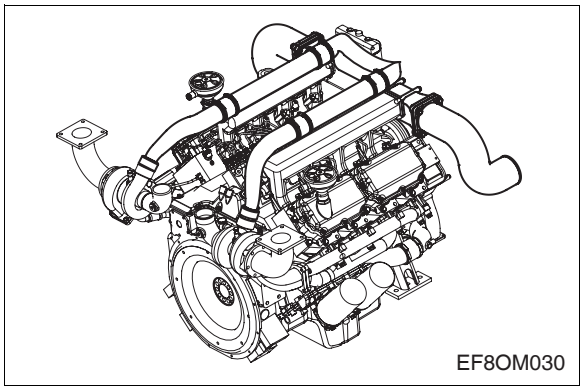
3.1.9. Fuel filter

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



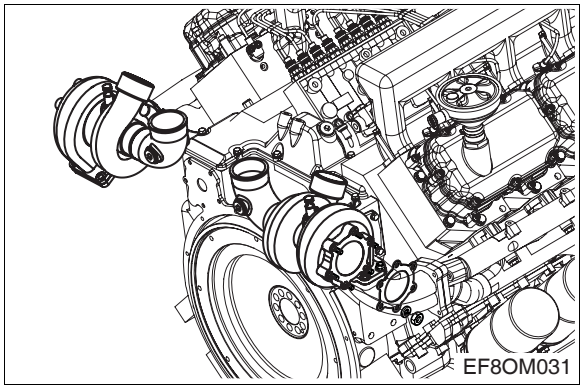
3.1.10. Air pipe

- Remove fixing bolts, then take off the air pipe.
- Be careful about the mixing of foreign material into interior of the turbocharger.


EF8OM030

3.1.11. Turbocharger

- Loosen the hose clamp for connecting the intake stake and tear down the air pipe.
- Unscrew the turbo charger lubrication supplying bolt and tear down oil pipe.
- Unscrew the turbo charger fixing nuts and take off the turbo charger from the exhaust manifold.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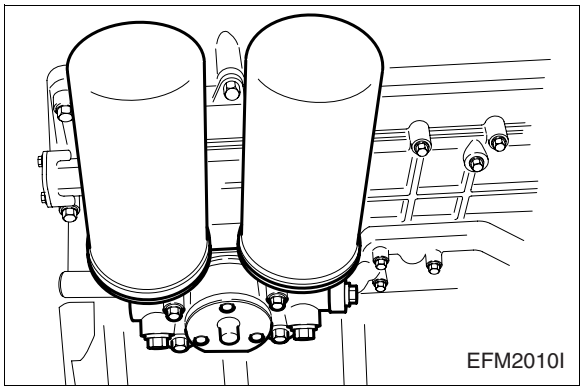
3.1.12. Oil filter

- Disassemble the oil filter cartridge with filter wrench by means of a filter wrench.
- Do not use again the cartridge removed after use.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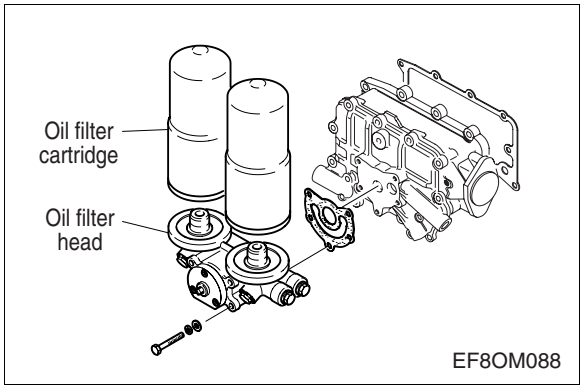
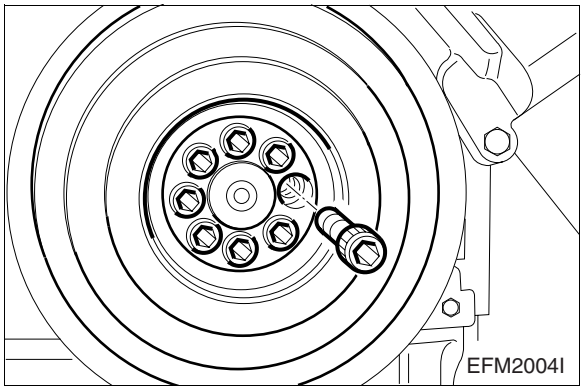
- Remove the oil filter head fixing bolts and disassemble the filter head.



EF8OM088

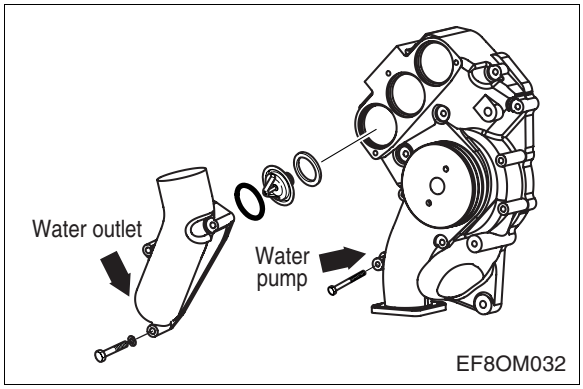
3.1.13. Vibration damper

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



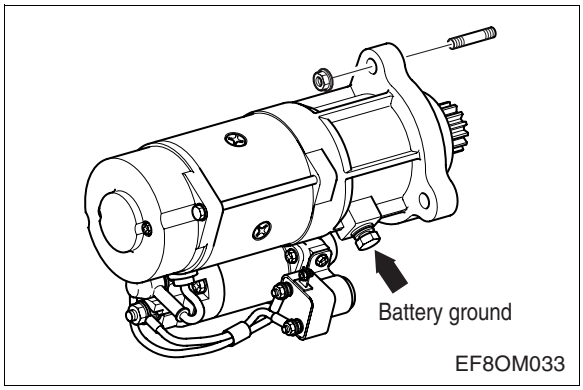
3.1.14. Cooling water pump and thermostat

- 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.



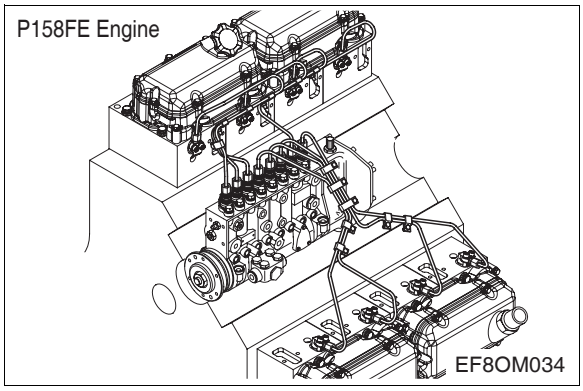
3.1.15. Starting motor

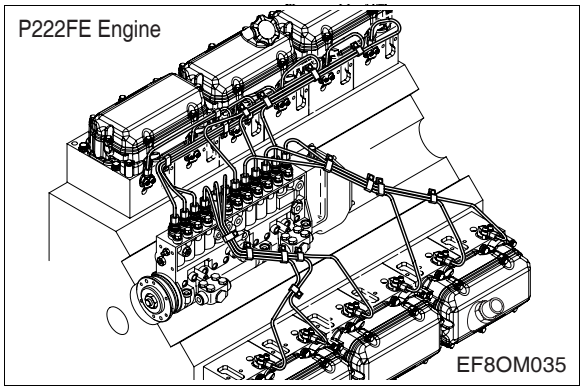
- Remove the starting motor fixing nuts and disassemble the starting motor.



3.1.16. Fuel injection pipe

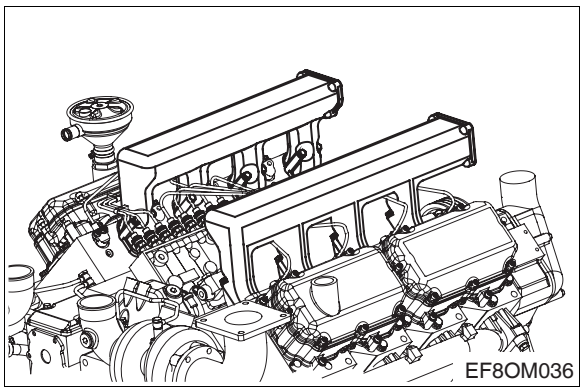
- Disassemble various fuel pipe and hose.
- Disassemble the fuel injection pipe from the high pressure injector and disassemble the fuel injection pump.





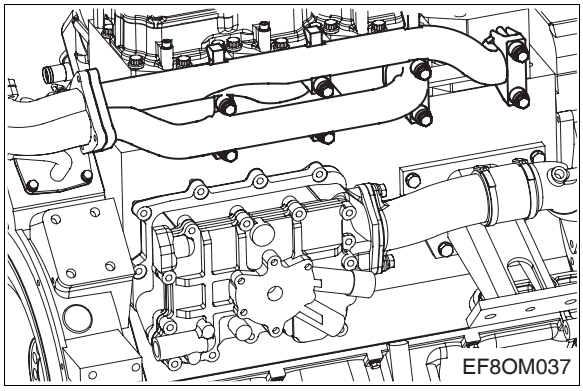
3.1.17. Intake manifold

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



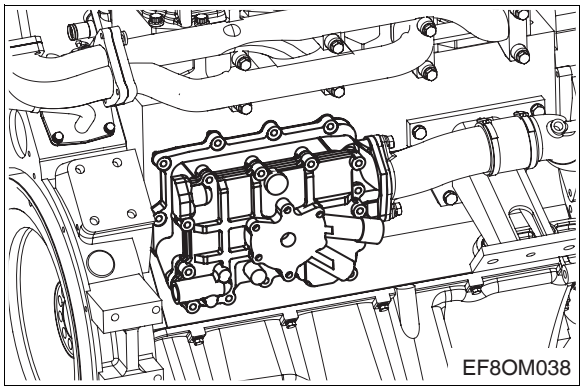
3.1.18. Exhaust manifold

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

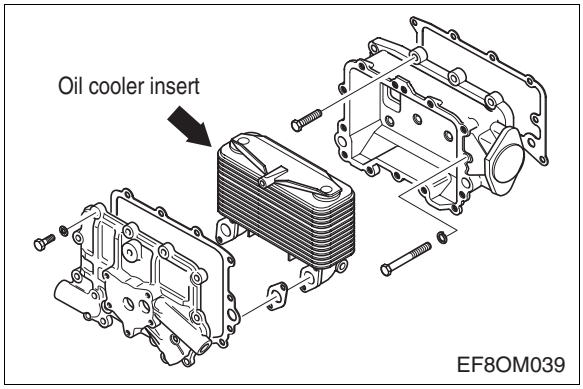


3.1.19. Oil cooler

- Remove the drain plug from the oil cooler cover and drain out the cooling water.
- Remove the oil cooler cover fixing bolts and disassemble the oil cooler.

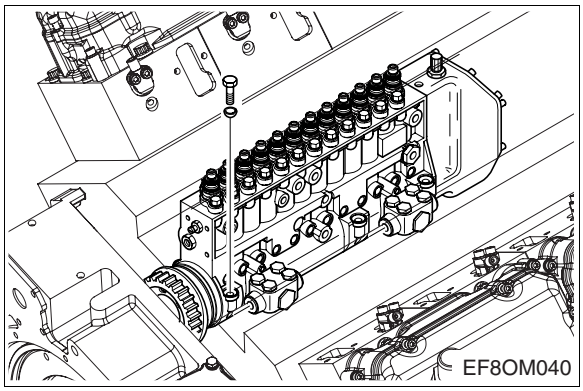


- Clamp the oil cooler assembly to the vise, remove the oil cooler insert fixing bolts, then disassemble the cooler insert.
  (Only need to changed the cooler insert)



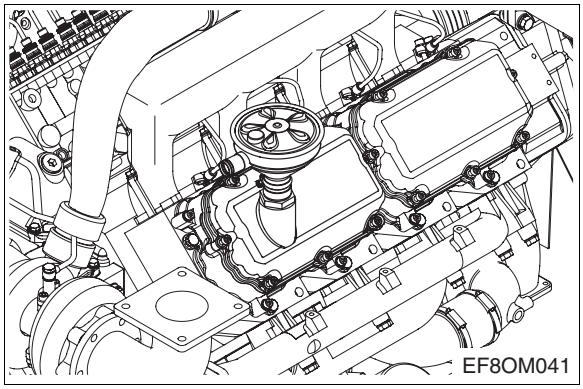
3.1.20. Fuel injection pump

- Remove the oil pipes for lubrication and the fuel hoses.
- Remove the fixing bolts of fuel injection pump and take out the fuel injection pump and O-ring.
- Do not use again the O-ring under the injection pump removed after use.



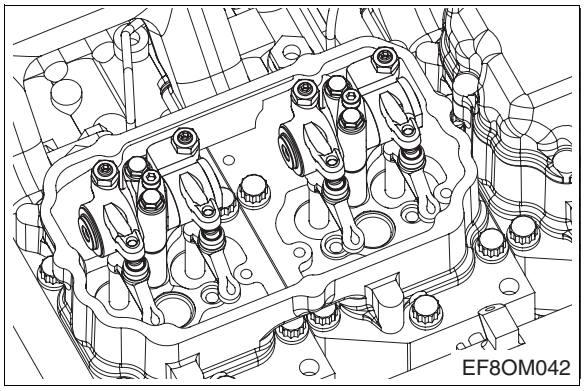
3.1.21. Cylinder head cover

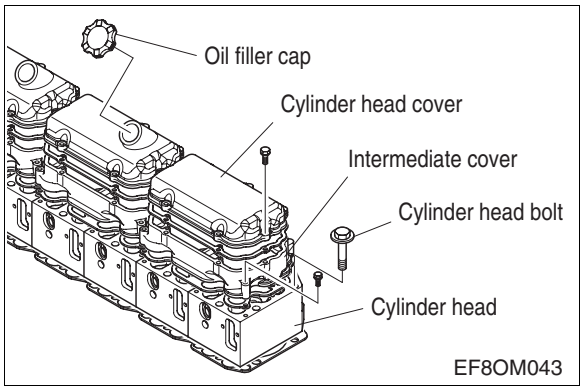
- Remove cylinder head cover fixing bolts and take off the cylinder head cover and breather.



3.1.22. Rocker arm

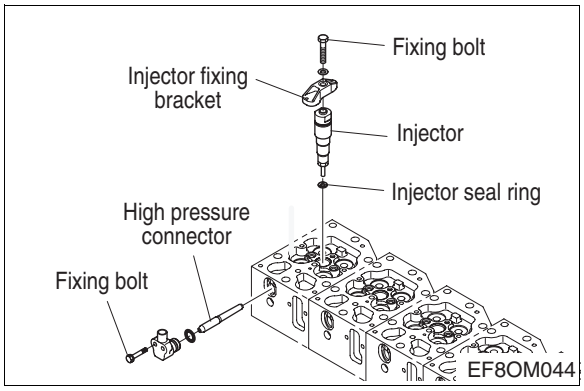
- Remove the rocker arm bracket fixing bolts and take out the rocker arm.
- Pull out the caliper and push rod.





3.1.23. Injector

- Remove the high pressure connecter fixing flange and take off the fuel high pressure connecter.
- Do not use again the high pressure connector removed after use.
- Remove injector fixing bracket bolts and take off the injector.
- Be careful about damage of the nozzle when take off the injector.
- Take out the sealing from the nozzle hole of the cylinder head and scrap it.



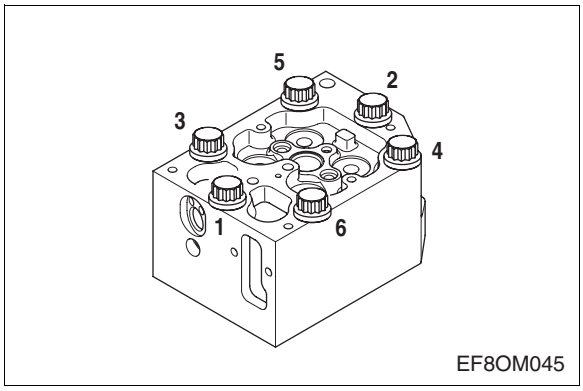
CAUTION:

1) When disassemble the injector, after the fuel high pressure connecter is separated perfectly by removing the fuel high pressure connecter fixing flange, then remove injector caliper fixing bolts and take off the injector.

2) Seal the injector and the fuel high pressure connecter to prevent from mixing foreign material into inside of the injector and the fuel high pressure connecter after disassembling.

3.1.24. 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.

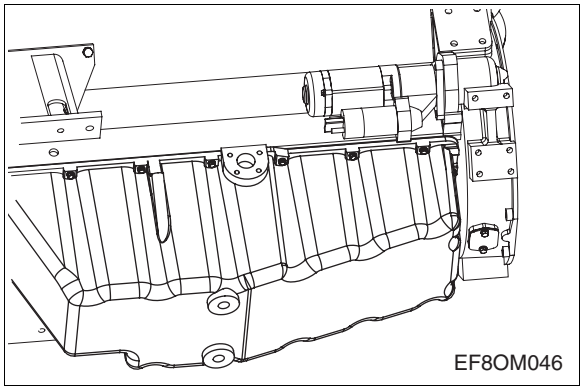


EF8OM045

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

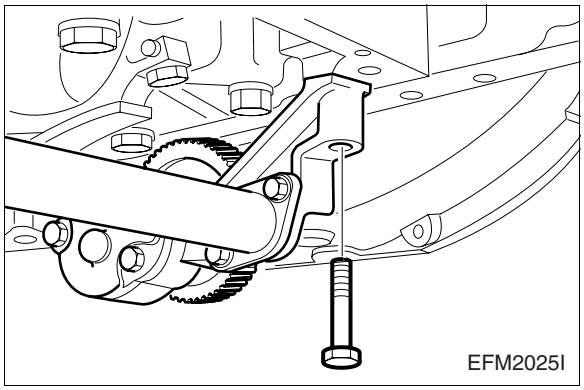
3.1.25. Oil pan

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


EF8OM046

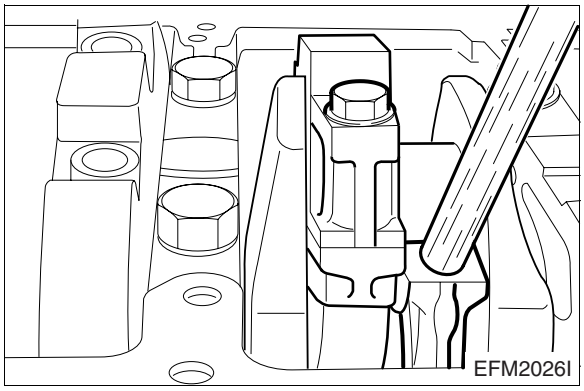
3.1.26. Oil pump

- 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.


EFM2025I

3.1.27. 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.

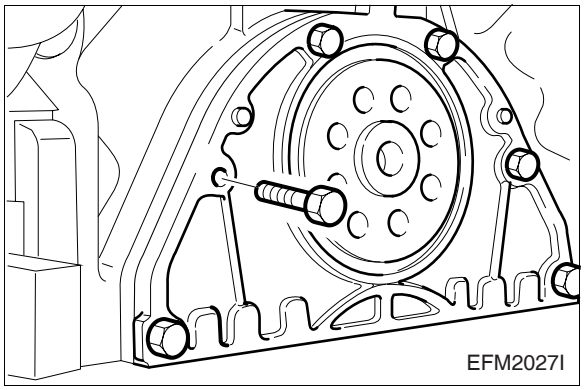

EFM2026I

NOTES:

- **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.)**

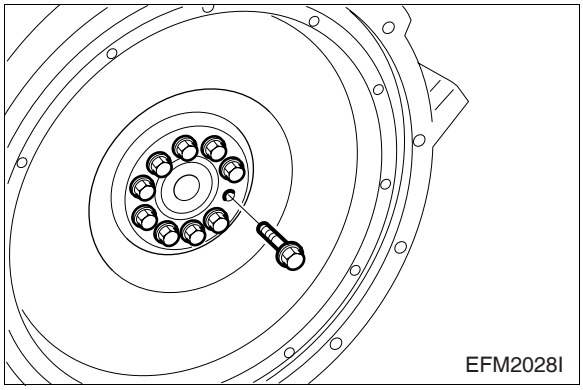
3.1.28. Front oil seal holder

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

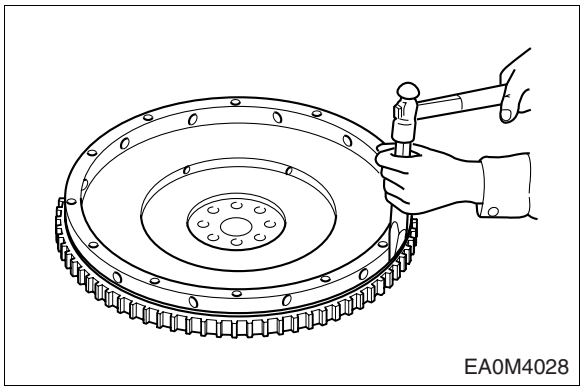

EFM2027I

3.1.29. Flywheel

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


EFM2028I

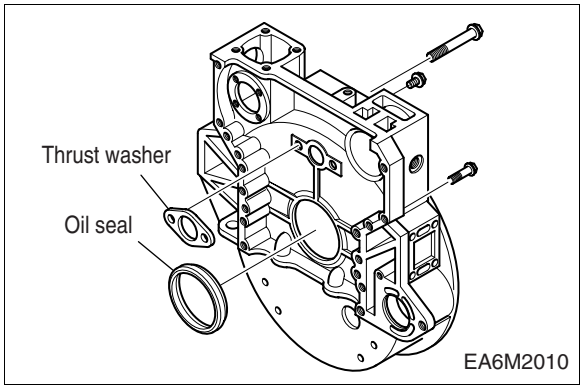
- Remove the flywheel ring gear.
  - Heat the ring gear evenly with a gas burner (up to 200 °C) to invite volumetric expansion.
  - Tapping around the edges of the ring gear with a hammer and brass bar to remove it.


EA0M4028

CAUTION:
Do not damage the flywheel.

3.1.30. Flywheel housing

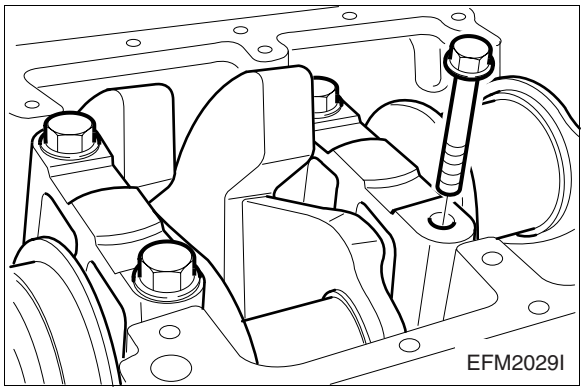
- Remove the flywheel housing fixing bolts and take them out.
- Remove the oil seal from the flywheel housing.



EA6M2010

3.1.31. Crank shaft

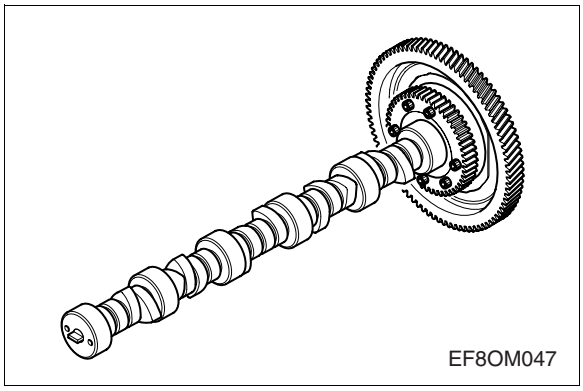
- Remove the bolts from bearing caps.
- Remove the main bearing cap fixing bolts in the order of assembling. (Remove them in the same way of the cylinder head bolts.)
- Maintain the removed bearing caps in the order of cylinders.
- Temporarily install the bolts at the both side of crankshaft, and lift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


EFM2029I

NOTES :
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.

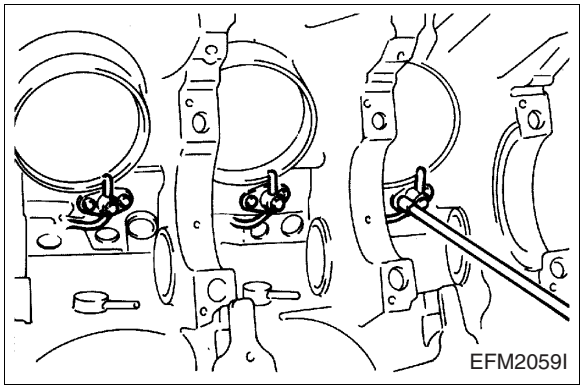
3.1.32. Camshaft and tappet

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



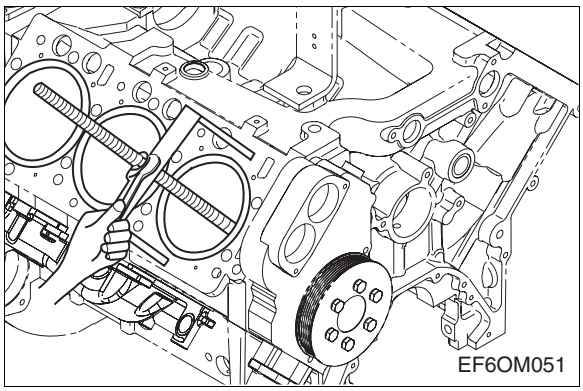
3.1.33. Oil spray nozzle

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



3.1.34. Cylinder liner

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



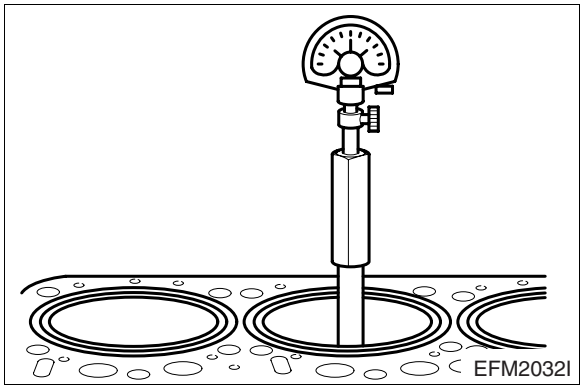
3.2. Measurement and Inspection of Major Parts

3.2.1. Cleaning and inspection of cylinder block

1) Clean the cylinder block and inspect it for any crack or damage.
2) If there is any crack or severe damage, replace it and if there is minor one, correct it.
3) Inspect the oil passage and water passage for any clog and erosion.
4) By performing the hydraulic test, inspect for any leaks. With plugging the water and oil passages of cylinder block, put in the air of 5 kg/cm^2 pressure in the inlet port of cylinder block and then soak the cylinder block in the water for about 1 minute to check for any leaks. (water temperature : 70 °C)
5) Inspect the cylinder block's camshaft bush to any damage and the alignment of oil supply holes and if abnormal, replace it.

3.2.2. Cylinder liner measurement

- Assemble the cylinder liner at the cylinder block and measure inner diameters at upper, middle, lower 3 levels by 45° interval and calculate the average values after eliminating the max. and min. values.
- If the measured values are very close to the limit value or beyond, replace it.

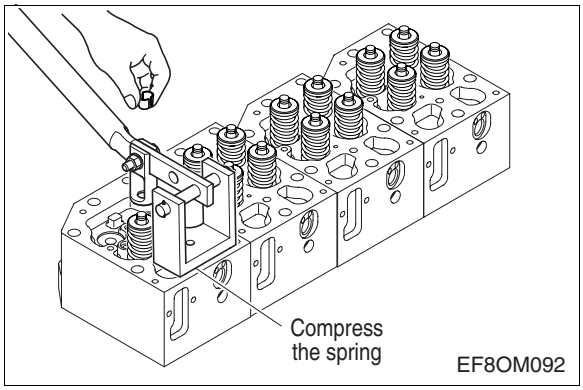


Liner inner diameter	Standard	Limit
	⌀127.990 ~ ⌀128.010 mm	0.15 mm

3.2.3. Cylinder head

1) Cylinder head disassembly

- 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.



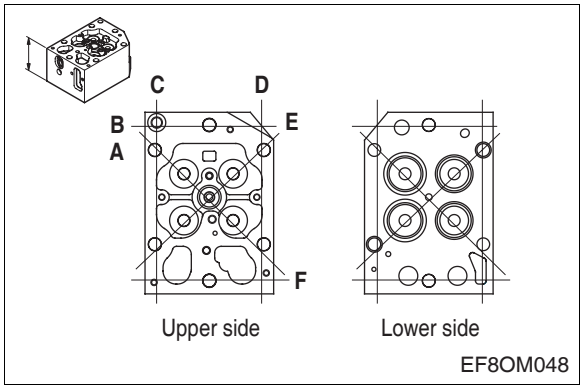
2) Inspection and measurement of cylinder head

a) Damage check

- Inspect the cylinder head for any crack or 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.
- The cracks or damages that are difficult to search may be inspected by a hydraulic test or a magnetic powder test. (Hydraulic test is same as for cylinder block.)

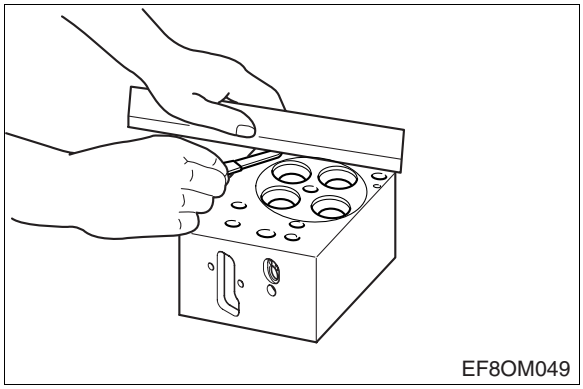
b) Distortion

- As shown in figure, measure the cylinder head's distortion at 6 directions with horizontal ruler and clearance gauge.
- If the measured value is beyond the limit value, correct it by means of the fine grinding paper or grinding machine.
- If it is beyond the max. allowable value, replace the cylinder head.



< Lower face warpage and thickness>

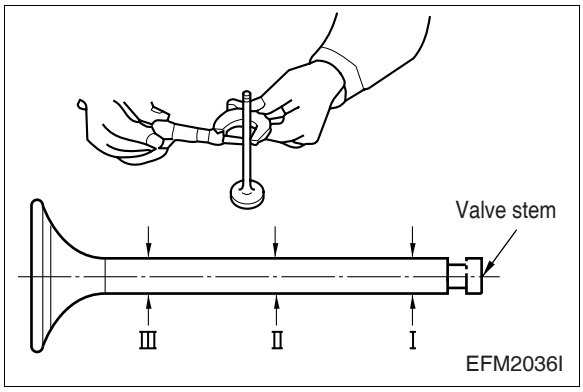
	Standard	Limit
Warpage	0.05 mm or less	0.2 mm
Thickness : t (reference)	116.95 ~ 117.05	116.4



3) Inspection and measurement of valve and valve guide

a) Valve

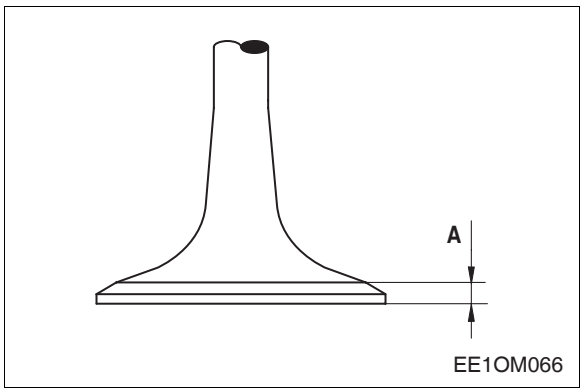
- After cleaning the valves with clean diesel oil, measure the valve stem's outside diameter at upper, middle, and lower to determine the wears and if there is minor damage, correct it and when the wears is more than max allowable limit value, replace the valves.



