Doosan Infracore

65.99897-8121

# Operation & Maintenance Manual

# Diesel Engine

# DL06

PS-MMA0418-E1

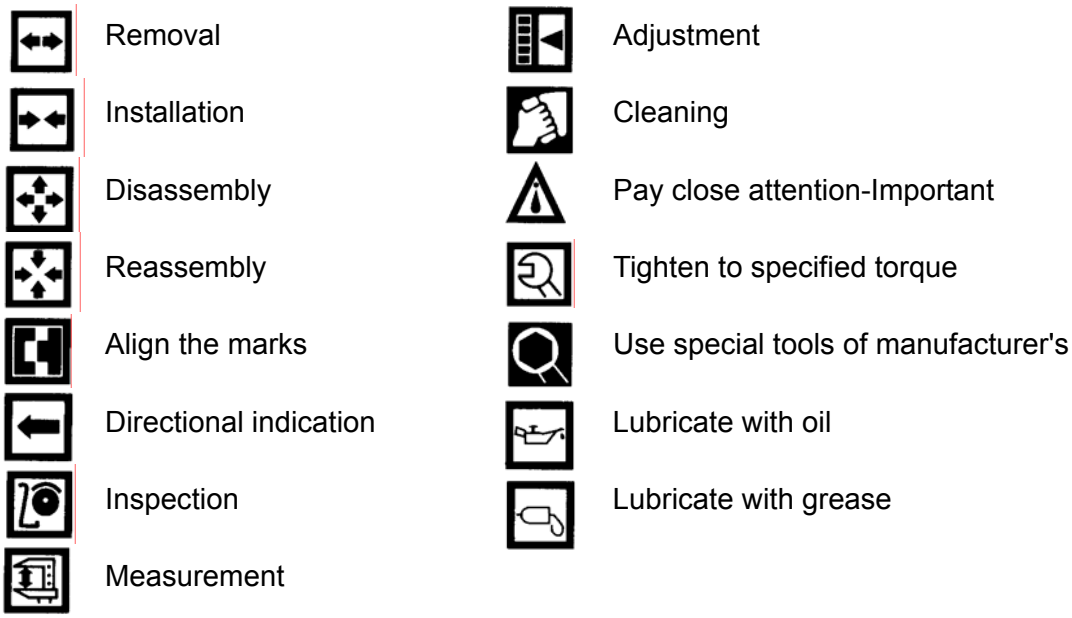
# FOREWORD

This maintenance manual is designed to serve as a reference for DOOSAN Infracore (here after DOOSAN's) customers and distributors who wish to gain basic product knowledge on DOOSAN 's **DL06** Diesel engine.

This economical and high-performance diesel engine (6 cylinders, 4 strokes, in-line, direct injection type) has been so designed and manufactured to be used for the overland transport or industrial purpose. That meets all the requirements such as low noise, fuel economy, high engine speed, and durability.

To maintain the engine in optimum condition and retain maximum performance for a long time, CORRECT OPERATION and PROPER MAINTENANCE are essential.

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 near by your location for any services.

For the last, the content of this maintenance instruction may be changed without notice for some quality improvement. Thank you.

**Nov. 2006**

# CONTENTS

**1. Safety regulations & engine specifications**
1.1. Safety regulations 1
1.2. Engine specifications 6
1.3. Engine power 8
1.4. Engine performance curve 9
1.5. Engine assembly 14

**2. Technical information**
2.1. Engine model and serial number 19
2.2. Diagnostic tool (SCAN-200) 20
2.3. Engine character 20
2.4. Diagnosis and remedy 44
2.5. Engine inspection 54

**3. Maintenance**
3.1. Engine disassembly 56
3.2. Measurement and inspection on major parts 72
3.3. Reassembly 96
3.4. Fuel injection system 122
3.5. Electrical system 136
3.6. Engine diagnostic 149
3.7. Engine control unit (ECU) 155

**4. Commissioning and operation**
4.1. Preparations 159
4.2. Operation of a new engine (Break-in) 159
4.3. Inspections after Starting 161
4.4. Operation in winter time 163
4.5. Tuning the engine 165
4.6. Maintenance and care 166
4.7. Cooling system 169

**5. Maintenance of major components**
5.1. Cooling system 171
5.2. Lubrication system 175
5.3. Turbo charger 178
5.4. Air cleaner 188
5.5. Belt 190

**6. Special tool list** 193

- **Appendix**
- **Worldwide network**

# 1. Safety Regulations & 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.

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

### 1.1.2. To prevent accidents with injury to persons

**(1) Engine starting and operation**

- Before putting the engine into operation for the first time, read the operating instructions carefully and familiarize yourself with the “critical” points. If you are unsure, ask your DOOSAN representative or service man.
- For reason of safety we recommend you attach a notice to the door of the engine room prohibiting the access of unauthorized persons and that you draw the attention of the operating personal to the fact that they are responsible for the safety of person who enter the engine room.
- The engine must be started and operated only by authorized personnel.
- Ensure that the engine cannot be started by unauthorized person.
- 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.

### (2) 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.
- If change or refill the cooling water, disassemble the drain plug when the engine has cooled down. Heated cooling water has the risk of scalding and safety accidents.
- 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.
- 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.**
**Therefore it should be done by an expert of the handling professionally.**

### (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. Slip caused by the worn open-end wrench 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 do electric weld, stop the engine, power off, then remove the wire harness' connector which is connected to the ECU.
- Do not weld the electric control unit (ECU) absolutely, and do not damage on it by electrical or mechanical shock.
- 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**. Engine control unit 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.
- Pay attention to cleanliness. The Diesel fuel must be free of water.
- Use only DOOSAN approved service products (engine oil, anti-freeze and anticorrosion agent)
- Refer to the subjects of recommendation of the fuel.
- 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.
- 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.
- Always ensure that the testing and monitoring equipment (for battery charge, oil pressure, coolant temperature) function satisfactorily.

- 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.
  - 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.

**CAUTION:**

**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.
13. Work the fuel line after the common rail pressure and engine temperature is checked with the SCAN-200. (past about 5 minutes after engine stop)

## 1.2. Engine Specifications

| Items / Engine model | | DL06 |
|---|---|---|
| Engine type | | Water-cooled, 4 cycle, In-line, Turbo charged & inter-cooled |
| Combustion chamber type | | Direct injection type |
| Cylinder liner type | | Replaceable dry liner |
| Timing gear system | | Gear driven type |
| No. of piston ring | | 2 compression ring, 1 oil ring |
| No. of cylinder-bore x stroke (mm) | | 6 – 100 ×125 |
| Total piston displacement (cc) | | 5,890 |
| Compression ratio | | 17.4 : 1 |
| Engine dimension (length x width x height) (mm) | | 1,069 x 815 x 1,164 |
| Rotating direction (view from flywheel) | | Counter clockwise |
| Engine weight (kg) | | 560 |
| Firing order | | 1 – 5 – 3 – 6 – 2 - 4 |
| Fuel high pressure pump type | | Bosch CP3.3 fuel high pressure pump type |
| Engine control type | | Electric control type (ECU) |
| Injector type | | Multi – hole (8 x Ø0.136) |
| Fuel injection pressure ($kg/cm^2$) | | 250bar(operating pressure 1,600bar) |
| Valve clearance (mm) | Intake valve | 0.3 |
| | Exhaust valve | 0.4 |
| Intake valve | Open at | 21° (B.T.D.C) |
| | Close at | 33° (A.B.D.C) |
| Exhaust valve | Open at | 56.2° (B.B.D.C) |
| | Close at | 22.2° (A.T.D.C) |
| Fuel filter type | | Full-flow (cartridge) |
| Oil pressure ($kg/cm^2$) | at idle speed | 1.5 ~ 3.0 |
| | at rated speed | 3.0 ~ 5.5 |
| Using lubrication oil | | ACEA-E5(API CI-4 class) |
| Lubrication method | | Full forced pressure feed type |
| Oil pump type | | Gear type driven by crankshaft |
| Oil filter type | | Cartridge type |
| Lubricating oil capacity (max./min.) (lit) | | 27 / 17 , 22 / 16 |
| Oil cooler type | | Water cooled |
| Hydraulic indicator | | Oil pressure unit |
| Water pump | | Belt driven centrifugal type |
| Cooling method | | Pressurized circulation |
| Cooling water capacity(engine only) (lit) | | 10.6 |
| Thermostat | Type | Wax pallet type |
| | Open at (° C) | 71°C (82°C) |
| | Open wide at (° C) | 90°C (95°C) |
| | Valve lift (mm) | 10 (10) |

| Items / Engine model | | DL06 |
|---|---|---|
| Water temperature indicator | | Water temperature sensor mounted |
| Air compressor | Type | Water cooled |
| | Capacity (cc/rev) | 305 |
| | Revolution ratio | 1 : 0.93 (engine speed : air compressor speed) |
| Power steering pump | Type | Gear driven, vane type |
| | Capacity (l/min) | 18 |
| | Adjusting pressure ($kg/cm^2$) | 125 (Pump speed 1,300 rpm) |
| | Revolution ratio | 1 : 1.303 (engine speed : pump speed) |
| Turbo charger | | Exhaust gas driven type (waste gate) |
| Engine stop system | | Fuel feeding shut-off by ECU |
| Alternator (voltage – capacity) (V - A) | | 24 - 50 |
| Starting motor(voltage–output) (V - kW) | | 24 – 4.5 |
| Air heater capacity (V – A) | | 24V – 2.1kW |
| Battery capacity (V - AH) | | 24 - 100 |

## 1.3. Engine Power

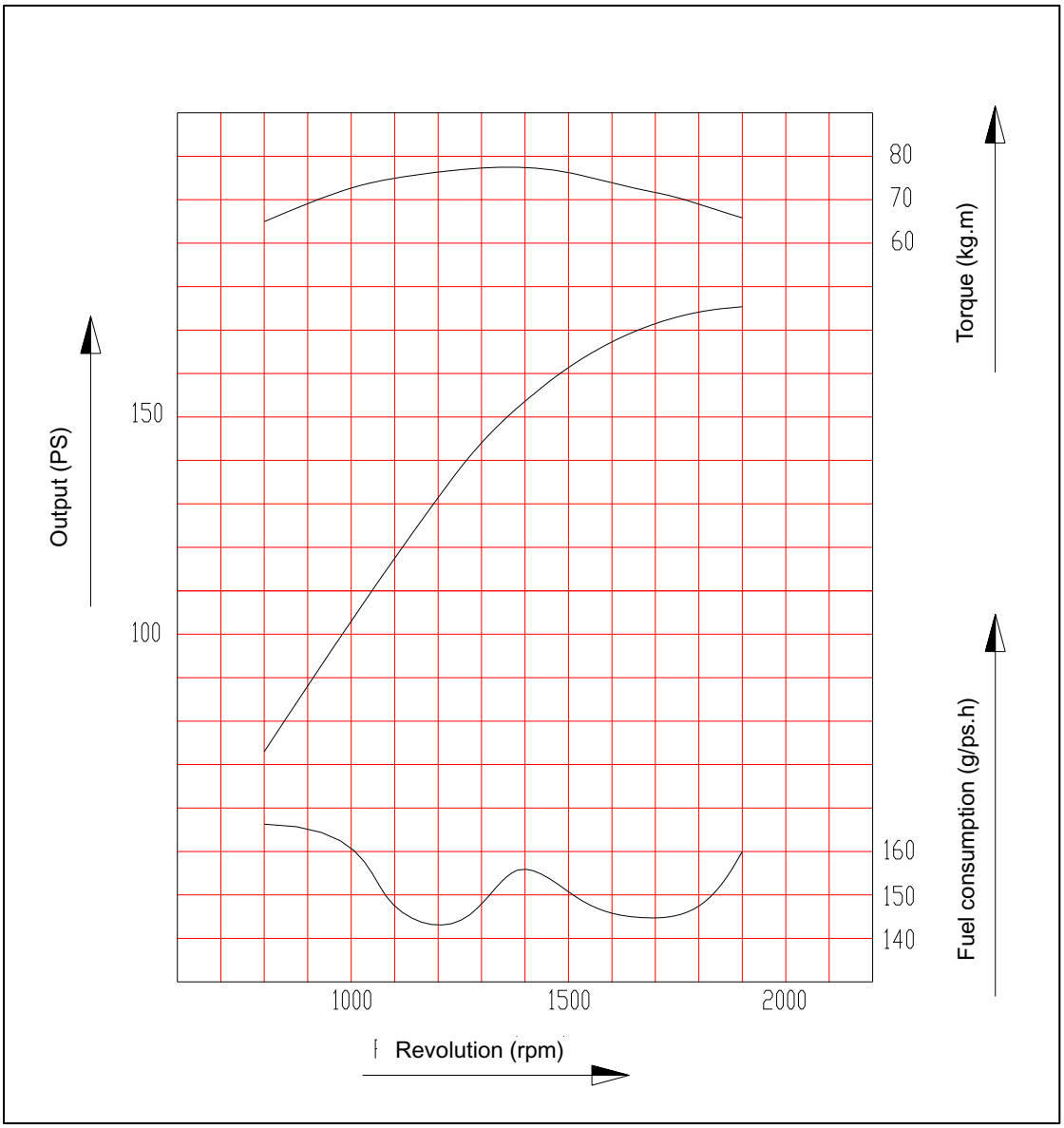
tolerance : ±5%

| Engine model | | Performance | | | | Remark |
|---|---|---|---|---|---|---|
| Model | Suffix | Power (PS / rpm) | Torque (kg.m / rpm) | Low idle (rpm) | High idle (rpm) | |
| DL06 | EUTCA | 240/2,500 | 82/1,400 | | | Euro-3 |
| | EUTEA | 157/1,900 | 70/1,400 | 800 | 2,000 | Tier-2 |
| | EUTEB | 136/2,000 | 55/1,400 | 800 | 2,100 | Tier-2 |
| | EUTEC | 172/2,000 | 75/1,400 | 800 | 2,100 | Tier-2 |
| | EUTED | 136/2,000 | 55/1,400 | 800 | 2,100 | Tier-2 |
| | EUTEF | 175/1,900 | 78/1,400 | 800 | 2,000 | Tier-3 |
| | EUTEG | 157/1,900 | 70/1,400 | 800 | 2,000 | Tier-3 |
| | EUTEH | 172/2,000 | 75/1,400 | 800 | 2,100 | Tier-3 |
| | EUTEI | 165/1,900 | 72/1,400 | 800 | 2,000 | Tier-3 |
| | EUTEJ | 124/1,950 | 47/1,400 | 800 | 2,050 | Tier-3 |
| | EUTEK | 136/2,000 | 55/1,400 | 800 | 2,080 | Tier-3 |
| | EUTEL | 100/1,850 | 40/1,400 | 800 | 1,950 | Tier-3 |
| | EUTFA | 160/2,100 | 67/1,400 | 750 | 2,420 | Tier-2 |
| | EUTFB | 140/2,100 | 59/1,400 | 750 | 2,420 | Tier-2 |
| | EUTFC | 160/2,100 | 67/1,400 | 750 | 2,420 | Tier-3 |
| | EUTFD | 140/2,100 | 59/1,400 | 750 | 2,420 | Tier-3 |
| | EUTLA | 165/2,100 | 82/1,400 | 900 | 2,250 | Tier-2 |
| | EUTLB | 145/2,100 | 70/1,400 | 900 | 2,250 | Tier-2 |
| | EUTLC | 165/2,100 | 82/1,400 | 900 | 2,250 | Tier-3 |
| | EUTLD | 145/2,100 | 70/1,400 | 900 | 2,250 | Tier-3 |

* Note : All data are based on operation without cooling fan at ISO 1585(SAE J1349)

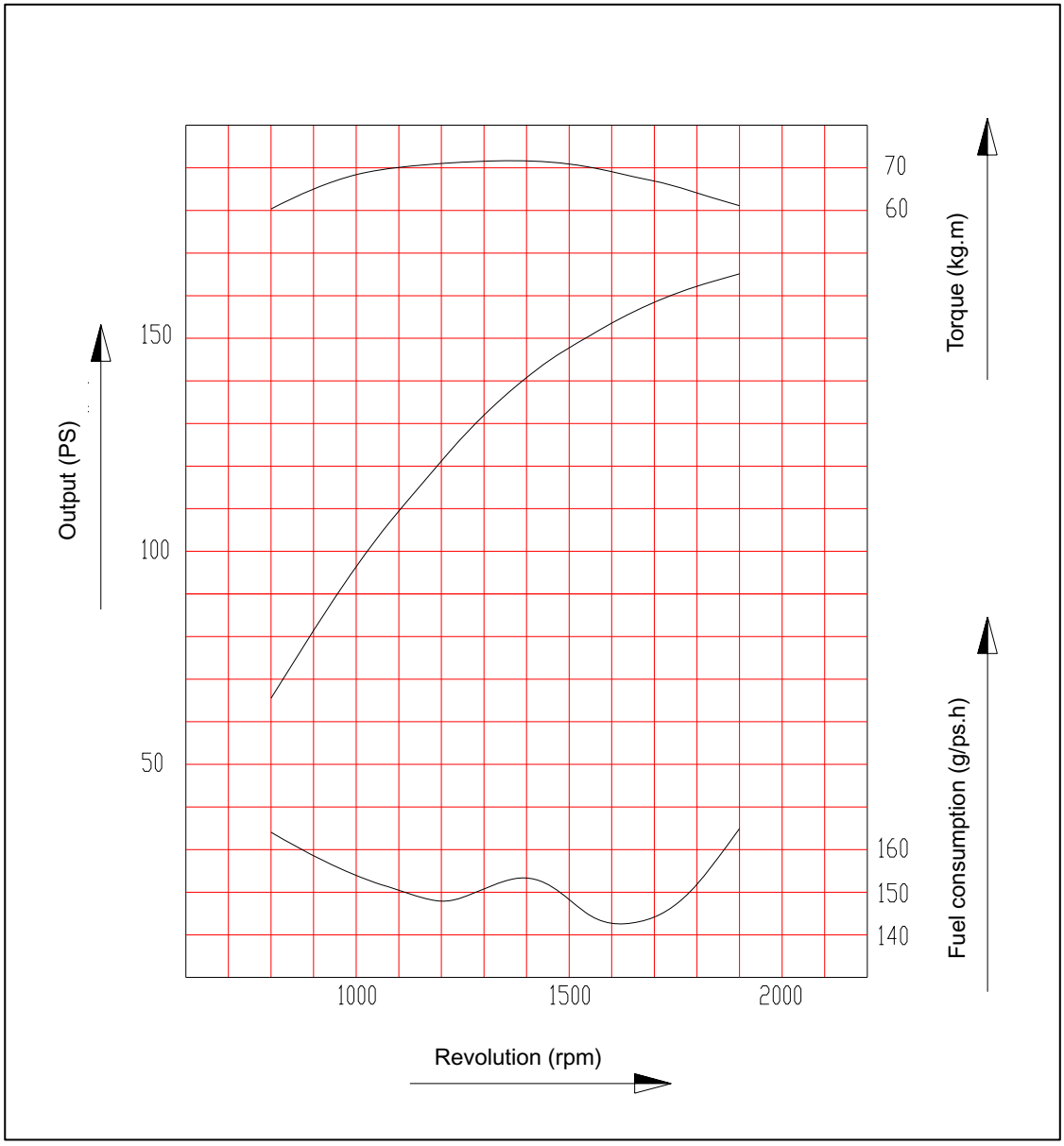
## 1.4. Engine Performance Curve

### 1.4.1. Performance curve (175 PS)



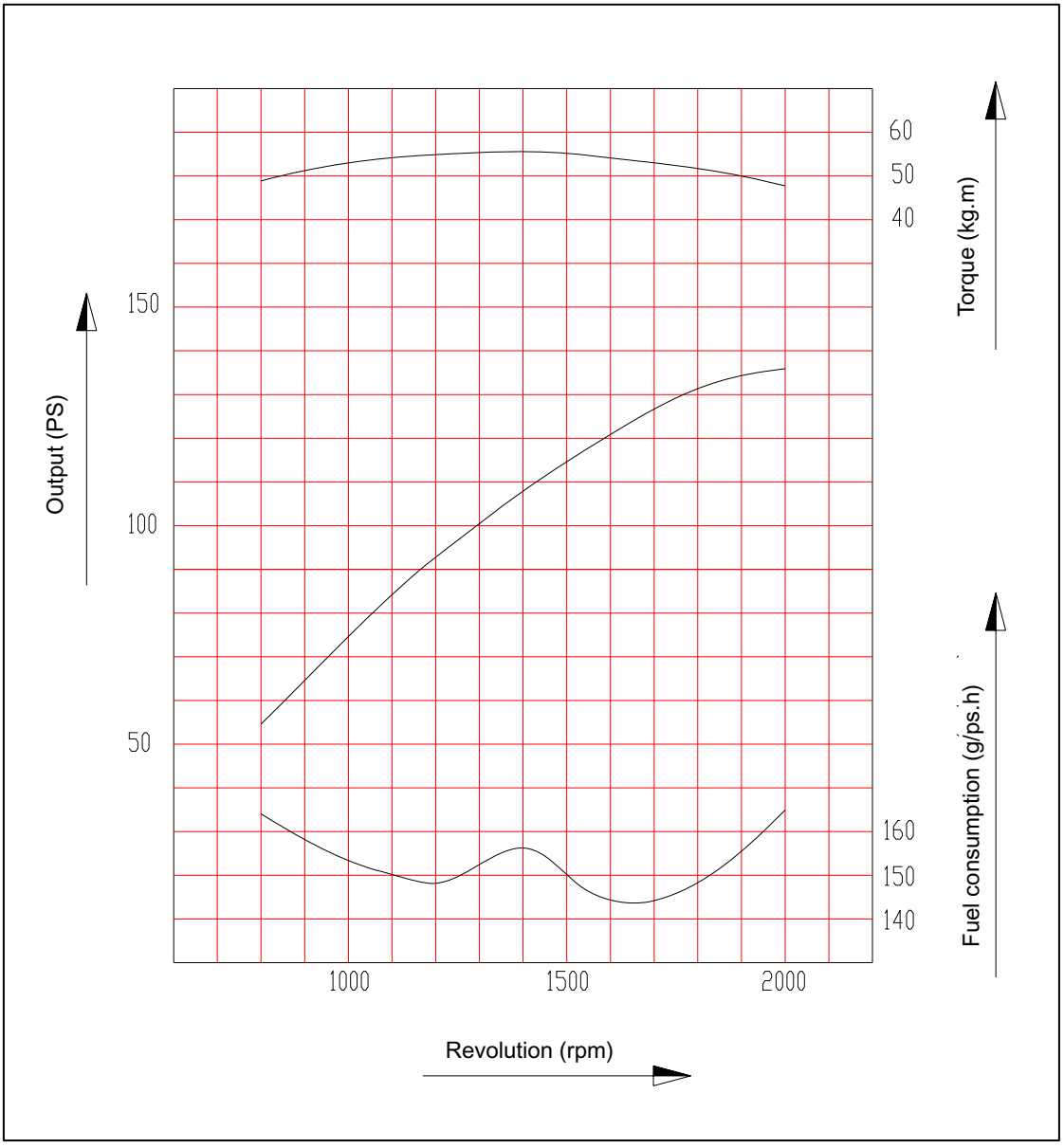

| Performance | | ISO 1585 (SAE J1349) |
|---|---|---|
| Output | (max.) | 129 kW (175 PS) / 1,900 rpm |
| Torque | (max) | 765 N.m (78 kg.m) / 1,400 rpm |
| Fuel consumption | (min.) | 218 g/kW.h (160 g / PS.h) |