<Valve stem outer diameter>

	Standard	Limit
Intake	∅7.963 ~ ∅7.977 mm	∅7.94 mm
Exhaust	∅7.950 ~ ∅7.964 mm	∅7.93 mm

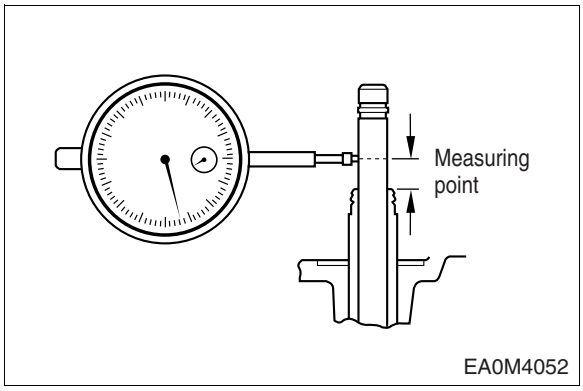
- Inspect the scratch and wear of valve stem seal contacting face, and if necessary correct with the grinding paper but if severe replace it.
- If valve head thickness (H) becomes less than 1.6 mm for intake and exhaust, replace the valve.



	Standard	Limit
Intake	2.7 ~ 2.9 mm	1.6 mm
Exhaust	2.8 ~ 3.0 mm	1.6 mm

b) 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.



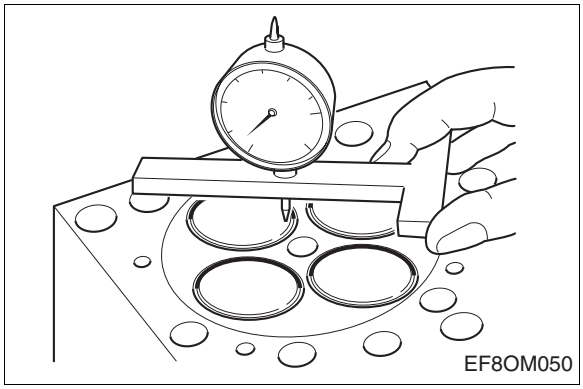
<Valve stem end play>

	Standard	Limit
Intake	0.038 ~ 0.067 mm	0.10 mm
Exhaust	0.051 ~ 0.08 mm	0.15 mm

- When replacing the valve guide and seat, work simultaneously by special tool.
- Assemble the valve at cylinder head valve guide and see if it is centered with the valve seat using a special tool.

c) Valve seat

- Inspect the damage and wear of valve seat and if necessary replace it.
- 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 value is more than the use limit, replace the valve seat.
- When replacing the valve guide and seat, work simultaneously by special tool.

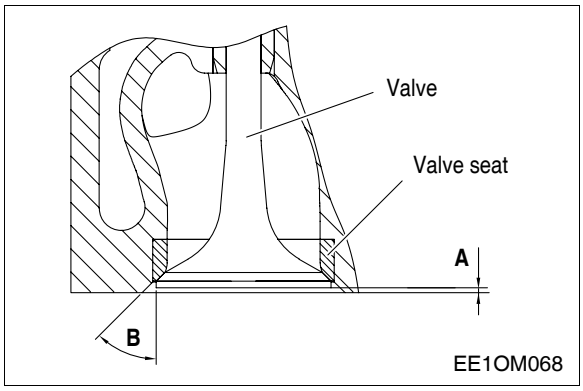


<Valve seat thickness>

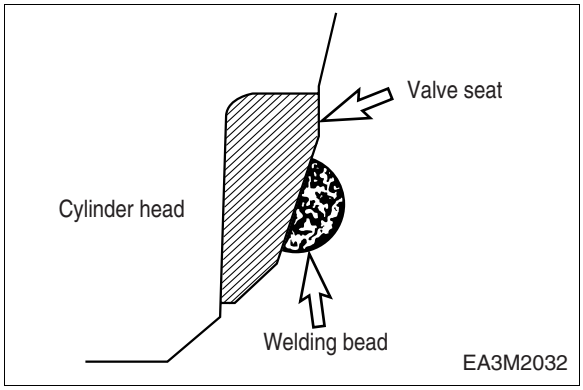
	Standard
Intake (A)	0.8 ~ 1.1 mm
Exhaust (A)	0.8 ~ 1.1 mm

<Valve seat angle>

Intake valve (B)	60°
Exhaust valve (B)	45°



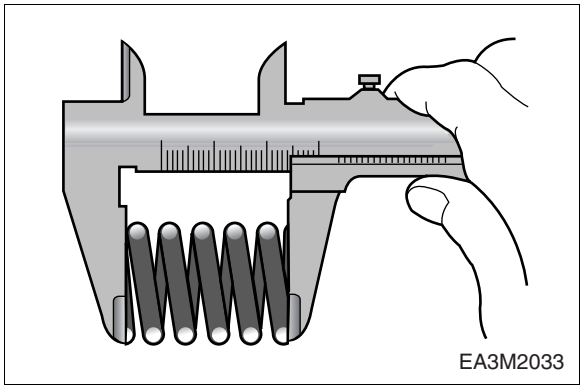
- The disassembly of valve seat can be pulled out by means of a special tool with the arc welding done at two points of valve seat rotating tool or valve seat.
- Regarding the valve seat assembling, shrink the valve seat by putting it in the dry ices for about 1 hour or so, and then press it into the cylinder head by means of a special tool.
- It is necessary to work boring of inner diameter of it when replace the valve seat.
- 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

- Inspect the outlook of valve spring and if necessary replace it.
- By means of spring tester, measure the tension and free length.

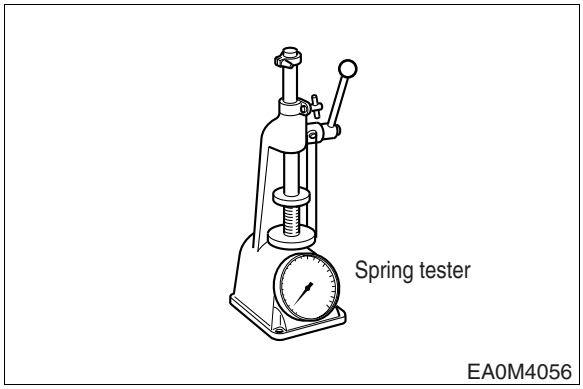
Free length		Standard
Intake and Exhaust	Inside	59.5 mm
	Outside	57 mm



- Measure the perpendicularity of valve spring.
- In case that the measured value exceeds the limit value, replace it.

<Perpendicularity regular>

	Set length		Spring force	Limit
Intake and Exhaust	Inner	41 mm	14.8 kg	±1.5 kg
		28.6 mm	25.0 kg	±2 kg
	Outer	44 mm	25.5 kg	±2 kg
		31.6 mm	52.3 kg	±2.5 kg

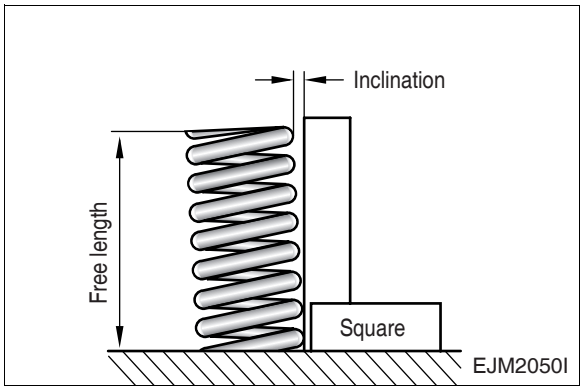


- **Valve spring inclination**

  Use a surface plate and a square to measure the valve spring inclination.

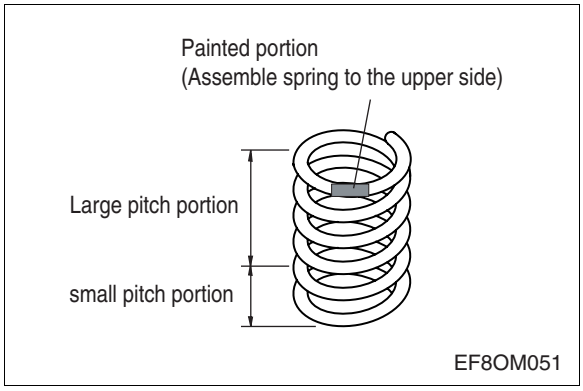
  If the measured value exceeds the specified limit, the valve spring must be replaced.

	Standard	Limit
Valve spring inclination	Less than 1.5	2.0 mm



4) Cylinder head assembling

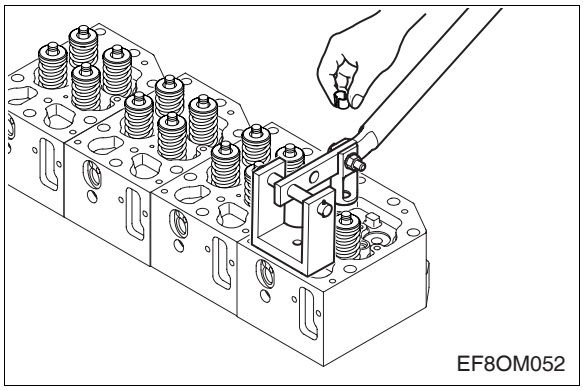
- Clean the cylinder head thoroughly.
- Coat the valve stems and valve guides with engine oil and assemble the valves.
- Replace the valve stem seals with new ones and insert the stem seals to the valve guides of cylinder head with a special tool. (Be careful for the valve stem seals not to be damaged.)
- Install the valve spring washer to valve guide.
- After putting on the inside, outside spring, install the valve spring seat on them.



NOTES:

Install the valve spring seat with "TOP" (painted in red) side up.

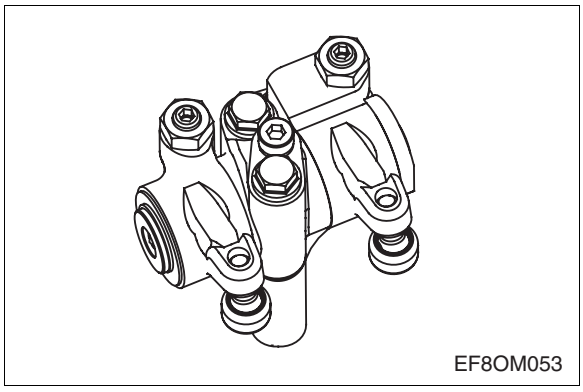
- Pressing the spring down with a special tool, assemble by inserting the valve cotter.
- After the valve is assembled, inspect the valve tapping it lightly with an urethane hammer if accurate assembling was done.


EF8OM052

3.2.4. Rocker arm

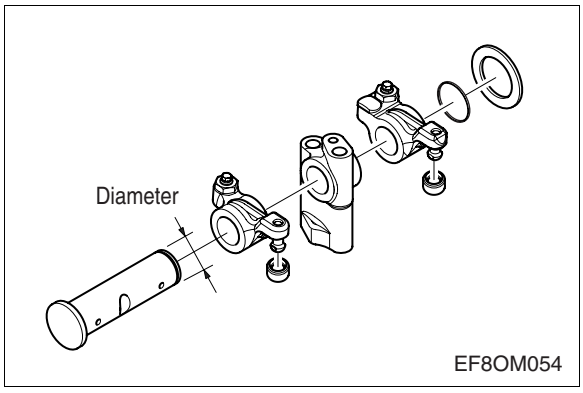
1) Rocker arm disassembling

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


EF8OM053

2) Inspection and measurement

- 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.



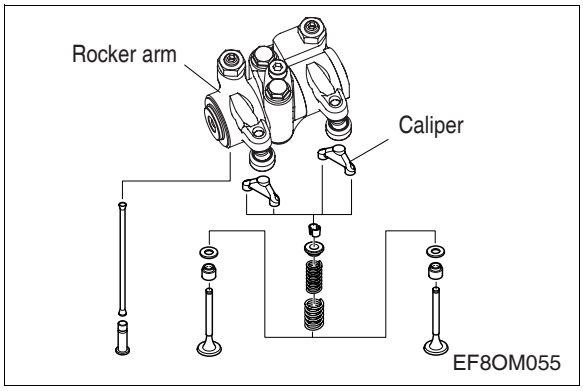
EF8OM054

< Rocker arm Specification >

	Standard	Limit
Bush inner diameter	∅24.991 ~ ∅25.012 mm	∅25.04 mm
Shaft outer diameter	∅24.953 ~ ∅24.976 mm	∅24.90 mm
Clearance	0.015 ~ 0.059 mm	0.14 mm

a) Rocker arm

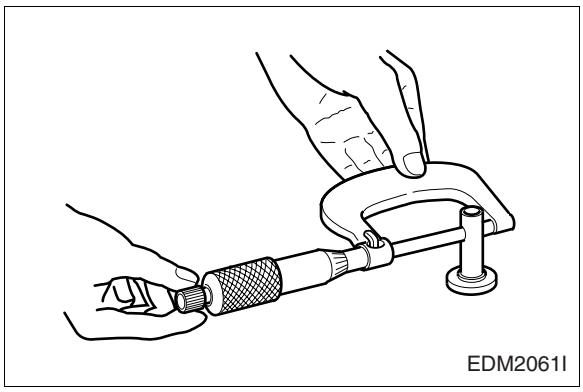
- Inspect the rocker arm surface that contacts with the valve stem for any scratch, step wear and correct the minor degree of wear with an oil stone or the fine grinding paper and replace if they are severe.



b) Tappet and push rod

- By means of outside micrometer, measure the clearance of the tappet and tappet holes of the cylinder block. If the value is beyond the specified limit, replace tappets.

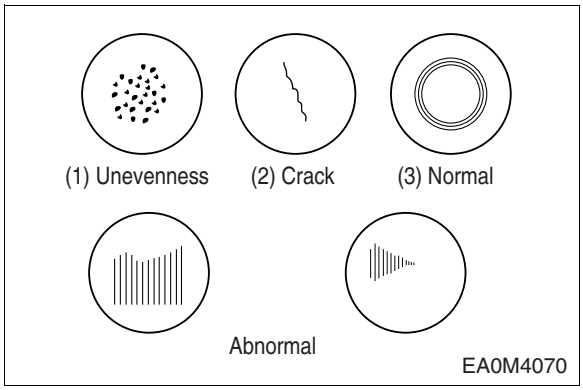
Standard	∅20.000 ~ ∅20.021



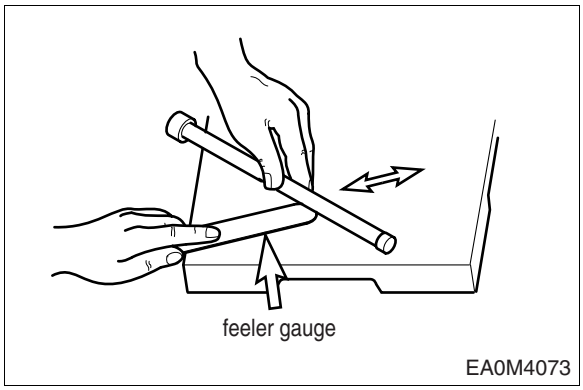
< Clearance of cylinder block and tappet >

Standard	Limit
0.035 ~ 0.077 mm	0.25 mm

- By inspecting the tappet surface that contacts with the camshaft's cam for any crack and scratch etc., and if the degree is small, correct them with an oil stone or the grinding paper but if severe replace them.



- Place the push rod on the surface plate and rolling it, Inspect the curving degree with a clearance gauge and if abnormal, replace it.



<Run-out>

Limit	0.3 mm or less

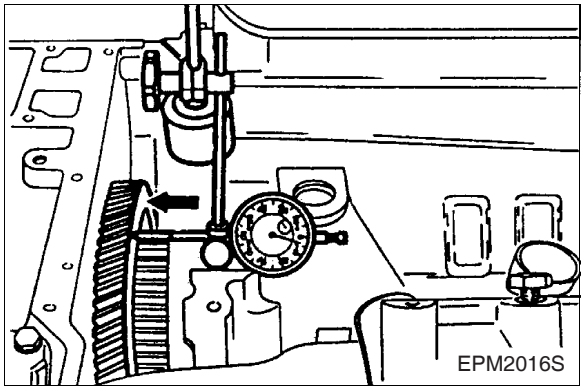
3) Rocker arm reassembling

- 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 crankshaft 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.



Standard	0.5 ~ 1.05 mm

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

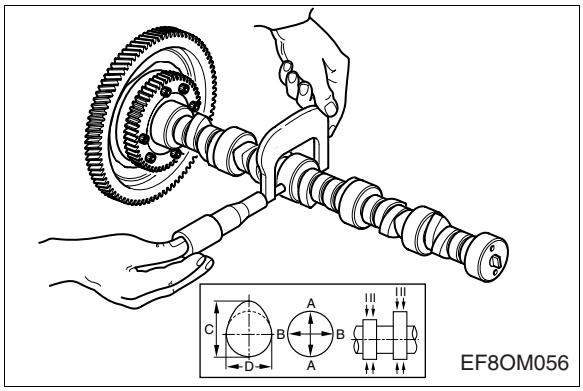
2) Inspection and measurement of camshaft

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

- **Cam lobe height and cam journal diameter**

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

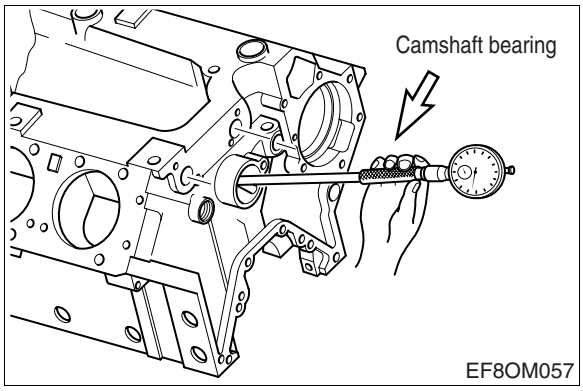
If the measured number is less than the specified limit, the camshaft must be replaced.



		Standard	Limit
Cam lobe height (C)	Intake	55.06 mm	54.76 mm
	Exhaust	55.89 mm	55.59 mm
Cam journal diameter (A,B)		∅69.91 ~ ∅69.94 mm	∅69.64 mm

- **Camshaft bearing diameter**

Measure the camshaft bush inside diameter with a cylinder gauge.



< Cam bearing inside diameter >

Standard		Limit
Inner diameter of thrust bush	∅70.0 ~ ∅70.09 mm	–
Inner diameter of cam bush	∅70.0 ~ ∅70.03 mm	∅70.06

- **Clearance between camshaft journal and bush**

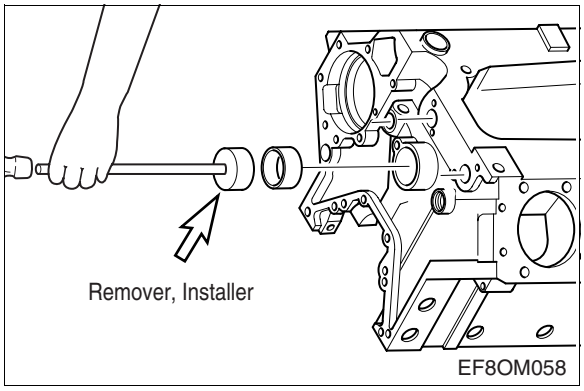
Calculate the clearance by complying measured value of the camshaft bearing inside diameter and journal bearing outside diameter. Replace the camshaft bearing if the calculated value is beyond the specified limit.

<Clearance >

Standard	Limit
0.060 ~ 0.120 mm	0.18 mm

3) Camshaft bearing replacement

- Use with the special tool for replacement of bearing.

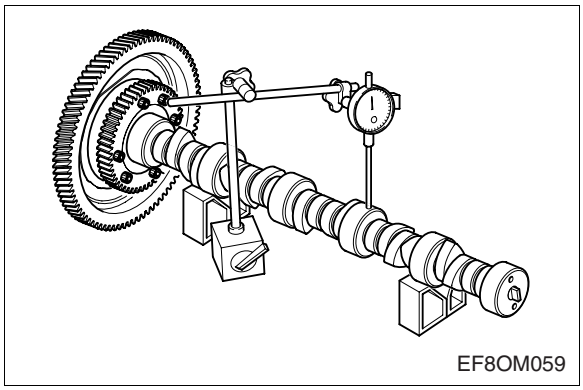


- Camshaft run-out

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

< Camshaft run-out >

Standard	Limit
0.05 mm	0.1 mm



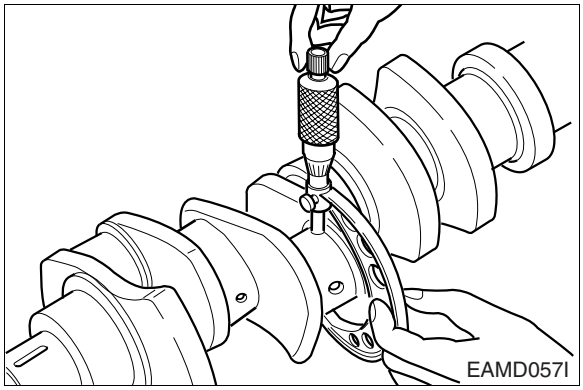
3.2.6. Crankshaft

1) Inspection and measurement

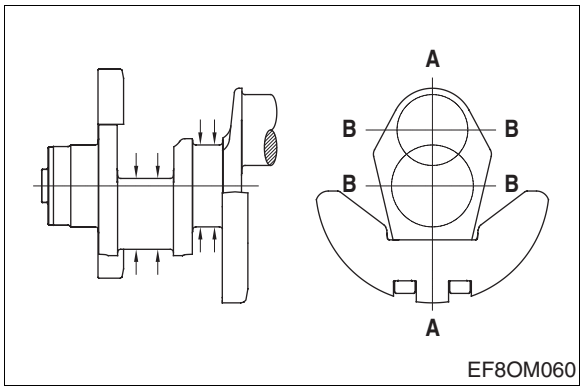
- Inspect for any scratch or damage with naked eyes, and grind to the undersize according to the damaged degree and use the undersized bearing.
- Inspect for any crack by means of magnetic powder and color check, and replace the cracked ones.

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



- If the amount of wear is within the limit, you can correct the wear using an oil stone or oiled grinding paper of fine grain size.
  (be sure to use grinding paper which has been immersed in oil)



<Journal and pin outside diameter>

	Standard
Journal diameter	∅103.98 ~ ∅104.00 mm
Pin diameter	∅89.98 ~ ∅90.00 mm

<Kinds of bearings for undersize>

(a) Standard

(b) 0.25 (Inside diameter 0.25 mm less than standard)

(c) 0.50 (Inside diameter 0.50 mm less than standard)

(d) 0.75 (Inside diameter 0.75 mm less than standard)

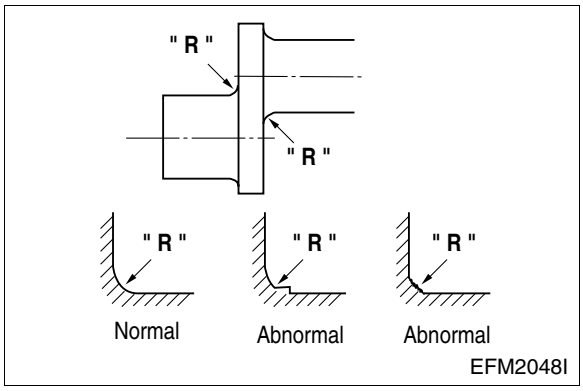
(e) 1.00 (Inside diameter 1.00 mm less than standard)

NOTE:

There are 4 kinds as above, and the crankshaft also can be used by regrinding as above.

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.



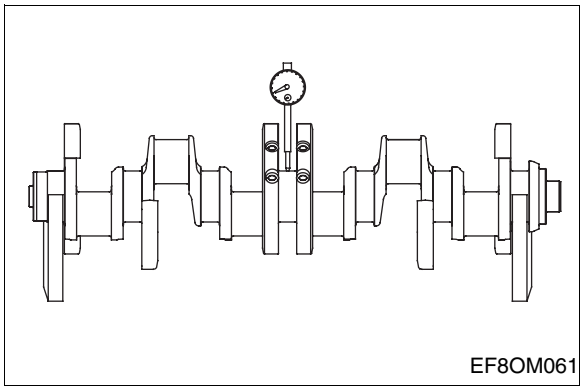
<"R" part standard value>

① Crank pin 'R' : $3.0^{0}_{-0.5}$

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

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.


EF8OM061

< Run out of crankshaft >

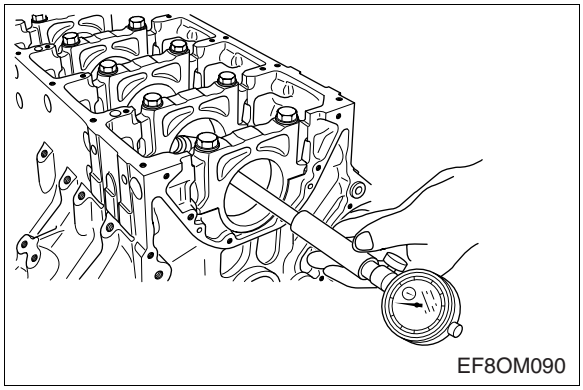
Standard		Limit
P158FE P180FE	0.06 mm	0.4 mm
P222FE	0.08 mm	0.4 mm

2) Crankshaft bearing and connecting rod bearing

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

a) Oil clearance of crankshaft and bearing

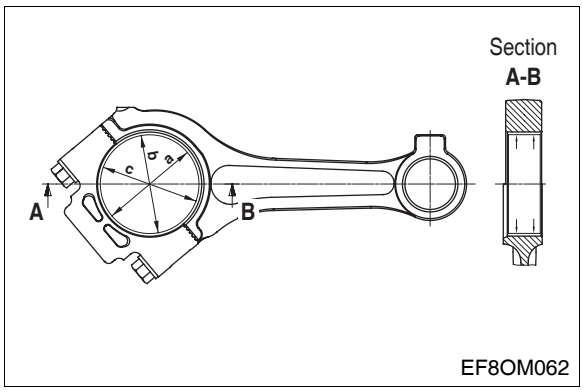
- Assemble the main bearing at the cylinder block and after tightening the bearing cap at the specified torque, measure the inside diameter of bearing.


EF8OM090

Bearing cap Bolt torque	Initial 30 kg·m + angle 90°+10°

Journal bearing nominal diameter	∅103.98 ~ ∅104.00 mm

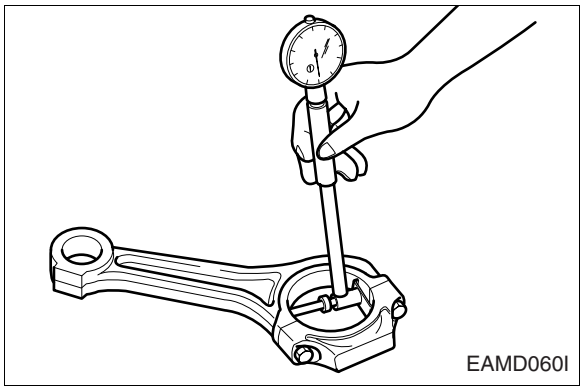
- Assemble the bearing at the bigger end of connecting rod, and after tightening the bearing cap at the specified torque, measure the inside diameter.



EF8OM062

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

Connecting rod bearing journal diameter	∅90.064 ~ ∅90.106 mm


EAMD060I

b) Bearing oil clearance

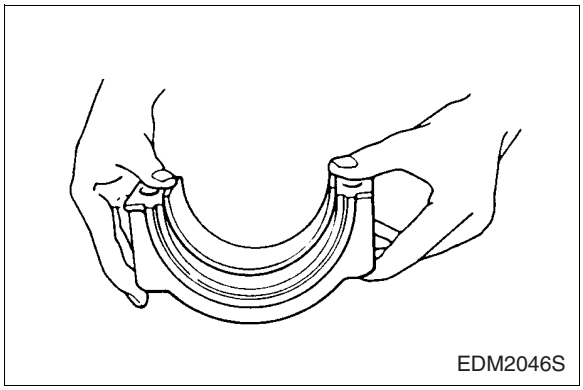
- Compare the two values obtained through measurement of bearing inside diameter (journal bearing, connecting rod bearing) with the outside diameter of journal and pin of crankshaft to determine the oil clearance.

	Standard	Limit
Journal bearing	0.066 ~ 0.132 mm	0.166 mm
Connecting rod bearing	0.064 ~ 0.126 mm	0.154 mm

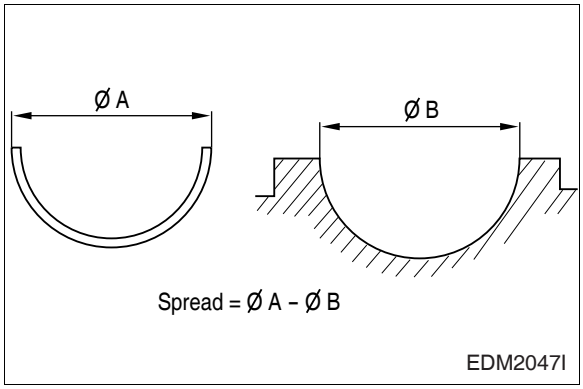
- In case that this clearance value exceeds the limit value, grind the crankshaft journal and pin and then use the undersized bearing.

c) Inspection of journal and connecting rod bearing

- Check to see that the bearing requires a considerable amount of finger pressure at reassembly operation.


EDM2046S

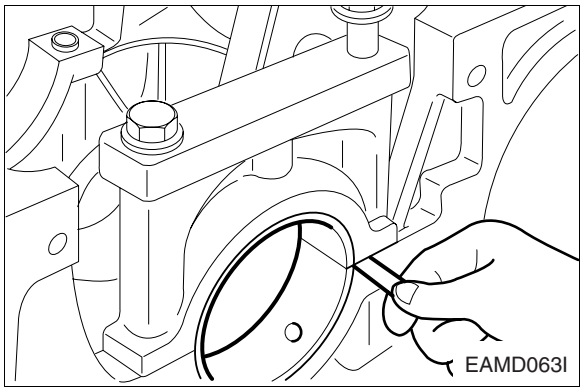
- The spread of journal bearing and connecting rod bearing should be measured with special tool as a figure, but measure it under condition of assembling as below for convenience of working in the field.



EDM2047I

- **Journal bearing**

  Install the bearing and cap in the cylinder block, retighten the bolts to specified torque, unscrew out one bolt completely, then measure the clearance between the bearing cap and cylinder block using a feeler gauge.

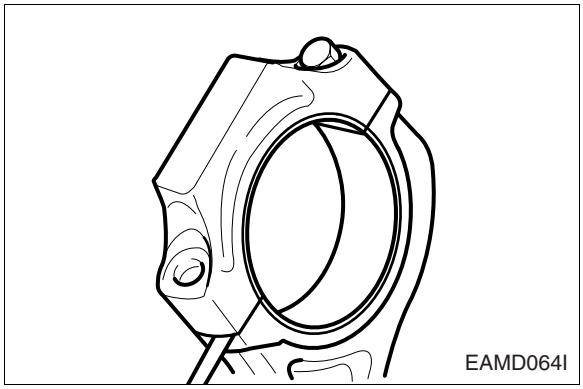


< Crush of main bearing cap >

Standard	0.3 ~ 1.2 mm

- **Connecting rod bearing crush**

  Install the bearing and cap in the connecting rod big end, retighten the bolts to specified torque, unscrew out one bolt completely, then measure the clearance between the bearing cap and connecting rod big end using a feeler gauge.

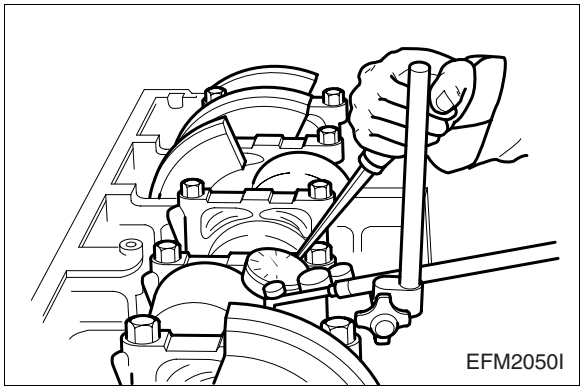


< Crush of connecting rod bearing >

Standard	0.5 ~ 1.4 mm

d) Crank shaft end play

- Assemble the crankshaft to the cylinder block with a dial gauge, measure crankshaft end play.



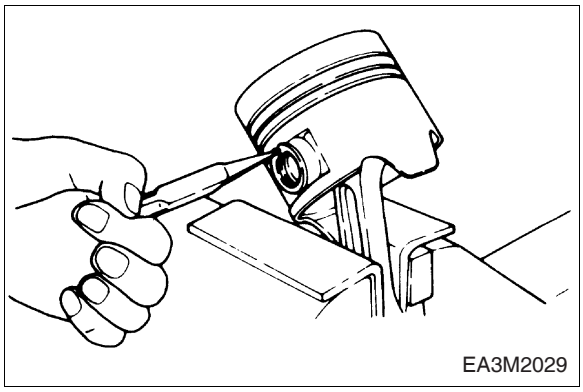
< Crank shaft end play >

Standard	Limit
0.190 ~ 0.322 mm	0.452 mm

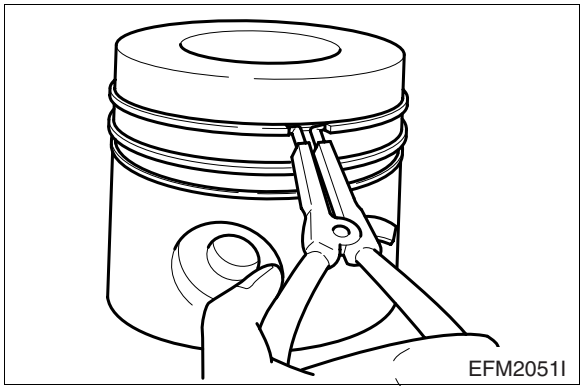
3.2.7. Piston

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.

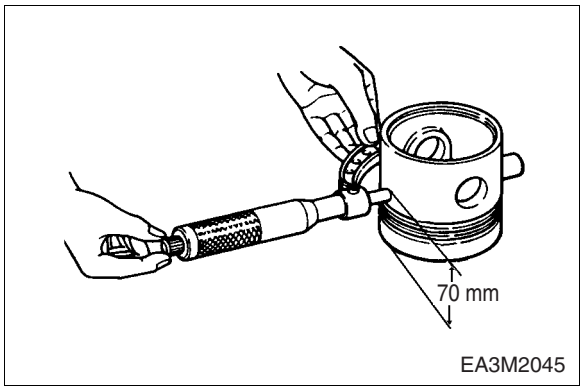

EA3M2029

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


EFM2051I

2) Check and measurement

- 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 from the piston lower end, and the direction of measurement must be perpendicular to the piston pin direction.

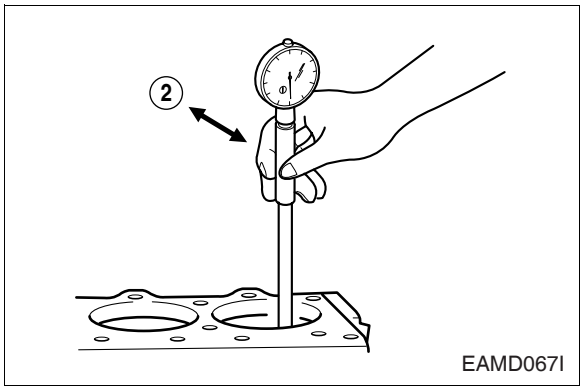


EA3M2045

Standard	∅127.739 ~ ∅127.757 mm

a) Cylinder bore diameter

- Measure cylinder liner inside diameter at 3 points (cylinder top ring contacting face, middle, and oil ring contacting face on BDC) in a direction at an angle of 45°. Take the mean value with the largest and smallest values excepted.



Standard	∅127.99 ~ ∅128.01 mm

b) Piston and cylinder clearance

- The clearance is computed by subtracting the piston outside diameter from the cylinder liner inside diameter. Replace either piston or cylinder liner, whichever damaged more, if the clearance is beyond the specified limit.

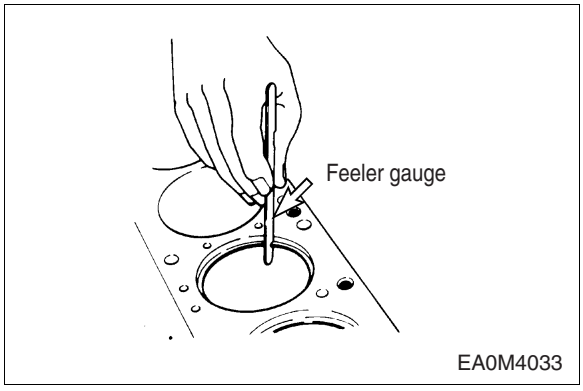
Standard	0.233 ~ 0.271 mm

c) Piston ring and ring groove

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

d) Piston ring cut part 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.

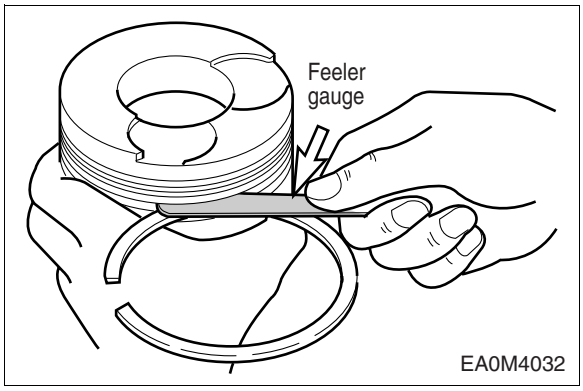


< Piston ring gap >

Division	Standard	Limit
Top ring	0.35 ~ 0.55 mm	1.5 mm
2nd ring	0.80 ~ 0.95 mm	1.5 mm
Oil ring	0.40 ~ 0.70 mm	1.5 mm

e) Piston side clearance

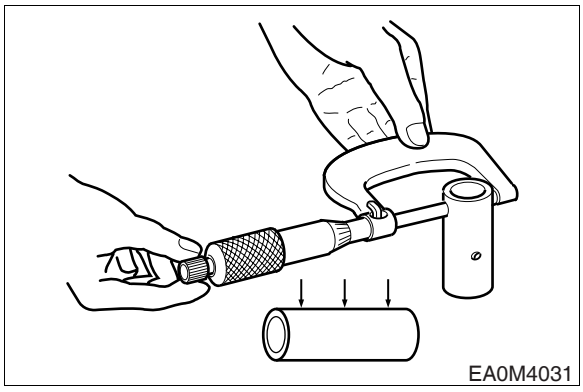
- Assemble the piston ring at the piston.
- Measure the each ring's side clearance and if the measured value exceeds the limit value, replace rings or piston.



Division	Specified value	Limit value
Top ring	–	–
2nd ring	0.05 ~ 0.085 mm	0.15 mm
Oil ring	0.03 ~ 0.07 mm	0.15 mm

f) Piston pin

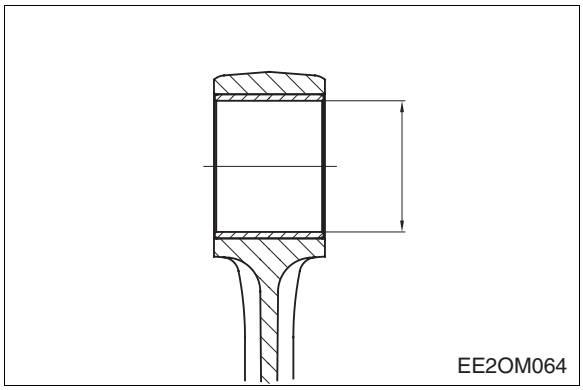
- Measure the amount of wear on the piston pin at the points as shown. The measured values are beyond the limit replace the pin.



Standard	Limit
∅45.994 ~ ∅46.000 mm	∅45.983 mm or less

g) Piston pin and connecting rod bush clearance

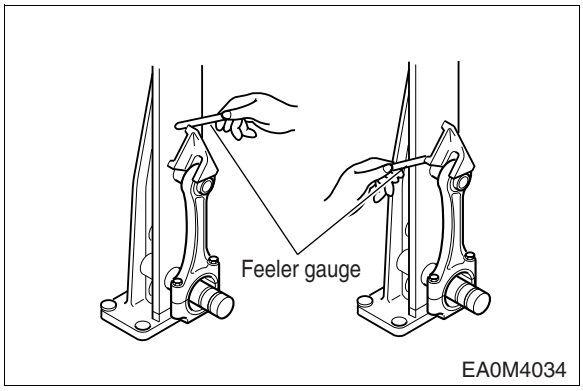
- Inspect the clearance between the piston pin and the connecting rod bush, if it is more than the use limit value, replace either one which exceeds the limit by measurement.



Limit	0.005 ~ 0.061 mm

h) Connecting rod

- Check the connecting rod for distortion. If the connecting rod is found distorted, never re-use it but replace with a new one.
- Measure the alignment of the connecting rod piston pin bushing holes with connecting rod big end holes.



Standard	Limit
0.02 mm	0.1 mm

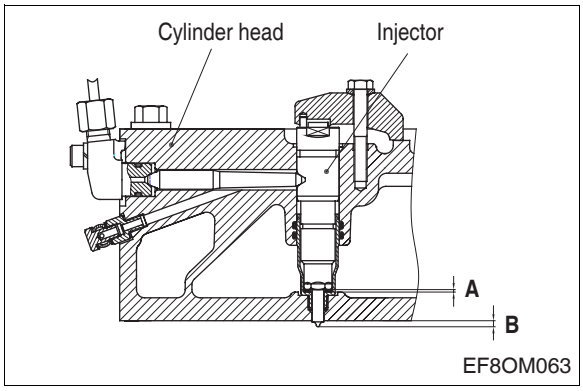
- Assemble the connecting rod to the crankshaft and measure connecting rod big end side clearance using a feeler gauge.

Standard	Limit
0.24 mm ~ 0.392 mm	0.5 mm

- Assemble the connecting rod to the piston and measure connecting rod small end side clearance.
- If the measured values are beyond the limit, replace the connecting rod.

3.2.8. Injector projection

- Insert a seal ring on the cylinder head and assemble the injector.
- Measure the clearance between the cylinder head bottom and injector. If the measured values are beyond the limit, replace the seal ring.



	Standard
A (Thickness of seal ring)	1.0 , 1.5 , 2.0 mm
B (Projection of injector)	3.0 mm

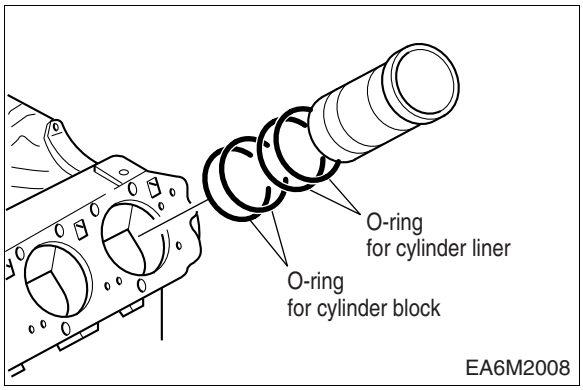
3.3. Engine Reassembly

3.3.1. Preparation and precaution before and after engine reassembly

- Clean all the parts thoroughly and also clean thoroughly by blowing into each passage of oil and cooling water.
- Disposition the various special and general tools for assembling in order.
- In order to coat the lapping parts with engine oil, prepare the clean engine oil.
- Prepare the sub-material such as an adhesive etc.
- Use three bond as an adhesive in the engine oil system and use silicone in the cooling system.
- Scrap the used gasket and seal ring, consumable parts etc. and replace with new ones.
- Tighten the various bolts in the specified tightening torque, and also according to the tightening order but the excessive torque must be avoided.
- Inspect if the movement of engine is smooth after assembling.
- After completion of assembling, whether various bolts are loose or not should necessarily be insured.
- Make sure that there is any missing parts or insufficient parts after full completion of assembling.
- Work only with clean hands.

3.3.2. Cylinder liner

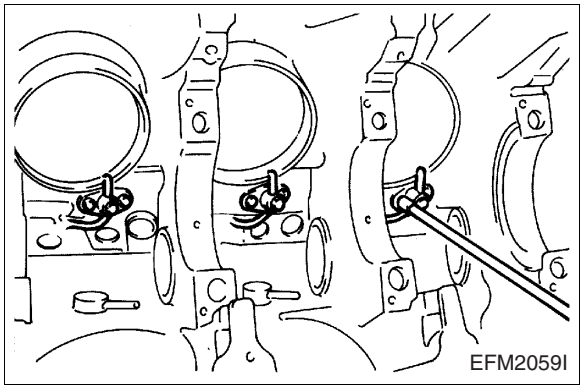
- Replace O-ring with new one without fail and at the upper side, insert to the cylinder liner, but at the lower side, to the cylinder block.
- Coat the joint parts where O-ring contacts with oil.
- After slipping the cylinder liner smoothly into the cylinder block, press it in being careful for O-ring not to damage.
- After completion of assembling the cylinder liner, confirm no leaks with 4 kg/ cm^2 hydraulic test.



3.3.3. Oil spray nozzle

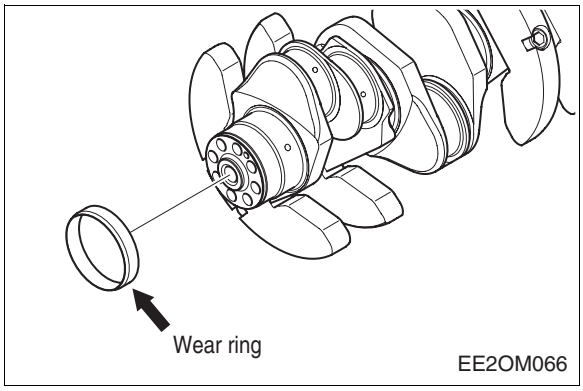
- Tighten the oil injection nozzle flange with hollow screws.
- Assemble the oil injection nozzle with the fixing bolts.

Torque	Fixing bolt	1.2 kg·m
	Hollow screw	7 kg·m

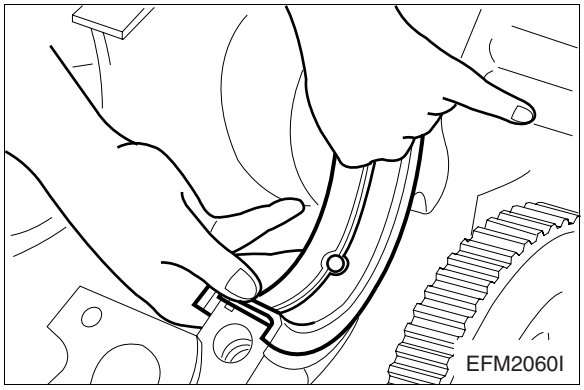


3.3.4. Crank shaft

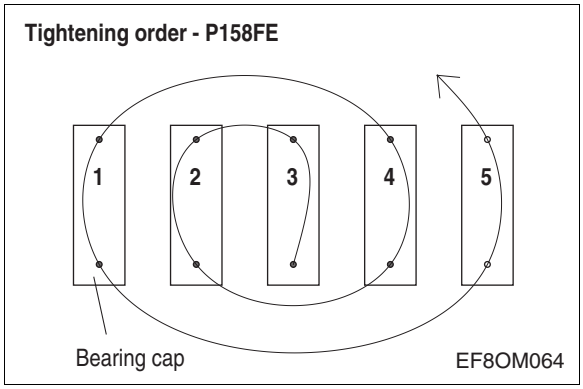
- Put the wear ring into the heater to heat it up to 150 ~ 200 °C level, push it over the crankshaft by means of a jig.

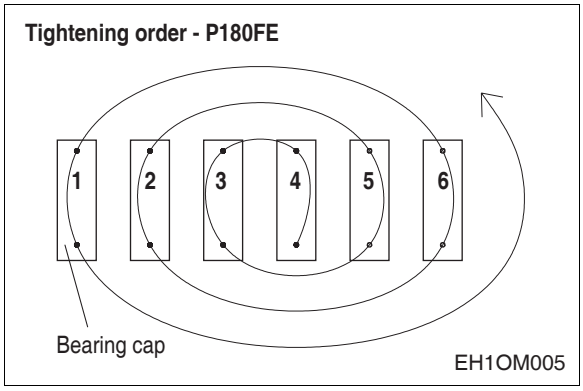


- Assemble the main bearing to the cylinder block and coat it with engine oil. Then assemble the bearing that has a hole to the cylinder block side and one that has no hole to the bearing cap and be careful not to change.

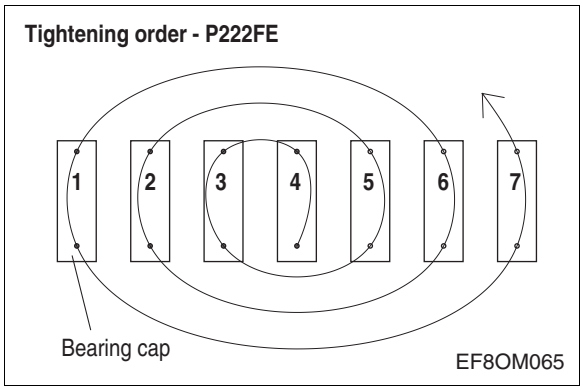


- Assemble temporarily one bolt each at both bolt holes and by connecting the wire to the bolts, lift it with crane or chain block and put down on the cylinder block carefully.

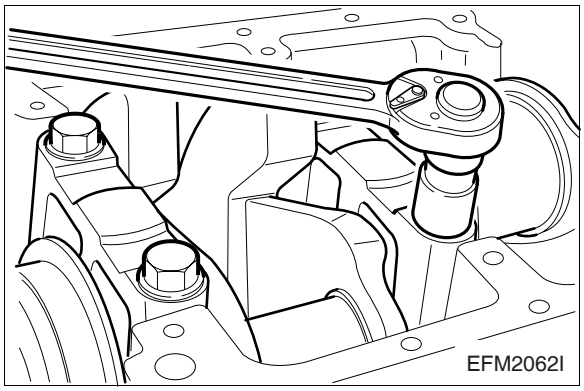




- Coat the crankshaft journal and pin parts with engine oil, and after fitting the main bearing into the bearing cap and assemble it to the cylinder block making sure of the number in order not to change the bearing cap.



- 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° $^{+10°}$) and tightening order are 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.

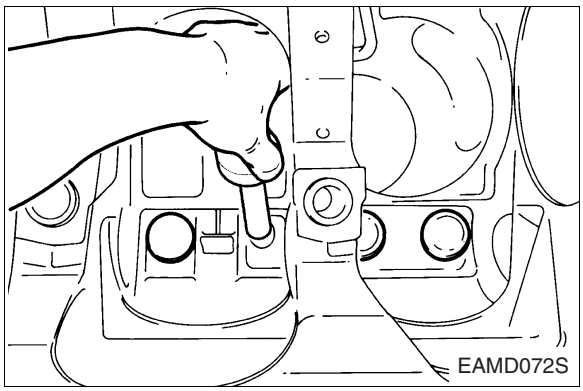
(6) Sixth step: Tighten with final rotating angle method 90°$^{+10°}$.

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.

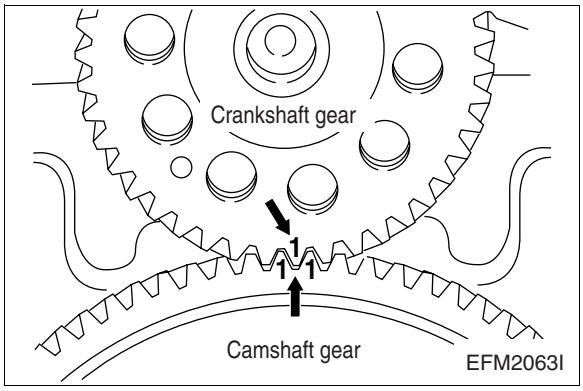
3.3.5. Tappet

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



3.3.6. Cam shaft

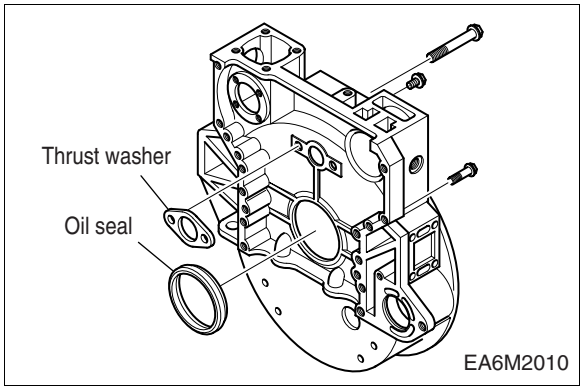
- Coat the cam bush of cylinder block and camshaft with engine oil.
- Assemble the cam bush and camshaft for them not to be damaged.
- Assemble the crankshaft gear and the camshaft gear making sure that the gear marks on both gears are aligned together.



3.3.7. Flywheel housing

- Assemble the following parts in the flywheel housing before installing the flywheel housing onto the cylinder block.
- Apply loctite to the fixing bolt and assemble the thrust washer.

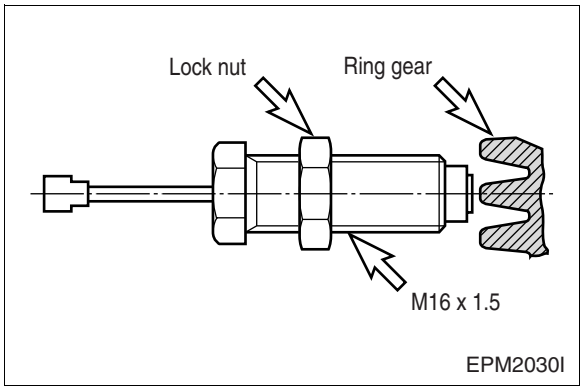
Torque	M10	4 kg·m
	M12 × 1.5	7 kg·m



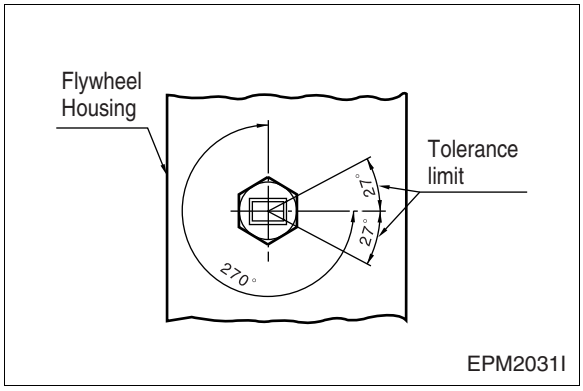
- Coat the oil seal (P.T.F.E.) with lubricating oil and assemble the oil seal carefully for it not to deviate or be damaged by means of special tool. (Mandrel for assembling).
- Attach the gasket on the surface of cylinder block where the flywheel housing is to be installed. (In order to prevent the 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.

3.3.8. Magnetic pick up sensor

- Move the lock nut to hexagonal side of sensor completely.
- Rotate (CW) the pick up sensor on flywheel housing, until the end of it reach on flywheel ring gear.
- Rotate (CCW) the pick up sensor for 270° (gap 1.0 mm) and fix lock nut.

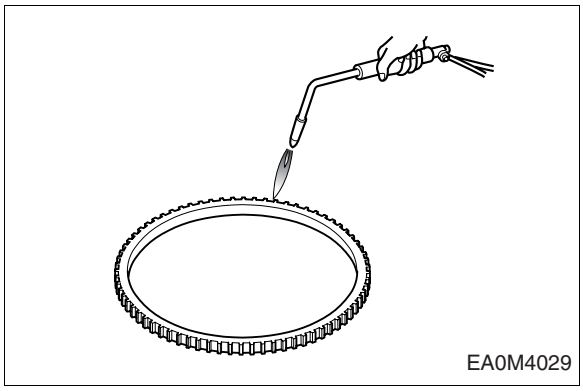


- Tolerance limit is 27°. (gap ± 0.1 mm)

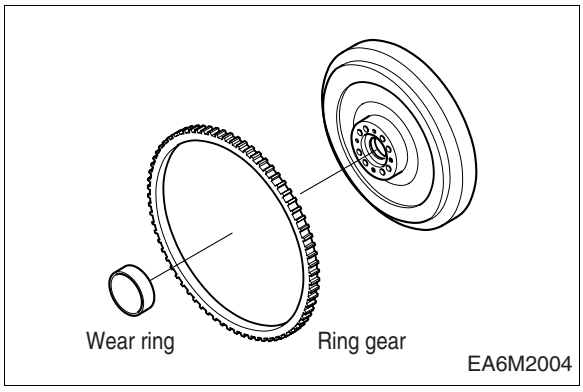


3.3.9. Fly wheel

- 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).

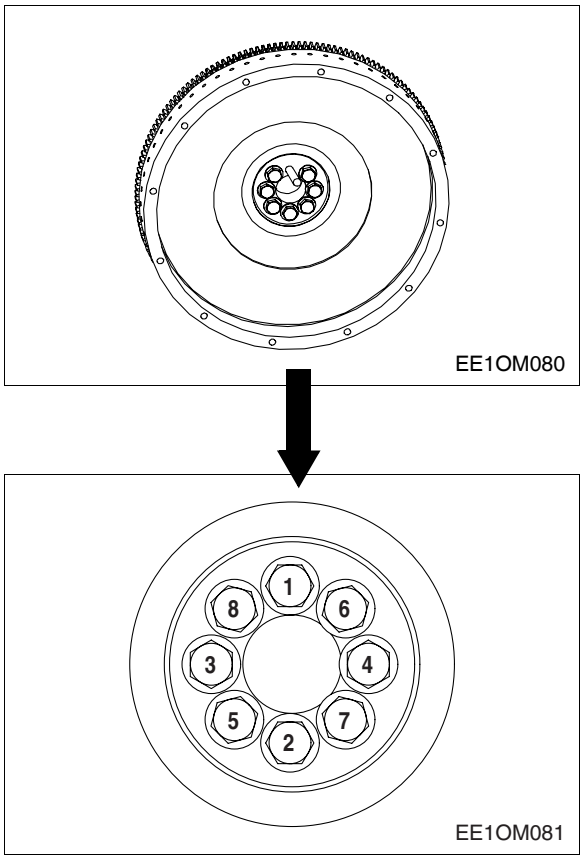


- Heat the wear ring evenly until heat (150 °C ± 10 °C) expansion takes place, then install it using a special tool.
- Apply the loctite #262 on the wear ring seat face of the fly wheel before assemble the wear ring.



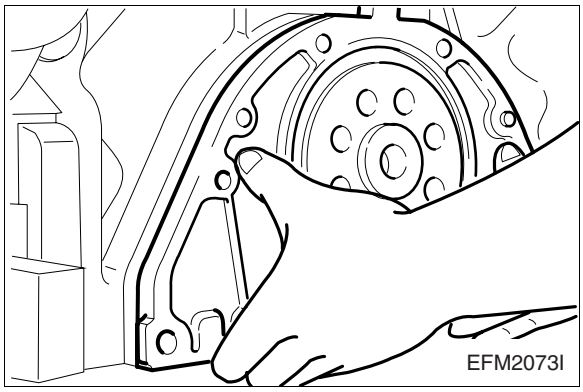
- Install two guide bolts for installing the flywheel to the crankshaft.
- After letting the guide pin insert through the flywheel holes and engaging the fixing bolts by 2 ~ 3 threads temporarily, tighten them to the specified torque according to lightening order. (Zigzag order)

Torque	26 kg·m



3.3.10. Front oil seal holder

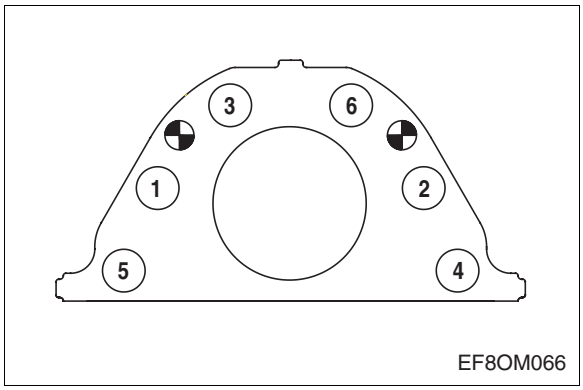
- After placing the oil seal in the oil seal holder hole properly, press it in with a special tool. (Be careful for oil seal not be damaged.)
- Attach a gasket at the oil seal holder.
- Align the dowel pin with the oil seal holder dowel hole and assemble them by tapping lightly the dowel pin part with the 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.

- Apply lubricating oil to the inside of oil seal and tighten the fixing bolts in right orders.

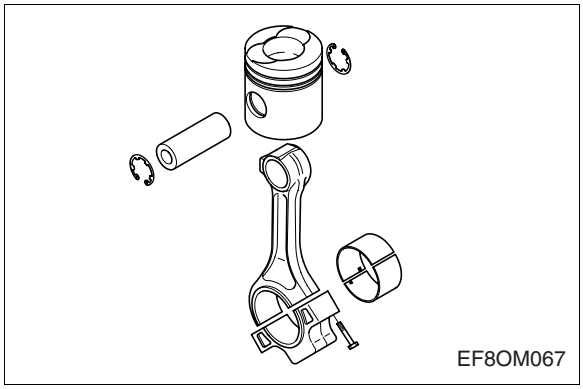
Torque	2.2 kg·m



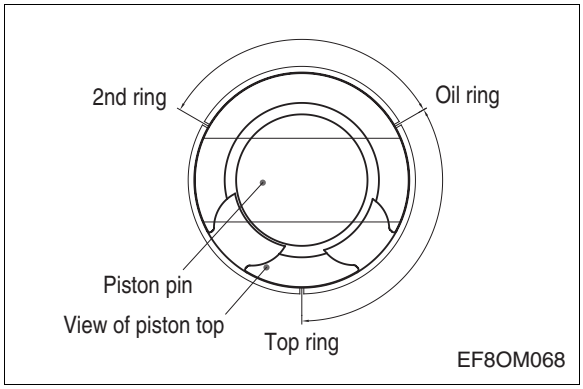
EF8OM066

3.3.11. Piston

- Line up the piston assembly in the order of cylinders 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.

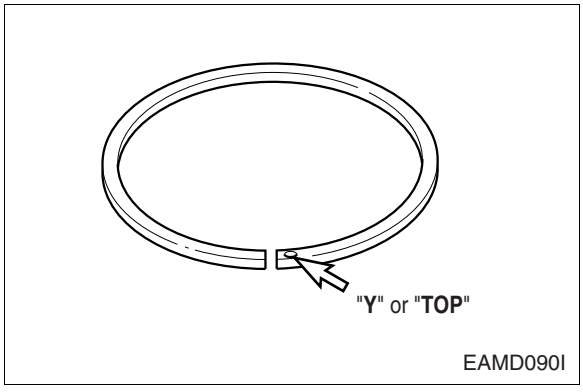

EF8OM067

- By means of a special tool, insert the piston rings and adjust the angles between the ring gaps at 120°.



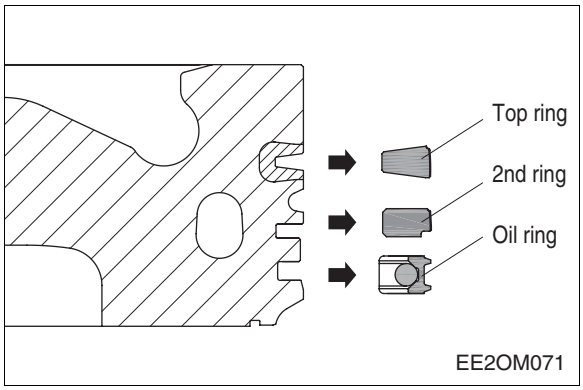
EF8OM068

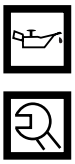
- Identify the mark "**Y**" or "**TOP**" on the ring end to prevent the top and bottom of the piston ring from being interchanged and make the marked portion face upward.
(The surface marked as "**Y**" or "**TOP**" is upper surface.)



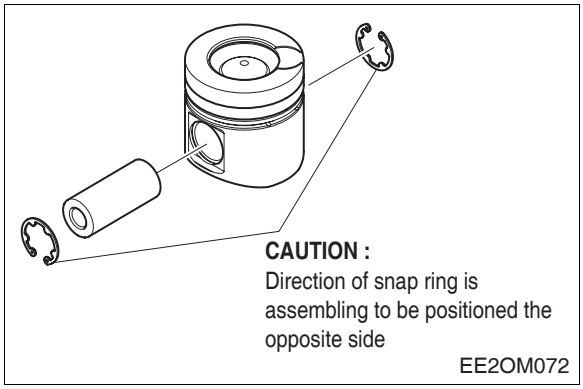
EAMD090I

- Push in the piston with hands or wooden bar into cylinder. (Be careful for piston and rings not 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 + $90^{\circ+10^{\circ}}$)



<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.