### 1.4.2. Performance curve (165 PS)



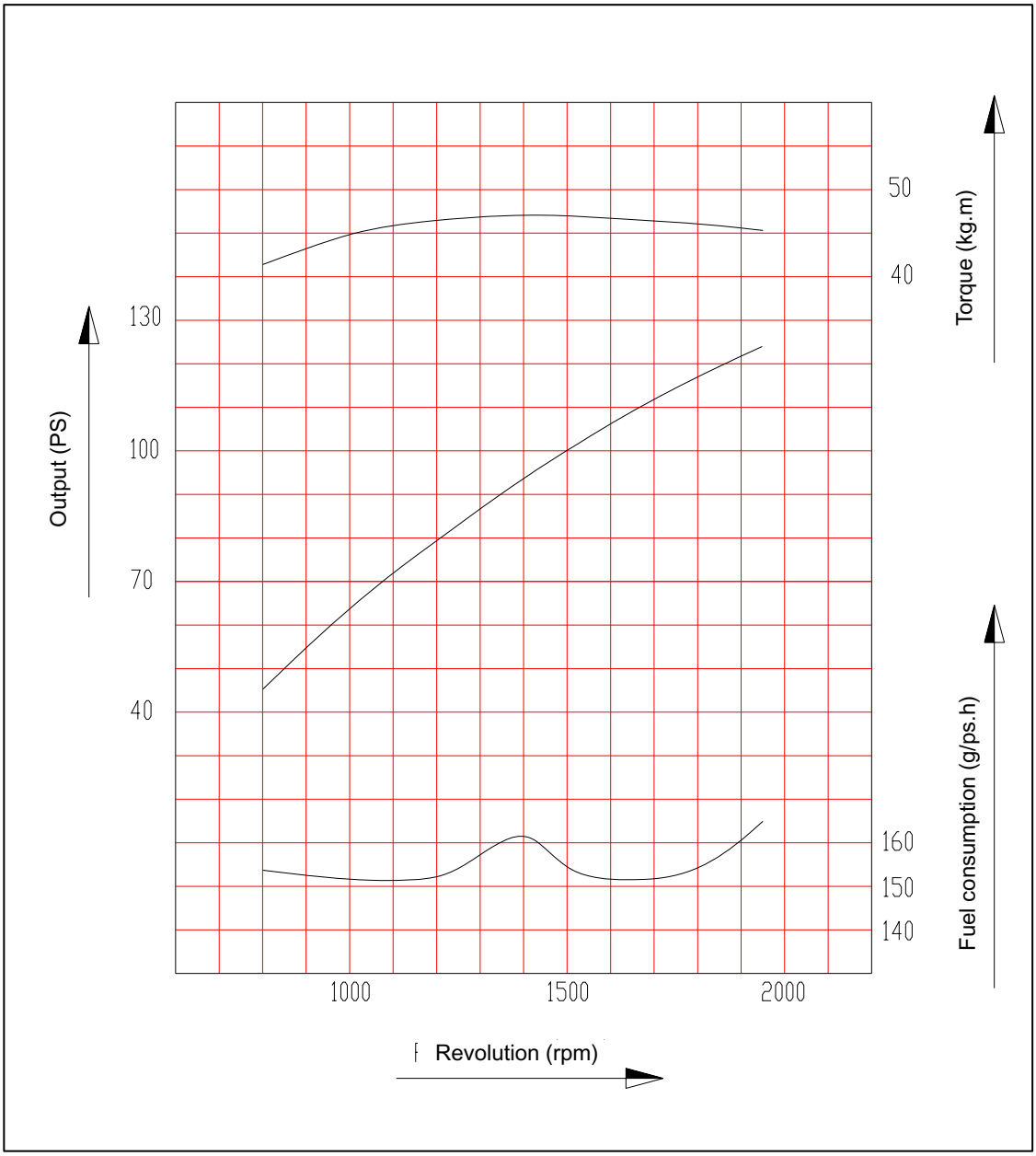

| Performance | | ISO 1585 (SAE J1349) |
|---|---|---|
| Output | (max.) | 121 kW (165 PS) / 1,900 rpm |
| Torque | (max) | 706 N.m (72 kg.m) / 1,400 rpm |
| Fuel consumption | (min.) | 224 g/kW.h (165 g / PS.h) |

### 1.4.3. Performance curve (136 PS)



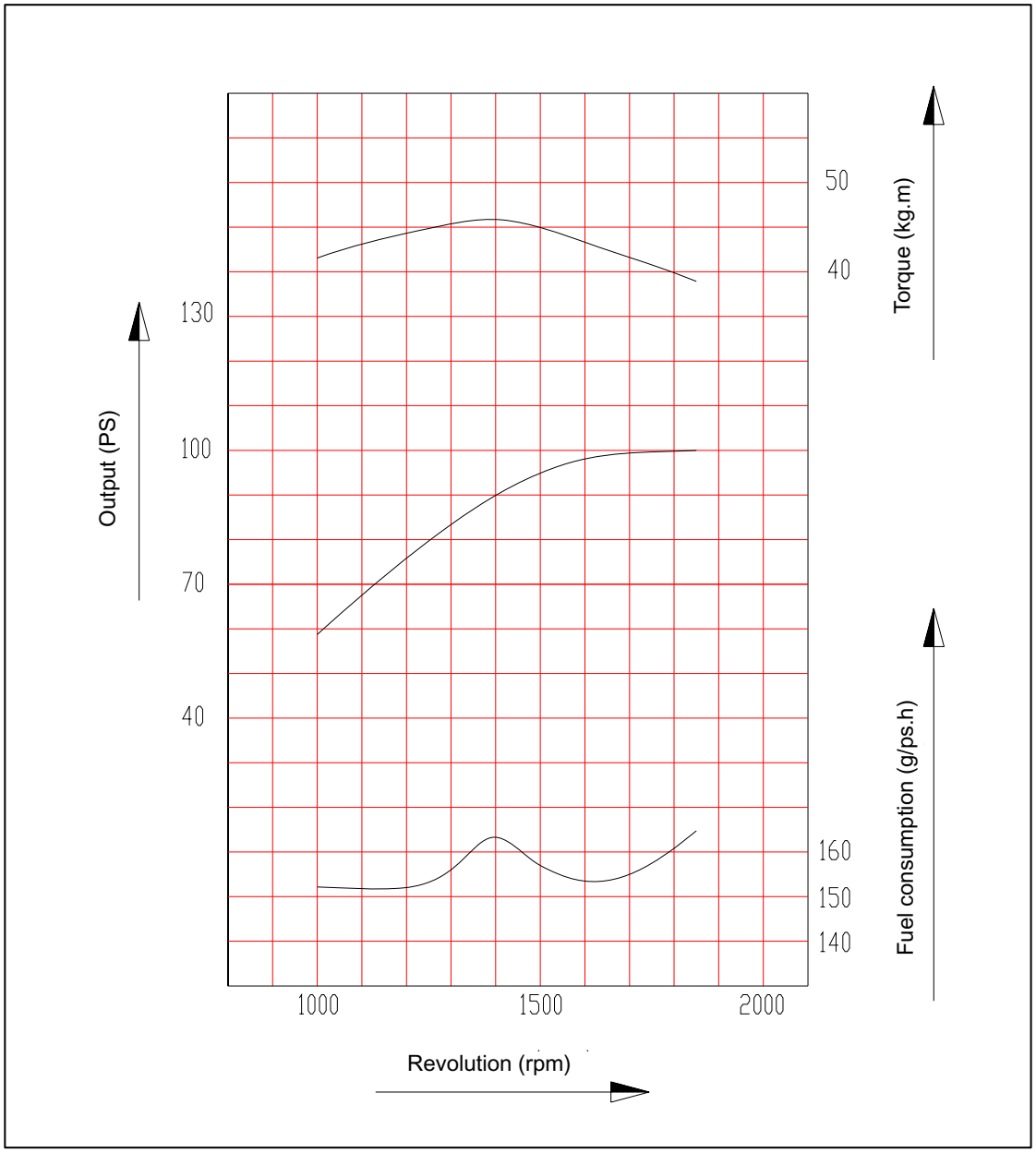

| Performance | ISO 1585 (SAE J1349) |
|---|---|
| Output (max.) | 100 kW (136 PS) / 2,000 rpm |
| Torque (max) | 540 N.m (55 kg.m) / 1,400 rpm |
| Fuel consumption (min.) | 224 g/kW.h (165 g / PS.h) |

### 1.4.4. Performance curve (124 PS)




| Performance | | ISO 1585 (SAE J1349) |
|---|---|---|
| Output | (max.) | 91 kW (124 PS) / 1,950 rpm |
| Torque | (max) | 461 N.m (47 kg.m) / 1,400 rpm |
| Fuel consumption | (min.) | 224 g/kW.h (165 g / PS.h) |

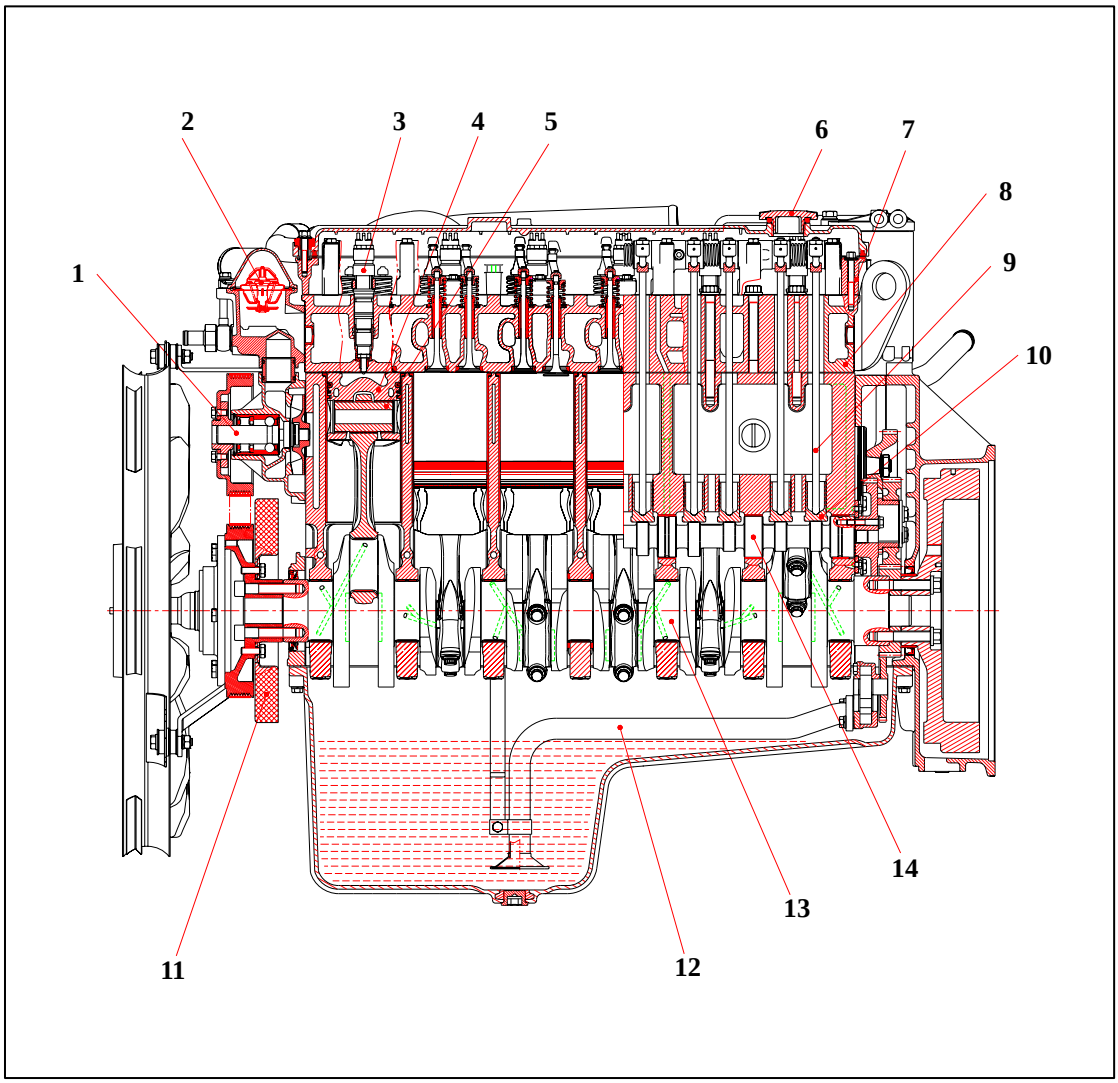
### 1.4.5. Performance curve (100 PS)




| Performance | ISO 1585 (SAE J1349) |
|---|---|
| Output (max.) | 74 kW (100 PS) / 2,000 rpm |
| Torque (max) | 451 N.m (46 kg.m) / 1,400 rpm |
| Fuel consumption (min.) | 224 g/kW.h (165 g / PS.h) |

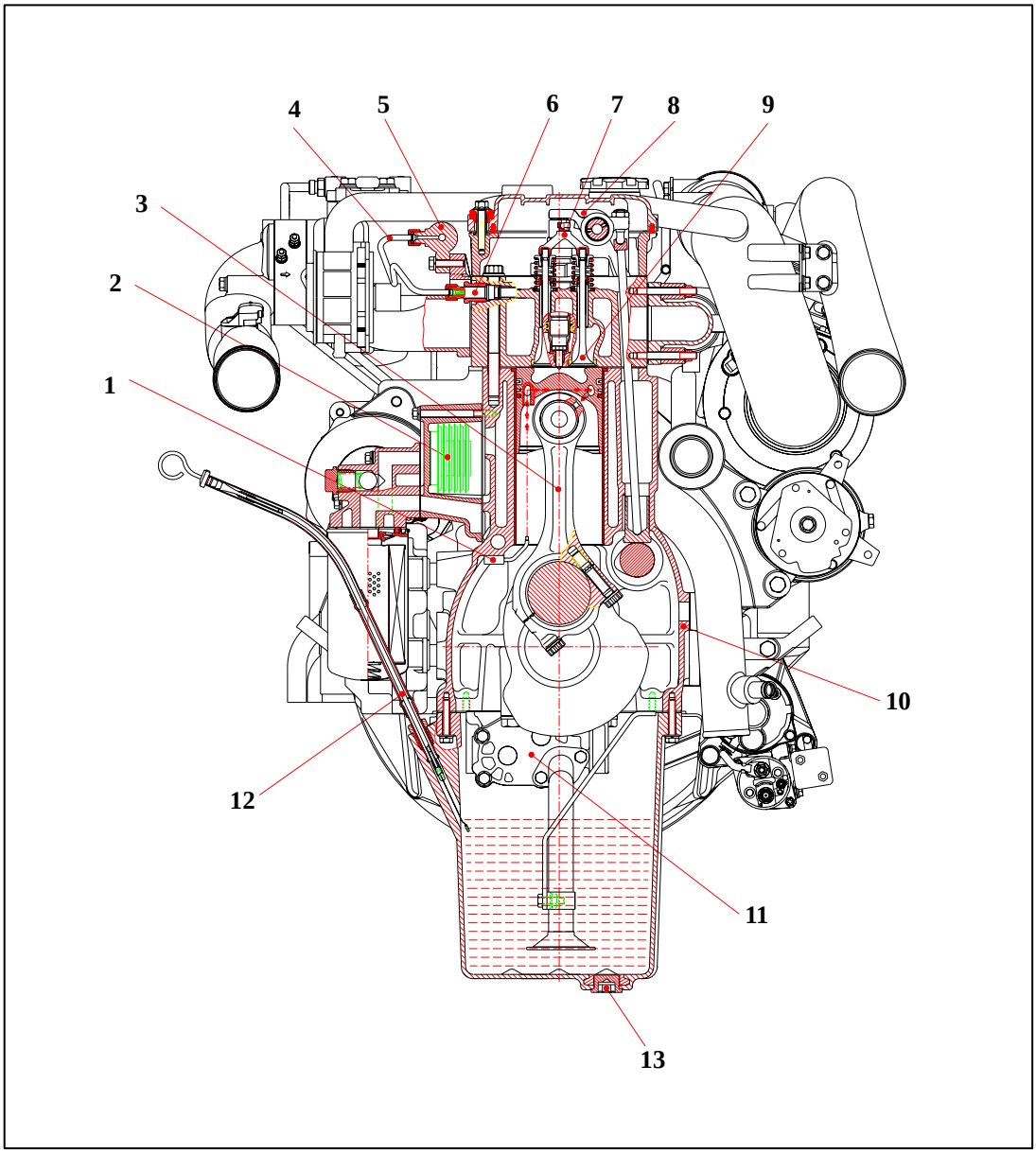
## 1.5. Engine Assembly

### 1.5.1. Sectional drawing (longitudinal)




| | | | |
|---|---|---|---|
| 1 | Cooling water pump | 8 | Cylinder head |
| 2 | Thermostat | 9 | Push rod |
| 3 | Injector | 10 | Tappet |
| 4 | Piston | 11 | Vibration damper |
| 5 | Piston pin | 12 | Oil suction pipe |
| 6 | Oil filler cap | 13 | Crank shaft |
| 7 | Intermediate cover | 14 | Cam shaft |