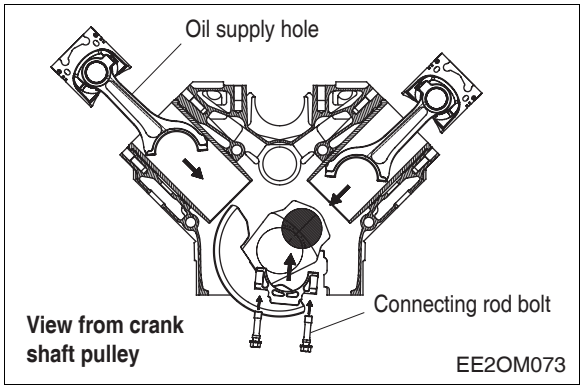
(5) Fifth step: Finally assemble by means of rotation angle method $90^{\circ+10^{\circ}}$.

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

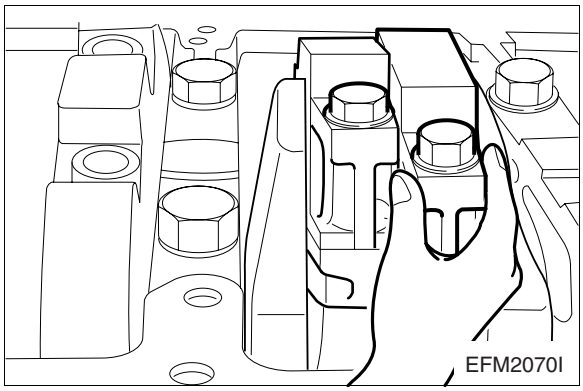
*** Standard length of bolt and use limit :**

from head seat to bolt tip

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

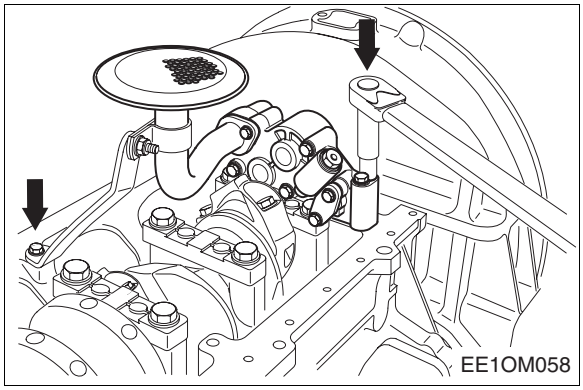


- By moving the connecting rod bearing cap by hands, make sure if there is any play in left and right.
- With the same method as above, assemble in each cylinder rotating the crankshaft.



3.3.12. Oil pump

- Put the oil pump at the place to be installed on the cylinder block.
- Attach a gasket at the surface of oil pump where the pressure regulating valve is to installed and place the regulating valve on a gasket.
- Assemble the oil pump by tightening the fixing bolts.



Oil pump back lash	0.1 ~ 0.45 mm

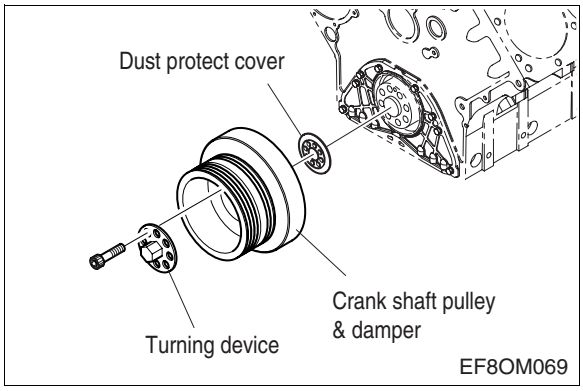
- Attach a gasket at the surface of the oil pump where the oil suction pipe is to be installed, and install the oil suction pipe by tightening the fixing bolts.
- Assemble the pipe bracket on the cylinder block side with bolts.

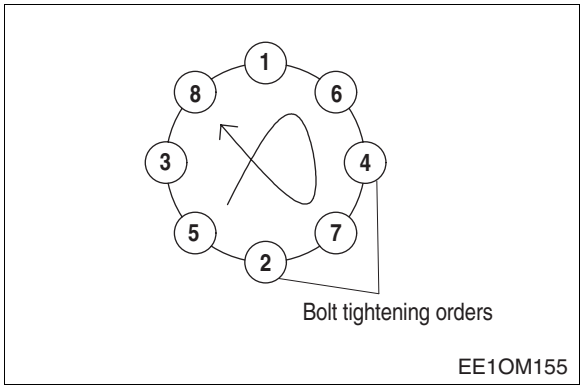
Torque	2.2 kg·m

3.3.13. 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



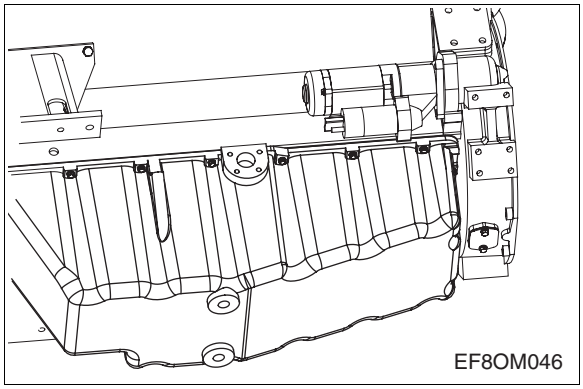


3.3.14. Oil pan

- 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.
- Apply silicon to each joint and attach a gasket to the cylinder block.
- Install the oil pan and tighten the fixing bolts. Then takes care not to squeeze out the gasket.

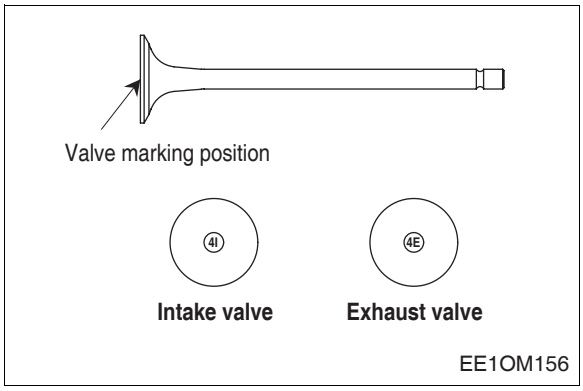
Torque	Fixing bolt	2.2 kg·m
	Drain plug	10 kg·m

- Install the guide tube and insert the oil level gauge.



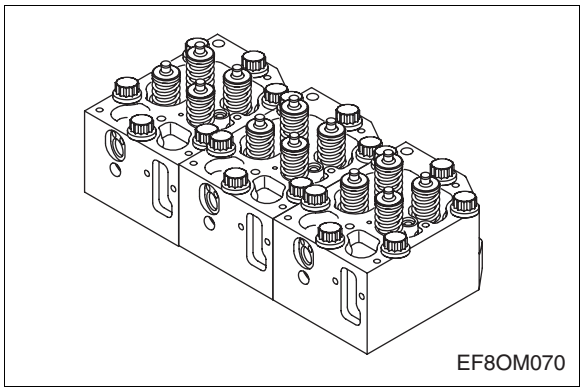
3.3.15. Intake and exhaust valve

- Identify the marks of "**4I**" and "**4E**" impressed on the valve head before assembling the valve with the valve head.
- With a valve stem seal fitting jig, assemble the valve stem seal on the valve guide.

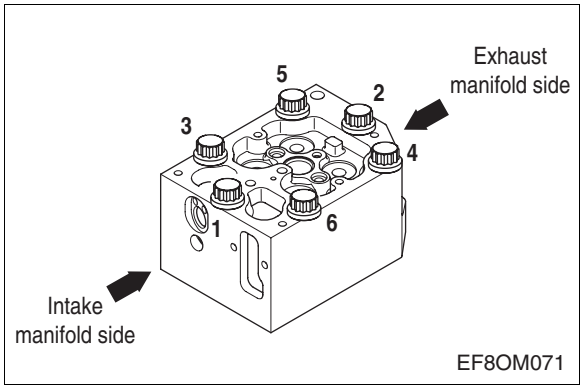


3.3.16. Cylinder head

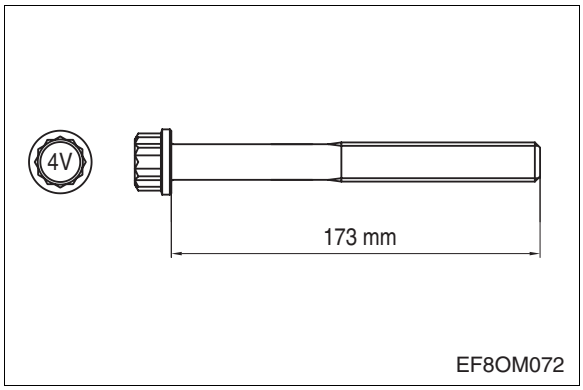
- Blow the cylinder head bolt holes with compressed air to remove the foreign material cleanly.
- Wipe off cleanly the junction part of cylinder block's head gasket.
- After confirming whether there is foreign material or not necessarily, if there is, remove it.



- Assemble a gasket fitting with the fixing pin of cylinder block.
- Position the cylinder head assembly on the cylinder block aligning with its dowel pin. (Take care not to damage the head gasket.)



- Coat the cylinder head bolts with engine oil and tighten them to the specified torque according to step by step. However, prior to tightening the bolts, with a long steel rule, the parallelness between the cylinder heads must be adjusted.



Standard length	Use limit
173 mm	175.5 mm or less (assemble less 3 times)

< Cylinder head bolts tightening order >

1) First step: Coat bolts with engine oil.

2) Second step: Tighten temporarily 1 ~ 2 threads by hands.

3) Third step: Tighten to about 6 kg·m with a wrench.

4) Forth step: Rotate 90° by rotation angle method.

5) Fifth step: Rotate 90° by rotation angle method.

6) Sixth step: Rotate 90° by rotation angle method.

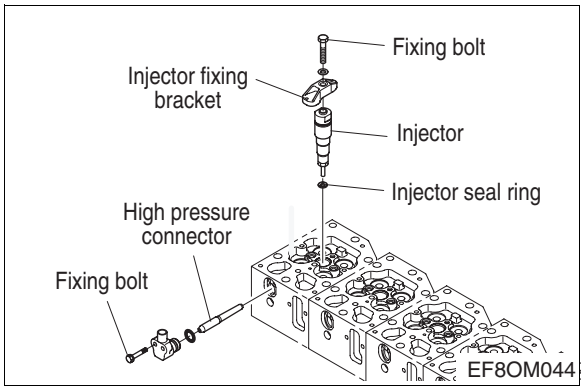
7) Final step: Finally tighten additionally rotating 30°.

NOTE:

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

3.3.17. Injector

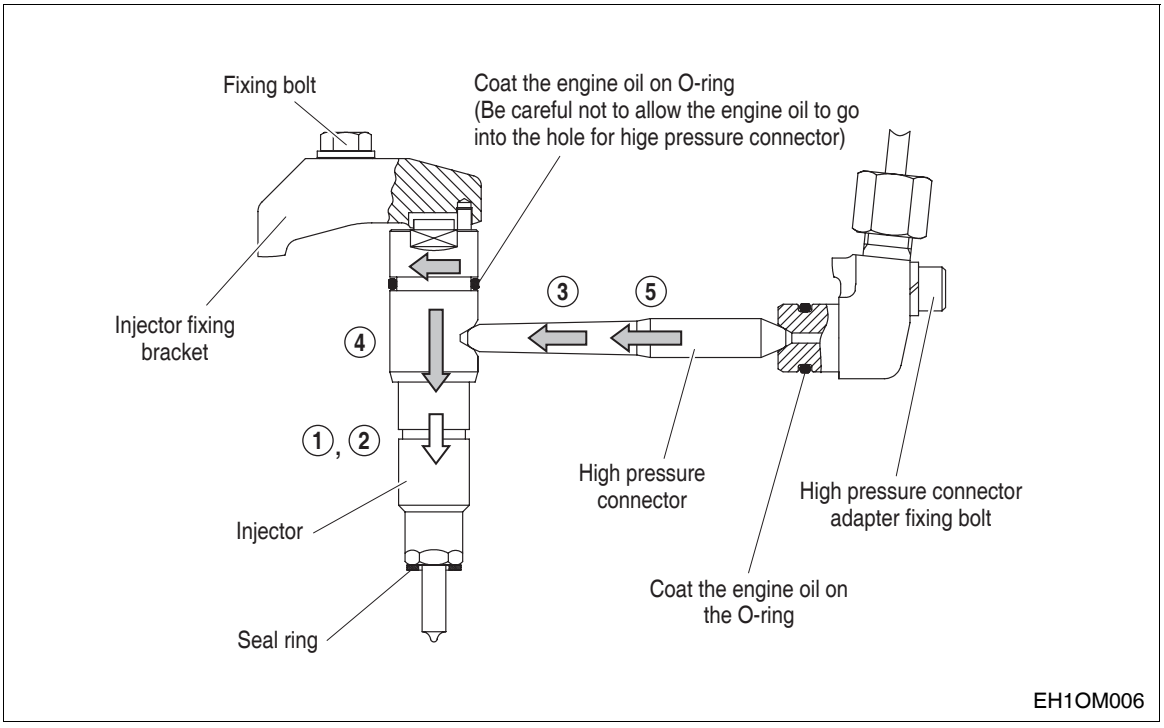
- Clean all the parts thoroughly and be careful not to fall into the foreign material.
- Especially take deeper care on fuel line from common rail up to injector because this area has no filtering function.



- Clean the holes which an injector and a high pressure connector will be put into before they are assembled.
- Whenever disassembling the injector, fuel high pressure connector must be replaced with a new one.
- If fuel goes in the combustion chamber during disassembling the injectors from the fuel return line and/or gap around the injector and high pressure connector, please remove the fuel by sucking with hand pump or short cranking with fuel stop.

< Injector and high pressure connector assembly procedure >

1) The injector should be assembled correctly on the following procedure.

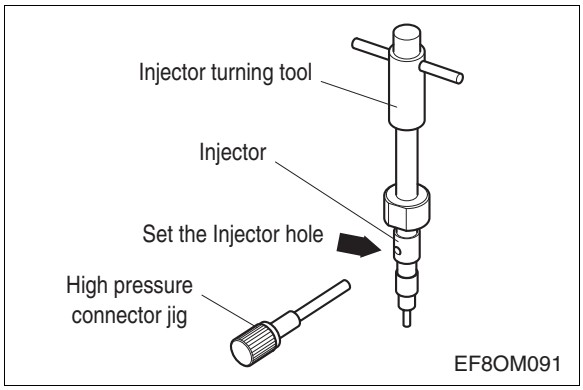


2) Clean the holes which an injector and a high pressure connector will be put into before they are assembled. Engine oil and fuel that might went into during disassembly should be wiped out especially for the holes where a fuel high pressure connector & an injector will be put into.

3) Coat the fresh engine oil on the O-ring of the injector. At the same time, be careful not to allow the engine oil or foreign material to go into the holes for a fuel high pressure connector.

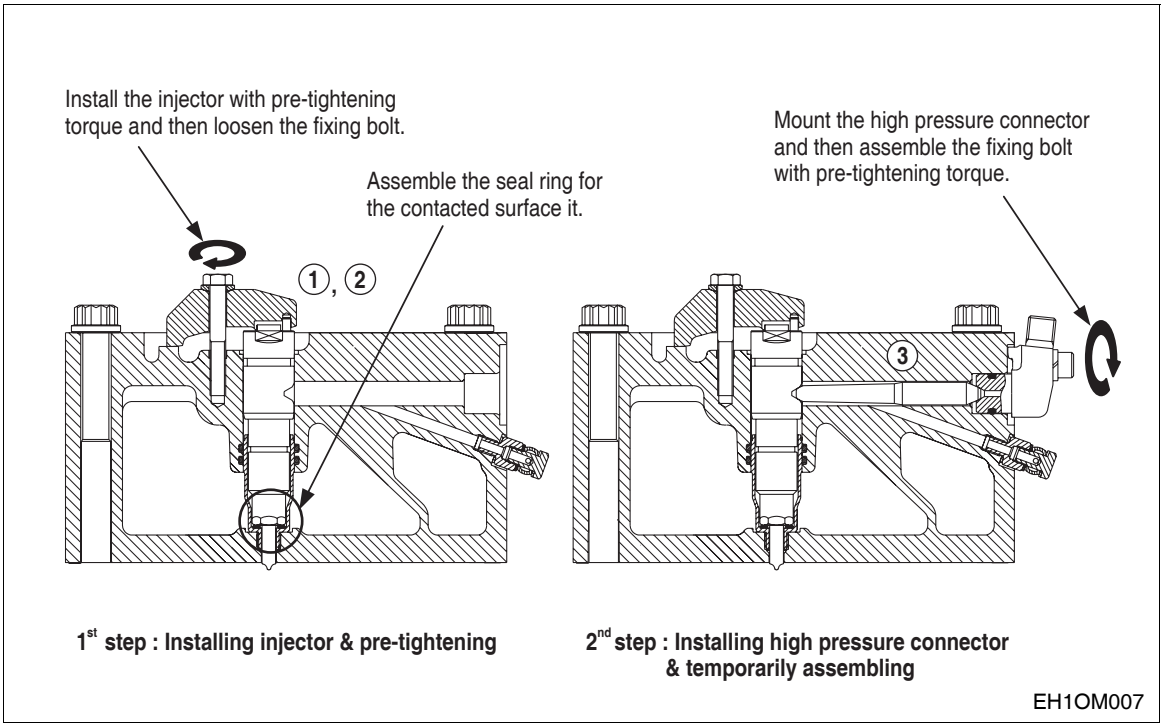
4) First, set the position between the hole of fixing bracket and the tap hole of the bolt for injector fixing bracket. Second, insert the injector vertically to the hole. Put the bolt of the injector fixing bracket into a thread on the head and tighten about 2 ~ 3 turns with hands.

- Assembling injector jig : EF.120-277
- Assembling high pressure connector jig : EF.120-277



5) ①, ②Temporarily mount the fixing bolt assemble with pre-tightening torque while aligning an injector and a fuel high pressure connector. Through this step, the sealing and O-ring is placed correctly on the cylinder head and fuel lines are to be fit together. **Afterwards release the injector by loosening the fixing bolt and then injector pre-load leads to 0 (zero) kg·m.**

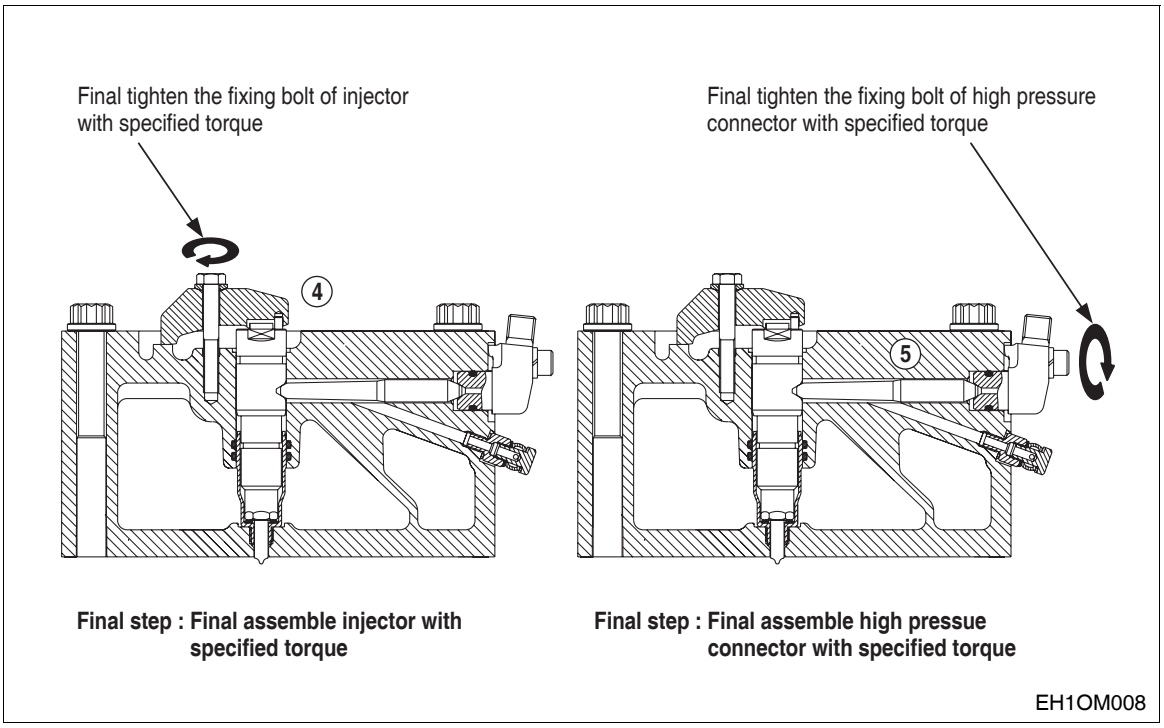
6) ③ Coat the fresh and clean engine oil on O-ring on the adapter of high pressure connector. Insert the high pressure connector and fuel delivery adapter into the cylinder head. Push the connector into the hole until feeling it contacted.



Temporarily torque	Injector fixing bracket bolt	Fuel high pressure connector fixing bolt
	0.3 kg·m	0.25 kg·m

7) The injector and high pressure connector should be assembled correctly by the following order.
④ Finally tighten the fixing bolt of injector up to the specified torque while the high pressure connector is still pre-tightened.

8) ⑤ Finally assemble the high pressure connector. Tighten the fixing bolt of high pressure connector adapter according to the specified torque by the torque wrench. Please keep and obey this procedure and work order.

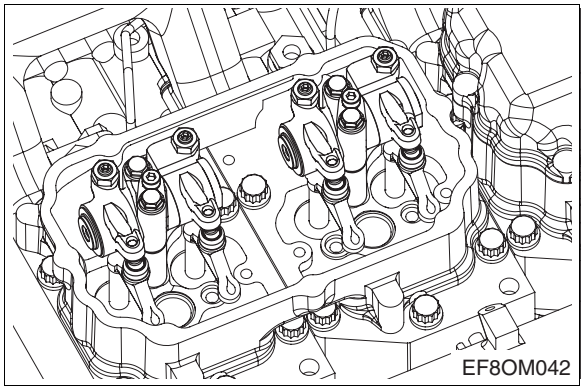


Final torque	Injector fixing bracket bolt	Fuel high pressure connector fixing bolt
	3.5 ~ 4.0 kg·m	1.0 kg·m

3.3.18. Rocker arm

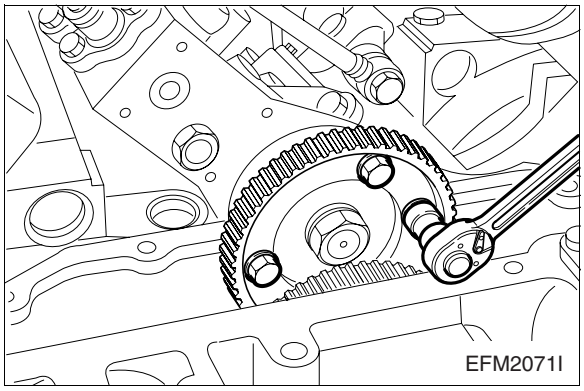
- Coat the push rod with engine oil and put it into the push rod hole.
- Position the rocker arm assembly on the cylinder head and tighten the fixing bolts to the specified tightening torque.

Torque	6.2 kg·m

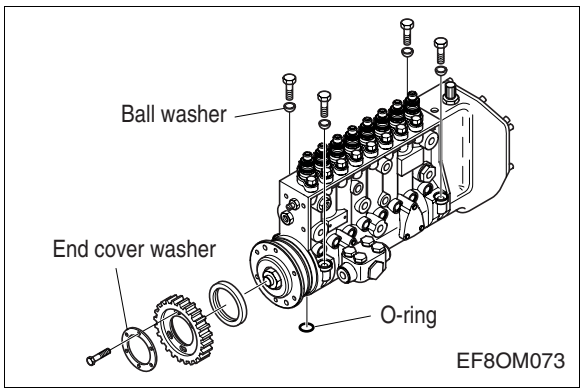


3.3.19. Fuel injection pump

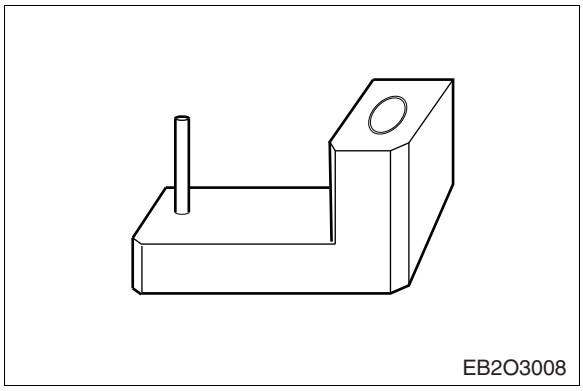
- Turn the crankshaft so as to let the cylinder No. 6 for P158FE, P222FE engines and the cylinder No. 7 for P180FE come to TDC (top dead center).
- Rotate the crankshaft to reverse about 30°(in order to remove a backlash) and then rotate it to engine rotating direction to set the fuel injection timing 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.

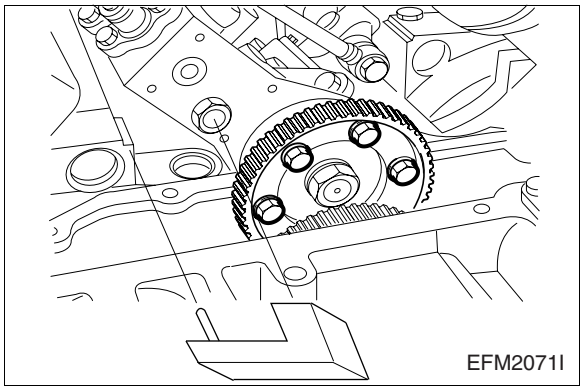


- Fit the injection pump in the appropriate position using a special tool.
- After fixing the jig hole on the limit cap of the injection pump rotate the jig counterclockwise and align the jig pin to the machined corner of the cylinder block, then assemble the injection pump.
- After completing the preparation 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.

Torque	3.1 kg·m

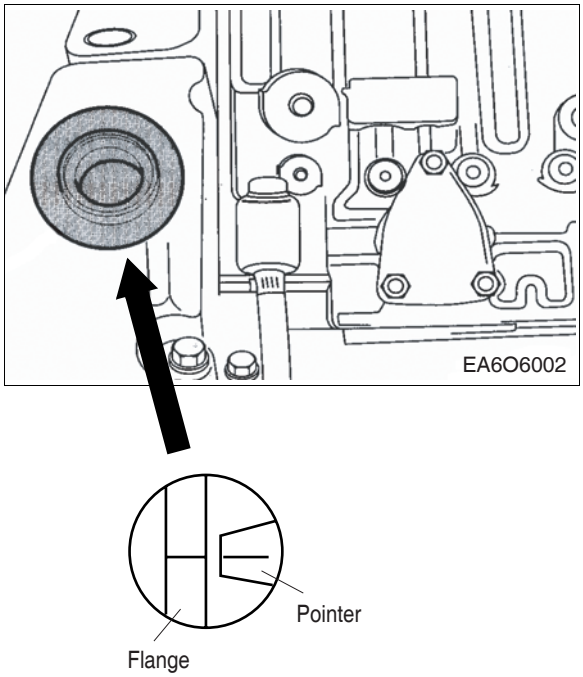


3.3.20. Injection timing

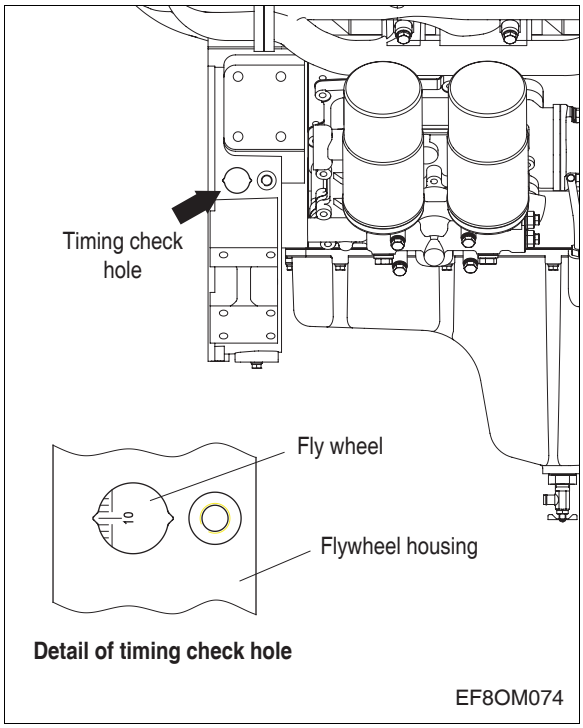
- **How to check the injection timing**

  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 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.

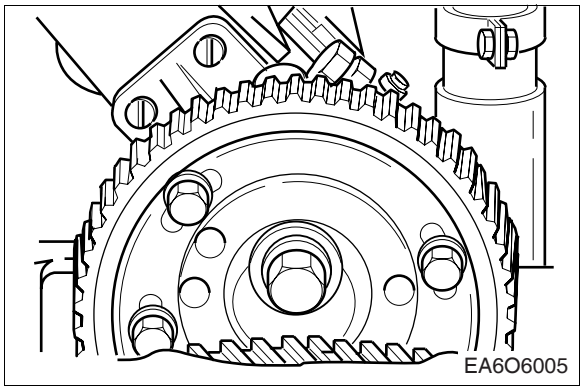


- **How to adjust injection timing**

  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 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.

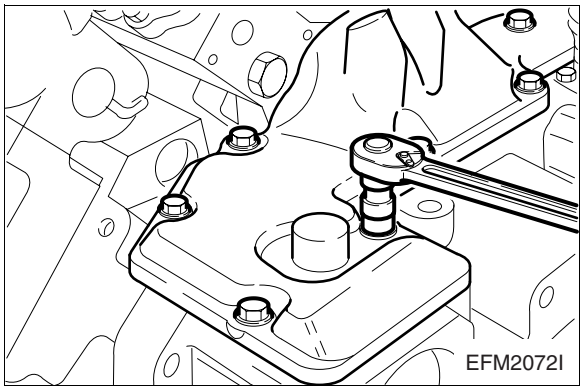
<Fuel injection timing degree>

- Refer the fuel injection timing degree on 1.3. Engine Power.

3.3.21. Flywheel housing cover

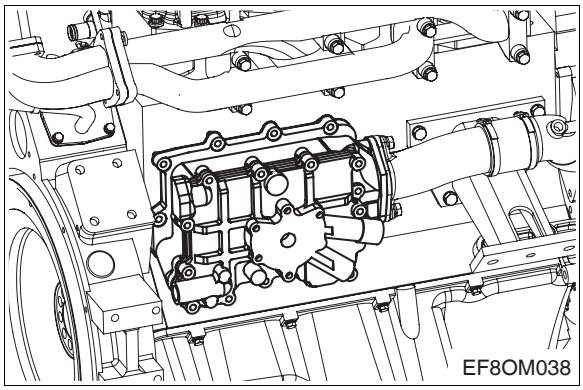
- Attach a gasket to the flywheel housing cover.
- Install the flywheel housing cover and tighten the fixing bolts by the zigzag method.

Torque	4.4 kg·m

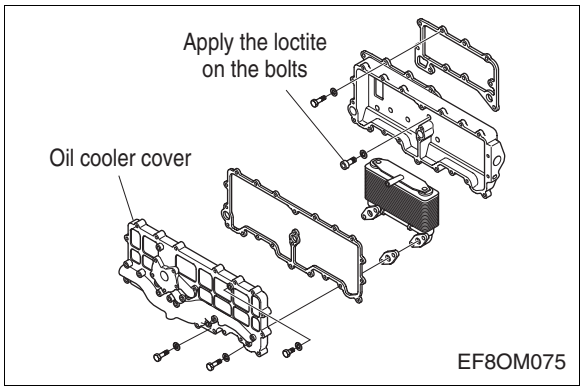


3.3.22. Oil cooler

- 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.



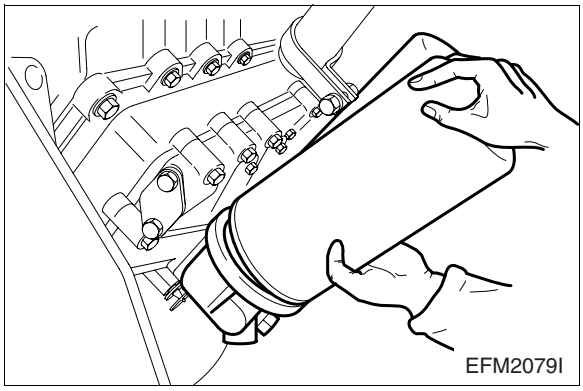
Torque	M8	4.4 kg·m
	M10	5.5 kg·m

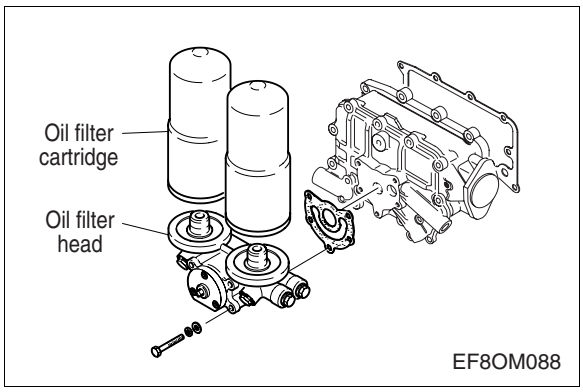


3.3.23. Oil filter

- Attach a gasket on the surface in the oil cooler cover, then assemble the oil filter housing.
- Install the oil filter cartridge.

Torque	7.5 kg·m



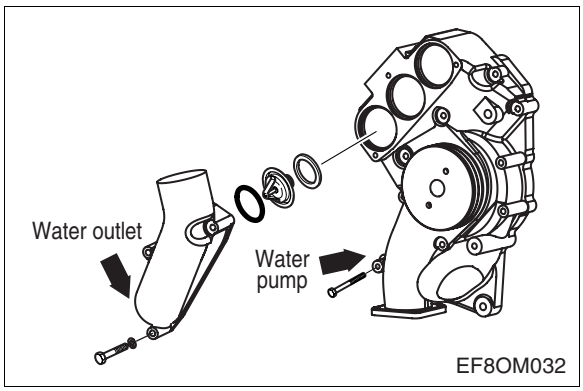


3.3.24. Cooling water pump

- Attach a gasket at the cooling water pump and apply the sealant on the gasket face of cylinder block side.

Torque	4.4 kg·m

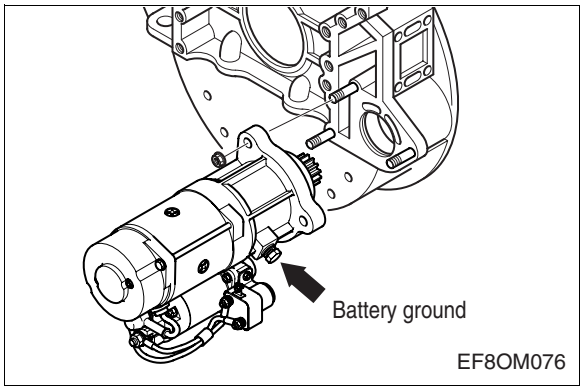
- Assemble the cooling water pump by tightening the fixing bolts. (zigzag method)
- Insert the O-ring to the thermostat and assemble the cooling water pipes by tightening the fixing bolts.



3.3.25. 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 nuts.

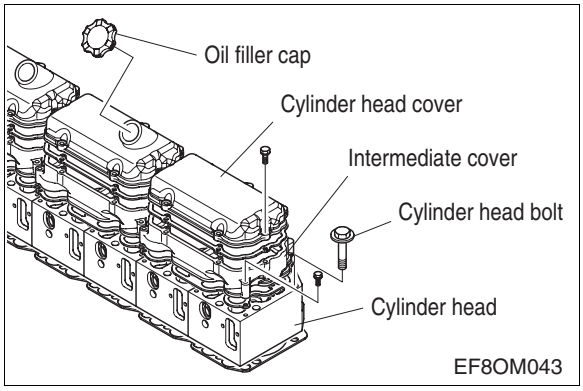
Torque	8 kg·m



3.3.26. Cylinder head cover and intermediate cover

- Attach a new gasket on the surface of intermediate cover where the cylinder head is to be installed.
- Assemble the cylinder head cover by tightening the fixing bolts.
- Insert the oil filler cap.
- After inserting the oil bleeder pipe, assemble by tightening clamp.

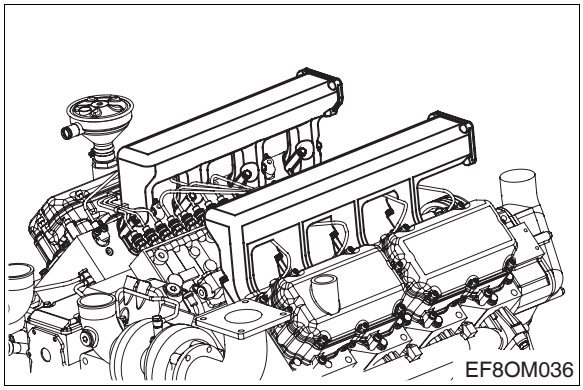
Torque of Intermediate cover bolt	2.2 kg·m



3.3.27. Intake manifold

- Attach a new gasket to the cylinder head side.
- Assemble the intake manifold by tightening the fixing bolts.

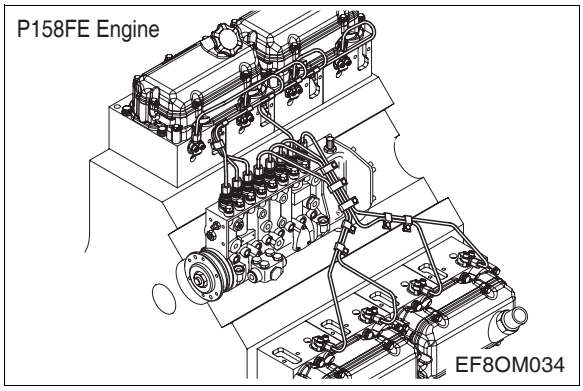
Torque	4 kg·m

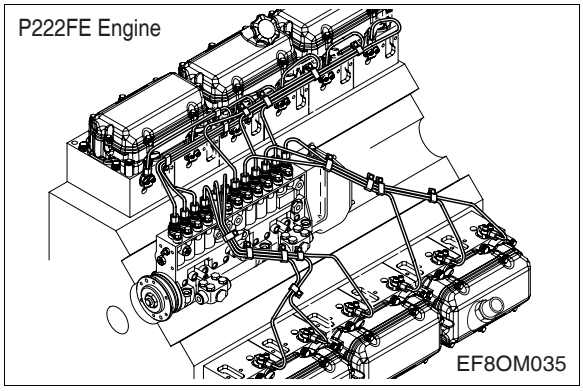


3.3.28. Fuel injection pipe

- Connect the fuel injection pipes between the fuel injection pump and the high pressure connector of cylinder head, and then tighten clamping nuts.
- Fix the fuel return pipe by tightening hollow screw.

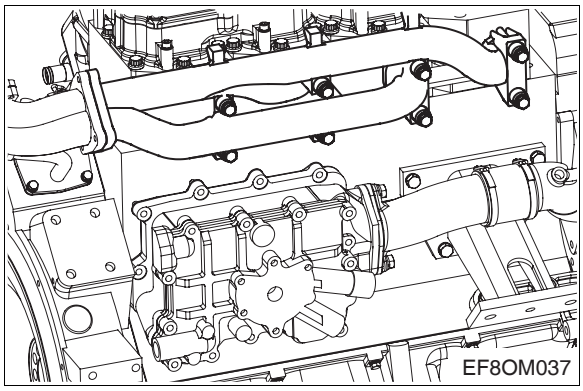
Torque of injection pipe nut	3 kg·m





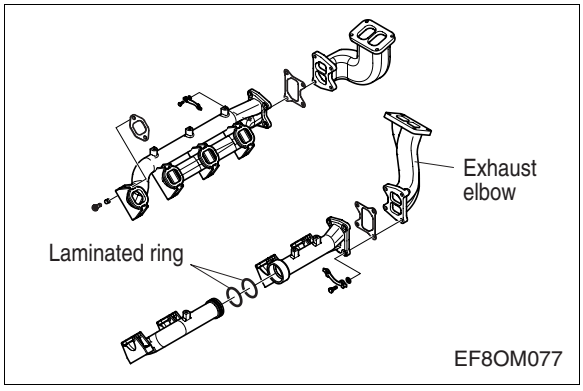
3.3.29. Exhaust manifold

- Connect the exhaust manifold that is 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 tighten the bolts for connection.
- Assemble both sides in the same method as above.

Torque	8 kg·m

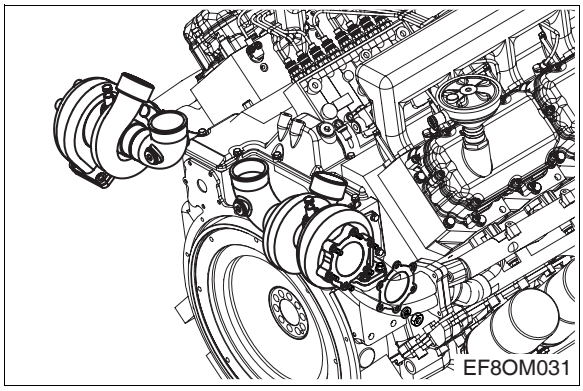


3.3.30. Turbocharger

- Attach a gasket to the exhaust elbow and assemble the turbocharger with fixing nuts.
- 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.

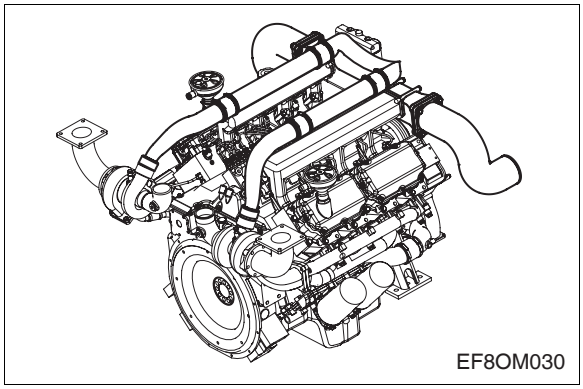
- At the same method as above, both sides are assembled.

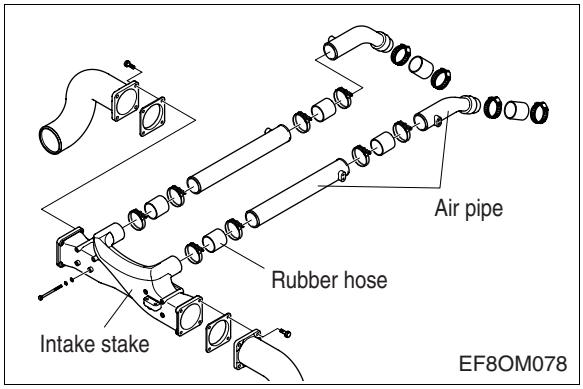
Torque of turbocharger fixing nut	6.2 kg·m



3.3.31. Intake stake and air pipe

- Install the connecting pipes and hoses between the intake stake and turbocharger. Then it is assembled with the hose clamps.

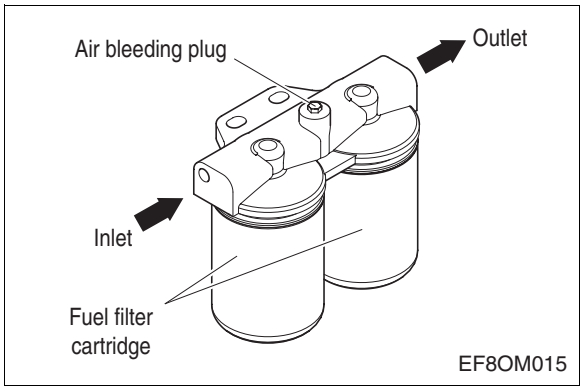




3.3.32. Fuel filter

- Assemble the fuel filter to the intake stake by tightening bolts.
- Assemble the fuel feed hose according to the direction of an arrow impressed on the fuel filter head.

Torque	4 kg·m

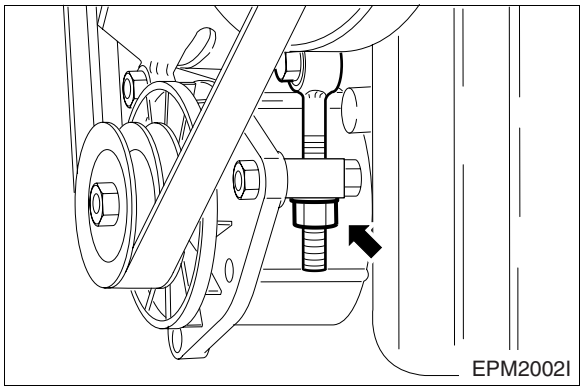


3.3.33. Hoses and pipes

- Connect fuel strainer to fuel feed pump and assemble the fuel hoses therewith.
- Connect fuel delivery and return hoses

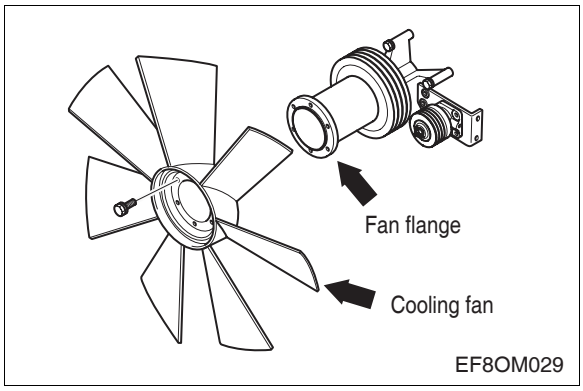
3.3.34. Alternator

- Assemble the alternator mounting bracket to 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.



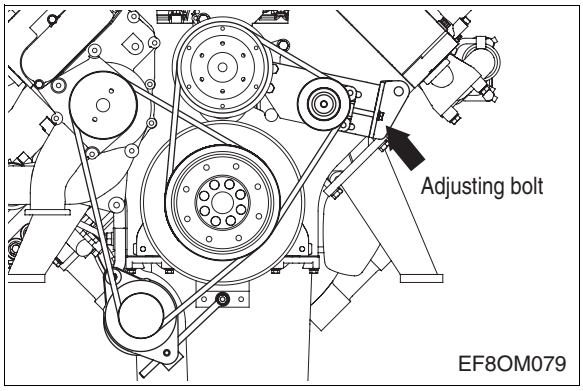
3.3.35. Cooing fan and fan mounting

- Assemble the fan mounting on the cylinder block and then install the fan flange.
- Assemble cooling fan to fan flange with fixing bolts and tighten to the specified torque.



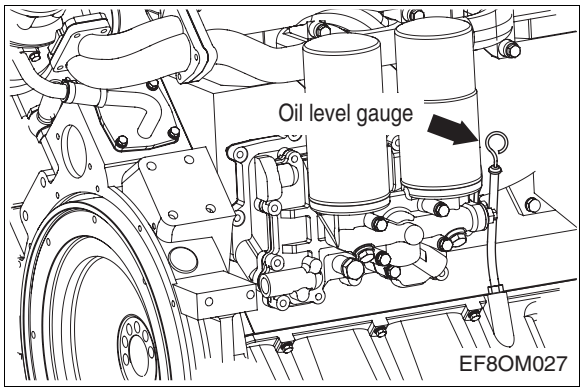
3.3.36. Idle pulley and belt

- Install the idle pulley.
- Connect the cooling fan pulley, the crank shaft pulley, and the idle pulley with driving V-belts.
- Adjust the tension adjusting bolt. (10 ~ 15 mm or so pushing with a thumb)



3.3.37. Oil level gauge and guide tube

- Assemble the guide tube on the oil pan and then insert the oil level gauge.



3.3.38. Others

- Assemble by connecting the other sensor, harness, oil and fuel lines.

4. Commissioning and Operation

4.1. Preparations

At the time of initial commissioning of a new or overhauled engine make sure to have observed the Technical information for the installation DOOSAN generator engines.

- **Oil filler neck on cylinder head cover**

  Before daily starting of the engine, check the fuel, coolant and oil level, replenish if necessary.
- The oil level must be between Max. and Min. lines on the gauge. The notches in the oil level gauge indicate the highest and lowest permissible oil levels.

IMPORTANT:
Do not fill above the top of the mark by over lifting. Over lifting will result in damage to the engine.

- **Cleanliness**

  Ensure outmost cleanliness when handling fuels, lubricants and coolants, be careful about mixing of the foreign matter during the supplement.

  In case that DOOSAN recommended the fuel and lubrication oil and coolant do not used, DOOSAN do not guarantee the field claim.

4.2. Breaking-In

- DOOSAN engine for the vehicle is operated during a short time for the engine last Approving test, therefore operator must execute the process of proper breaking in the engine during the first 50 hours, then The maximum performance of the engine have the maximum performance , and the life of the engine can be prolonged.

4.2.1. 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.

4.2.2. Check points for break-in

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

- 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 the oil level gauge, rotate the oil level gauge 180° and re-insert for check.

- 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 level gauge. 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.

- 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 cartridge.
- Fill oil pan with recommended engine oil. Refer to following table

SAE no.	Oil grade
SAE15W40 SAE10W40	ACEA-E2 or ACEA-E3 (API CH-4)

- Engine Oil capacity

Engine oil capacity			
Engine model	in Oil pan		Total (lit)
	Max. (lit)	Min. (lit)	
P158FE	28	26	31
P180FE	35	28	38
P222FE	40	33	43

4.2.3. Operating after break-In

When starting a cold engine, always allow the engine to warm up gradually. Never run the engine at full throttle until the engine is thoroughly warmed up. Be sure to check the oil level frequently during the first 50 hours of operation, since the oil consumption will be high until the piston rings are properly seated.

4.3. Inspections after Starting

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.

And the charge warning lamp of the alternator should go out when the engine is running.

- 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.
- Engine should be stopped if the color, the noise or the odor of exhaust gas is not normal.
- Confirm the following things through warning lamps and gauge panel.

4.3.1. Pressure of lubricating oil

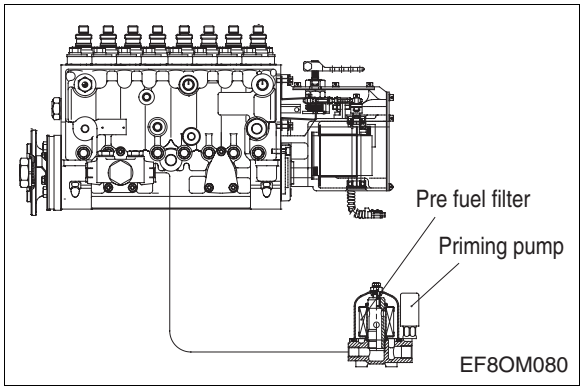
The normal pressure comes up to 1.0 ~ 3 kg/cm^2 at idling and 3 ~ 5 kg/cm^2 (3.0 ~ 4.9 bar) at maximum speed. If the pressure fluctuates at idling or does not reach up to the expected level at high speed, shut down the engine immediately and check the oil level and the oil line leakage.

4.3.2. Temperature of cooling water

The cooling water temperature should be 85 °C in normal operating conditions. Abnormally high cooling water temperature could cause the overheating of engine and the sticking of cylinder components. And excessively low cooling water temperature increases the fuel consumption, accelerates the wears of cylinder liners and shortens the engine life-time.

4.3.3. Bleeding the fuel system

- After the cleaning of the fuel filter or after the engine stop by the lack of fuel, the bleeding of the fuel system must be executed by all means.
- Order of the bleeding
  (1) Turn the feed pump cap counter-clockwise, then it rises upwards.
  (2) Open the bleeding valves of the fuel filter.
  (3) Press the feed pump cap repetitively until the fuel without bubbles comes out from the bleeding valves.
  (4) After the whole air is pulled out, close the valve of the bleeding valve.
  (5) Confirm the resistance of fuel delivery by the repetitional pressing of the feed pump cap.
  (6) Press and turn the feed pump cap simultaneously to close it.



4.4. Operation in Winter Time (Option)

Pay special attention to the freezing of cooling water and the viscosity of lubricating oil.

4.4.1. Starting of winter

CAUTION :

1. Preheating devices are attached to the engine for improving the starting abilities at extremely low temperature.

2. Do not actuate the starter for longer than 10 seconds. If starting fails regardless of the preheating, start the preheating again after 30 seconds.

Operation 1 : Turn the key switch to the **HEAT** position, then the pilot lamp lights up for about 22 seconds When the pilot lamp is extinguished, do operation 2

Behavior – When the coolant temperature is below 25 °C in cold weather, you'd better operate the pre-heating system (Air heater)

– If the pre-heating is not necessary, the pre-heating system is not operated with the pilot lamp.

Operation 2 : After checking the pilot lamp, turn the key switch to the **START** position to crank the engine, at once.

Behavior – When the key switch is placed in the **START** position, air heater is continuously heated to facilitate starting operation and to reduce white smoke during 5 minutes automatically.

– If the coolant temperature is above 25 °C, air eater needs not be heated.

Operation 3 : After the engine is cranked, convert the key switch to the ON position.

Behavior – As the engine is cranked, air heater is heated for 5 minutes (after-heating) to reduce and to element quickly white smoke.

4.4.2. Prevention against freezing of cooling water

- When not using anti-freeze, cause the diffusion of corrosion in inner part of the engine, cause drop the cooling efficiency, cause being frozen to burst in winter, therefore the whole cooling water should be completely discharged after engine running.
- The freezing of cooling water is the reason of fatal damage on the engine, always use by mixing the anti-freeze. (anti-freeze quantity filled : 40 ~ 50 % of the cooling water) the anti-freeze is used to prevent cooling water from freeze.

4.4.3. Prevention against excessive cooling

- Drop of thermal efficiency caused by excessive cooling increases fuel consumption, therefore prevent the engine from excessive cooling. If the temperature of coolant does not reach to normal condition (78 ~ 85 °C) after continuous operation, examine the thermostat or the other cooling lines.

4.4.4. Lubricating oil

As cold weather leads to the rise of oil viscosity, engine speed becomes unstable after starting. Therefore the lubricating oil for winter should be used to prevent this unstability. Refer to lubricating system section.

4.5. Engine Components Check after Long Time Running

- The purpose of an engine tune-up is to restore power and performance that's been lost through wear, corrosion or deterioration of one or more parts or components.
- In the normal operation of an engine, these changes can take place gradually at a number of points, so that it's seldom advisable to attempt an improvement in performance by correction of one or two items only. Thorough procedure of analysis and correction, it is desirable to change or correct of all items affecting power and performance.
- In case that the engine is perform in advance the prevention against trouble, the engine can be run safely during a long time as that time , there can be used more reliably.
- Economical, trouble-free operation can better be ensured if a complete tune-up is performed once every years, preferably in the spring.
- Below components that affect power and performance to be checked are:
  - Components affecting fuel injection
    Nozzle, delivery valve, fuel filter, water separator, etc
  - Components affecting intake & exhaust
    Air cleaner, inter-cooler, turbo charger, silencer, etc
  - Components affecting lubrication & cooling
    Air & oil filter, anti- freeze, etc

4.6. Maintenance and Care

4.6.1. Periodical inspection and maintenance

In order to insure maximum, trouble-free engine performance at all times, regular inspection, adjustment and maintenance are vital.

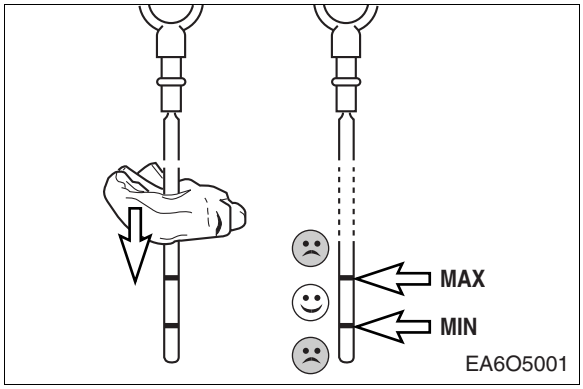
4.6.2. Exchanging of lubrication oil

Engine oil and the oil filter are important factors affecting engine life. They affect ease of starting, fuel economy, combustion chamber deposits and engine wear.

At the end of the break-in period, change the oil sump oil and replace the oil filter cartridge.

4.6.3. Oil level gauge

- Check the oil level in the engine sump daily with an oil level gauge.
- The notches in oil level gauge must indicate the oil level between the max.
- The oil level should be checked with the engine horizontal and only after it has been shut down for about 5 minutes.
- Examining the viscosity and the contamination of the oil smeared at the oil level gauge replace the engine oil if necessary.

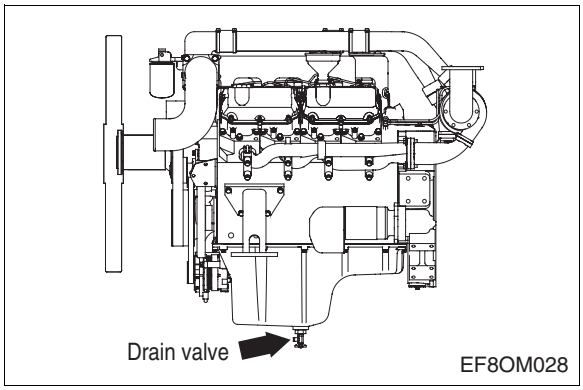


CAUTION:
Do not add so much engine oil that the oil level rises above the max. marking on the oil level gauge. Over lifting will result in damage to the engine.

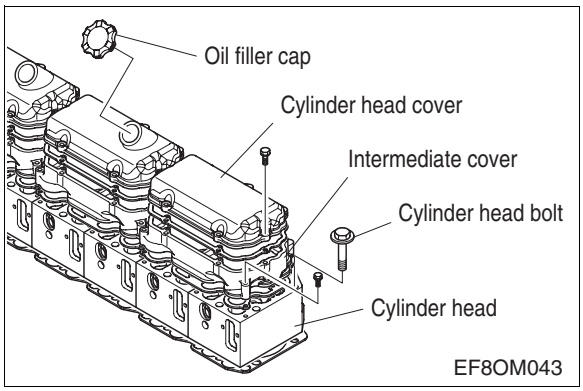
4.6.4. Oil exchange procedure

While the oil is still hot, exchange oil as follows.

- Take out the oil level gauge.
- Remove the drain plug from oil pan, then drain out the engine oil into a container.

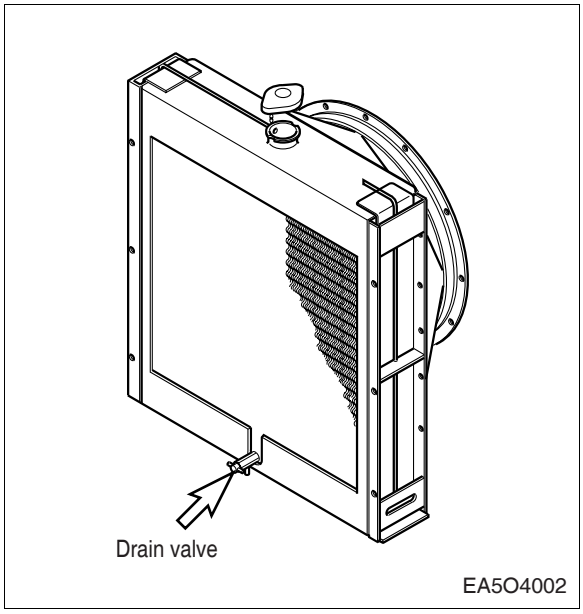


- Refill with new engine oil at the oil filler neck on the head cover and the lubricating oil in accordance with the oil capacity of the engine through oil filler.
- Be careful about the mixing of dust or contaminator during the supplement of oil. Then confirm that oil level gauge indicates the vicinity of its maximum level.
- For a few minutes, operate the engine at idling in order to circulate oil through lubrication system.
- Thereafter shut down the engine. After waiting for about 10 minutes measure the quantity of oil and refill the additional oil if necessary.



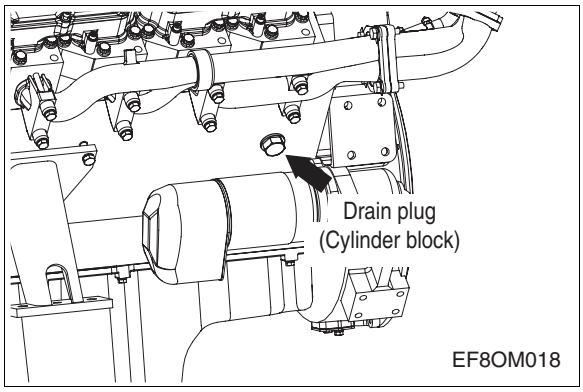
4.7. Cooling System

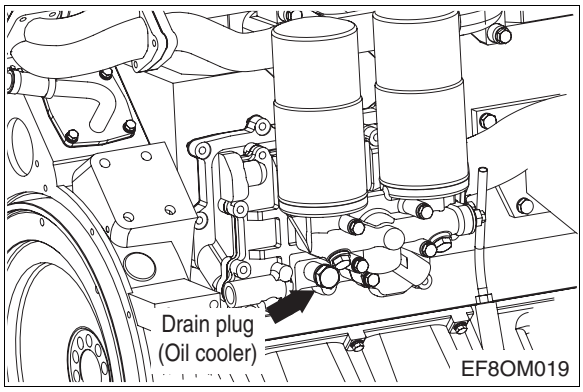
- The coolant must be changed at intervals of 1,200 hour operation or six months whichever comes first. If the coolant is being fouled greatly, it will lead an engine overheat or coolant blow off from the expansion tank.



4.7.1. Coolant draining

- Remove the pressure cap.
- Open the drain valve at the radiator lower part to drain the coolant as the right figure.
- Loosen the coolant drain plug of the cylinder block.





4.7.2. Cleaning of the cooling inside system circuit

When the cooling system circuits are fouled with water scales or sludge particles, the cooling efficiency will be lowered. When the cooling system circuits are clogged, the water pump mechanical seal is damaged.

The poor condition of the cooling system is normally due to use of unsuitable or no anti-freezing agents and corrosion inhibitor or defect.

If twice in a short time (within 6 months) the water pump of an engine develops leases or the coolant is heavily contaminated (dull, brown, mechanically contaminated, gray or black sings of a leakage on the water pump casing) clean the cooling system prior to removing that water pump as follows.

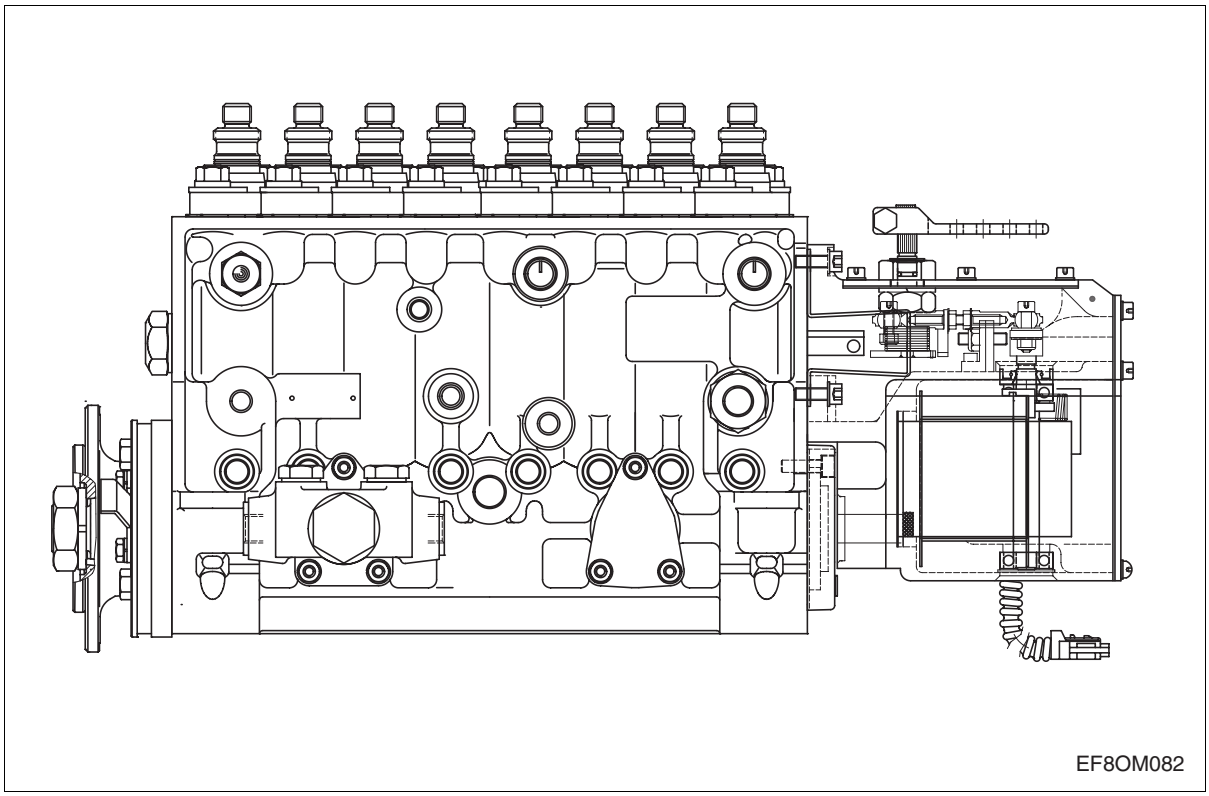
a) Drain coolant.
b) Remove thermostats, so that the whole cooling system is immediately flown through when cleaned.
c) Fill the cooling system with a mixture of potable water and 1.5 % by volume of cleaner. (Henkel P3T5175)
d) Warm up engine under load. After a temperature of 60 °C is reached, run engine for a further 15 minutes.
e) Drain cleaning fluid.
f) Repeat steps c) and d).
g) Fill cooling system with hot water.
h) Run engine at idle for 30 minutes. At the same time continuously replenish the water leaking from the bore in drain plug by adding fresh water.