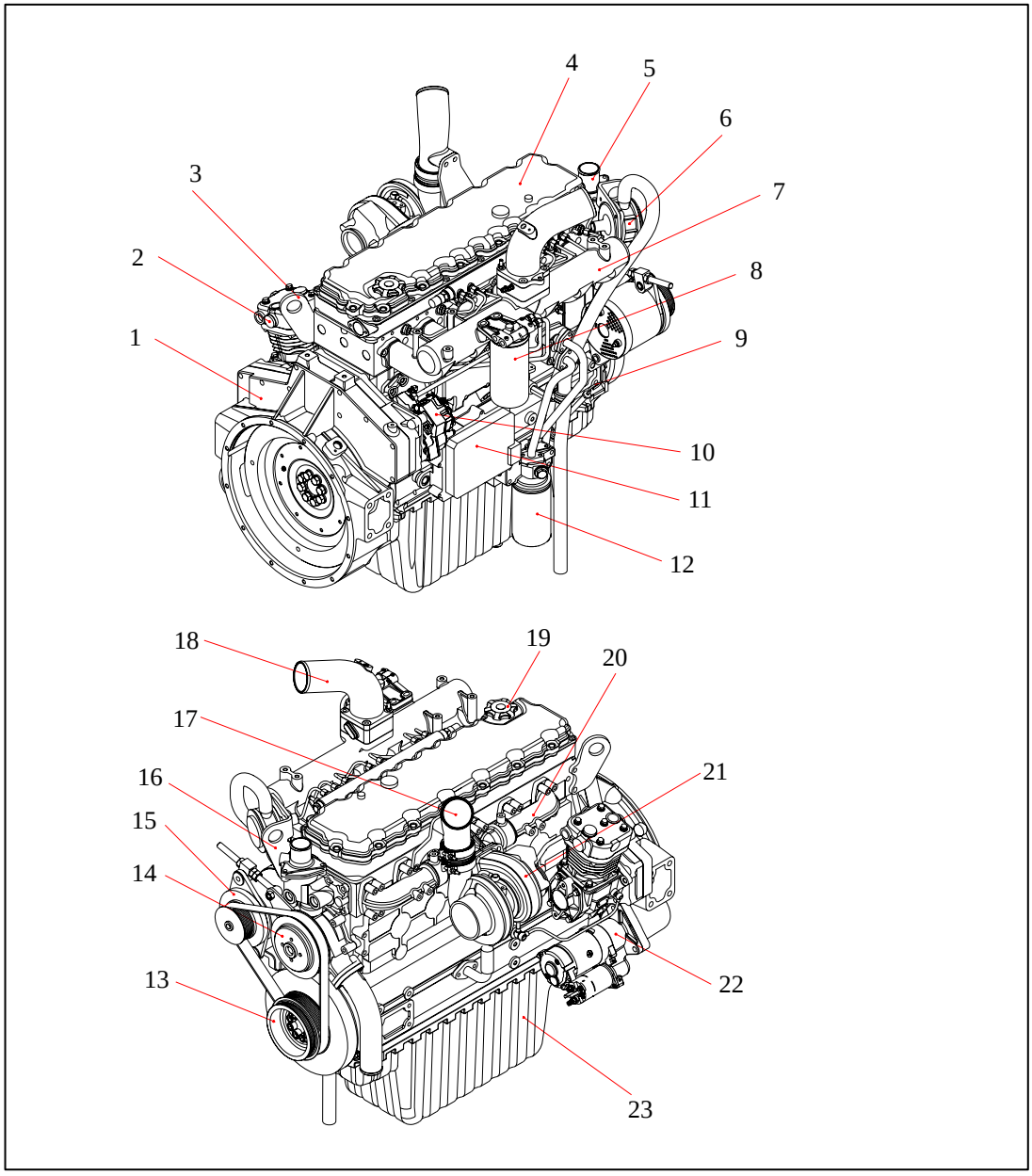
### 1.5.2. Sectional drawing




| | | | |
|---|---|---|---|
| 1 | Oil spray nozzle | 8 | Rocker arm |
| 2 | Oil cooler | 9 | Valve |
| 3 | Connecting rod | 10 | Cylinder block |
| 4 | Fuel high pressure pipe | 11 | Oil pump |
| 5 | Common rail | 12 | Oil level gauge |
| 6 | High pressure connector | 13 | Drain plug |
| 7 | Caliper | | |

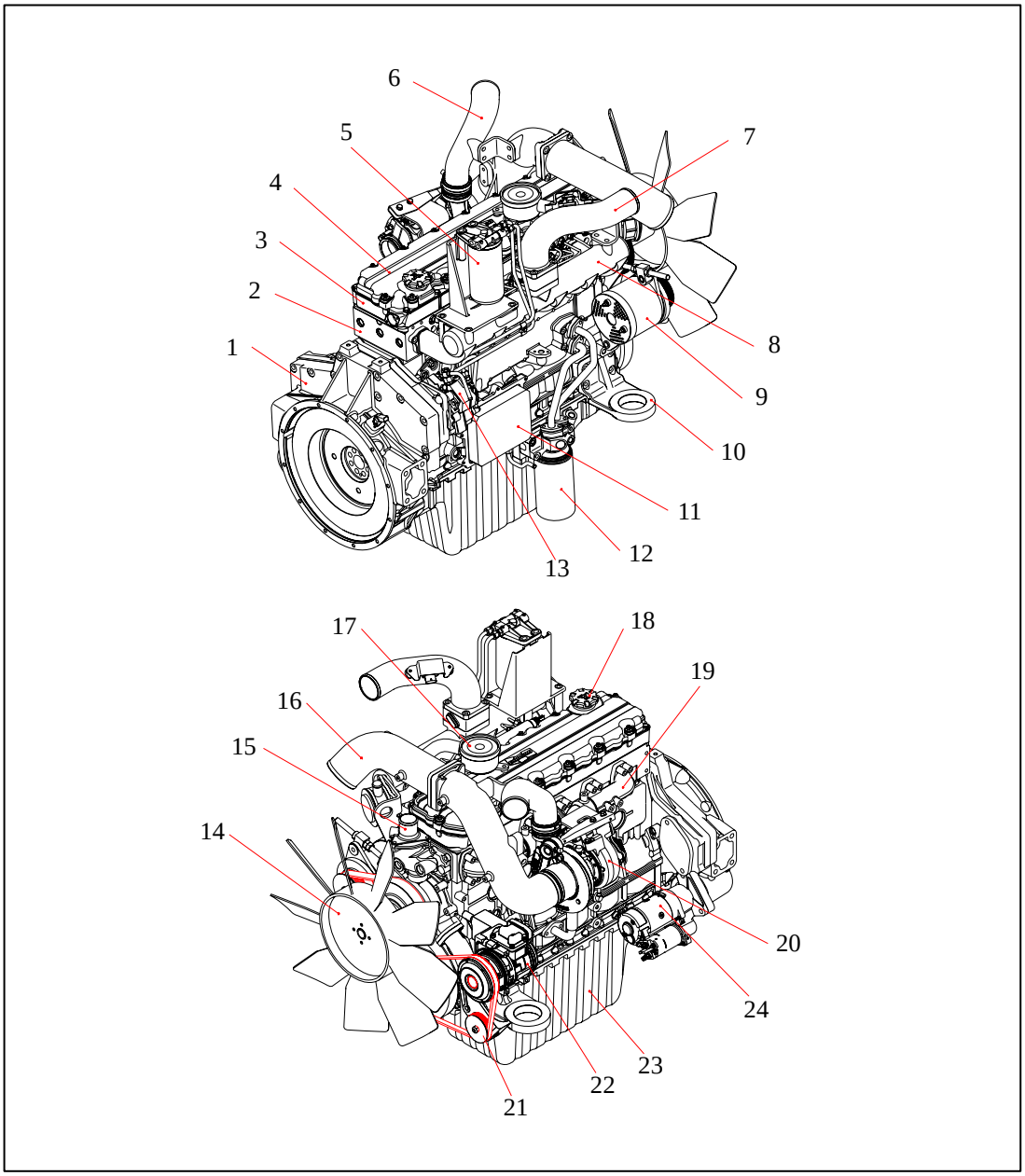
### 1.5.3. Engine assembly

#### (1) DL06 (Fork lift)



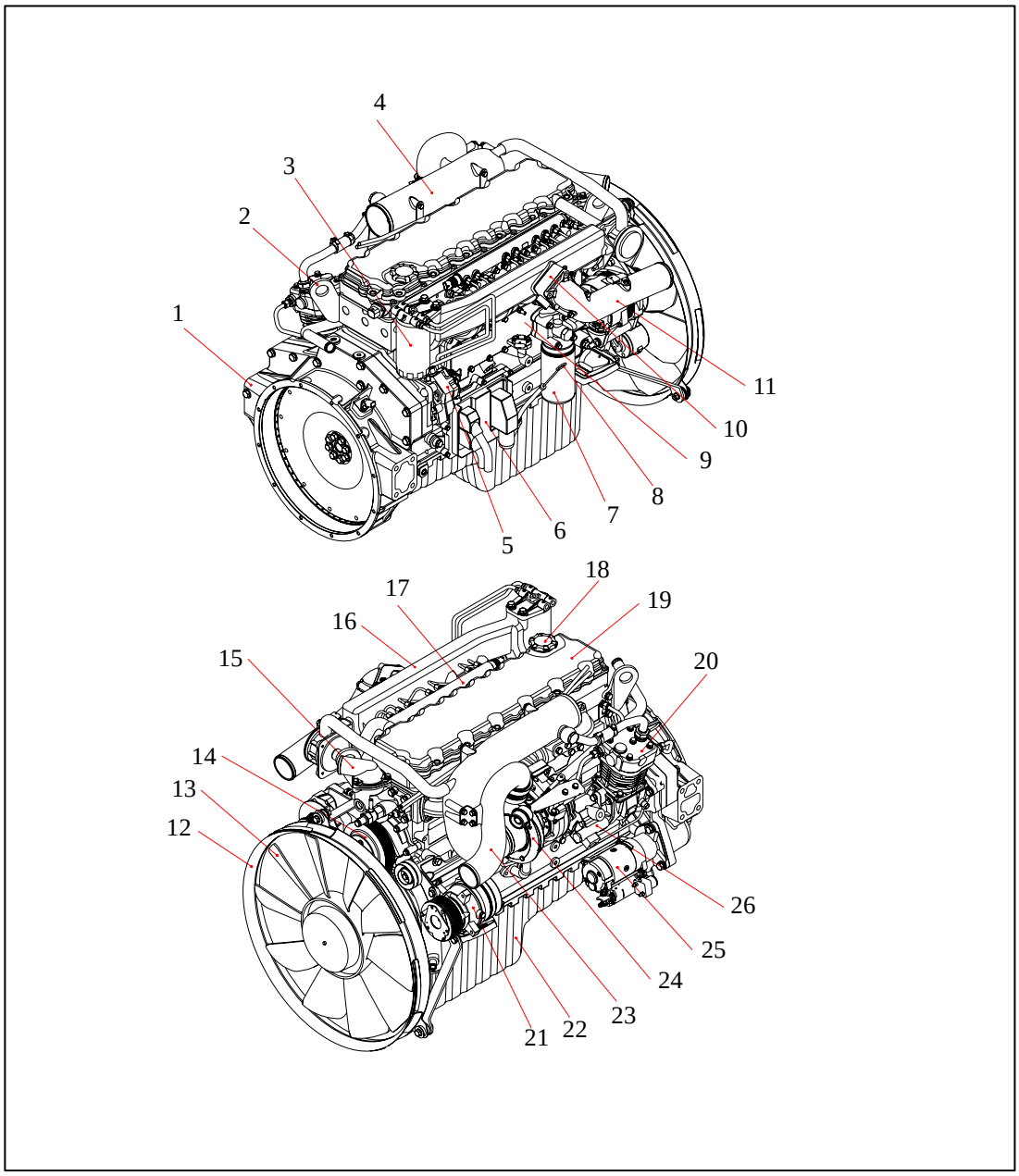

| | | | | | |
|---|---|---|---|---|---|
| 1 | Flywheel housing | 10 | Fuel high pressure pump | 18 | Air pipe (intercooler to intake manifold) |
| 2 | Air compressor | 11 | Engine control unit(ECU) | | |
| 3 | Lifting hook (rear) | 12 | Oil filter | 19 | Oil filler cap |
| 4 | Cylinder head cover | 13 | Crank shaft pulley | 20 | Exhaust manifold |
| 5 | Cooling water outlet | 14 | Cooling water pump | 21 | Turbo charger |
| 6 | Breather (CCV) | 15 | Alternator | 22 | Starter |
| 7 | Intake manifold | 16 | Lifting hook (front) | 23 | Oil pan |
| 8 | Fuel filter | 17 | Air pipe (turbocharger to intercooler) | | |
| 9 | Oil level gauge | | | | |

## (2) DL06 (Excavator)




| | | | | | |
|---|---|---|---|---|---|
| 1 | Flywheel housing | 8 | Intake manifold | 16 | Air pipe (air cleaner to turbocharger) |
| 2 | Cylinder head | 9 | Alternator | 17 | Breather |
| 3 | Intermediate cover | 10 | Mounting bracket | 18 | Oil filler cap |
| 4 | Cylinder head cover | 11 | Engine control unit(ECU) | 19 | Exhaust manifold |
| 5 | Fuel filter | 12 | Oil filter | 20 | Turbo charger |
| 6 | Air pipe (turbocharger to intercooler) | 13 | Fuel high pressure pump | 21 | Idle pulley |
| 7 | Air pipe (intercooler to intake manifold) | 14 | Cooling fan | 22 | Air con. compressor |
| | | 15 | Cooling water outlet | 23 | Oil pan |

### 3) DL06 (Truck)

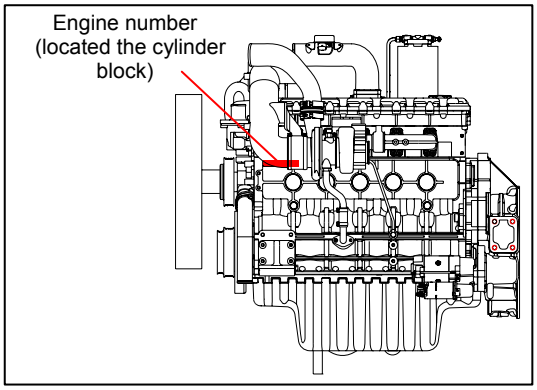



| | | | | | |
|---|---|---|---|---|---|
| 1 | Flywheel housing | 10 | Air heater | 19 | Cylinder head cover |
| 2 | Lifting hook | 11 | Air pipe (intercooler to intake manifold) | 20 | Air compressor |
| 3 | Fuel filter | | | 21 | Air con. compressor |
| 4 | Air pipe (air cleaner to turbocharger) | 12 | Fan guide | 22 | Oil pan |
| | | 13 | Cooling fan | 23 | Air pipe (turbocharger to intercooler) |
| 5 | Fuel high pressure pump | 14 | Cooling water pump | | |
| 6 | Engine control unit (ECU) | 15 | Cooling water outlet | 24 | Turbo charger |
| 7 | Oil filter | 16 | Intake manifold | 25 | starter |
| 8 | Oil level gauge | 17 | Common rail | 26 | Power steering pump |
| 9 | Oil cooler | 18 | Oil filler cap | | |

# 2. Technical Information

## 2.1. Engine Model and Serial Number

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




- **Engine serial No. (example 1 : DL06 Truck)**

DL08 6 00001 CA

**Engine model suffix (EUTCA)**
**Serial no.**
**Production year (2006)**
**Engine model**

- **Engine serial No. (example 2 : DL06 Fork lift)**

**DL06 6 00001 FA**

**Engine model suffix (EUTFA)**
**Serial no.**
**Production year (2006)**
**Engine model**

- **Engine serial No. (example 3 : DL06 Excavator)**

**DL06 600001 EA**

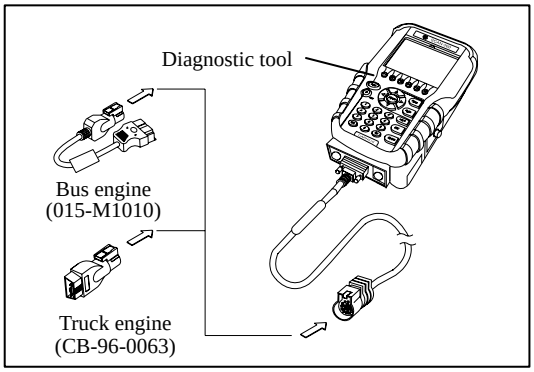
**Engine model suffix (EUTEA)**
**Serial no.**
**Production year (2006)**
**Engine model**

## 2.2. Diagnostic tool

The Diagnostic tool is a powerful tool to support the service personal diagnosing and repairing of electric system for vehicle with installed DL06 engine.

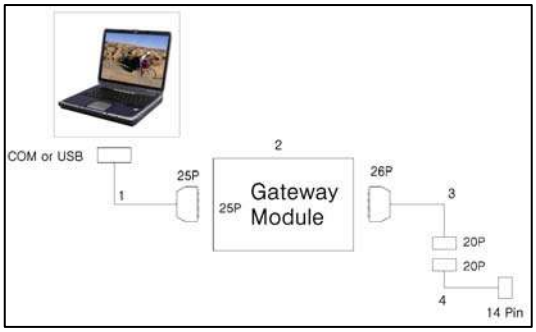
### 1) Diagnostic by SCAN-200

- High resolution digital type display.
- Soft touch key-board.
- Diagnosis trouble code or sensor data operation via help.
- Large memory expansion ROM pack data storage area for flight recorded data.




### 2) Diagnostic by notebook computer

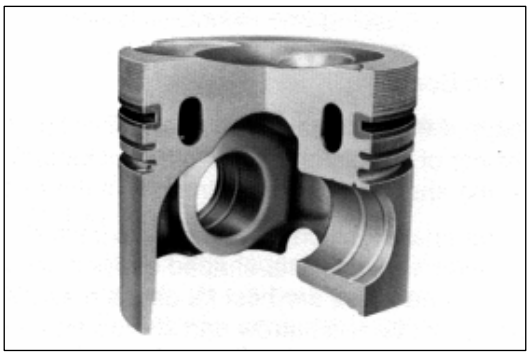
- Inspect the electrical parts problem with diagnostic tool and refer diagnostic manual.




## 2.3. Engine character

- DOOSAN ‘s DL06 diesel engine apply the over head valve and the turbocharger, is the electric control engine of the air cooling type by the cooling fan.
- The fuel is stored under pressure in the high-pressure accumulator (the "Common Rail") ready for injection. The injected fuel quantity is defined by the driver, and the start of injection and injection pressure are calculated by the ECU on the basis of the stored map. The ECU then triggers the solenoid valve sensor that the injector (injection unit) at each engine cylinder injects accordingly.

- Oil gallery cooling is used for the piston of the engine. The design of the gallery, the design and location of the oil spray nozzle and the quantity of oil flowing in the gallery are critical in order to achieve the desired temperature reduction. The cross section shape of the gallery should be designed to achieve sufficient oil movement to maximize cooling efficiency.



### 2.3.1. Cylinder block

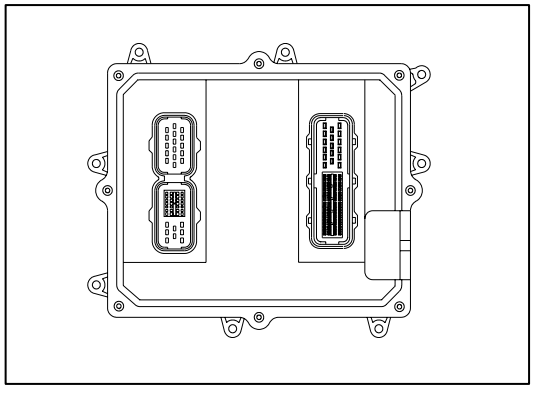
- The cylinder block is a single piece of alloy cast iron. To increase its stiffness, it is extended to a level below the crankshaft center line. The engine has replaceable dry cylinder liners and a cylinder head.

### 2.3.2. Piston, connecting rod, crank shaft

- 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.

### 2.3.3. Electric control unit : ECU

- This electric control unit is used to control the engine feed fuel.
- ECU is connected with various sensors, control the engine to keep the optimum condition on the basis of input values from this sensors.