CAUTION:
Periodically clean the circuit interior with a cleaner.

5. Maintenance of Major Components

5.1. Fuel Injection System

5.1.1. Speed control unit for governor system (DWC-2000 series speed control unit)

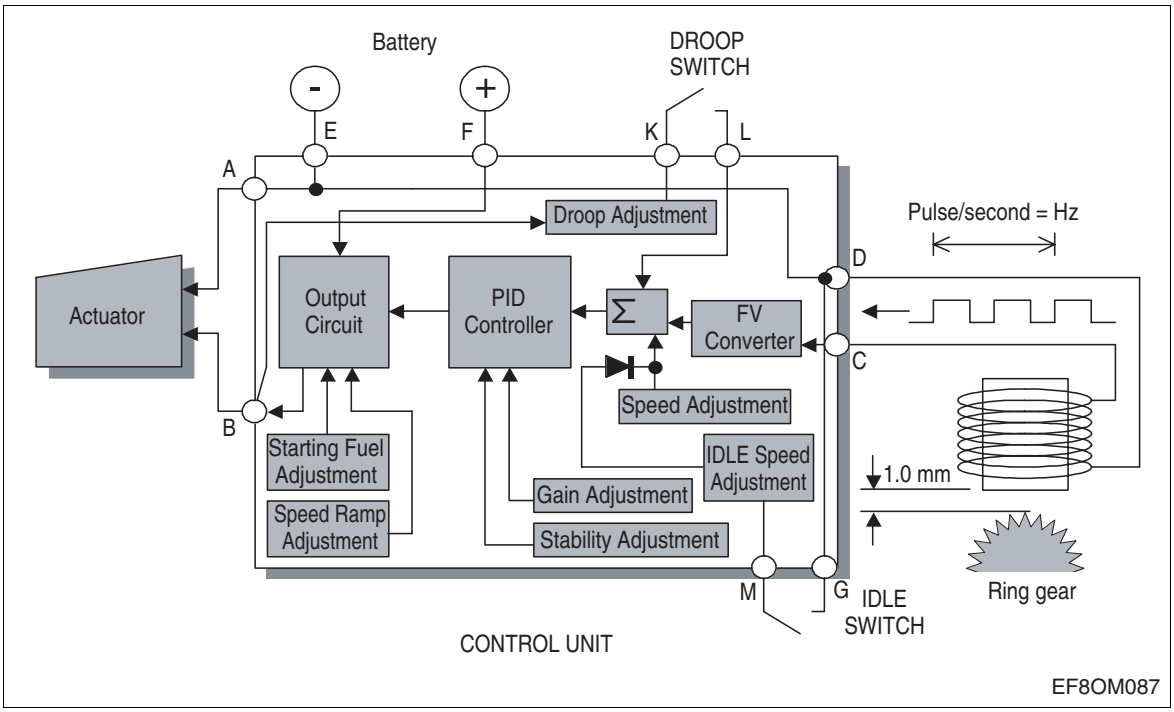


EF8OM082

- This speed control unit performs the electronic function of the engine governing system. The speed control unit senses the pulses from the magnetic speed sensor, compares them with the speed control unit's set point and supplies the appropriate current output to the actuator to control the engine's fuel system.
- An integral, independent single element speed switch is provided internally which can be used to initiate engine shutdown in the event that an overspeed condition is reached. The performance of the speed control unit is fast and responsive in either isochronous or droop operation.
- Adjustments are provided for: operating speed, idle speed, overspeed shutdown setting, droop, run ramp, crank ramp, starting fuel, speed ramping and two performance adjustments(gain and stability). All adjustments are accessible from the front cover. The primary features of the DWC-2000 Series speed control unit are the engine STARTING FUEL and SPEED RAMPING adjustments. The use of these features will minimize engine exhaust smoke experienced prior to attain engine operating speed.
- The speed control unit also includes other features such as adjustable droop and idle operation, inputs for accessories used in multi-engine or special applications and protection against reverse voltage polarity, transient voltages and accidental short circuit of the actuator. Loss of battery supply, loss of speed sensor and overspeed signaling are built-in to provide engine shutdown.

5.1.2. Governor system schemetic

- The engine speed signal is usually obtained from a magnetic speed sensor mounted in close proximity to the teeth of a ferrous ring gear that is driven by the engine. The frequency of the speed sensor signal is proportional to the engine speed.
- The speed control unit will accept any signal if the frequency is proportional to engine signal, and in the frequency range of the speed control unit (1K to 7.5K Hz.). The speed sensor is typically mounted in close proximity to an engine driven ferrous gear, usually the engine ring gear. As the teeth of the gear pass the magnetic sensor, a signal is generated which is proportional to engine speed. The signal strength must also be within the range of the input amplifier.
- An amplitude of 1 to 120 volts RMS is required to allow the unit to function within its design specifications. The speed control unit has an input impedance of 20K-ohms between the speed sensor input terminals. (“C” & “D”). Terminal “D” is connected internally to the battery negative. Only one end of the shielded cable should be connected.



- When a speed sensor signal is received by the controller, the signal is amplified and shaped by an internal circuit to form constant area pulses. If the speed sensor monitor does not detect a speed sensor signal, the output circuit of the speed control unit will turn off all current to the actuator.
- The summing point of the speed sensor and the speed adjust control is the input to the dynamic control section of the governor. The dynamic control circuit, of which the gain and stability adjustments are part, has a control function that will provide isochronous and stable performance for most engine types and fuel systems.

- The speed control unit circuit is influenced by the gain and stability performance adjustments. The governor system sensitivity is increased with clockwise rotation of the gain adjustment. The gain adjustment has a non-linear range of 33:1.
- The stability adjustment, when advanced clockwise, increases the time rate of response of the governor system to match the various time constants of a wide variety of engines. The speed control unit is a PID device, the “D”, derivative portion can be varied when required. (See Instability section.)
- During the engine cranking cycle, STARTING FUEL can be adjusted from an almost closed, to a nearly full fuel position. Once the engine has started, the speed control point is determined, first by the IDLE speed set point and the SPEED RAMPING circuit, After engine speed ramping has been completed, the engine will be at its governed operating speed. At the desired governed engine speed, the actuator will be energized with sufficient current to maintain the desired engine speed, independent of load (isochronous operation).
- The output actuator current switching circuit provides current to drive the actuator. The output transistor is alternately switched off and on at a frequency of 300Hz. which is well beyond the natural frequency of the actuator, hence no visible motion from the switching results. Switching the output transistors reduces its internal power dissipation for efficient power control. The output circuit can provide current of up to 10 amps continuous at 25 °C for 24VDC battery systems. The actuator responds to the average current to position the engine fuel control lever.
- In standard operation, the speed control unit performance is isochronous. Droop governing can be selected by connecting terminals K & L and the percent of droop governing can be varied with the droop adjustment control. The droop range can be decreased by connecting terminals G and H.
- The speed control unit has several performance and protection features which enhance the governor system. A speed anticipation circuit minimizes speed overshoot on engine startup or when large increments of load are applied to the engine.

5.1.3. Specification

- Performance

  Isochronous operation / steady state stability ..... ±0.25 % or better
  Speed range / governor ..... 1K ~ 7.5 K Hz continuous
  Speed drift with temperature ..... ±0.5 % maximum
  Idle adjust CW ..... 60 % of set speed
  Idle adjust CCW ..... less than 1,200 Hz
  Droop range ..... 1 ~ 5% regulation *
  Droop adjust max. (K-L jumpered) ..... 450 Hz, ± 90 Hz per 1.0 A change
  Droop adjust min. (K-L Jumpered) ..... 20 Hz, ± 8 Hz per 1.0 A change
  Speed trim range ..... ±210 Hz
  Remote variable speed range ..... 500 ~ 7.5 Hz or any part thereof
  Terminal sensitivity
    J ..... 100 Hz ± 15 Hz / Volt @ 6.0K impendence
    L ..... 680 Hz ± 50 Hz/Volt @ 165K impendence
    N ..... 135 Hz ± 10 Hz/Volt @ 1M impendence
    P ..... 10 VCD supply @ 20 [mA] max.

- Environmental

  Ambient operating temperature range ..... -40 ~ 85 °C
  Relative humidity ..... up to 95 %
  All surface finishes ..... fungus proof and corrosion resistant

- Power input

  Supply ..... 24 VDC battery system(transient and reverse voltage protected)**
  Polarity ..... negative ground(case isolated)
  Power consumption ..... 50[mA] continuous plus actuator current
  Maximum controllable actuator current at 25 °C- (Inductive Load) ..... 10{A} continuous***
  Magnetic speed sensor signal ..... 1 ~ 120[V] RMS

- Reliability

  Vibration ..... 1G @ 20 ~ 100 Hz
  Testing ..... 100 % functionally tested

- Physical

  Dimensions ..... see outline
  Weight ..... 705 grams
  Mounting ..... any position, vertical preferred

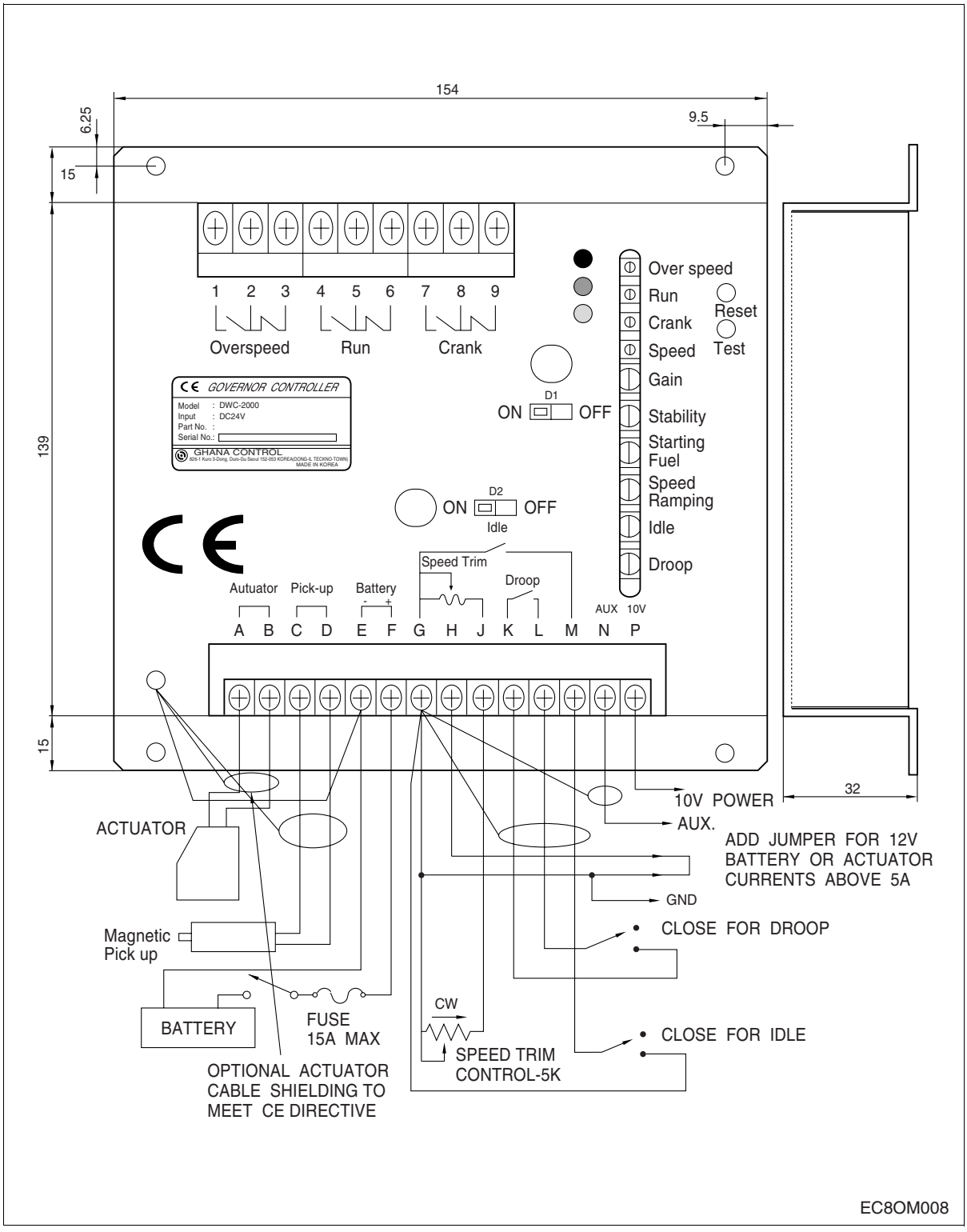
NOTE:

*** Droop is based on a speed sensor frequency of 4,000 Hz. and an actuator current change of 1 amp from no load to full load. Applications with higher speed sensor signals will experience less percentage of droop. See droop description for specific details on operation of droop ranges.**

**** Protected against reverse voltage by a series diode. A 15 amp fuse must be installed in the positive battery lead.**

***** Protected against short circuit to actuator (shuts off current to actuator), unit automatically turns back on when short is removed.**

5.1.4. Governor system of DWC-200 wiring and diagram



5.1.5. Application and installation information

- The speed control unit is rugged enough for mounting in a control cabinet or engine mounted enclosure or in a remote console up to 20 meters(65ft.) from the engine. Care should be taken to insure that the speed control unit, mount it vertically so that condensation will not accumulate in the speed control unit.

CAUTION:

An overspeed shutdown device, independent of the governor system, should be provided to prevent loss of engine control which may cause personal injury or equipment damage. Do not rely exclusively on the governor system electric actuator to prevent over speed. A Secondary shutoff device, such as a fuel solenoid must be used.

5.1.6. Wiring

- Wiring to the speed control unit should be as shown in DWC-200 wiring diagram. Wire leads to the battery and actuator from the speed control unit terminals A, B, E and F should be #16 AWG(1.3 mm sq.) or larger. Long cables require an increased wire size to minimize voltage drops. An external 15 amp fuse is recommended in series with terminal F, the positive (+) battery input terminal.
- The magnetic speed sensor leads must be twisted and/or shielded for their entire length. If shielded cables are used, connect all the shields to terminal D only. The shield should be insulated to insure no other part of the shield comes in contact with engine ground, otherwise stray speed signals may be introduced to the speed control unit. With the engine stopped, adjust the gap between the magnetic speed sensor and the ring gear teeth. The gap should be 1.0 ± 0.1 mm. Usually, gear tooth will achieve a satisfactory air gap. The magnetic speed sensor voltage should be at least 1 VAC RMS during cranking.

5.1.7. Adjustments

- **Before starting engine**

  Confirm the following adjustment positions. The adjustments are factory pre-set as follows :

  – Check to insure the GAIN and STABILITY adjustments, and if applied, the external SPEED TRIM CONTROL are set to mid position.

- **Preset the DWC-2000 as follows:**

  – Gain ..... minimum CCW
  – Stability ..... mid-range
  – Speed adjust ..... 3,650 Hz
  – Idle ..... 1,950 Hz
  – Droop ..... maximum CCW (minimum setting)
  – Overspeed ..... maximum CW
  – Run ramp ..... maximum CW
  – Crank ramp ..... maximum CW
  – Starting fuel ..... full CW (maximum fuel)
  – Speed ramping ..... full CCW (fastest)

- **Start engine**

  The speed control unit governed speed setting is factory set at approximately engine idle speed. Crank the engine with DC power applied to the governor system. The actuator will energize to the maximum fuel position until the engine starts. The governor system should control the engine at a low idle speed. If the engine is unstable after starting, turn the GAIN and STABILITY adjustments counterclockwise until the engine is stable.

- **Governor speed setting**

  The governed speed set point is increased by clockwise rotation of the SPEED adjustment control. Remote speed adjustment can be obtained with an optional 5 K speed trim control.

- **Governor performance**

  Once the engine is at operating speed and at no load, the following governor performance adjustment can be made.

  (1) At no load, turn the gain control CW until instability results. Then back-off slightly CCW (1/8 turn) beyond the point where stability returns.

  (2) Turn the stability control CW until instability results. Then back-off slightly CCW (1/8 turn) beyond the point where stability returns. Excellent performance should result from these adjustments.

  If instability cannot be corrected or further performance improvements are required, refer to the section on SYSTEM TROUBLESHOOTING.

- **Starting fuel adjustment**

  The engine's exhaust smoke at start-up can be minimized by completing the following adjustments.

  (1) Place the engine in idle by connecting terminals M & G.

  (2) Adjust the IDLE speed for as low a speed setting as the application allows.

  (3) Adjust the STARTING FUEL CCW until the engine speed begins to fall. Increase the STARTING FUEL slightly so that the idle speed is returned to the desired level.

  (4) Stop the engine.

- **One of two methods of operation for the DWC-2000 may now be selected.**

  Method 1 : Start the engine and accelerate directly to the operating speed (Gen Sets, etc.). Remove the connection between terminals M & G. Start the engine and adjust the SPEED RAMPING for the least smoke on acceleration from idle to rated speed. If the starting smoke is excessive, the STARTING FUEL may need to be adjusted slightly CCW. If the starting time is too long, the STARTING FUEL may need to be adjusted slightly CW.

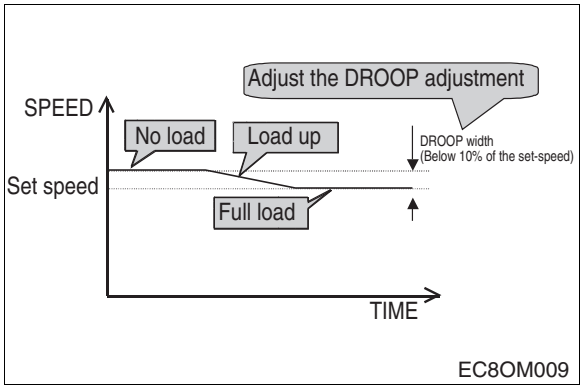
  Method 2 : Start the engine and control at an idle speed for a period of time prior to accelerating to the operating speed. This method separates the starting process so that each may be optimized for the lowest smoke emissions. Replace the connection between terminals M & G with a switch, usually an oil pressure switch. Start the engine. If the starting smoke is excessive, the STARTING FUEL may need to be adjusted slightly CCW. If the starting time is too long, the STARTING FUEL may need to be adjusted slightly CW. When the switch opens, adjust the SPEED RAMPING for the least amount of smoke when accelerating from idle speed to rated speed.

- **Idle speed setting**

  If the IDLE speed setting was not adjusted as detailed in “Starting Fuel Adjustment” section, then place the optional external selector switch in the IDLE position. The idle speed set point is increased by clockwise rotation of the IDLE adjustment control. When the engine is at idle speed, the speed control unit applies droop to the governor system to insure stable operation.

- **Speed droop operation**

  Droop is typically used for the paralleling of engine driven generators.
  Place the optional external selector switch in the DROOP position, DROOP is increased by clockwise rotation of the DROOP adjustment control. When in droop operation, the engine speed will decrease as engine load increases. The percentage of droop is based on the actuator current change from engine no load to full load. A wide range of droop is available with the internal control. Droop level requirements above 10 % are unusual.



  If droop levels experienced are higher or lower than those required, contact the factory for assistance.
  After the droop level has been adjusted, the rated engine speed setting may need to be reset. Check the engine speed and adjust the speed setting accordingly.

- **Accessory input**

  The auxiliary terminal N accepts input signals from load sharing units, auto synchronizers, and other governor system accessories, DWC accessories are directly connected to this terminal. It is recommended that this connection from accessories be shielded as it is a sensitive input terminal.
  If the auto synchronizer is used alone, not in conjunction with a load sharing module, a 3M ohm resistor should be connected between terminals N and P. This is required to match the voltage levels between the speed control unit and the synchronizer.
  When an accessory is connected to terminal N, the speed will decrease and the speed adjustment must be reset.
  When operating in the upper end of the control unit frequency range, a jumper wire or frequency trim control may be required between terminals G and J. This increases the frequency range of the speed control to over 7,000 Hz

- **Accessory supply**

  The +10 volt regulated supply, terminal P, can be utilized to provide power to DWC-2000 governor system accessories. Up to 20 mA of current can be drawn from this supply. Ground reference is terminal G.

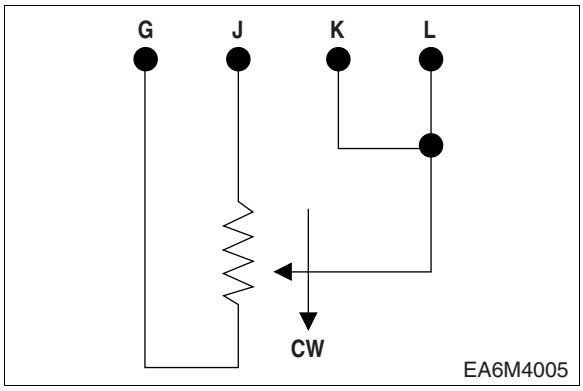
CAUTION:
A short circuit on this terminal can damage the speed control unit.

- **Wide range remote variable speed operation**

  Simple and effective remote variable speed can be obtained with the DWC-2000 Series control unit. A single remote speed adjustment potentiometer can be used to adjust the engine speed continuously over specific speed range. Select the desired speed range and the corresponding potentiometer value. (Refer to table) If the exact range cannot be found, select the next higher range potentiometer. An additional fixed resistor may be placed across the potentiometer to obtain the exact desired range. Connect the speed range potentiometer as shown.
  To maintain engine stability at the minimum speed setting, a small amount of droop can be added using the DROOP adjustment. At the maximum speed setting the governor performance will be near isochronous, regardless of the droop adjustment setting.

  <Variable speed range potentiometer value>

Speed range	Potentiometer value
900 Hz	1 k
2,400 Hz	5 k
3,000 Hz	10 k
3,500 Hz	25 k
3,700 Hz	50 k



- **OVERSPEED shutdown setting**

  DWC-2000 has a Test switch to determine the OVERSPEED set point and test the engine shutdown function. If you want to adjust the OVERSPEED set point at the speed about 10 % higher than the RUN set speed, use the Test switch. When the engine is operating at the Run set speed in pushing the Test switch, rotate the Overspeed adjust. By CCW until the Overspeed shutdown function is operated. When the Test switch is pushed, the Overspeed set point is reduced to 10/11 of the real set point.

- **RUN lamp turn-on speed setting**

  When the engine is operating at the Run set speed, adjust the Run lamp adjustment CCW until the lamp is on. Then, more rotate 1/2 turn by CCW.

- **Crank lamp turn-on speed setting**

  When the engine is operating at the idle set speed (800 rpm), adjust the Crank lamp adjustment CCW until the lamp is on. Then, more rotate 1.5 turns by CCW.

5.1.8. System troubleshooting

- **System inoperative**

  If the engine governing system does not function, the fault may be determined by performing the voltage tests described in steps 1, 2, 3 and 4(+) and (-) refer to meter polarity. Should normal values be indicated as a result of following the trouble shooting steps, the fault may be with the actuator or the wiring to the actuator. See the actuator publication for testing details.

Step	Terminals	Normal value	Probable cause of abnormal reading
1	F(+) & E(-)	Battery supply voltage(24V)	1. DC battery power not connected. Check for blown fuse. 2. Low battery voltage. 3. Wiring error.
2	C & D	1.0 VAC RMS min., while cranking	1. Gap between speed sensor and gear teeth too great. Check gap. 2. Improper or defective wiring to the speed sensor. Resistance between terminals C and D should be 30 to 1,200 ohms. 3. Defective speed sensor.
3	P(+) & G(-)	10VDC internal supply	1. Short on terminal P. (This will cause a defective unit.) 2. Defective speed control.
4	F(+) & A(-)	1.0 - 2.0 VDC while cranking	1. SPEED adjustment set too low. 2. Short / open in actuator wiring. 3. Defective speed control. 4. Defective actuator. See actuator troubleshooting.

- **Unsatisfactory performance**

  If the governing system functions poorly, perform the following tests.

Symptom	Test	Probable fault
Engine overspeeds	Do not crank. Apply DC power to the governor system.	Actuator goes to full fuel. then, disconnect speedsensor at terminals C & D. – If actuator still at full fuel → speed controlunit defective. – If actuator at minimum fuel position → errorneous speed signal. Check speed sensor data.
	Manually hold the engine at the desired running speed. Measure the DC voltage between terminals A(-) & F(+) on the speed control unit.	1) If the voltage reading is 4.0 to 6.0 VDC. a) SPEED adjustment set above desired speed b) Defective speed control unit. 2. If the voltage reading is above 6.0 VDC a) Actuator or linkage binding. 3. If the voltage reading is below 4.0 VDC. 4. Gain set too low.
Actuator does not energize fully.	Measure the voltage at the battery while cranking.	If the voltage is less than 15V for a 24V system, replace the battery if it is weak or undersized.
	Momentarily connect terminals A and F. The actuator should move to the full fuel position.	1. Actuator or battery wiring in error. 2. Actuator or linkage binding. 3. Defective actuator. See actuator troubleshooting. 4. Fuse opens. Check for short in actuator or actuator wiring harness.
Engine remains below desired governed speed.	Measure the actuator output. Terminals A & B, while running under governor control.	1. If voltage measurement is within approximately 3 volts of the battery supply voltage, then fuel control restricted from reaching full fuel position. Possibly due to interference from the mechanical governor, carburetor spring or linkage alignment. 2. Speed setting too low.

- **Insufficient magnetic speed sensor signal**

  A strong magnetic speed sensor signal will eliminate the possibility of missed or extra pulses. The speed control unit will govern well with 0.5volts RMS speed sensor signal. A speed sensor signal of 3 volts RMS or greater at governed speed is recommended. Measurement of the signal is made at terminals C and D.

  The amplitude of the speed sensor signal can be raised by reducing the gap between the speed sensor tip and the engine rind gear. The gap should be 1.0 ± 0.1 mm. When the engine is stopped, back the speed sensor out by 3/4 turn after touching the ring gear tooth to achieve a satisfactory air gap.

- **Electromagnetic compatibility (EMC)**

  EMI susceptibility - The governor system can be adversely affected by large interfering signals that are conducted through the cabling or through direct radiation into the control circuits.
  All DWC-2000 speed control units contain filters and shielding designed to protect the units sensitive circuits from moderate external interfering sources.
  Although it is difficult to predict levels of interference, applications that include magnetos, solid state ignition systems, radio transmitters, voltage regulators or battery chargers should be considered suspect as possible interfering sources.
  If it is suspected that external fields, either those that are radiated or conducted, are or will affect the governor systems operation, it is recommended to use shielded cable for all including the speed sensor shield, is connected to a single point on the case of the speed control unit. Mount the speed control unit to a grounded metal back plate or place it in a sealed metal box.
  Conduction is when the interfering signal is conducted through the interconnecting wiring to the governor system electronics. Shielded cables and installing filters are common remedies.
  As an aid to help reduce the levels of EMI of a conductive nature, a battery line filter and shielded cables are conveniently supplied by DWC.

- **Instability**

  Instability in a closed loop speed control system can be categorized into two general types. PERIODIC appears to be sinusoidal and at a regular rate. NON-PERIODIC is a random wandering or an occasional deviation from a steady state band for no apparent reason.
  Switch D1 controls the differential function. When the position of switch D1 is “ON”, the function is operated. Move the switch to the “OFF” position if there is fast instability in the system.
  The PERIODIC type can be further classified as fast or slow instability. Fast instability is a 3Hz. or faster irregularity of the speed and is usually a jitter. Slow periodic instability is below 3Hz., can be very slow, and is sometimes violent.
  If fast instability occurs, this is typically the governor responding to engine firings. Raising the engine speed increases the frequency of instability and vice versa. In this case, placing switch D1 in the “OFF” position will reduce the speed control unit's sensitivity to high frequency signals. Should instability still be present, placing switch D2 to the “OFF” position may help stabilize the engine. Again, readjust the GAIN and STABILITY for optimum control. Interference from powerful electrical signals can also be the cause. Turn off the battery chargers or other electrical equipment to see if the system disappears.
  Slow instability can have many causes. Adjustment of the GAIN and STABILITY usually cures most situations by matching the speed control unit dynamics. If slow instability is unaffected by this procedure, evaluate the fuel system and engine performance. Check the fuel system linkage for binding, high friction, or poor linkage. Be sure to check linkage during engine operation. Also look at the engine fuel system. Irregularities with carburetion or fuel injection systems can change engine power with a constant throttle setting. This can result in speed deviations beyond the control of the governor system. Adding a small amount of droop can help stabilize the system for troubleshooting.
  NON-PERIODIC instability should respond to the GAIN control. If increasing the gain reduces the instability, then the problem is probably with the engine. Higher gain allows the governor to respond faster and correct for disturbance. Look for engine misfirings, an erratic fuel system, or load changes on the engine generator set voltage regulator. If the throttle is slightly erratic, but performance is fast, move switch D1 to the “OFF” position. This will tend to steady the system.

5.1.9. Injection pump calibration of P158FE engine : EUZOA

1) Fuel injection pump ass`y : 65.11101-7412B
   (65.11101-7301 and 65.11501-7006B)
   - Injection pump : 65.11101-7301 (0 402 618 813 BOSCH)
   - Model : PE8P120A500/4LS7935 (0 412 628 937)
   - Governor : GAC Control
   - Plunger & barrel : 2 418 455 545
   - Delivery valve : 2 418 559 045
   - Feed pump : FP/KD22P78-2 (0 440 008 152)
   - Prestroke : 4.08 ± 0.05 mm at 12.95 ± 1.5 mm
2) Nozzle holder assembly : 65.10101-7097 (0 432 191 241)
3) Nozzle : 65.10102-6067 (0 433 171 969)
4) Injection pipe : 65.10301-6185, 65.10301-6186
5) Injection order : 1 - 5 - 7 - 2 - 6 - 3 - 4 – 8
6) Injection timing : BTDC 10° (TIER-2)

(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)	–	∅3.0 x ∅8.0 – 600 mm
	Test oil	ISO4113	Temperature : 40 ± 5 °C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7097	286 kg/cm^2
	Nozzle	65.10102-6067	Nozzle (8 × ∅0.284)
	Injection pipe (ID × OD - L)	65.10301-6185 65.10301-6186	∅2 × ∅6.35 - 700 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	
Prime power	A	12.30	750	325 ± 3	–	–
Stand by power	A	12.95	750	357 ± 3	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	Boost pressure : zero boost					

5.1.10. Injection pump calibration of P158FE engine : EUZOB

1) Fuel injection pump ass`y : 65.11101-7412B
   (65.11101-7301 and 65.11501-7006B)
   - Injection pump : 65.11101-7301 (0 402 618 813 BOSCH)
   - Model : PE8P120A500/4LS7935 (0 412 628 937)
   - Governo : GAC Control
   - Plunger & barrel : 2 418 455 545
   - Delivery valve : 2 418 559 045
   - Feed pump : FP/KD22P78-2 (0 440 008 152)
   - Prestroke : 4.08 ± 0.05 mm at 13.3 ± 1.5 mm
2) Nozzle holder assembly : 65.10101-7097 (0 432 191 241)
3) Nozzle : 65.10102-6067 (0 433 171 969)
4) Injection pipe : 65.10301-6185, 65.10301-6186
5) Injection order : 1 - 5 - 7 - 2 - 6 - 3 - 4 - 8
6) Injection timing : BTDC 12° (TIER-2)

(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)	–	∅3.0 x ∅8.0 – 600 mm
	Test oil	ISO4113	Temperature : 40 ± 5 °C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7097	286 kg/cm^2
	Nozzle	65.10102-6067	Nozzle (8 × ∅0.284)
	Injection pipe (ID × OD - L)	65.10301-6185 65.10301-6186	∅2 × ∅6.35 - 700 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	
Prime power	A	12.91	900	318 ± 3	–	–
Stand by power	A	13.30	900	354 ± 3	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	Boost pressure : zero boost					

5.1.11. Injection pump calibration of P180FE engine : EUSOA

1) Fuel injection pump ass`y : 65.11101-7413B
   (65.11101-7302 and 65.11501-7006B)
   - Injection pump : 65.11101-7302 (0 402 619 802 BOSCH)
   - Model : PE10P120A500LS7936 (0 412 629 815)
   - Governor : GAC Control
   - Plunger & barrel : 2 418 455 545
   - Delivery valve : 2 418 559 045
   - Feed pump : FP/KD22P78-1 (0 440 008 090)
     FP/KD22P78-2 (0 440 008 152)
   - Prestroke : 4.08 ± 0.05 mm at 13.3 ± 1.5 mm
2) Nozzle holder assembly : 65.10101-7097 (0 432 191 241)
3) Nozzle :65.10102-6067 (0 433 171 969)
4) Injection pipe : 65.10301-6204, 65.10301-6205
5) Injection order : 1 – 6 – 5 – 10 – 2 – 7– 3 – 8 – 4 – 9
6) Injection timing : BTDC 8° (TIER-2)

(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)	–	∅3.0 x ∅8.0 – 600 mm
	Test oil	ISO4113	Temperature : 40 ± 5 °C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7097	286 kg/cm^2
	Nozzle	65.10102-6067	Nozzle (8 × ∅0.284)
	Injection pipe (ID × OD - L)	65.10301-6204 65.10301-6205	∅2 × ∅6.35 - 775 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	
Prime power	A	11.85	750	298 ± 3	–	–
Stand by power	A	12.35	750	328 ± 3	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	Boost pressure : zero boost					

5.1.12. Injection pump calibration of P180FE engine : EUSOB

1) Fuel injection pump ass`y : 65.11101-7413B
   (65.11101-7302 and 65.11501-7006B)
   - Injection pump : 65.11101-7302 (0 402 619 802 BOSCH)
   - Model : PE10P120A500LS7936 (0 412 629 815)
   - Governor : GAC Control
   - Plunger & barrel : 2 418 455 545
   - Delivery valve : 2 418 559 045
   - Feed pump : FP/KD22P78-1 (0 440 008 090)
     FP/KD22P78-2 (0 440 008 152)
   - Prestroke : 4.08 ± 0.05 mm at 13.3 ± 1.5 mm
2) Nozzle holder assembly : 65.10101-7097 (0 432 191 241)
3) Nozzle : 65.10102-6067 (0 433 171 969)
4) Injection pipe : 65.10301-6204, 65.10301-6205
5) Injection order : 1 – 6 – 5 – 10 – 2 – 7– 3 – 8 – 4 – 9
6) Injection timing : BTDC 12° (TIER-2)

(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)	–	∅3.0 x ∅8.0 – 600 mm
	Test oil	ISO4113	Temperature : 40 ± 5 °C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7097	286 kg/cm^2
	Nozzle	65.10102-6067	Nozzle (8 × ∅0.284)
	Injection pipe (ID × OD - L)	65.10301-6204 65.10301-6205	∅2 × ∅6.35 - 775 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	
Prime power	–	–	–	–	–	–
Stand by power	A	12.90	900	320 ± 3	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	Boost pressure : zero boost					

5.1.13. Injection pump calibration of P222FE engine : EUYOA

1) Fuel injection pump ass`y : 65.11101-7414B
   (65.11101-7303 and 65.11501-7006B)
   - Injection pump : 65.11101-7303 (0 402 610 807 BOSCH)
   - Model : PE12P120A500LS7937 (0 412 620 854)
   - Governor : GAC Control
   - Plunger & barrel : 2 418 455 545
   - Delivery valve : 2 418 559 045
   - Feed pump : FP/KD22P80-1 (0 440 008 090)
     FP/KD22P78-2 (0 440 008 152)
   - Prestroke : 4.08 ± 0.05 mm at 12.3 ± 1.5 mm
2) Nozzle holder assembly : 65.10101-7097 (0 432 191 241)
3) Nozzle : 65.10102-6067 (0 433 171 969)
4) Injection pipe : 65.10301-6187A, 65.10301-6188A
   65.10301-6189, 65.10301-6190
5) Injection order : 1 - 12 - 5 - 8 - 3 - 10 - 6 - 7 - 2 - 11 - 4 - 9
6) Injection timing : BTDC 9° (TIER-2)

(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)	–	∅3.0 x ∅8.0 – 600 mm
	Test oil	ISO4113	Temperature : 40 ± 5 °C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7097	286 kg/cm^2
	Nozzle	65.10102-6067	Nozzle (8 × ∅0.284)
	Injection pipe (ID × OD - L)	65.10301-6187A 65.10301-6188A 65.10301-6189 65.10301-6190	∅2 × ∅6.35 - 775 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	
Prime power	A	11.83	750	303 ± 3	–	–
Stand by power	A	12.3	750	326 ± 3	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	Boost pressure : zero boost					

5.1.14. Injection pump calibration of P222FE engine : EUYOB

1) Fuel injection pump ass`y : 65.11101-7414B
   (65.11101-7303 and 65.11501-7006B)
2) Injection pump : 65.11101-7303 (0 402 610 807 BOSCH)
   - Model : PE12P120A500LS7937 (0 412 620 854)
   - Governor : GAC Control
   - Plunger & barrel : 2 418 455 545
   - Delivery valve : 2 418 559 045
   - Feed pump : FP/KD22P80-1 (0 440 008 090)
     FP/KD22P78-2 (0 440 008 152)
   - Prestroke : 4.08 ± 0.05 mm at 13.1 ± 1.5 mm
3) Nozzle holder assembly : 65.10101-7097 (0 432 191 241)
4) Nozzle : 65.10102-6067 (0 433 171 969)
5) Injection pipe : 65.10301-6187A, 65.10301-6188A
   65.10301-6189, 65.10301-6190
6) Injection order : 1 - 12 - 5 - 8 - 3 - 10 - 6 - 7 - 2 - 11 - 4 - 9
7) Injection timing : BTDC 12° (TIER-2)

(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)	–	∅3.0 x ∅8.0 – 600 mm
	Test oil	ISO4113	Temperature : 40 ± 5 °C
(B) Engine standard parts	Nozzle & holder Ass'y	65.10101-7097	286 kg/cm^2
	Nozzle	65.10102-6067	Nozzle (8 × ∅0.284)
	Injection pipe (ID × OD - L)	65.10301-6187A 65.10301-6188A 65.10301-6189 65.10301-6190	∅2 × ∅6.35 - 775 mm

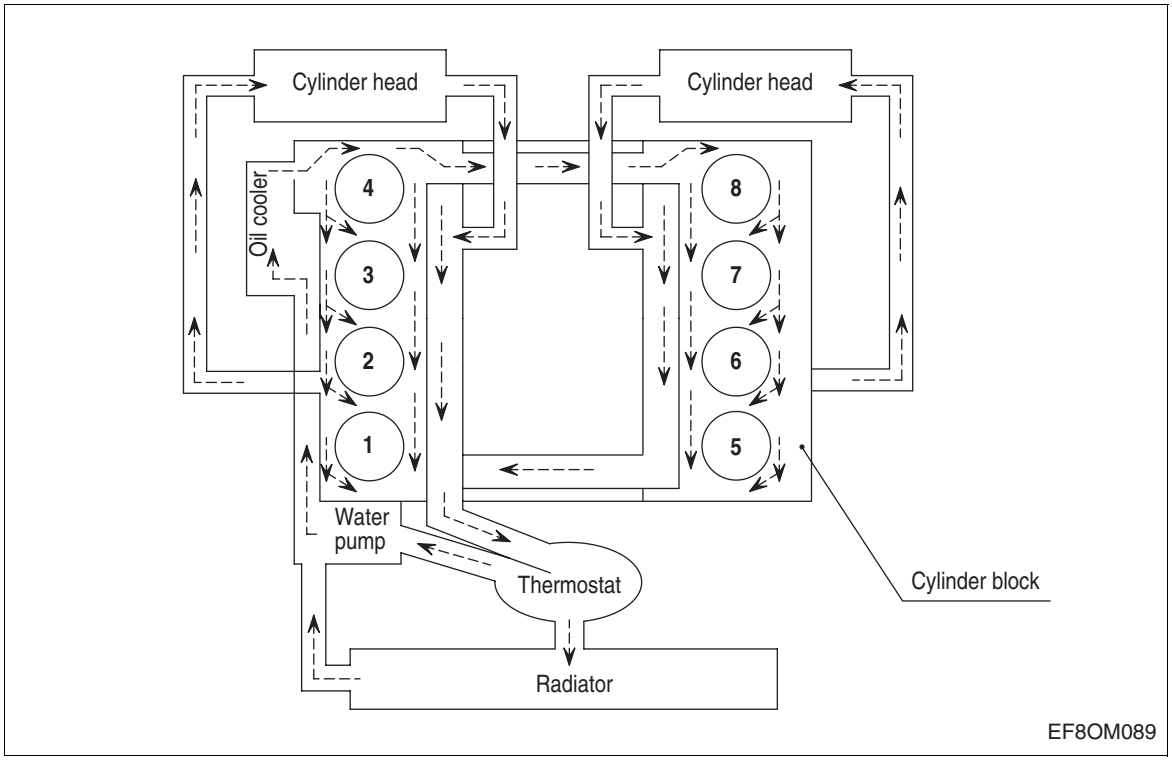
Rack diagram and setting valve at each point

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	
Prime power	A	12.84	900	311 ± 3	–	–
Stand by power	A	13.1	900	335 ± 3	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	–	–	–	–	–	–
	Boost pressure : zero boost					

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**

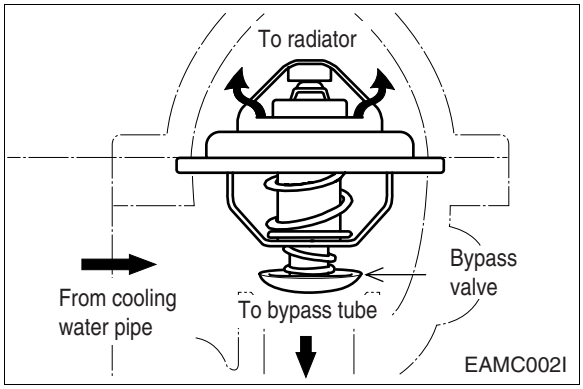
Item	Specification
1. Water pump	
Type	Centrifugal type
Delivery	About 700 liter/min
Pumping speed	3,500 rpm
Pumping back pressure	1.8 kg/cm^2
2. Thermostat	
Operating temperature	71 ~ 85 °C
3. Cooling fan and belt	
Fan diameter - Number of blades	915 mm - 7
Fan belt tension	10 ~15 mm / deflection by thumb

5.2.2. Thermostat

- **General descriptions and main data**

The thermostat maintains a constant temperature of coolant (90 ~ 95 °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.

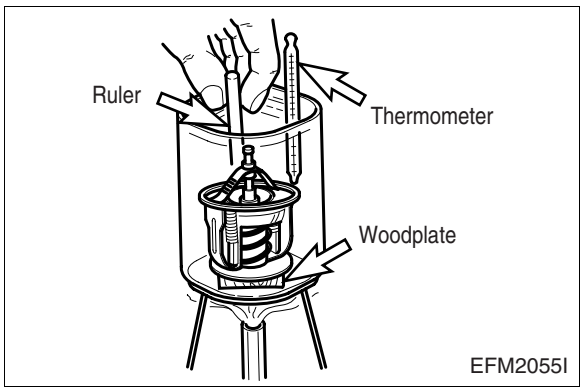


Item	Specifications
	In moderate climates
Type	Wax-pallet type
Open at	71 °C
Open wide at	85 °C
Valve lift	8 mm or more

- **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 83 °C and 8 mm or more (opening wide) at temperature of 95 °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 overspeed 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	● Lack of coolant	● Replenish coolant
	● Radiator cap pressure valve spring weakened	● Replace cap
	● Fan belt loosened or broken	● Adjust or replace fan belt
	● Fan belt fouled with oil	● Replace fan belt
	● Thermostat inoperative	● Replace thermostat
	● Water pump defective	● Repair or replace
	● Restrictions in water passages due to deposit of scales	● Clean radiator and water passages
	● Injection timing incorrect	● Adjust injection timing correctly
	● Restriction in radiator core	● Clean exterior of radiator
	● Gases leaking into water jacket due to broken cylinder head gasket	● Replace cylinder head gasket
2. Engine overcooling	● Thermostat inoperative	● Replace thermostat
	● Ambient temperature too low	● Install radiator curtain
3. Lack of coolant	● Radiator leaky	● Correct or replace
	● Radiator hoses loosely connected or damaged	● Retighten clamps or replace hoses
	● Radiator cap valve spring weakened	● Replace cap
	● Water pump leaky	● Repair or replace
	● Heater hoses loosely connected or broken	● Tighten or replace hoses
	● Cylinder head gasket leaky	● Replace cylinder head gasket
	● Cylinder head or cylinder block cracked	● Replace cylinder head block
4. Cooling system noisy	● Water pump bearing defective	● Replace bearing
	● Fan loosely fitted or bent	● Retighten or replace fan
	● Fan out of balance	● Replace fan
	● Fan belt defective	● Replace fan belt

5.3. Lubricating System

5.3.1. General descriptions and main data

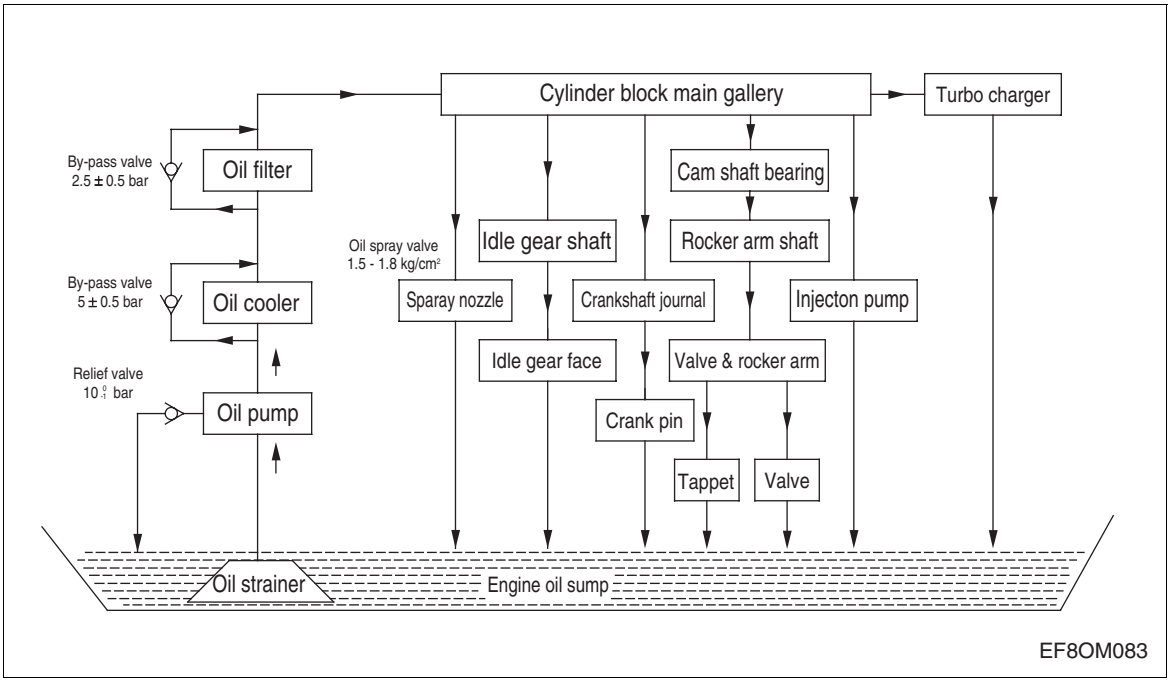
- **General descriptions**

  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**

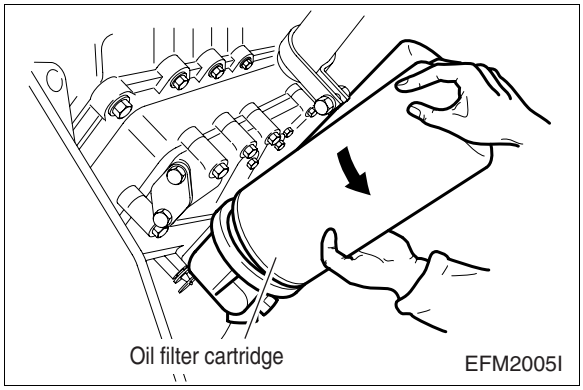
Item	Specifications	Item	Specifications
Lubricating system	Forced pressure circulation	Oil filter type	Full flow
Oil pump type	Gear type	Bypass for filter element	
Relief valve opening pressure	9 ~ 10 kg/cm^2	Valve opening pressure	2 ~ 2.5 kg/cm^2
Adjusting valve for spray nozzle		Bypass for oil cooler	
Opening pressure	1.5 ~ 1.8 kg/cm^2	Valve opening pressure	4.5 ~ 5.5 kg/cm^2

- **Diagram of lubricating system**



5.3.2. Oil filter

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



5.3.3. Diagnostics and troubleshooting

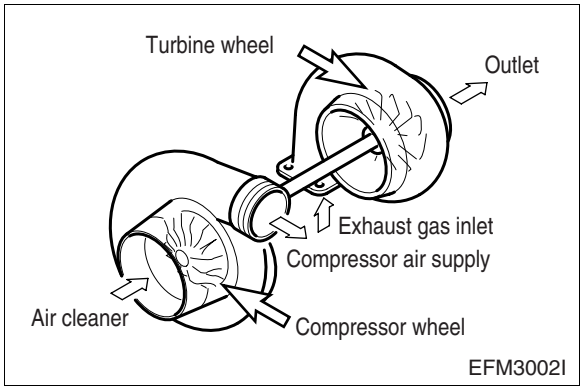
Complaints	Possible causes	Corrections
1. Oil consumption excessive	● Poor oil	● Use suggested oil
	● Oil seal or packing leaky	● Replace
	● Pistons or piston rings worn	● Replace pistons and/or piston rings
	● Cylinder liner worn	● Replace cylinder liner
	● Piston rings sticking	● Replace pistons and/or piston rings
	● Valve guide oil seals or valve guides, or valve stem worn	● Replace
2. Oil pressure too low	● Poor oil	● Use suggested oil
	● Relief valve sticking	● Replace
	● Restrictions in oil pump strainer	● Clean strainer
	● Oil pump gear worn	● Replace
	● Oil pump feed pipe cracked	● Replace
	● Oil pump defective	● Correct or replace
	● Oil pressure gauge defective	● Correct or replace
	● Various bearings worn	● Replace
3. Oil deteriorates quickly	● Restriction in oil filter	● Replace filter element
	● Gases leaking	● Replace piston rings and cylinder liner

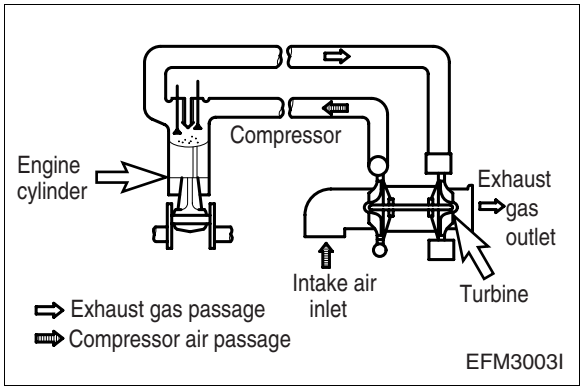
5.4. Turbo Charger

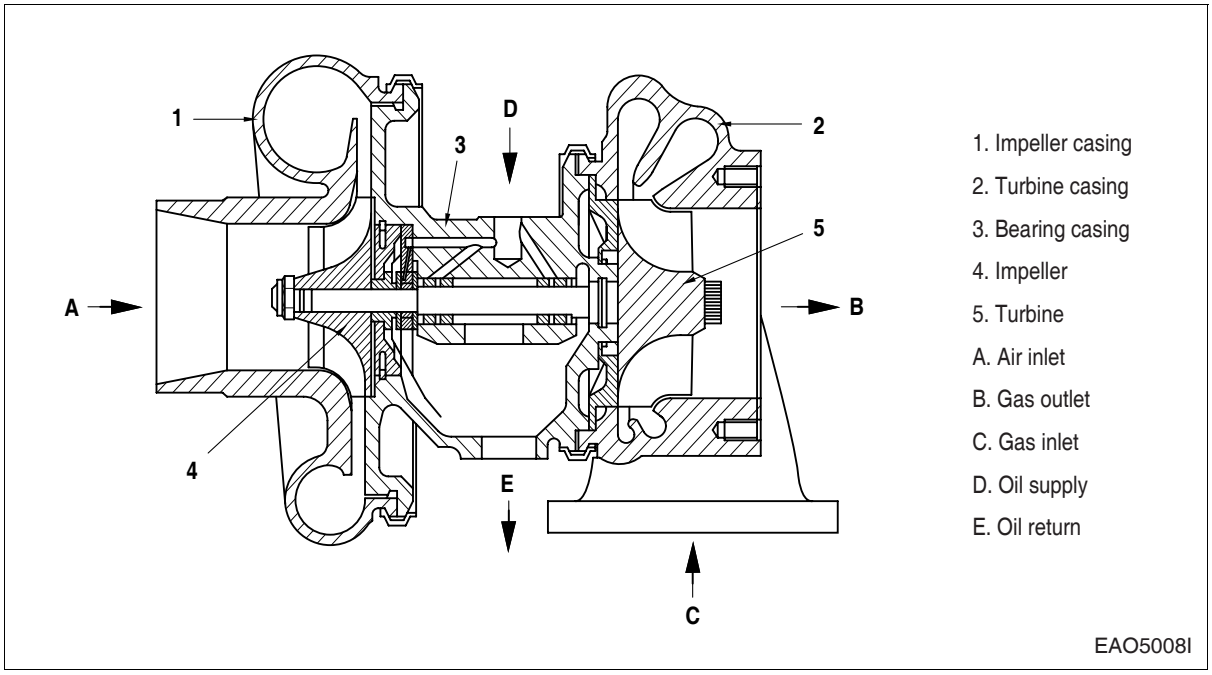
5.4.1. Main data and specification

Model		P158FE	P180FE	P222FE
At maximum output	Air pressure at compressor outlet	Allied Signal T04E	Allied Signal T45	Allied Signal G T45
	Air suction of turbine revolution	Approx. 33 m^3/min	Approx. 23 m^3/min	Approx. 53 m^3/min
	Speed of turbine revolution	Approx. 120,000 rpm	Approx. 107,000 rpm	Approx. 101,000 rpm
Maximum allowable speed		133,000 rpm	113,000 rpm	116,000 rpm
Maximum allowable temperature of exhaust gas at turbine inlet		750 °C	750 °C	750 °C
Lubricating system		External oil supply	External oil supply	External oil supply
Weight		14 kg	14 kg	14 kg

5.4.2. Operating principle

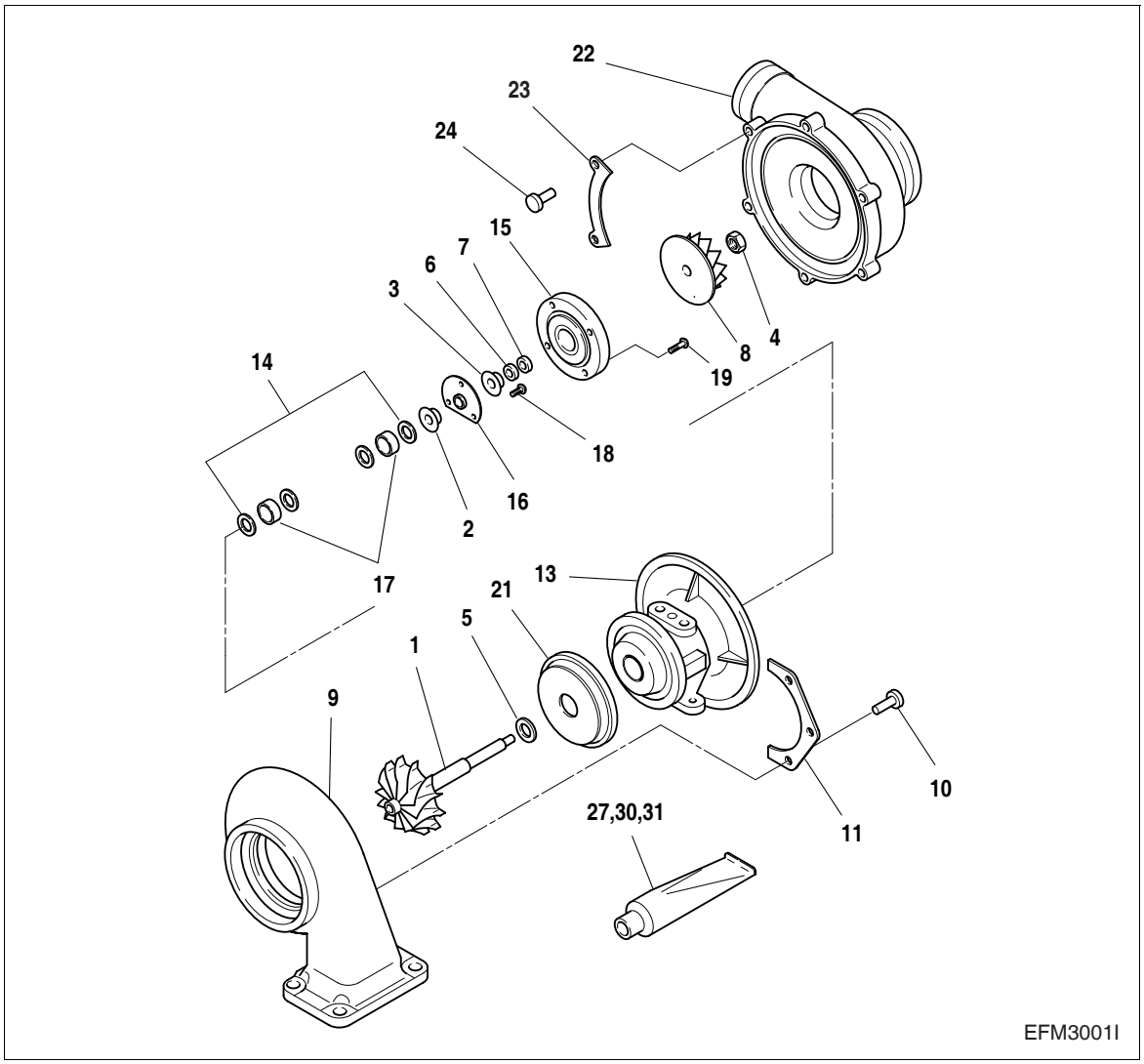






5.4.3. Construction

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



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

5.4.4. General information

- 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.

5.4.5. 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 inner and outer 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.

5.4.6. How to handle the engine

1) Precautions for operation of the engine

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

Operation	Caution	Reason
At starting	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.	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 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.	3) In case that engine stalled for long time and of cold weather, the fluidity of oil may be get worse.
Immediately After starting	1) Perform idling operation for about 5 min. immediately after engine starting.	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) Various inspections must insure that there are no leakage of oil, gas and air.	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	Following items must be confirmed.	
	1) Oil pressure at idling: 90 ~ 300 kPa (0.9 ~ 3.0 bar) at full load : 300 ~ 650 kPa (3.0 ~ 6.5 bar)	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) When abnormal noises and vibration are generated, slow down the revolution and must stop it to investigate the causes.	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	1) At stopping the engine, perform the idling operation for 5min. and then stop it.	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) Air intake system

- 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 used.

5.4.8. Periodical servicing

The turbocharger assembly must be inspected periodically.

1) Rotating condition of the rotor and checking tips

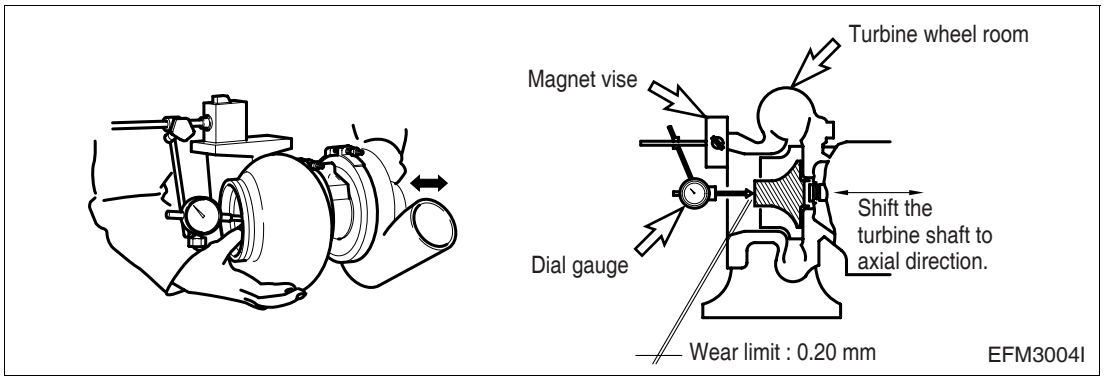
- Inspection on the revolving state of rotor is performed according to abnormal noises. In case of using an acoustic bar, touch the turbocharger housing with a tip of bar and raise the engine revolution slowly, Then, in case that high sound is heard by every 2 ~ 3 sec. continuously, for there should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

2) Measuring rotor clearance

- 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.

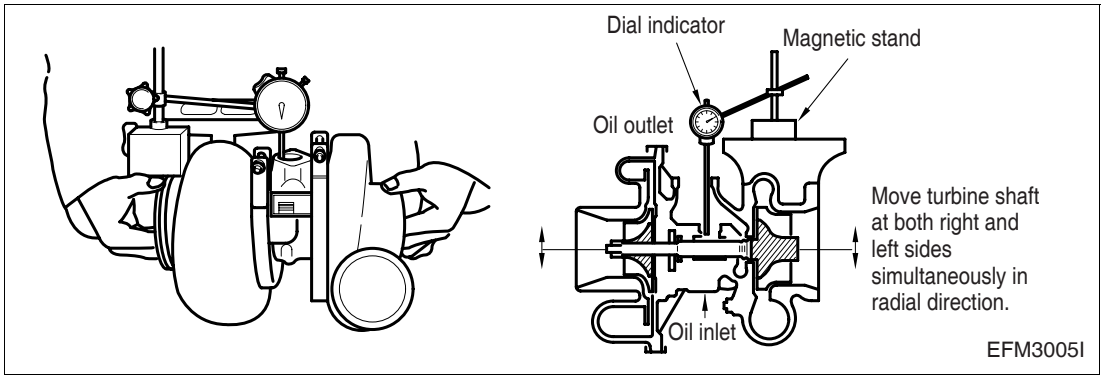
a) Rotor axial direction end play

- 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

- Be sure to dismantle the turbocharger from the engine before cleaning. Also, make sure to seal the oil inlet and outlet with tape or similar.