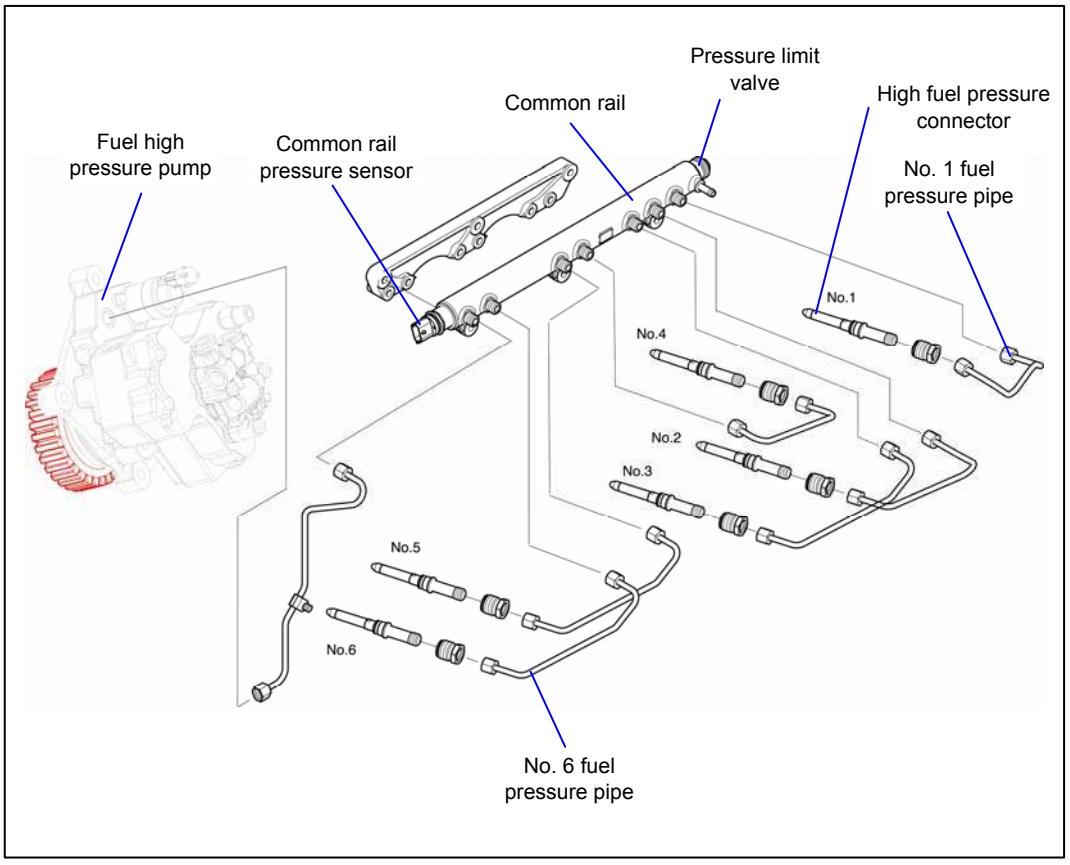


**CAUTION:**

**Do not connect or disconnect the ECU to/from the wiring harness without first removing the negative (-) battery cable from the battery. Do not perform remove the inner parts of ECU.**

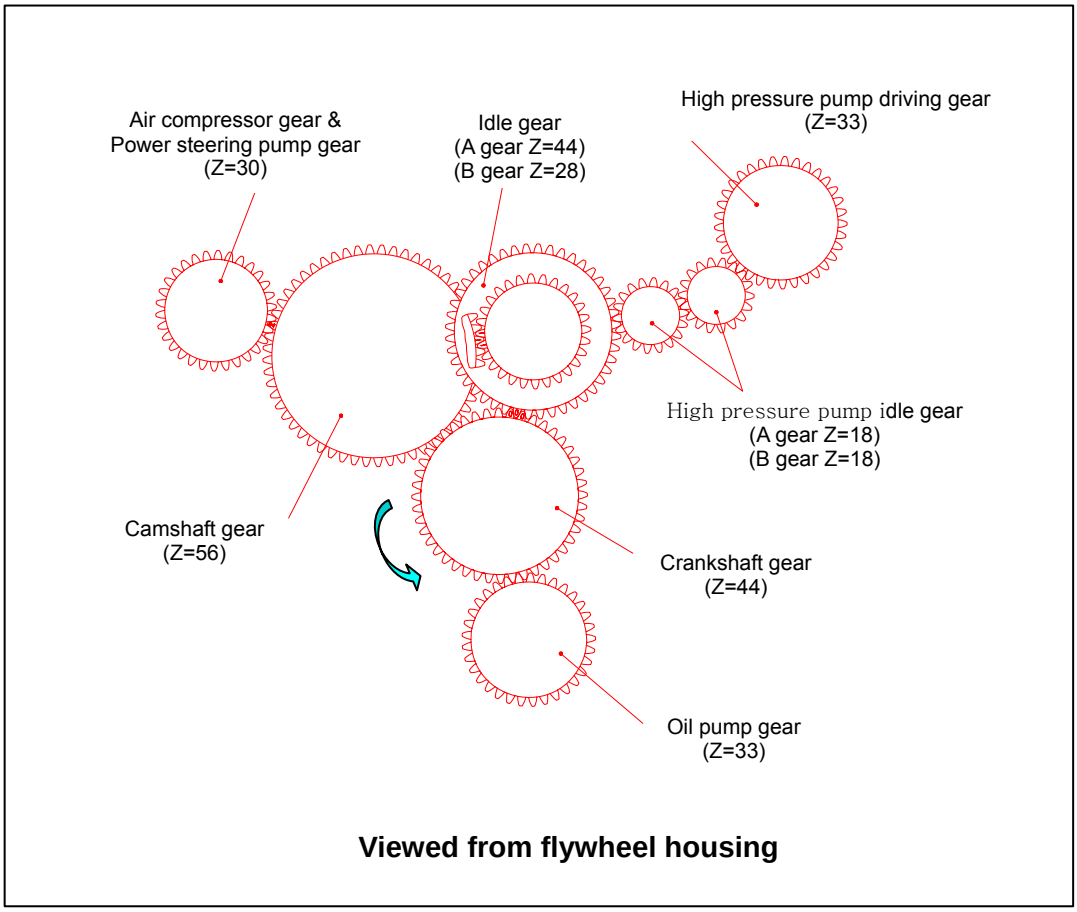
### 2.3.4. Common rail system

- Pressure generation and fuel injection are completely decoupled from each other in the "Common Rail" fuel injection system. The injection pressure is generated independent of engine speed and injected fuel quantity stored in the ECU.



### 2.3.5. Engine timing

- Camshaft, oil pump, air compressor, power steering pump, and fuel high pressure pump are driven by a gear train arranged at the inside of flywheel housing.

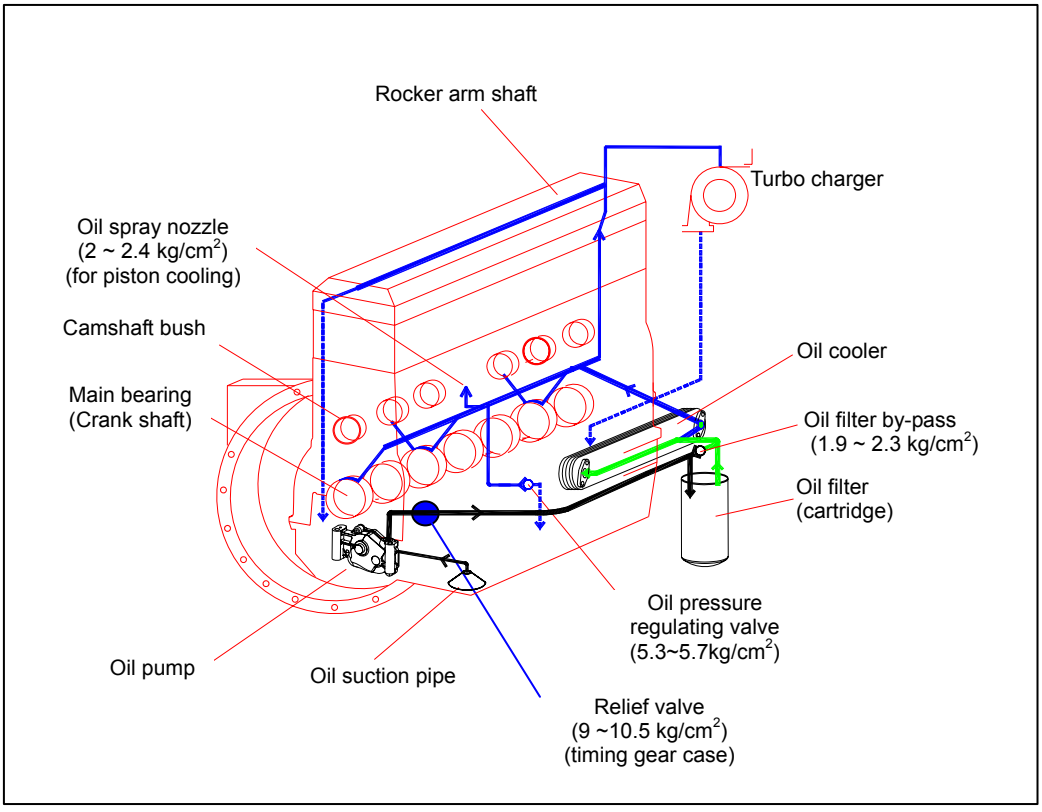



### 2.3.6. Valves

- The overhead valves are actuated via tungsten carbide tappets, push rods and rocker arms from the camshaft.

### 2.3.7. Lubrication system

- 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 turbocharger is 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.



### 2.3.8. Engine oil

- Check oil level with the oil level gauge and replenish if necessary.
- Check the oil level with the engine cooled. If the engine is warm, allow time for 5 ~ 10 minutes for oil drain into the crankcase before checking oil level. The oil level must be between Max and Min lines on the gauge.
- Engine oil should be changed at the specified intervals.
  Oil filter cartridge should be changed simultaneously.

  - First oil change :After 5,000km (50Hr) operating

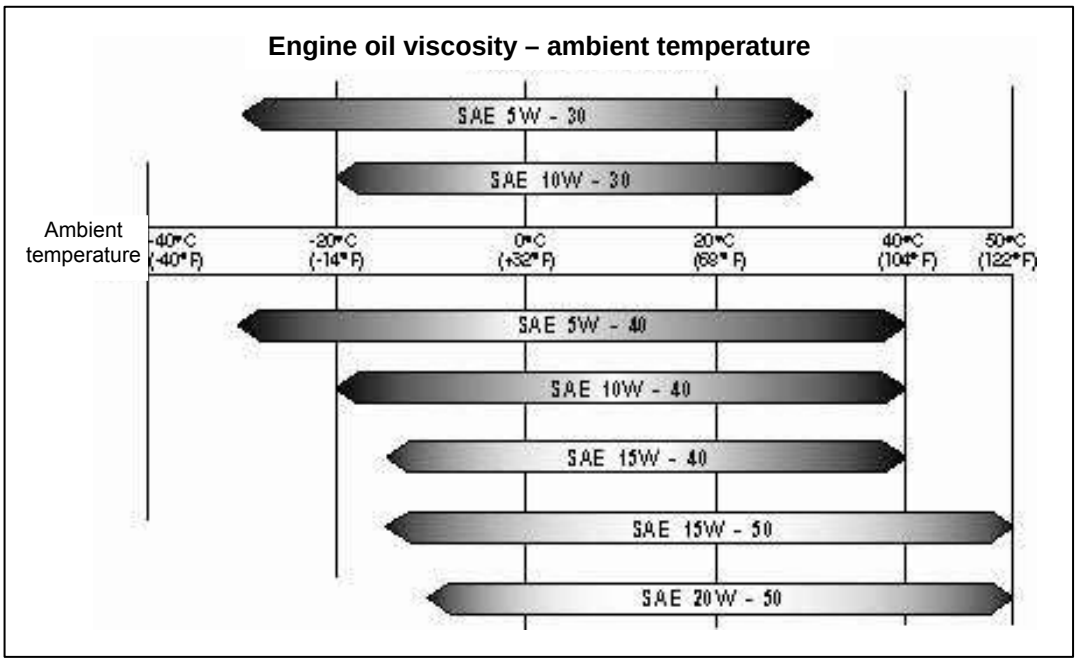
| Use | Conditions | Intervals |
|---|---|---|
| Vehicle engine | 1 day operating distance 500km less (Bus, truck) | After once replenishment, every 40,000km |
| | 1 day operating distance 500km more (Bus, truck) | After once replenishment, every 60,000km |
| Industrial engine | Excavator, fork lift | Every 500Hr |

- The following oils are also recommended.

| **Engine oil** | **SAE No.** | **API No.** |
|---|---|---|
| **DL06** | SAE 10W40 | ACEA-E5<br>(API CI-4) |

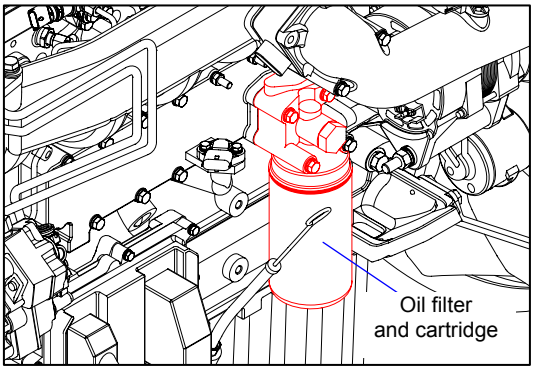
- **Engine oil capacity**

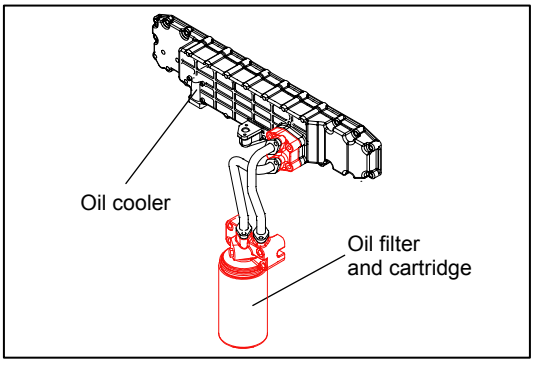
| Engine oil capacity | | | | |
|---|---|---|---|---|
| Engine model | | Oil pan inside | | Total |
| Use | Suffix | Max (lit) | Min (lit) | (lit) |
| Truck | EUTCA | 19 | 15 | 21 |
| Excavator | EUTEA/C/F/G/H/I | 27 | 17 | 29 |
| | EUTEB/D/J/K/L | 22 | 16 | 24 |
| | EUTLA/B/C/D | 27 | 20 | 29 |
| Fork lift | EUTFA/B/C/D | 27 | 17 | 29 |




### 2.3.9. Oil filter & cooler

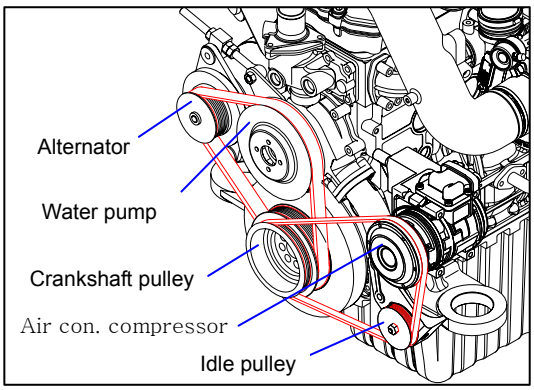
- Oil filter is assembled to the oil cooler. Oil cooler is plane tube and is cooled by the cooling water.
- Check for oil pressure and oil leaks, and repair or replace the oil filter if necessary.
- Change the oil filter cartridge simultaneously at every replacement of engine oil.



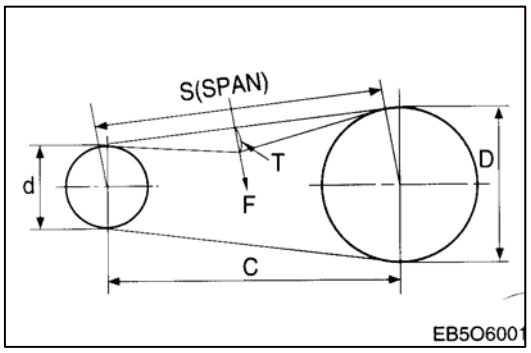
### 2.3.10. Fan belt

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



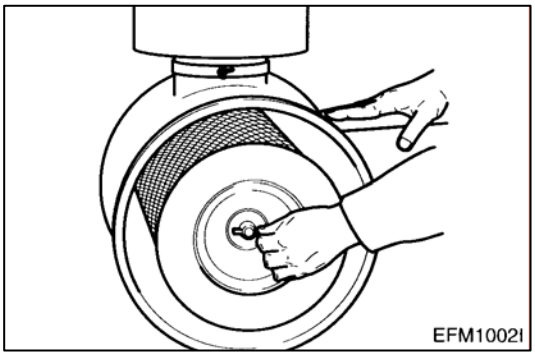

- Adjust the tension of poly belt when pressed down with specified force (F kg):

  (T) = 0.015 x S
  (Deflection : 1.5 mm per 100 mm)



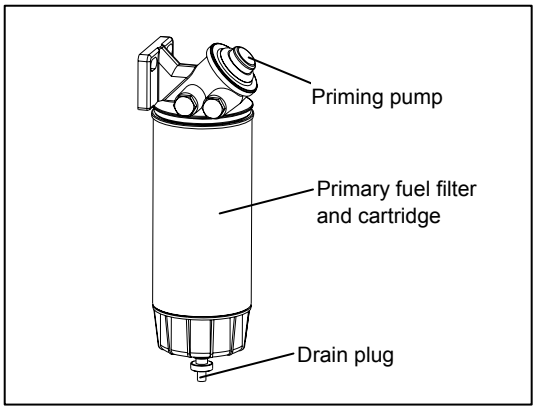

### 2.3.11. Air cleaner

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



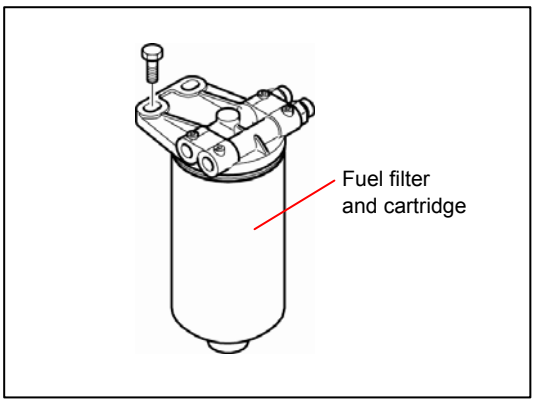

### 2.3.12. Pre fuel filter

- Drain water in cartridge with loosening the valve under cartridge manually from time to time.
- The filter cartridge should be replaced at every 40,000 km.



### 2.3.13. Fuel filter

- The filter cartridge should be replaced at every 40,000 km (500Hr).




### 2.3.14. Fuel requirements

- DOOSAN diesel engines was 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.

### 2.3.15. 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 low sulfur, 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**

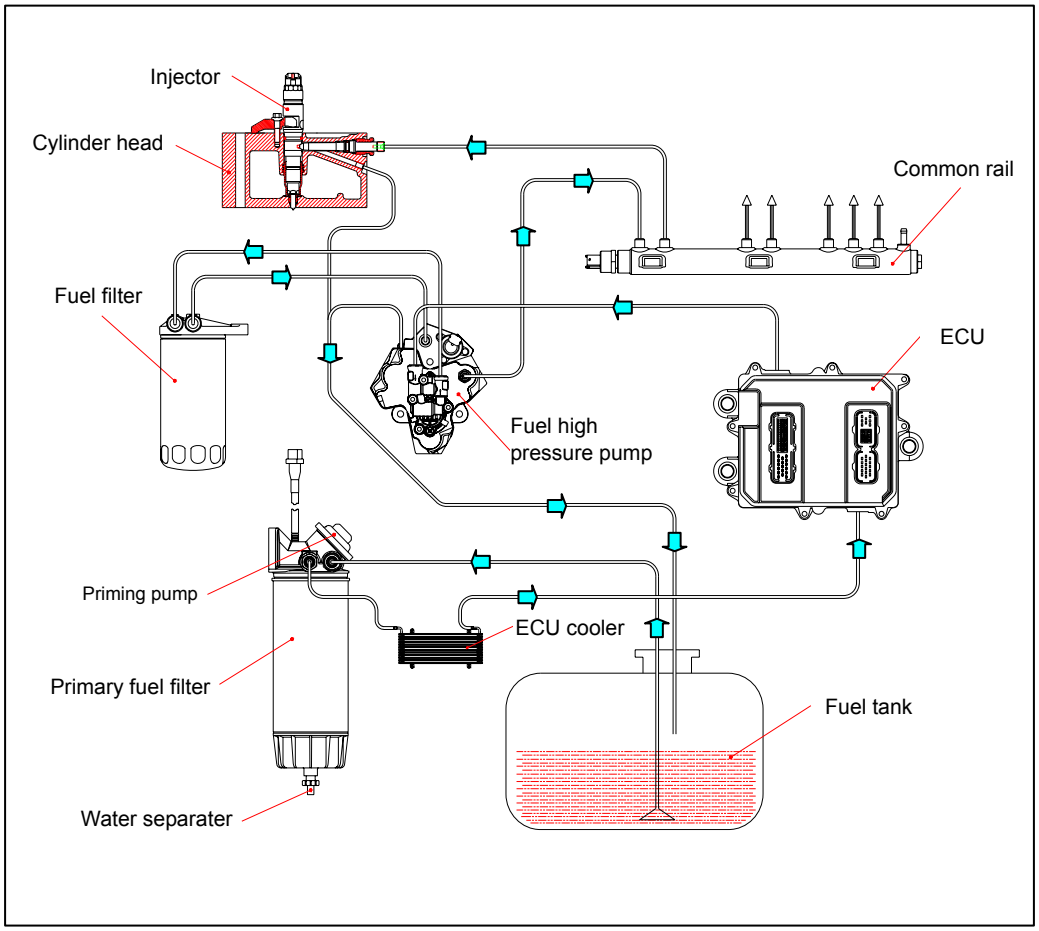
| Fuel classification | Unit | DIN EN 590 |
|---|---|---|
| Cetane number | - | ≥ 51 |
| Cetane index | - | ≥ 46 |
| Density @ 15°C | kg/m$^3$ | 820 ~ 845 |
| Poly aromatic hydrocarbon | % (m/m) | ≤ 11 |
| Sulfur content | mg/kg | ≤ 50 |
| Flash point | °C | ≥ 55 |
| Ash content | % (m/m) | ≤ 0.01 |
| 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

### 2.3.16. Fuel injection system

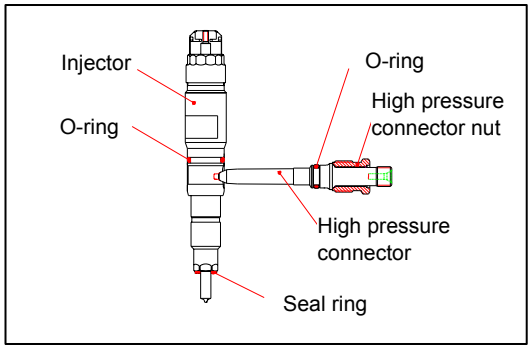
- The fuel is stored under pressure in the common rail ready for injection. The injected fuel quantity is defined by the driver, and the start of injection and injection pressure are calculated by the ECU on the basis of the stored maps. The ECU then triggers the solenoid valves so that the injector (injection unit) at each engine cylinder injects accordingly.




### 2.3.17. Bleeding the fuel system

- Loosen the fuel delivery pipe connected to the fuel high pressure pump from the secondary fuel filter, operate manually the priming pump until bubbles are not found, and bleed the system.

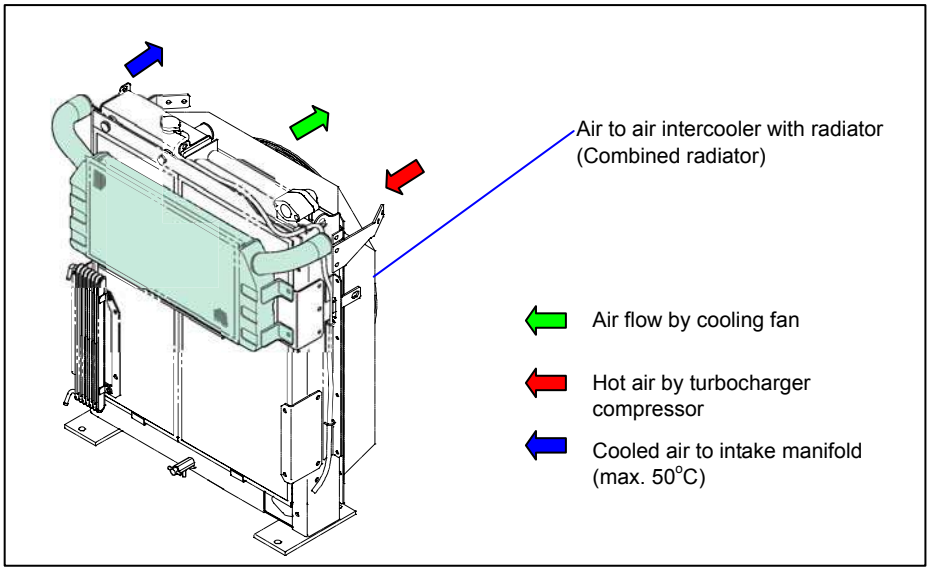
### 2.3.18. Injector & high pressure connector



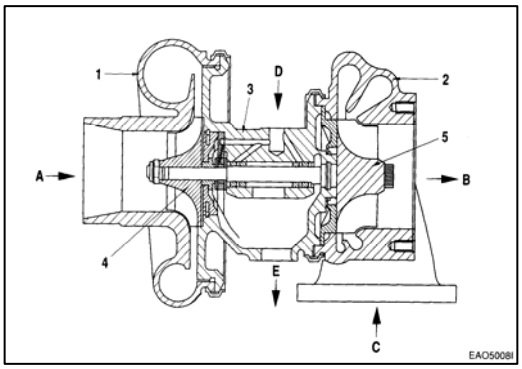

- Be careful to mix the foreign matter into the injector and inside of the connector for connecting the high pressure at disassembly and check.
- O-ring and cupper washer should be changed with new one at reassembly.
- Assemble after coat the oil on the O-ring.
- Assemble after check serial number at replacement.
- Have to assemble according to assembly order refer to the chapter of the disassembly and reassembly.

### 2.3.19. Inter cooler

- 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.



### 2.3.20. Turbo charger

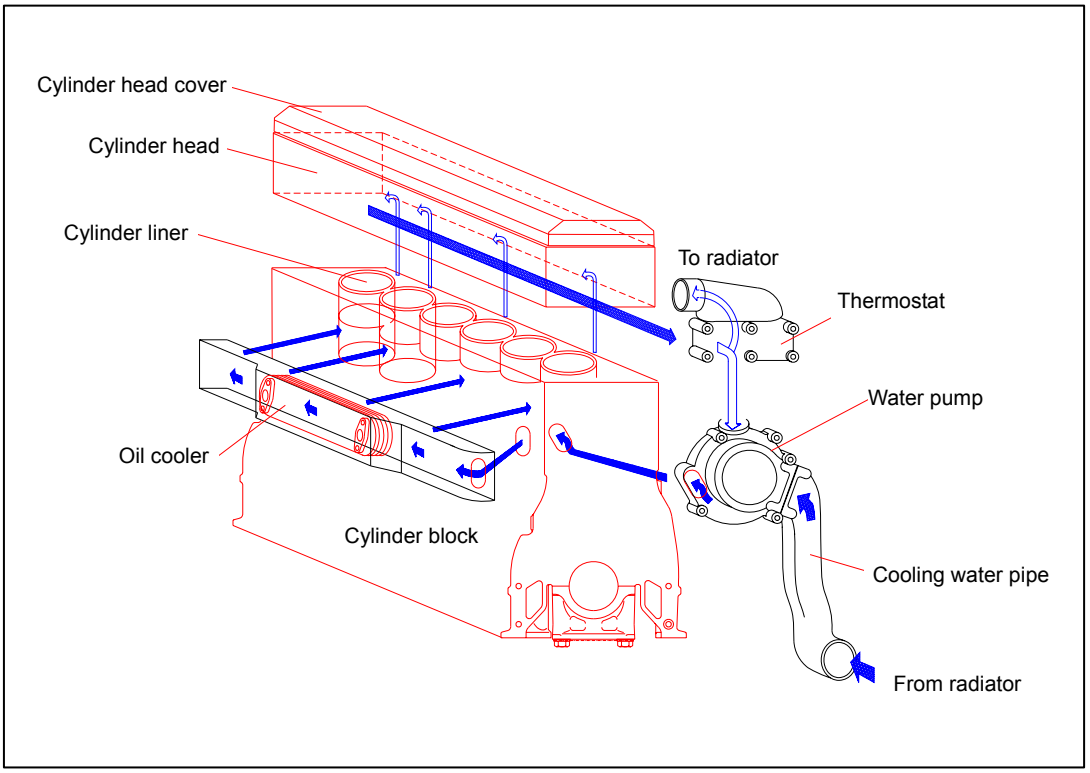



- The turbocharger needs not any specific maintenance.
- Every time of engine replacement, a leakage or clogging of oil pipes should be inspected.
- Air cleaner should be maintained carefully for nut or foreign material not to get in. Periodic inspection should be applied on the compressed air and exhaust gas pipes, For leaking air will bring the overheat engine, an immediate repair must be done.
- During the operation that is surrounded by the dust and oil mixed air, frequent cleaning must be done on the impellers. Tear down the impeller casing (attention: be careful not to bend) and must clean with non-acid solvent solution. If necessary, use plastic scraper If impeller is severely polluted, dip the impeller into solution and may be better to clean it with stiff brush. Then one thing to beware is to dip only impeller part and so do not support by impeller but bearing housing.

### 2.3.21. Cooling system

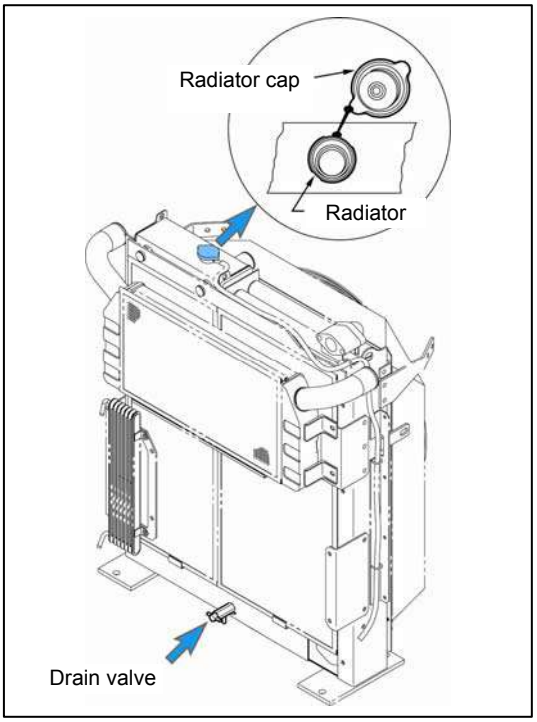
The engine has a liquid-cooling system. The fresh water pump is a maintenance-free by belt from the crankshaft pulley.

- Check the coolant level of the expansion tank by removing the expansion tank filler cap, and add coolant if necessary
- When injecting antifreeze solution, first drain out the old coolant from the cylinder block and radiator, and then clean them with cleaning solution.
- Be sure to mix soft water with antifreeze solution.



### 2.3.22. 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.




**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.**

### 2.2.23. 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.

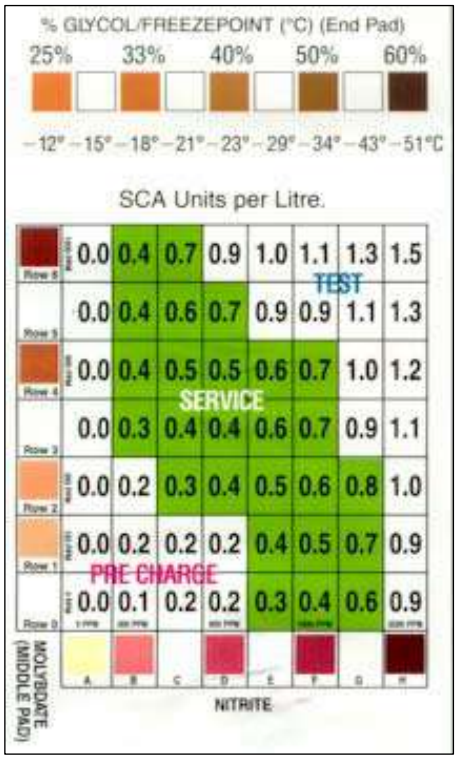
**NOTE:**
**All three readings must be completed no later than 75 seconds after dipping striped pad rapidly. Do not touch the striped pad with fingers.**

- **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 |

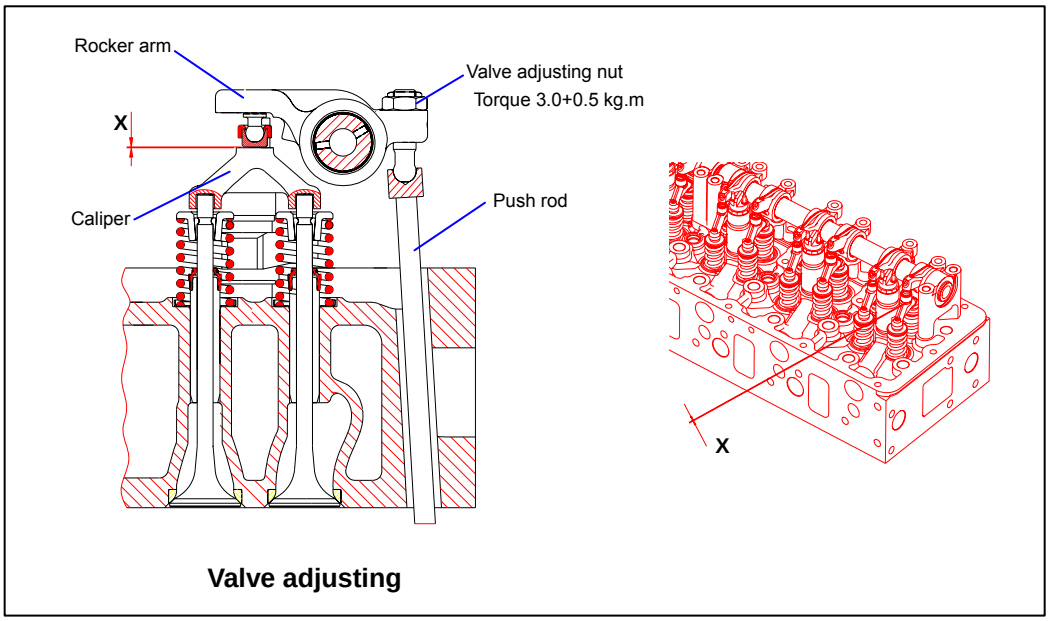
Any coolant loss due to engine operation must be replenished. But adding fresh water for coolant tends to lower the content of anti-freeze. Always replenish the coolant with a mixture of antifreeze and water, and keep the proper the content of anti-freeze (33 ~ 50%).

### 2.3.24. 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.

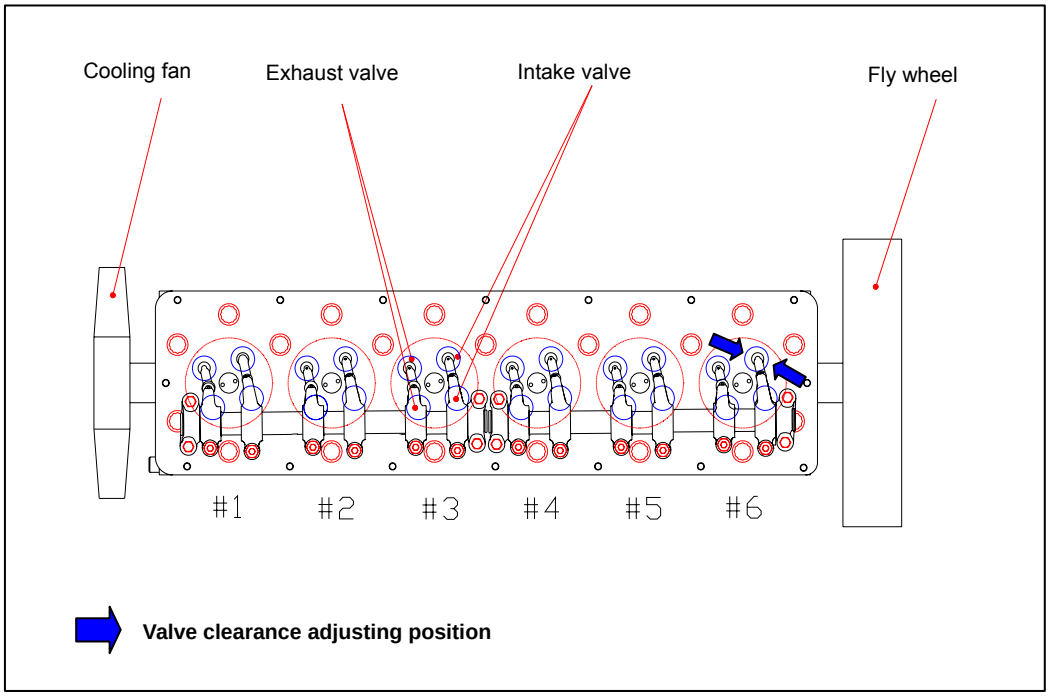
- Loosen the lock nuts of rocker arm adjusting screws and push the feeler gauge of specified value between a rocker arm and a caliper of valve stem and adjust the clearance with adjusting screw respectively and then tighten with the lock nut.
- As for the valve clearance, adjust it when in cold, as follows.

| Engine model | Intake valve (X) | Exhaust valve (X) |
|---|---|---|
| DL06 | 0.3 mm | 0.4 mm |




**Valve adjusting**

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



## ● Adjusting of valves (Type 1)

| Cylinder no. / Valve adjusting | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exhaust | Intake | Exhaust | Intake | Exhaust | Intake | Exhaust | Intake | Exhaust | Intake | Exhaust | Intake |
| #1 cylinder top dead center (#6 cylinder valve overlap) | ● | ● | | | | | | | ● | | | |
| Add 180° rotation | | | | | ◎ | ◎ | | | | ◎ | | |
| Add 180° rotation | | | ○ | | | | | | | | ○ | ○ |
| Add 180° rotation | | | | ◈ | | | ◈ | ◈ | | | | |

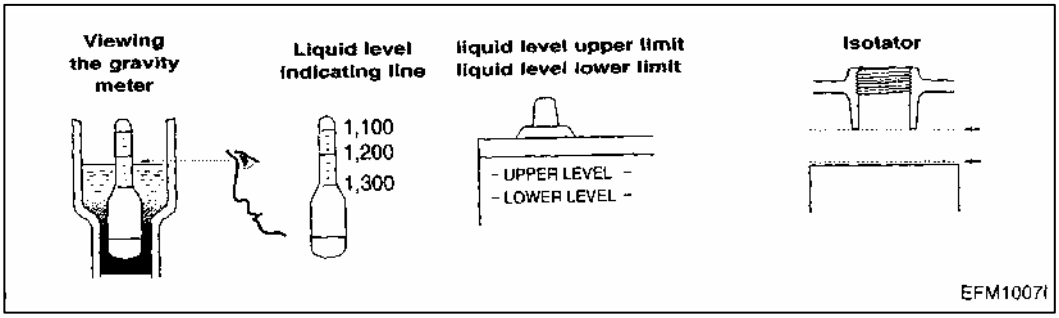
## ● Adjusting of valves (Type 2)

Adjusting of the valve overlapping on cylinder is done as follow.

| When each cylinder is valve overlap (Firing cylinder no. order) | 1 | 5 | 3 | 6 | 2 | 4 |
|---|---|---|---|---|---|---|
| Valve adjusting cylinder No | 6 | 2 | 4 | 1 | 5 | 3 |

### 2.3.25. Battery

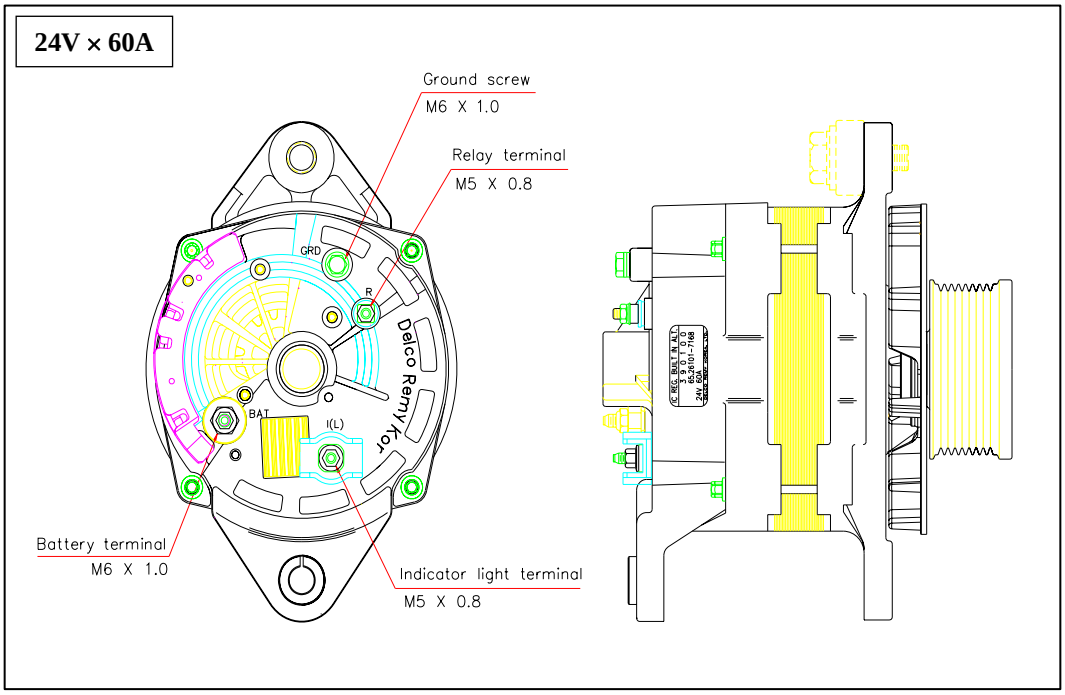
- Inspect for any leakage of electrolytic solution owing to battery crack, and replace the battery in case of poor condition.
- Inspect for amount of electrolytic solution, and replenish if insufficient.
- Measure the gravity of electrolytic solution, if less than specified value (1.12 ~ 1.28), replenish.