4) Precautions for turbocharger reassembly

- 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

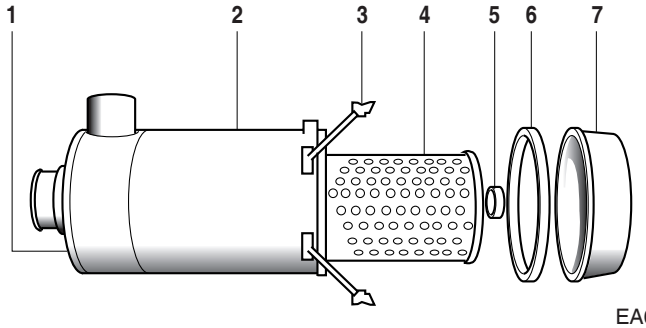
- Confirm if there is any foreign material in the exhaust system.
- Bolts and nuts must be made of anti-heat steel and in assembling, care should be taken not use the general nuts and coat the bolts and nuts with the anti-stuck agents at the same time.
- Assemble securely for gas not to leak from various 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	Replace or clean
	2) Air Inlet port clogged	Inspect or repair
	3) Air leaks from air intake system	Inspect or repair
	4) Turbocharger impossible to rotate due to stuck	Overhaul and repair or replace
	5) Turbine wing's contact	Overhaul and repair or replace
	6) Piping deformation or clogging of exhaust system	Inspect and repair
2. White smoke excessive	1) Oil leaks into turbine and compressor	Overhaul and repair or replace
	2) Seal ring's abnormal wear or damage	Overhaul and repair or replace
3. Output lowered	1) Gas leak from various parts of exhaust system	Inspect and repair
	2) Air cleaner's elements clogged	Replace or clean
	3) Turbocharger's pollution or damage	Overhaul and repair or replace
	4) Air leaks from discharge part of compressor side	Inspect and repair
4. Abnormal noises or vibrations	1) Revolving parts' contact	Overhaul and repair or replace
	2) Revolving imbalance of rotor	Overhaul and repair or replace
	3) Stuck	Overhaul and repair or replace
	4) Various connections loose	Inspect and repair

5.5. Air Cleaner

1. Connection port, fouling indicator
2. Cleaner housing
3. Clamp
4. Element
5. Hexagon nut
6. Cover
7. Dust bowl



EA6O5012

5.5.1. Maintenance (only when engine is switched off)

Empty the dust bowl (7) regularly. The bowl should never be filled more than halfway with dust.

On slipping off the two clamps (3), the dust bowl can be removed. Take off the cover (6) of the dust bowl and empty.

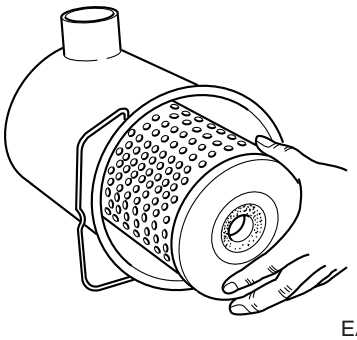
Be careful to assemble cover and bowl correctly.

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.

5.5.2. 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.

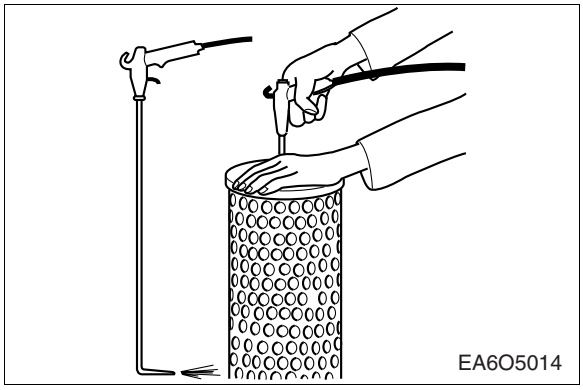


EA6O5013

5.5.3. Cleaning filter elements

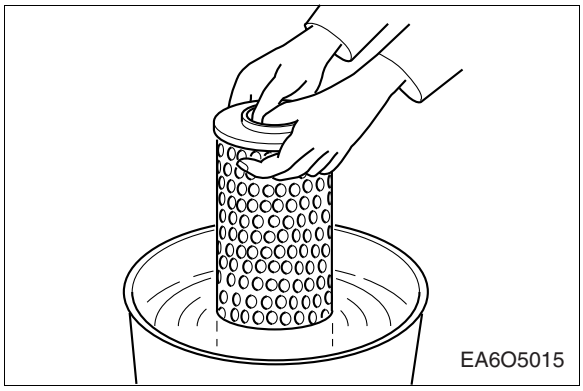
- **By compressed air (wear goggles)**

  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.



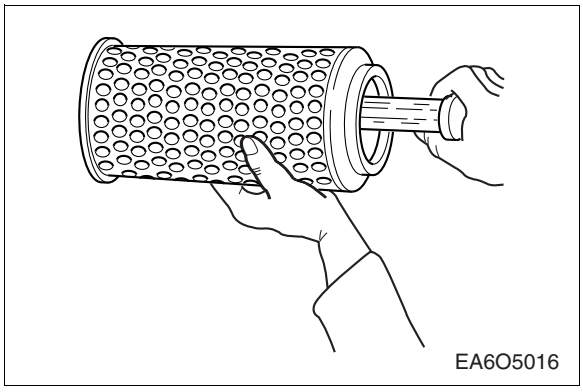
- **By washing**

  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.

5.6. V-belts

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 belts.

2) Checking condition

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

3) Testing by hand

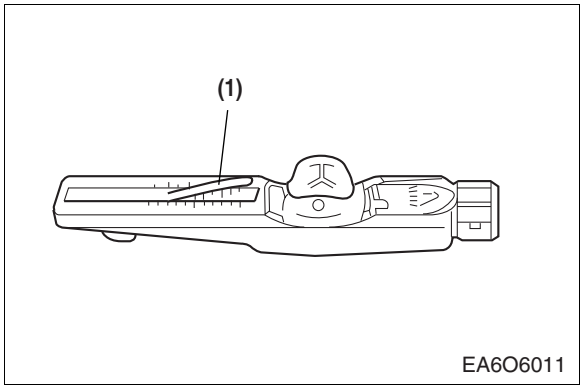
The tension is correct if the V-belts can be pressed in by about the thickness of the V-belt. (No more midway between the belt pulleys)

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

4) Measuring tension

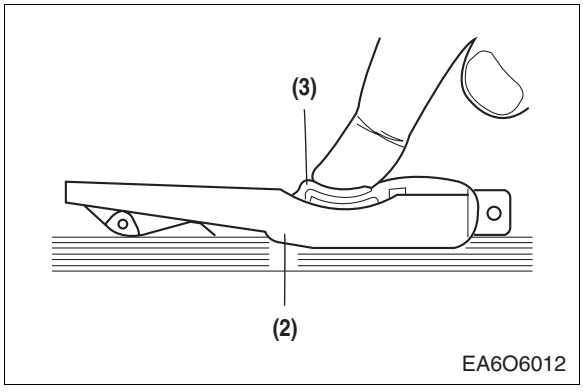
① Lower indicator arm (1) into the scale.

- 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!



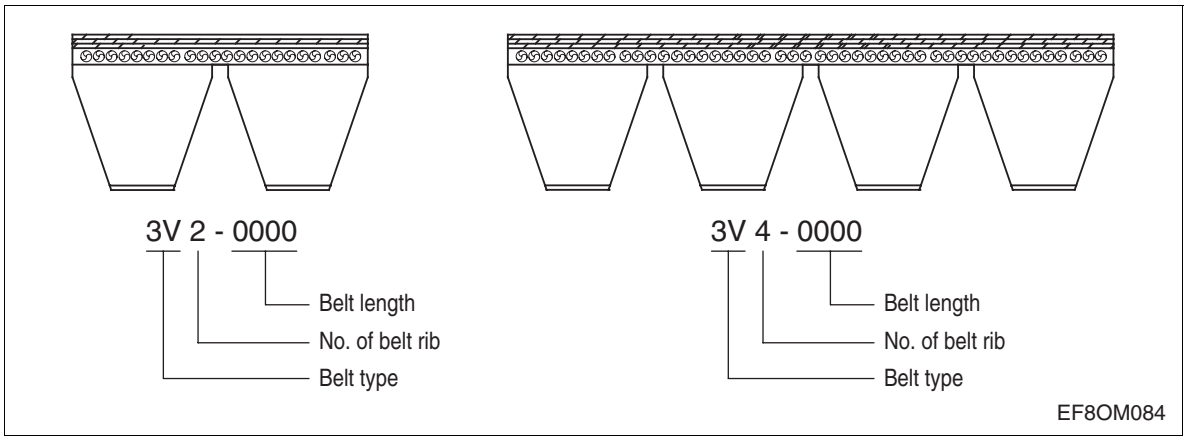
② Reading of tension

- 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.



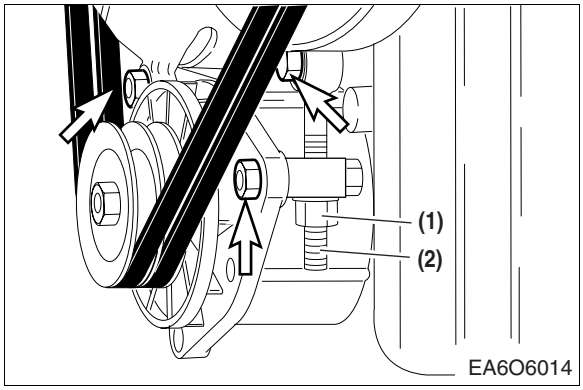
5) V-belt of raw edge cogged type

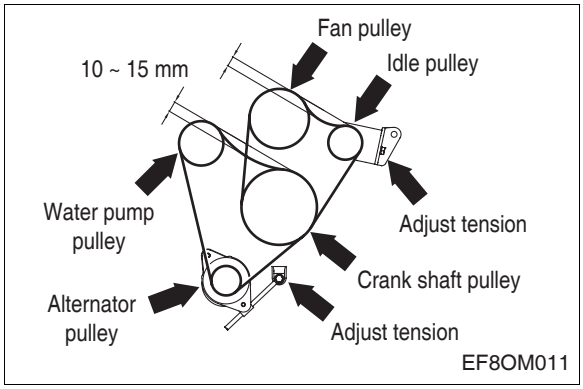
Type	New installation	When servicing after long running time
3V	45 kgf	41 kgf



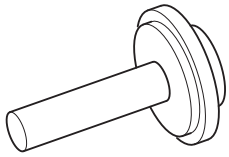
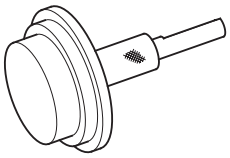
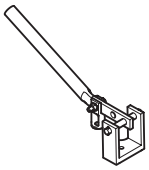
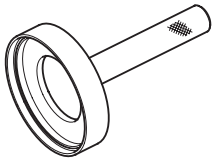
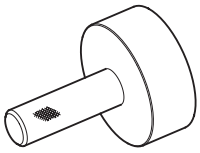
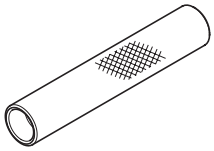
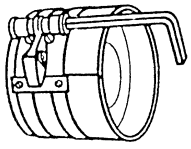
6) Tensioning and changing V-belt

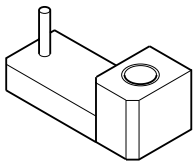
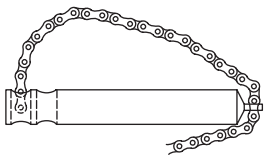
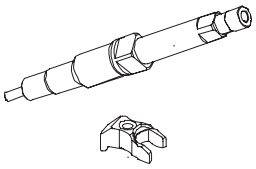
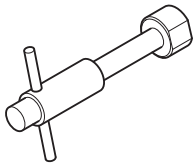
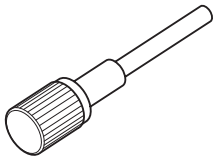
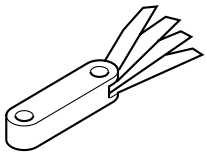
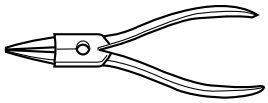
- Loosen the fixing bolts.
- Remove lock nut. (1)
- Adjust bolt (2) until V-belts have correct tensions.
- Retighten lock nut and fixing bolts.
  To change the V-belts loosen mounting bolts and lock nut (1) and push tension pulley inwards by turning adjusting bolt (2).
- Loosen the fixing bolts.
- Remove 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.





6. Special Tool List

No	Part no.	Figure	Tool name	Remark
1	EF.120-030		Front oil seal insert assembly	
2	EF.120-029		Rear oil seal insert assembly	
3	EF.120-281A		Valve cotter extractor	
4	E1.05508-0185		Wearing insert assembly (Crankshaft pulley)	
5	E1.05508-0025		Wearing insert assembly (Fly wheel)	
6	EF.120-246		Valve stem seal punch	
7	EF.120-208		Piston insert	All engine

No	Part no.	Figure	Tool name	Remark
8	EF.120-189		Injection pump alignment	
9	65.98801-0001		Filter wrench	
10	EF.110-119 65.10205-0007		Compression pressure gauge adapter Fixing bracket (use DV11 engine)	
11	EF.120-277		Injector insert	
12	EF.120-278		High pressure connector dummy	
13	60.99901-0027		Feeler gauge	
14	T7610001E		Snap ring plier	
15	T7621010E		Piston ring plier	

Appendix

● Tightening torque for major parts

Major parts	Screw (Diameter × pitch)	Strength (Grade)	Tightening torque
Cylinder block bearing cap			
– Main bolt	M18 × 2.0	12.9T	Initial 30 kg·m + angle torque 90°
– Side bolt	M12 × 1.5	10.9T	8 kg·m
Oil spray nozzle			
– Valve	M14 × 1.5	–	7 kg·m
– Fixing bolt	M6	8.8T	1.2 kg·m
Flywheel housing	M12 × 1.5	10.9T	11.2 kg·m
	M10 × 1.5	12.9T	7.5 kg·m
Balance weight	M16 × 1.5	10.9T	Initial 10 kg·m + angle torque 90°
Crank pulley	M16 × 1.5	12.9T	21 kg·m
Vibration damper	M10 × 1.5	10.9T	6 kg·m
Flywheel	M16 × 1.5	12.9T	26 kg·m
Connecting rod cap	M16 × 1.5	10.9T	Initial 10 kg·m + angle torque 90°
Cylinder head	M15 × 2.0	–	6 kg·m + 90°+ 90° + 90° + 30°
Cylinder intermediate cover	M8	8.8T	2.2 kg·m
Cylinder head cover	M8	8.8T	2.2 kg·m
Rocker arm bracket	M10 × 1.5	10.9T	6.2 kg·m
Lock nut (adjusting screw)	M10 × 1.0	8.8T	4.4 kg·m
Oil pump mounting	M8	8.8T	2.2 kg·m
Oil filter	M10	10.9T	4.4 kg·m
Oil cooler	M10	10.9T	5.5 kg·m
Oil pan	M8	8.8T	2.2 kg·m
Oil pan drain plug	M26 × 1.5	–	10 kg·m
Exhaust manifold	M10 × 1.5	–	8.0 kg·m
Intake manifold	M8	8.8T	4.4 kg·m
Hanger bracket bolt (rear side)	M16 × 1.5	–	18.5 kg·m
Starting motor	M12 × 1.5	8.8T	8 kg·m
Alternator bracket	M14 × 1.5	8.8T	12 kg·m
Coolant temperature sensor	M12 × 1.5	–	2.2 kg·m (max. 2.5 kg·m)

● Tightening torque for fuel injection system

Major parts	Screw (Diameter × pitch)	Strength (Grade)	Tightening torque
Fuel injection pipe nut	M12 × 1.5	8.8T	3.0 kg·m
Fuel filter bolt	M12 × 1.5	8.8T	4.0 kg·m
Fuel injector fixing bracket bolt	M8	10.9T	3.5 kg·m
Fuel high pressure connector flange bolt	M6	8.8T	1.0 kg·m

● 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/mm²)										
	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	0.5
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 MoS_2 should be tightened to 60 % or so of the standard value.

● **Tightening torque for plug screw**

M10	M12	M14	M16	M18	M22	M24	M26	M30
5.0	5.0	8.0	8.0	10.0	10.0	12.0	12.0	15.0

● **Tightening torque for hollow screw(4-hole)**

	M8	M10	M12	M14	M16	M18	M22	M26	M30	M38
SM25C	-	1.6	2.5	3.5	4.5	5.5	9.0	13.0	18.0	30.0
*SUM22L	0.8	1.8	3.0	4.0	5.5	6.5	11.0	16.0	20.0	35.0
STS304	0.8	1.8	3.0	4.0	5.5	6.5	11.0	16.0	20.0	35.0

* Adopted in DOOSAN engine

● 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		∅127.99 ~ ∅128.01	∅128.122	Replace liner	Measure unworn portion beneath the rim of the upper side
		Liner's roundness & columness (upper)		0.005	–		From top up to 168 mm
		Liner's roundness & columness (lower)		0.008	–		From bottom up to 85 mm
		Amount of liner projection		0.04 ~ 0.08	–		Measure at upper side of cylinder block
		The flatness of upper surface of cylinder block		0.03	–	Correct with a surface grinder	Referenced length : 150 mm
		Hydraulic test for 1 minute (kg/cm^2)		4	–	Replace if leaky	Temperature 70 °C
	Cylinder head & valve	Valve seat depression	Intake	0.8 ~ 1.1		Replace valve seat	Depression of valve from lower face of cylinder head
			Exhaust	0.8 ~ 1.1			
		Cylinder head height		116.95 ~ 117.05	116.4	Replace cylinder head	
		The flatness of lower surface of cylinder head		0.015	0.1		
		Inner diameter of valve guide	Intake	∅8.015 ~ ∅8.030	–		
			Exhaust	∅8.015 ~ ∅8.030	–		
		Thick of cylinder head gasket (at assembly status)		1.215 ~ 1.285	–		
		Hydraulic test for 1 minute (kg/cm^2)		4	–	Replace if leaky	Temperature 70 °C
Major moving parts	Piston	Outer diameter of piston		∅127.739 ~ ∅127.757	–	Replace liner	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		∅46.010 ~ ∅46.016	–		Standard diameter
		Width of piston ring grooves	Top ring	3.5	–	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	3.34 ~ 3.36	–	Replace ring	
			2nd ring	2.975 ~ 2.990	–		
			Oil ring	3.97 ~ 3.99	–		
		Piston ring gap	Top ring	0.35 ~ 0.55	1.5	Replace ring	Standard gauge inside diameter : ∅128
			2nd ring	0.80 ~ 0.95	1.5		
			Oil ring	0.40 ~ 0.70	1.5		
		Piston ring side clearance	Top ring	0.105 ~ 0.155	0.20	Replace ring or piston	Limit for use is if for standard clearance
			2nd ring	0.050 ~ 0.085	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		∅45.994 ~ ∅46.000	∅45.94	Replace piston pin	
		Clearance between piston pin and its bush		0.010 ~ 0.022	0.08	Replace one worn more	
	Crank shaft	Radial run-out of journal and pin		0.02	–	Correct with a grinder	Measure in horizontal and vertical directions
		Outside diameter of journal		∅103.98 ~ ∅104.00	∅102.98	Use under sized bearings respectively (0.25, 0.5, 0.75, 1.0)	
		Outside diameter of pin		∅89.980 ~ ∅90.000	∅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		
		Run-out of crankshaft	P158FE	0.06	0.4	Adjust by a press	Measure at journal # 1, 4 supported (# 1, 7 P222FE)
			P222FE	0.08	0.4		
		Clearance between crankshaft and bearing		0.066 ~ 0.132	0.166	Replace bearings	Measure at crown part not parting line
		End play of crankshaft		0.190 ~ 0.322	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		∅104.86 ~ ∅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	35.38 ~ 35.341	–		
			Big end	32.8 ~ 33.1	–		
			Cap	38.7 ~ 39.0	–		
		Inner diameter of small end with bush		∅46.055 ~ ∅46.065	–		
		Inner diameter of big end with bearing		∅90.064 ~ ∅90.106	–		
		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		0.064 ~ 0.126	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		0.1	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)		10 kg·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	∅70.07 ~ ∅70.09	–		
			Inner diameter of cam bush	∅70.00 ~ ∅70.03	∅70.06		
		Diameter of cam shaft journal		∅69.910 ~ ∅69.940	∅69.64		
		Clearance between cam shaft and cam bush		0.060 ~ 0.120	0.18	Replace cam bush	
		End play of camshaft		0.5 ~ 1.05	–	Replace thrust washer	
		Run-out of camshaft		0.05	0.1	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		∅432.490 ~ ∅432.645	–		Heating temperature at ring gear assembly (200 ~ 230 °C)
		Ring gear inner diameter		∅432.000 ~ ∅432.155	–		
		Overlap		0.335 ~ 0.645	–		
		Allowable shaking amount after assembly		0.5	–		
		Outer diameter after assembly wear ring		∅119.860 ~ ∅120.000	–		
Valve system	Valve and valve guide	Outer diameter of valve stem	Intake	∅7.963 ~ ∅7.977	∅7.94	Replace valve	When replacing valve guide & seat, work simultaneously by special tools
			Exhaust	∅7.950 ~ ∅7.964	∅7.93		
		Clearance between valve stem and valve guide	Intake	0.038 ~ 0.067	0.1		
			Exhaust	0.051 ~ 0.08	0.15		
		Degree of valve seat	Intake	60°	–		
			Exhaust	45°	–		
		Diameter of valve head	Intake	∅42.9 ~ ∅43.1	–		
			Exhaust	∅39.9 ~ ∅40.1	–		
		Thickness of valve head	Intake	3.0 ~ 3.4	2.5 or less		
			Exhaust	3.3 ~ 3.7			
		Projection amount of valve guide and valve spring seat	Intake	14.8 ~ 15.2	–	Use with assembly jig	To upper side of valve guide from spring seat side of cylinder head
			Exhaust	14.8 ~ 15.2	–		
		Valve seat assembly part's inner diameter of cylinder head	Intake	∅43.50 ~ ∅43.75	–		
			Exhaust	∅41.50 ~ ∅41.75	–		
		Diameter of valve seat	Intake	∅43.554 ~ ∅43.570	–		
			Exhaust	∅41.554 ~ ∅41.570	–		
		Valve seat assembly part's depth of cylinder head		11.9 ~ 12.1	–		
		Inner diameter of valve guide (not reamer)		∅7.4 ~ ∅7.6	–		When replacing valve guide & seat, work simultaneously by special tools
		Valve guide assembly part's inner diameter of cylinder head		∅14.000 ~ ∅14.018	–		
		Outer diameter of valve guide		∅14.028 ~ ∅14.039	–		

(unit : mm)

Group	Part	Inspection item			Stand value for assembly	Limit for use	Correction	Remark
Valve system	Valve and valve guide	Clearance between valve guide and cylinder head installing hole			-0.01 ~ -0.039	–		Apply oil over valve guide and press it into the hole
		Concentricity between valve seat and valve guide			0.05	–	Replace valve spring	Without spring seat
		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 (inner)	Free length		57	–	Replace valve spring	
			Tension force (kg)	44 mm	25.5	23.5 or less		
				28.6 mm	52.3	49.8 or less		
			Inclination (free length)		1.6 mm	2.0 or less		
	Rocker arm & push rod	Valve clearance (at cold)		Intake	0.4	–	Adjust	
				Exhaust	0.5	–		
		Joining surface of valve stem and rocker arm			–	–	Grind or replace if severely pitted on tip of rocker arm and stem	
		Inner diameter of rocker arm bush			∅24.991 ~ ∅25.012	∅25.04		
		Diameter of rocker arm shaft			∅24.953 ~ ∅24.976	∅24.90		
		Clearance between rocker arm shaft & rocker arm bush			0.015 ~ 0.059	0.14	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			∅20.000 ~ ∅20.021	–		
		Diameter of tappet			∅19.944 ~ ∅19.965	–	Replace tappet	
		Clearance between tappet & tappet hole of cylinder block			0.035 ~ 0.077	0.13	Replace tappet	
		Tappet face in contact with cam			–	–	Replace if severely worn or deformed	

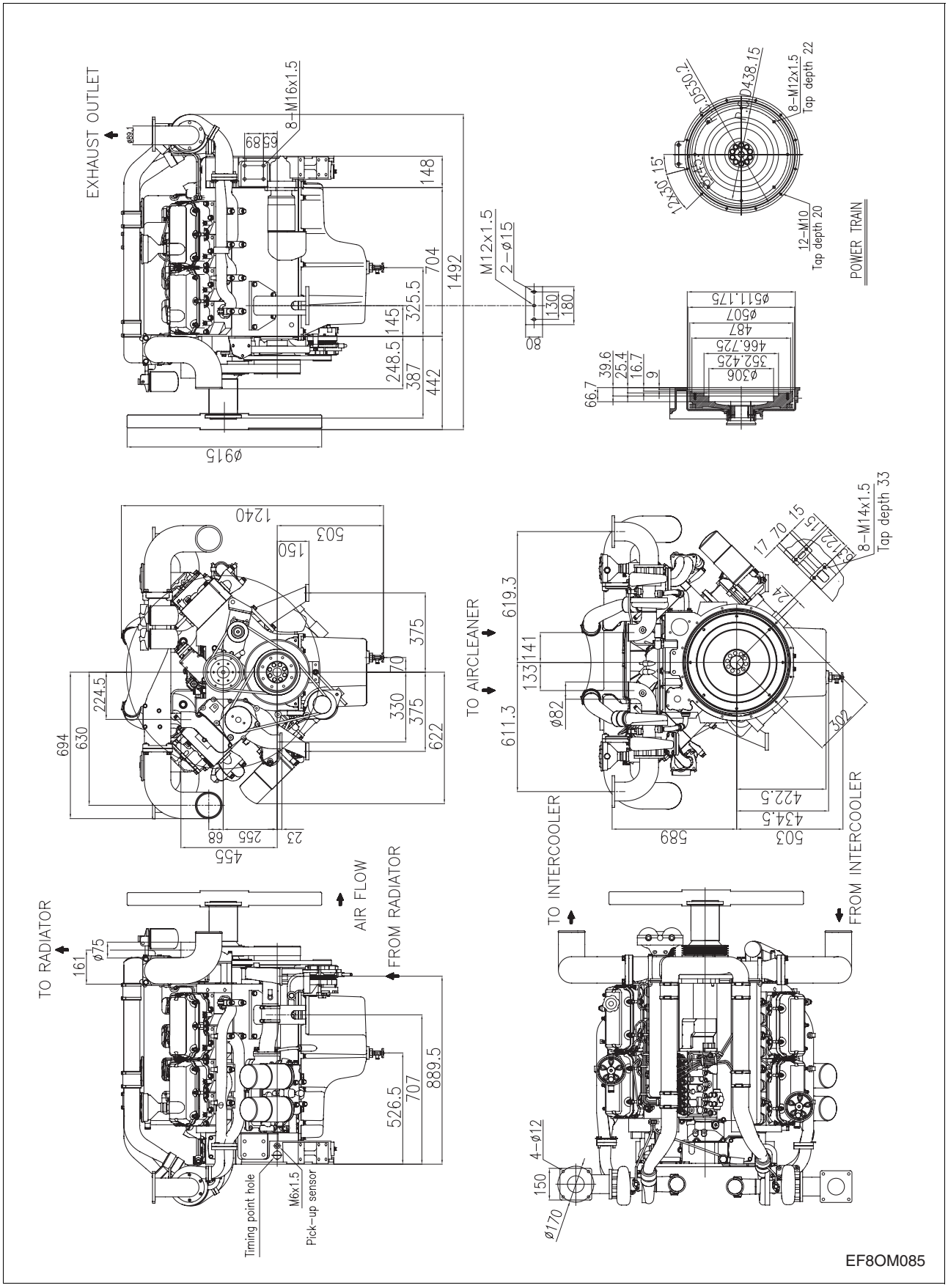
(unit : mm)

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	–		
		By-pass valve for filter element (kg/cm^2)	2 ~ 2.5	–		
		Oil spray nozzle / Operating pressure	1.5 ~1.8		Replace valve	
	Oil pump	Delivery volume lit/min – Pump speed : 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 spray nozzle opening pressure (kg/cm^2)	1.5 ~ 1.8	–	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 ~ 2.5			
		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)	0.5	–		
		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	

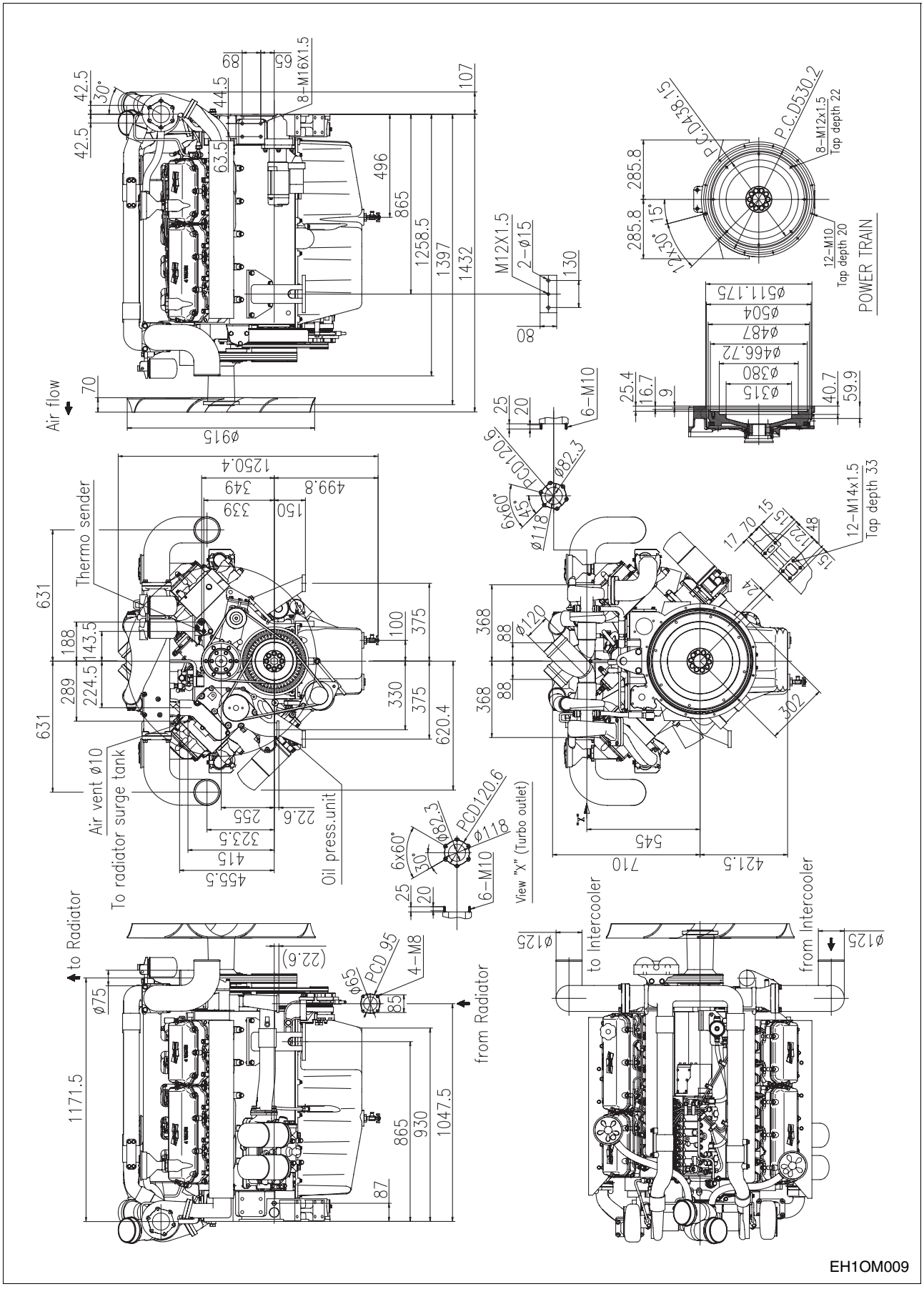
(unit: mm)

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	Opening temperature (°C)	71	–	Replace	
		Full opening temperature (°C)	85	–	Replace if defective Stroke : min. 8 mm	
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	
	njection pressure of injector (kg/cm^2)		280	–		
	Operating pressure of overflow valve (kg/cm^2)		1.3 ~1.8	–	Replace valve	
	Diameter of injector nozzle		8 - ∅0.284	–		
	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	0.118 ~ 0.242	0.3		
		Between drive gear & fuel pump gear	0.102 ~ 0.338	0.45		

1. Engine assembly drawing - P158FE



2. Engine assembly drawing - P180FE



3. Engine assembly drawing - P222FE