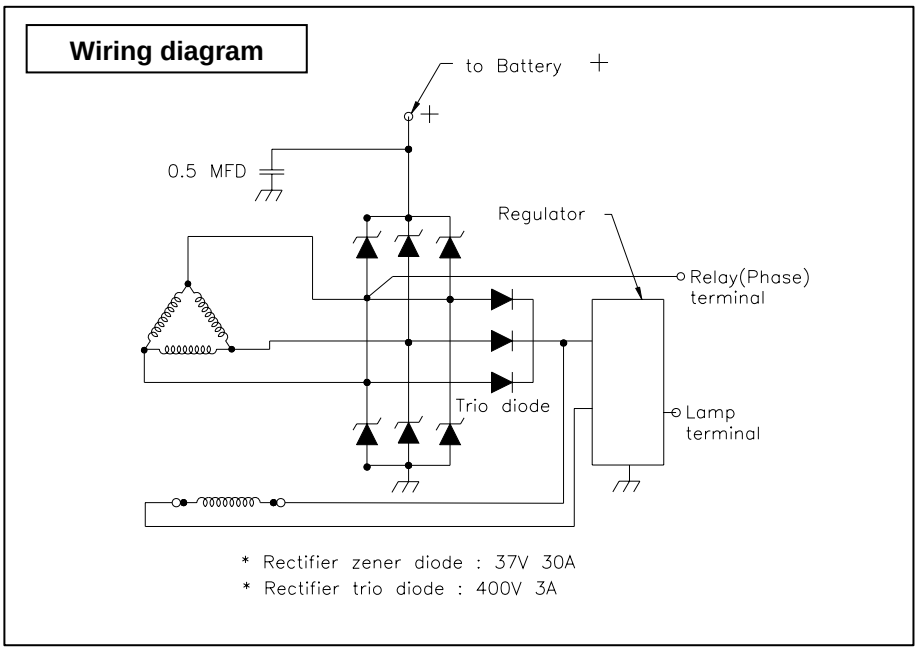
## 2.3.26. Alternator

### a) Alternator (24Vx60A)

- 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.

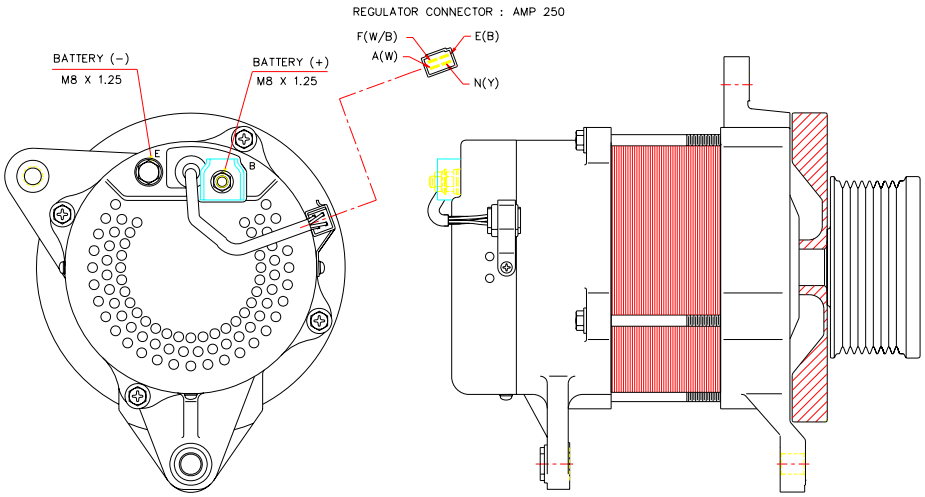



- The alternator is maintenance-free, nevertheless, it must be protected against dust and, above all, against moisture and water.



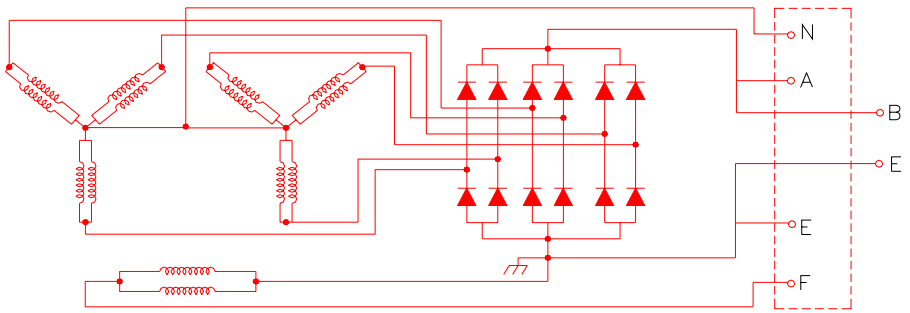
### b) Alternator (24Vx150A)

**24V x 150A**



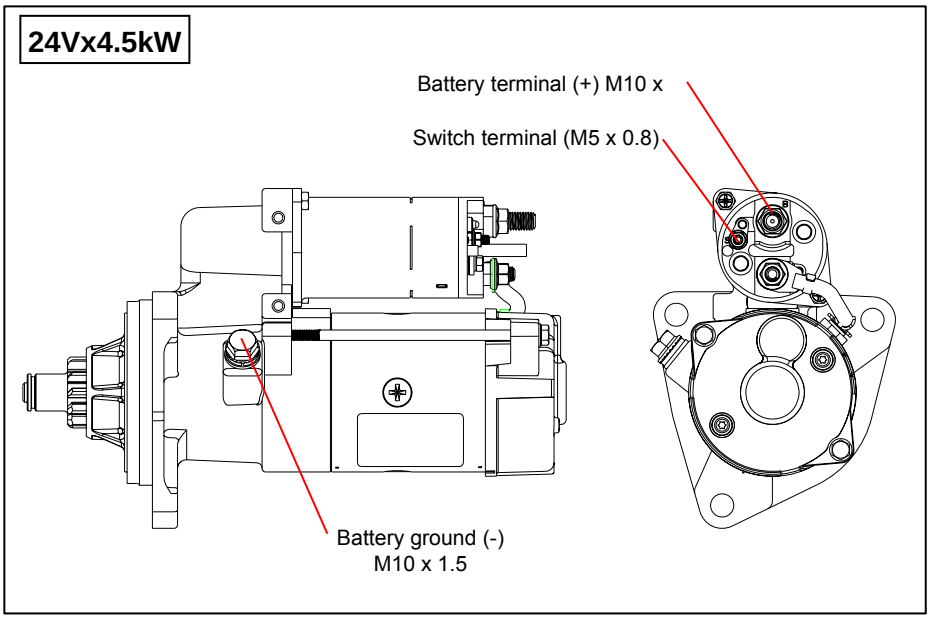

- **Regulator connector**
  - **N** terminal : cut off the charging lamp with detect the voltage by regulator.
  - **A** terminal : switching the regulator on sensing the output voltage
  - **E** terminal : Regulator earth terminal(-)
  - **F** terminal : supply the amperage on the rotor coil.

**Wiring diagram**

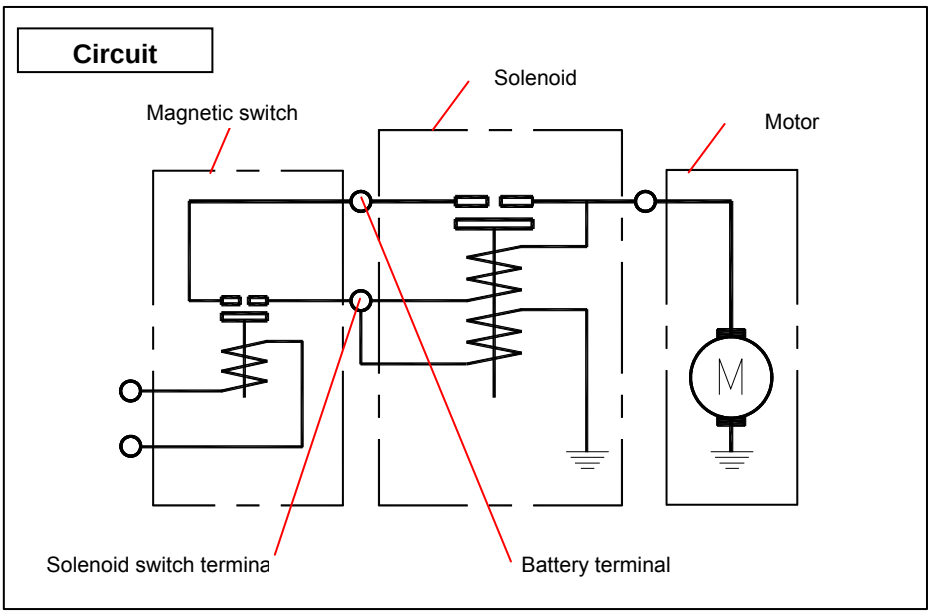


### 2.3.27. Starter

- 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.**

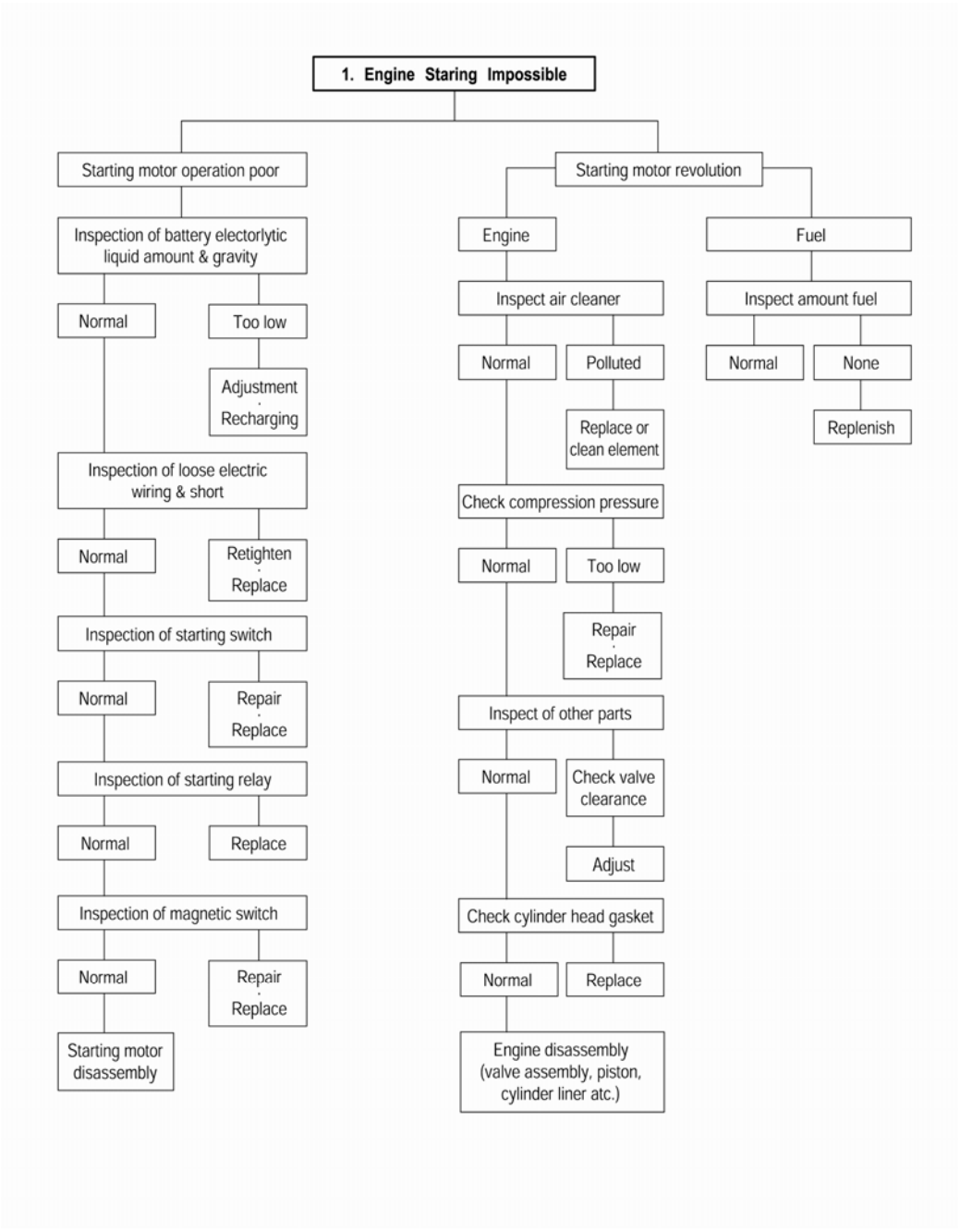


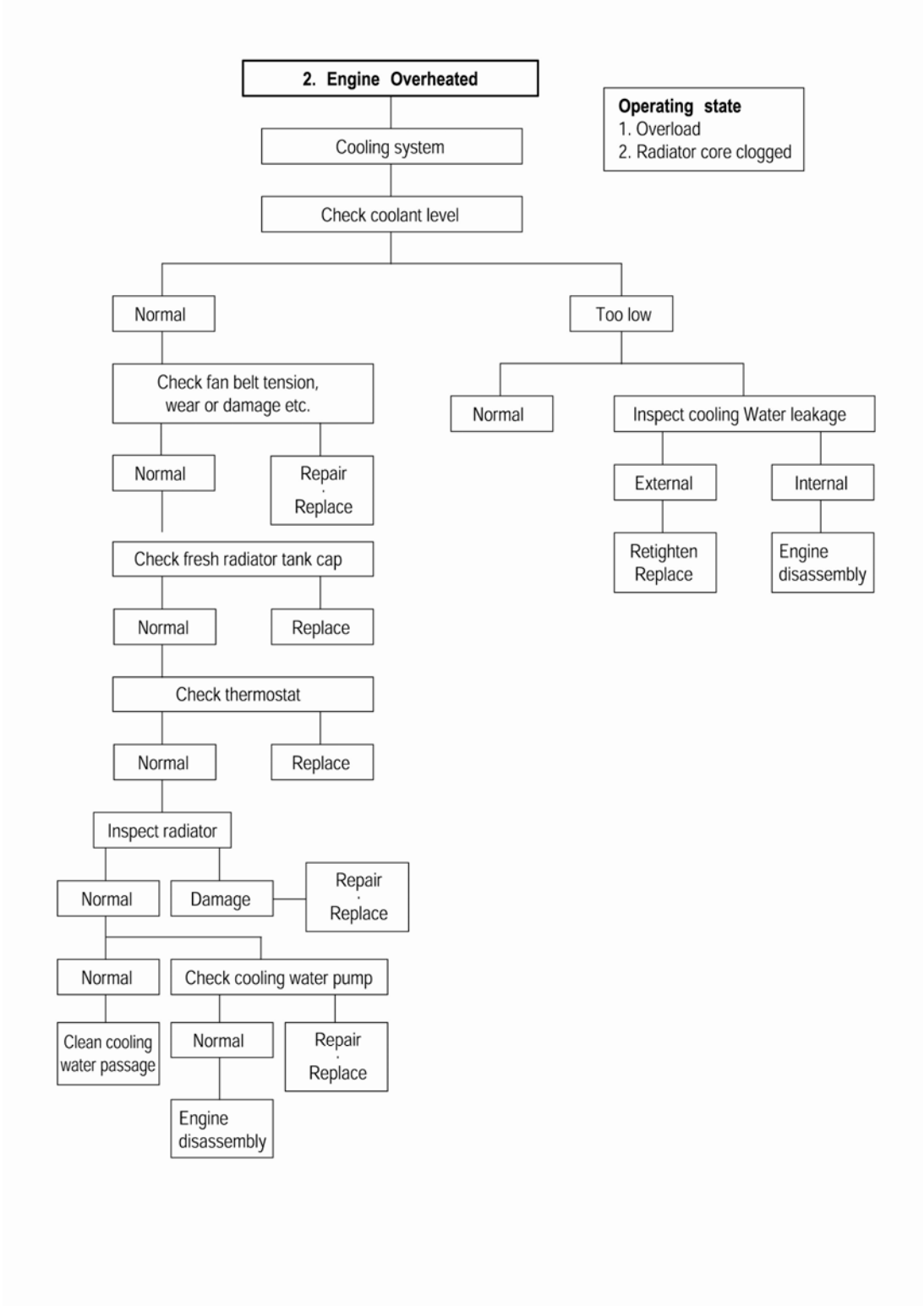

**IMPORTANT :**

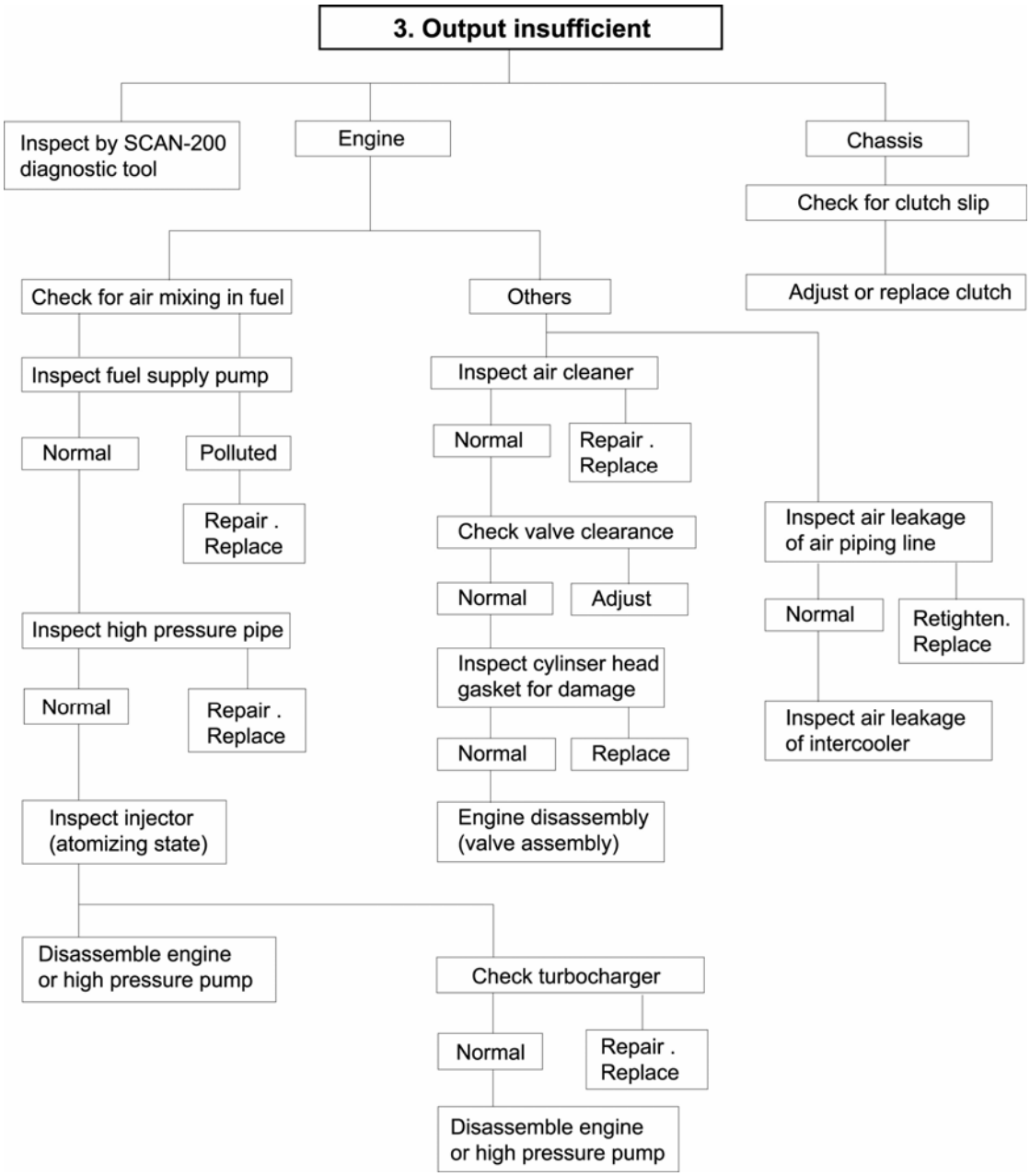
**Always disconnect the battery earth cable before starting work on the electrical system. Connect up the earth cable last, as there is otherwise a risk.**

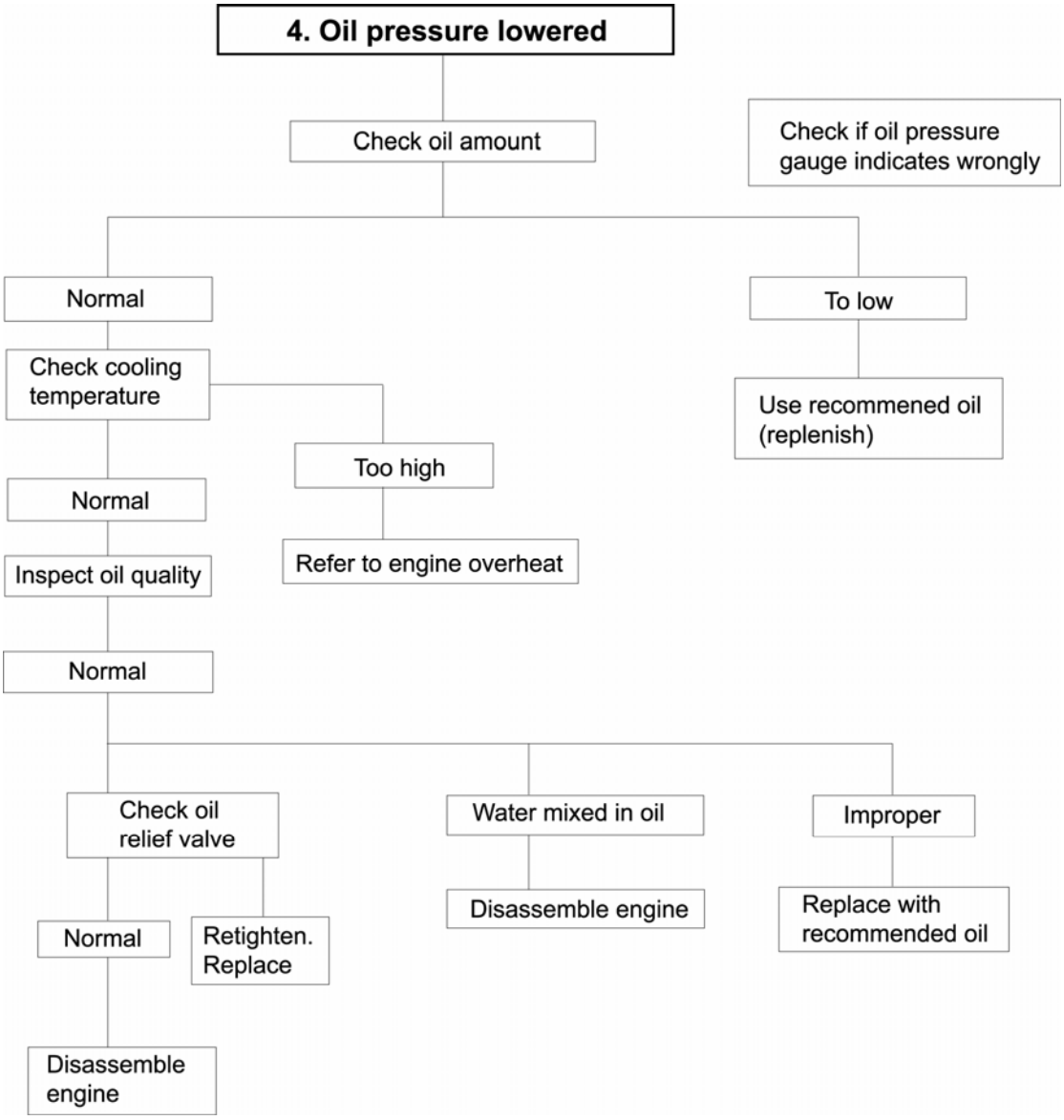
## 2.4. Diagnosis and Remedy

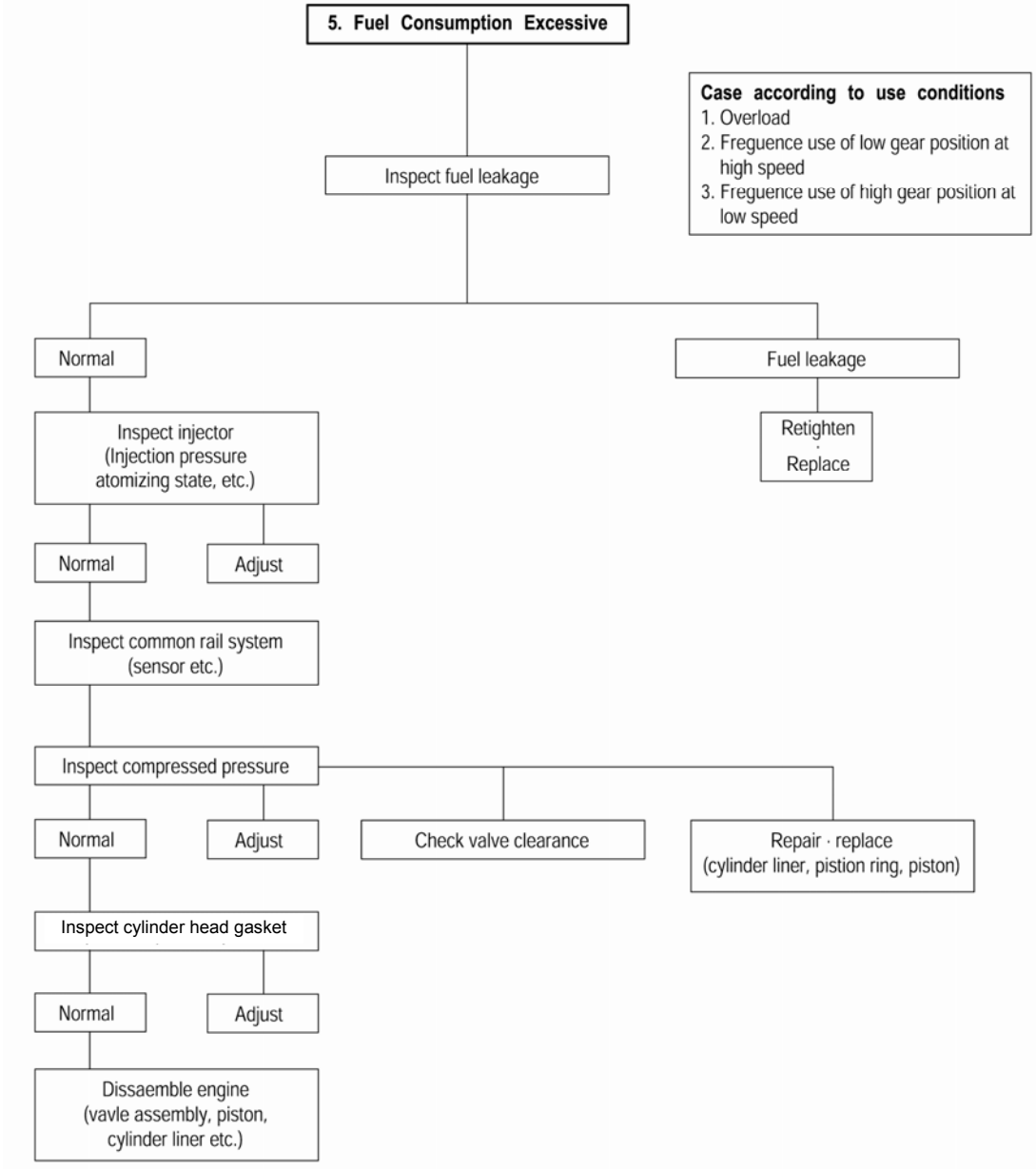
- The following description summarizes the probable cause of and remedy for general failure by item.
- Inspect the electrical parts problem with SCAN-200 and refer diagnostic manual.
- Immediate countermeasures should be taken before a failure is inflamed if any symptom is detected.

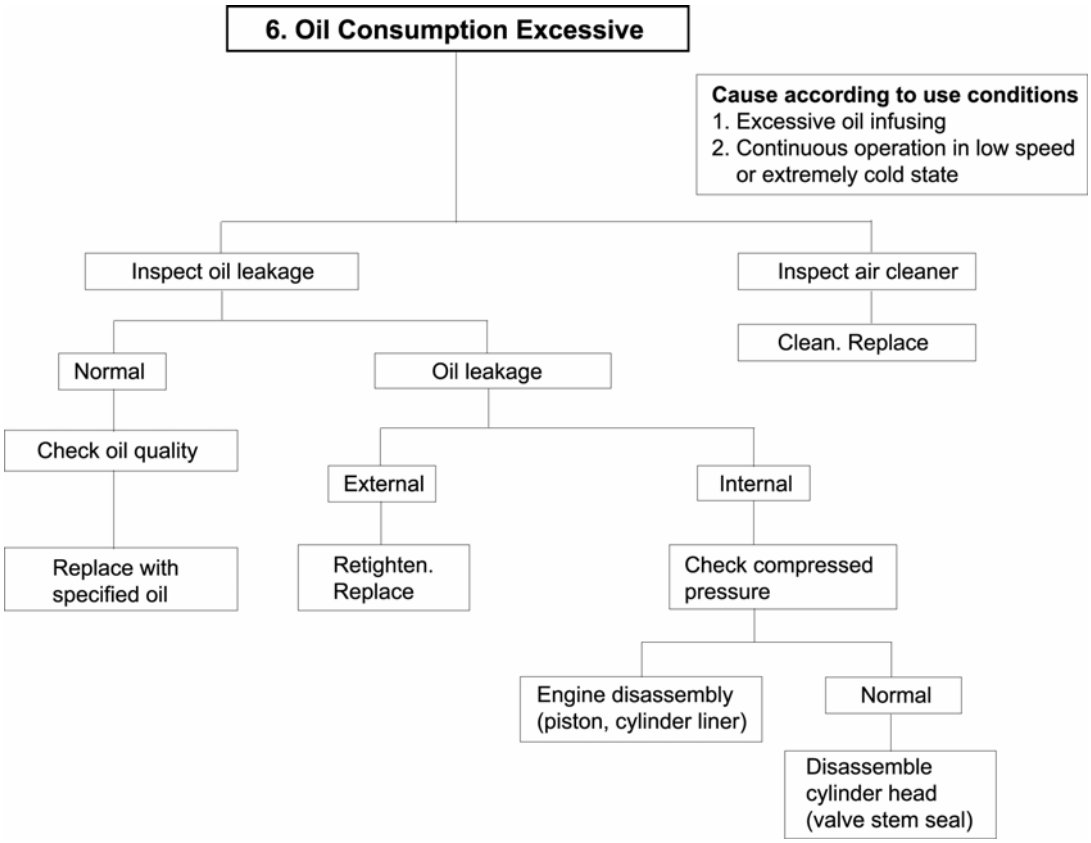


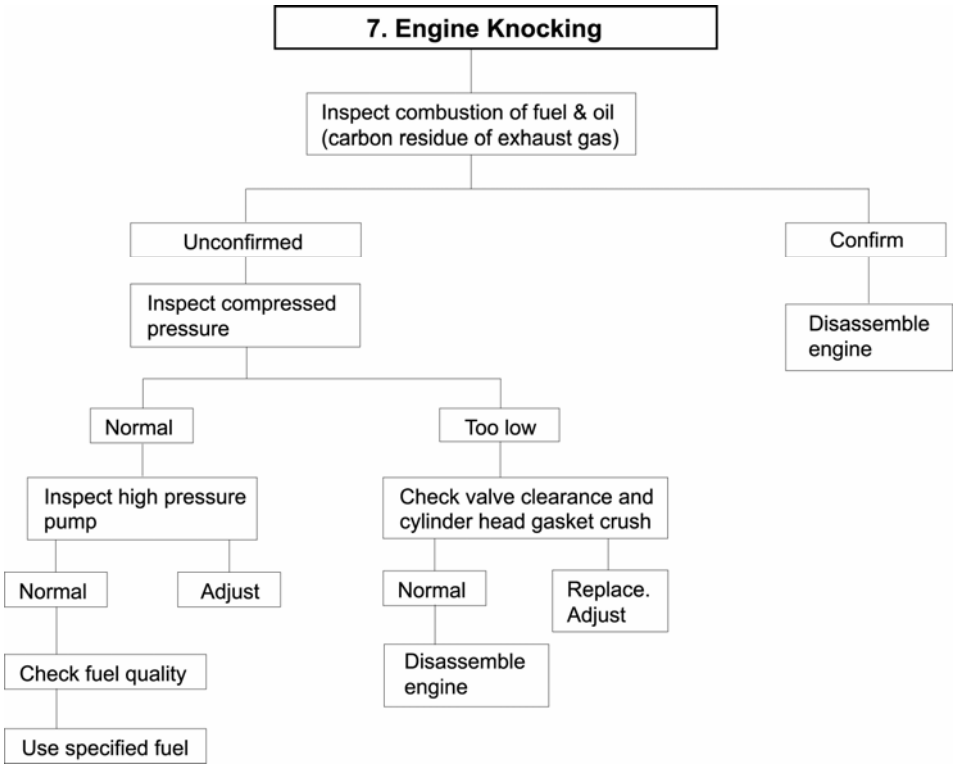

2. Engine Overheated
Operating state
1. Overload
2. Radiator core clogged
Cooling system
Check coolant level
Normal
Too low
Check fan belt tension, wear or damage etc.
Normal
Inspect cooling Water leakage
Normal
Repair · Replace
External
Internal
Check fresh radiator tank cap
Retighten Replace
Engine disassembly
Normal
Replace
Check thermostat
Normal
Replace
Inspect radiator
Normal
Damage
Repair · Replace
Normal
Check cooling water pump
Clean cooling water passage
Normal
Repair · Replace
Engine disassembly

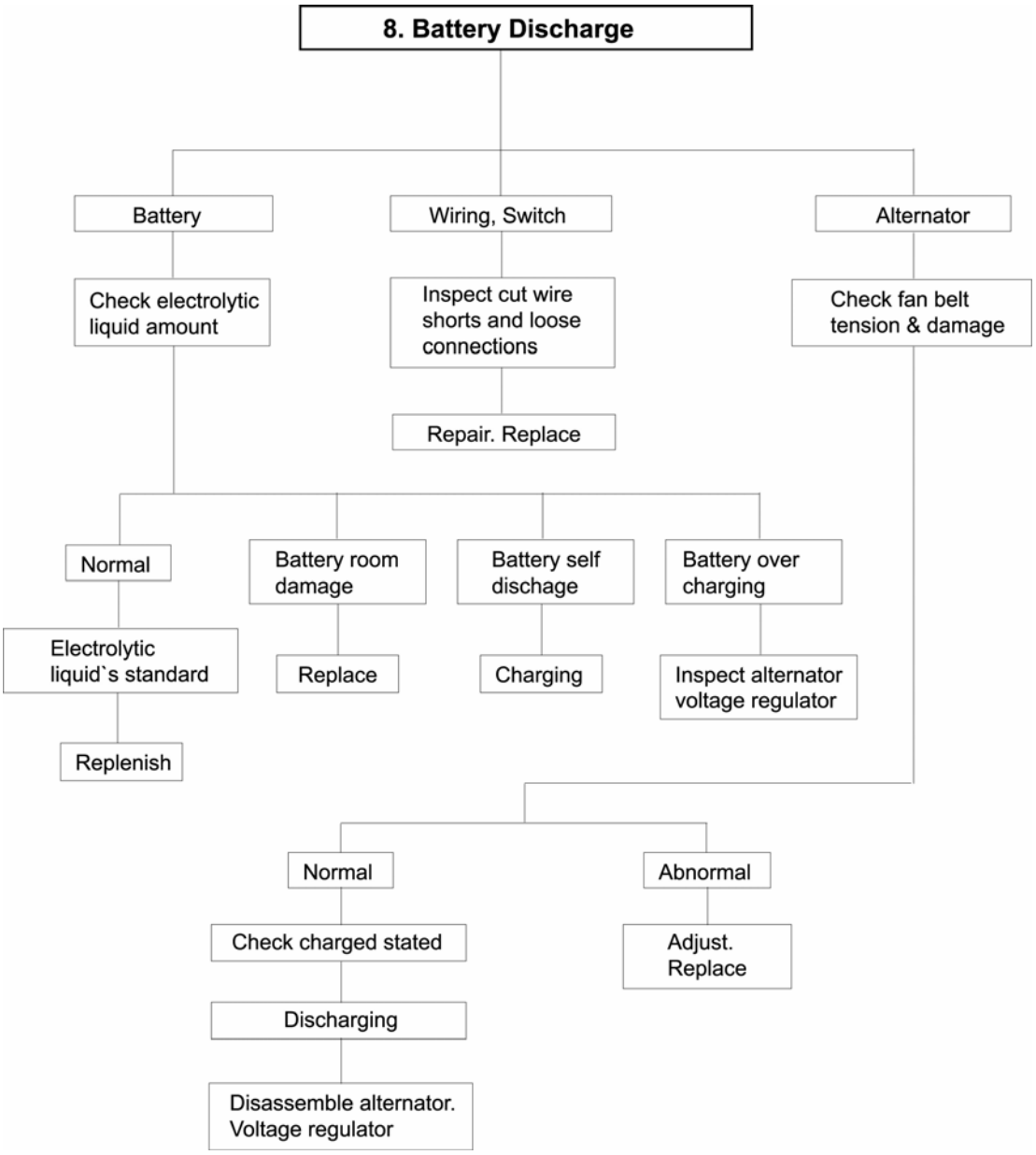

3. Output insufficient
Inspect by SCAN-200 diagnostic tool
Engine
Chassis
Check for clutch slip
Adjust or replace clutch
Check for air mixing in fuel
Others
Inspect fuel supply pump
Normal
Polluted
Repair . Replace
Inspect high pressure pipe
Normal
Repair . Replace
Inspect injector (atomizing state)
Disassemble engine or high pressure pump
Inspect air cleaner
Normal
Repair . Replace
Check valve clearance
Normal
Adjust
Inspect cylinser head gasket for damage
Normal
Replace
Engine disassembly (valve assembly)
Check turbocharger
Normal
Repair . Replace
Disassemble engine or high pressure pump
Inspect air leakage of air piping line
Normal
Retighten. Replace
Inspect air leakage of intercooler


4. Oil pressure lowered
Check oil amount
Check if oil pressure gauge indicates wrongly
Normal
To low
Check cooling temperature
Use recommened oil (replenish)
Too high
Normal
Refer to engine overheat
Inspect oil quality
Normal
Check oil relief valve
Water mixed in oil
Improper
Normal
Retighten. Replace
Disassemble engine
Replace with recommended oil
Disassemble engine


5. Fuel Consumption Excessive
Case according to use conditions
1. Overload
2. Freguence use of low gear position at high speed
3. Freguence use of high gear position at low speed
Inspect fuel leakage
Normal
Fuel leakage
Inspect injector (Injection pressure atomizing state, etc.)
Retighten
Replace
Normal
Adjust
Inspect common rail system (sensor etc.)
Inspect compressed pressure
Normal
Adjust
Check valve clearance
Repair · replace (cylinder liner, pistion ring, piston)
Inspect cylinder head gasket
Normal
Adjust
Dissaemble engine (vavle 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
Clean. Replace
Normal
Oil leakage
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
Normal
Too low
Inspect high pressure pump
Check valve clearance and cylinder head gasket crush
Normal
Adjust
Normal
Replace. Adjust
Check fuel quality
Disassemble engine
Use specified fuel


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

| 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 | Check by SCAN-200 |
| | ● Air mixing at high pressure 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 | Check |
| | ● Fuel injection amount insufficient | Check |
| | ● Injector 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 | Check |
| | ● Fuel injection amount insufficient | Check |
| | ● Injector 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 temperature 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.<br>● Lopsided wear of crankshaft<br>● Oil supply insufficient due to oil passage clogging<br>● Stuck bearing | Replace bearing & grind crankshaft<br>Grind or replace<br>Clean oil passage<br>Replace bearing & grind |
| (2) Connecting-rod and connecting-rod bearing | ● Lopsided wear of con rod bearing<br>● Lopsided wear of crank pin<br>● Connecting rod distortion<br>● Stuck bearing<br>● Oil supply insufficiency as clogging at oil passage progresses | Replace bearing<br>Grind crankshaft<br>Repair or replace<br>Replace & grind crankshaft<br>Clean oil passage |
| (3) Piston, piston pin & piston ring | ● Piston clearance increase as the wear of piston and piston ring progresses<br>● Wear of piston or piston pin<br>● Piston stuck<br>● Piston insertion poor<br>● Piston ring damaged | Replace piston & piston ring<br>Replace<br>Replace piston<br>Replace piston<br>Replace piston |
| (4) Others | ● Wear of crankshaft, thrust bearing<br>● Camshaft end play increased<br>● Idle gear end play increased<br>● Timing gear backlash excessive<br>● Valve clearance excessive<br>● Abnormal wear of tappet, cam<br>● Turbocharger inner part damaged | Replace thrust bearing<br>Replace thrust plate<br>Replace thrust washer<br>Repair or replace<br>Adjust valve clearance<br>Replace tappet, cam<br>Repair or replace |
| 6) Fuel consumption excessive | ● Injection timing incorrect<br>● Fuel injection amount excessive<br>● Tire air pressure incorrect<br>Use of low speed gear is too frequent | Check<br>Adjust |

| 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 |

## 2.5. Engine Inspection

### 2.5.1. Stopping engine

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

### 2.5.2. General engine inspection cycle for vehicle

O : Check & adjust ● : Replace

| Inspection | | Daily | Inspection time(km) | | | | | Remark |
|---|---|---|---|---|---|---|---|---|
| | | | 5,000 | 10,000 | 15,000 | 20,000 | 40,000 | |
| Cooling system | Check for leakage (hoses, clamp) | O | | | | | | |
| | Check the water level | O | | | | | | |
| | Check the V-belt tension | O | | | | | | |
| | Change the coolant water | | | | | | ● | |
| Lubrication system | Check for leakage | O | | | | | | |
| | Check the oil level gauge | O | | | | | | |
| | Change the lubricating oil | | ● 1st | | | | (●) | |
| | Replace the oil filter cartridge | | ● 1st | | | | (●) | |
| Intake & Exhaust System | Check the leakage for intercooler (hoses, clamp) | O | | | | | | |
| | Clean and change the air cleaner element | O | | | | | | |
| Fuel system | Drain the water in separator | | | O | | | | |
| | Check the fuel line leakage | O | | | | | | |
| | Replace the fuel filter cartridge | | | | | | ● | |
| | Check the injector nozzles | | | | | | | When necessary |
| Engine adjust | Check the exhaust gas state | O | | | | | | |
| | Check the battery charging | O | | | | | | |
| | Check the compression pressure | | | | | | | When necessary |
| | Adjust intake / exhaust valve clearance | | | O | | | | When necessary |
| | Adjust engine brake | | | O | | | | When necessary |

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

### 2.5.3. General engine inspection cycle for industrial

O : Check & adjust ● : Replace

| Inspection | | Daily | Inspection time (Hr) | | | Remark |
|---|---|---|---|---|---|---|
| | | | 50 | 250 | 500 | |
| **Cooling system** | Check for leakage (hoses, clamp) | O | | | | |
| | Check the water level | O | | | | |
| | Check the V-belt tension | O | | | | |
| | Change the coolant water | | | | ●(1,200Hr) | |
| **Lubrication system** | Check for leakage | O | | | | |
| | Check the oil level gauge | O | | | | |
| | Change the lubricating oil | | ● 1st | | (●) | |
| | Replace the oil filter cartridge | | ● 1st | | (●) | |
| **Intake & Exhaust System** | Check the leakage for intercooler (hoses, clamp) | O | | | | |
| | Clean and change the air cleaner element | O | | | | |
| **Fuel system** | Drain the water in separator | O | | | | |
| | Clean the fuel strainer of fuel feed pump | O | | | | |
| | Check the fuel line leakage | O | | | | |
| | Replace the fuel filter cartridge | | | | ● | |
| | Check the injector nozzles | | | | | When necessary |
| **Engine adjust** | Check the exhaust gas state | O | | | | |
| | Check the battery charging | O | | | | |
| | Check the compression pressure | | | | | When necessary |
| | Adjust intake / exhaust valve clearance | | | O | | When necessary |

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

### 2.5.4. 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

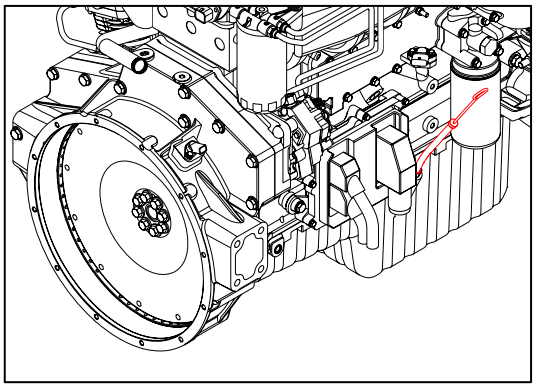
## 3.1. Engine Disassembly

### 3.1.1. General precautions

- Maintenance operation should be carried out in a bright and clean place.
- Before disassembly, provide parts racks for storage of various tools and disassembled parts.
- Arrange the disassembled parts in the disassembly sequence and use care to prevent any damage to them.

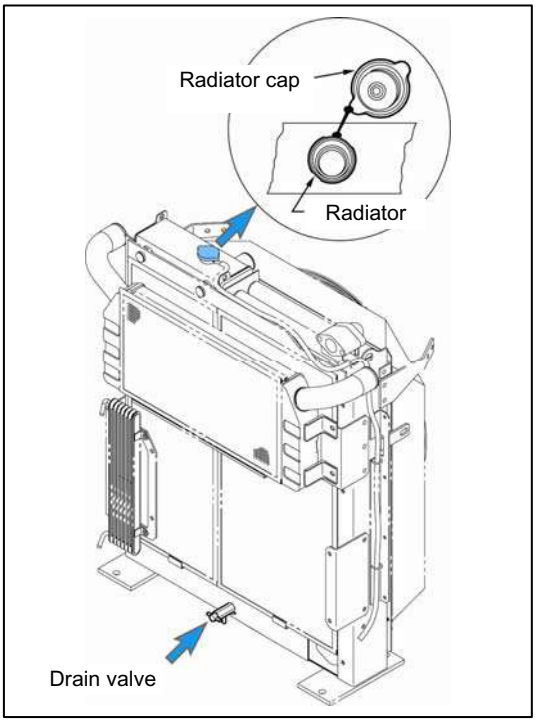
### 3.1.2. Oil level gauge

- Take out the oil level gauge.



### 3.1.3. Cooling water

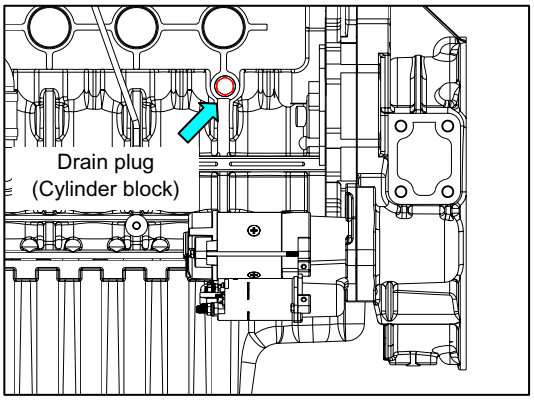
- Remove the radiator cap. Open the drain valve at the radiator lower part to drain the coolant as the right figure.




**CAUTION:**

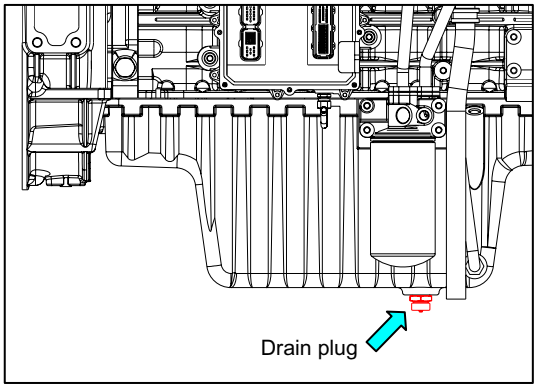
**When removing radiator filler cap while the engine is still hot, cover the cap with a rag, then turn it slowly to release the internal steam pressure This will prevent a person from scalding with hot steam spouted out from the filler port.**

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



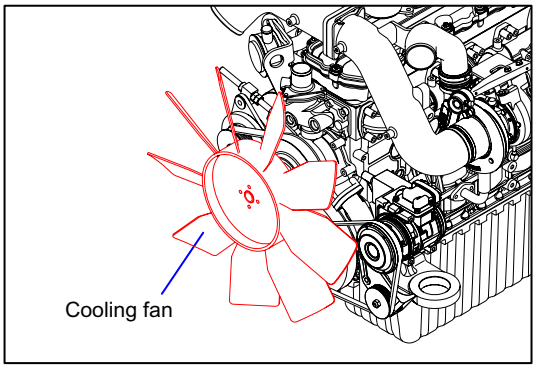

### 3.1.4. Engine oil

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



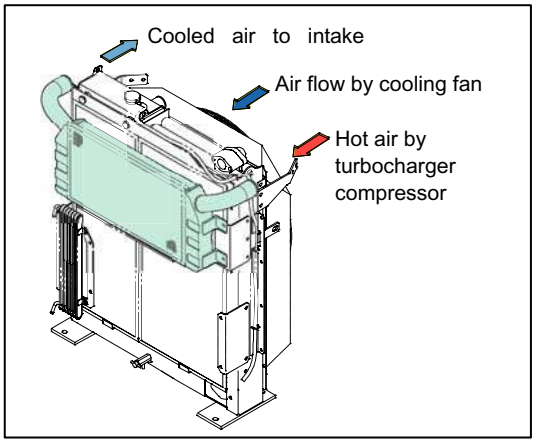

### 3.1.5. Cooling fan

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



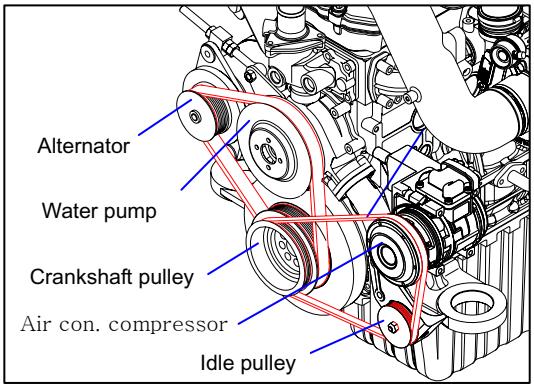
### 3.1.6. Inter cooler

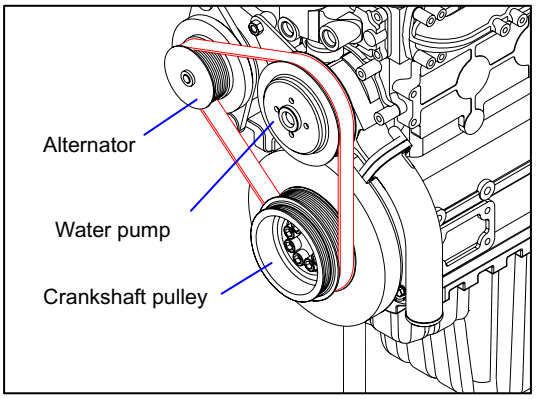
- Tear down the various hoses and air pipes from the inter cooler
- Remove the intercooler fixing bolts and tear it down.




### 3.1.7. Belt and alternator

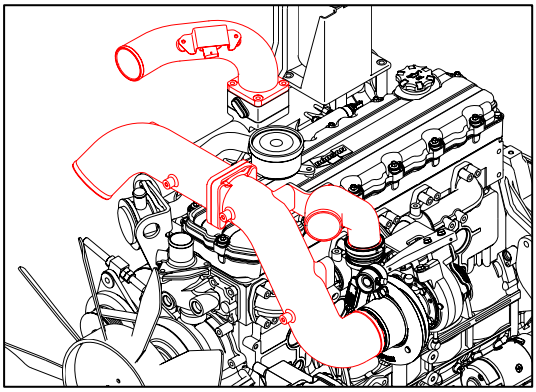
- Loosen the tension adjusting bolts of the alternator and air con. compressor, then take off the fan belt.

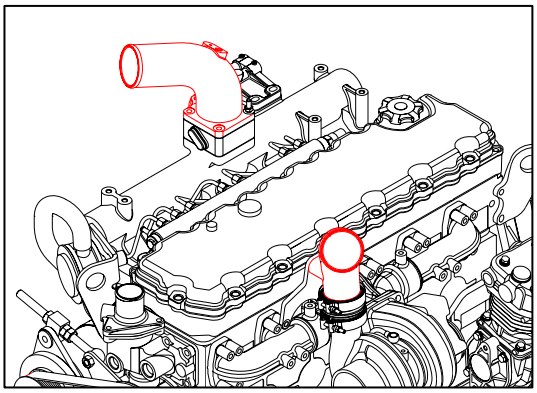


### 3.1.8. Air pipe & air heater

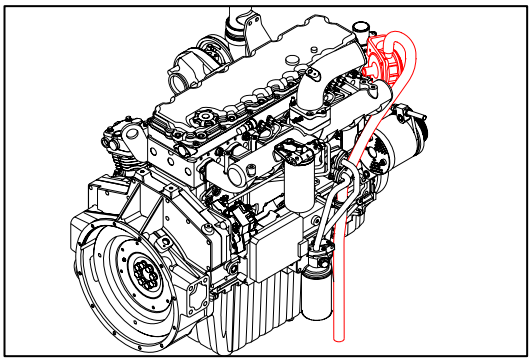
- Remove fixing bolts, then take off the air pipe and air heater.
- Be careful about the mixing of foreign matter into interior of the turbocharger.





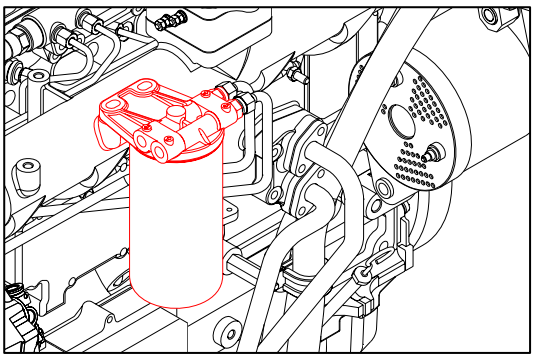
### 3.1.9. Breather

- Loosen the clamp screw to remove the rubber hose.
- Remove the breather valve assembly.



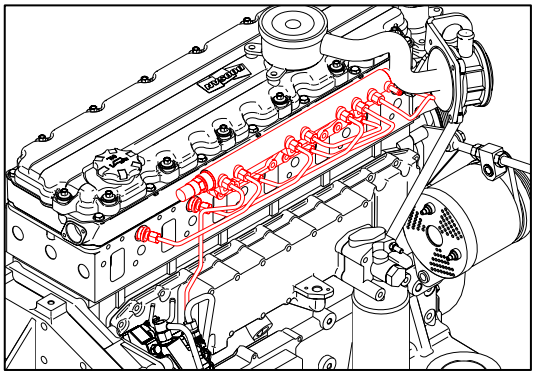
### 3.1.10. Fuel filter

- Loosen the hollow screws of filter and remove the fuel hose.
- Remove fuel filter fixing bolts and disassemble the fuel filter.



### 3.1.11. Common rail & high pressure pipe

- Remove the high pressure pipe of between fuel high pressure connecter and common rail
- Remove the common rail fixing bolts and take off the common rail.



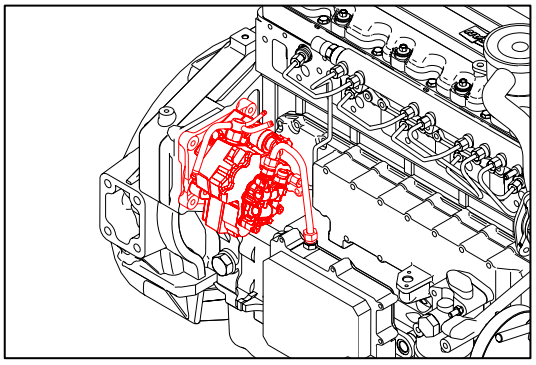
**NOTE:**

**1) Seal the pipe to prevent from mixing foreign material into inside of the pipe after disassembling.**

**2) Do not reuse the fuel high pressure pipe after remove its.**

### 3.1.12. Fuel high pressure pump

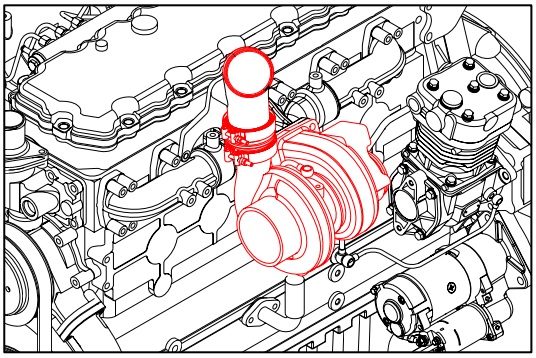
- Remove the fuel high pressure pump fixing bolts and take off the fuel high pressure pump by pushing to backward.



**NOTE:**
**Seal the fuel high pressure pump to prevent from mixing foreign material into inside of the fuel line.**

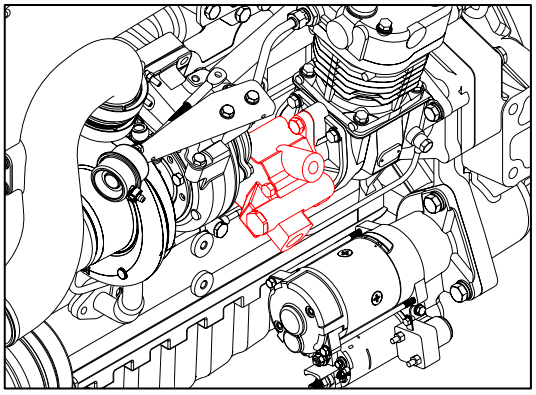
### 3.1.13. Turbocharger

- Remove the oil supply pipe and oil return pipe between the turbo charger and the cylinder block.
- Unscrew the turbo charger fixing bolts and take off the turbo charger from the exhaust manifold.



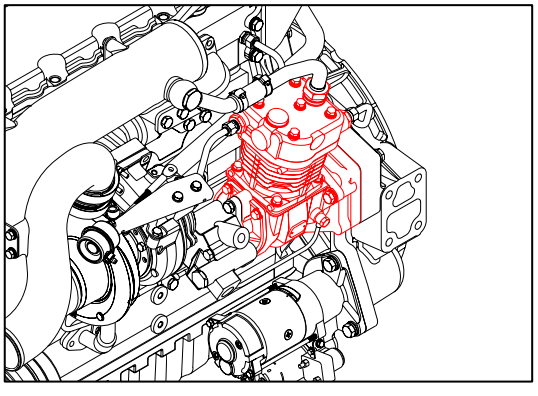
### 3.1.14. Power steering pump

- Remove the oil hose between power steering oil pump and control unit of the vehicle.
- Unscrew the power steering oil pump fixing bolts and remove the power steering pump.



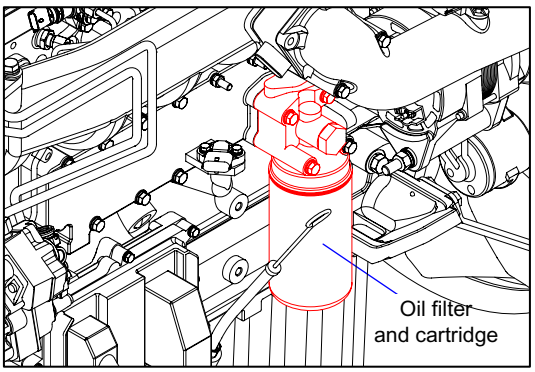
### 3.1.15. Air compressor

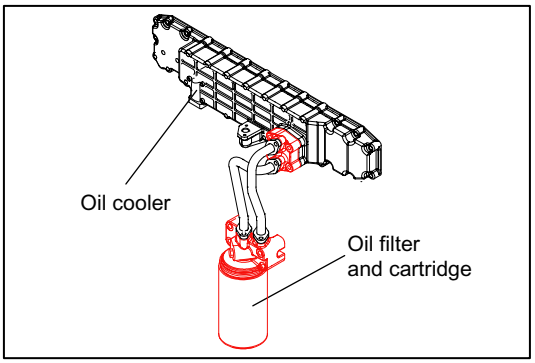
- Remove the oil pipe and cooling water pipe connected to the air compressor from the cylinder block and air compressor.
- Unscrew the air compressor fixing bolts and take off the air compressor.



### 3.1.16. Oil filter & cooler

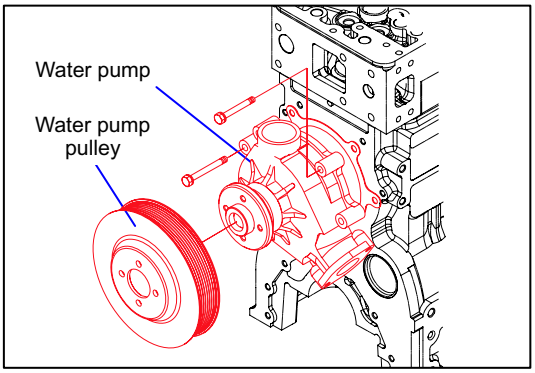
- Remove the oil filter fixing bolts and take off the oil filter from the oil cooler.
- Remove the oil cooler fixing bolts and take off the oil cooler.



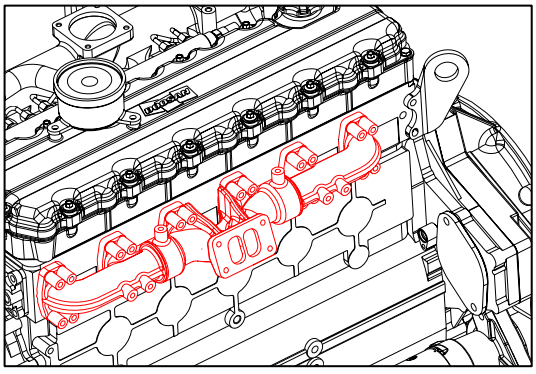

### 3.1.17. Cooling water pump

- Remove the cooling water pump fixing bolts and disassemble the cooling water pump.



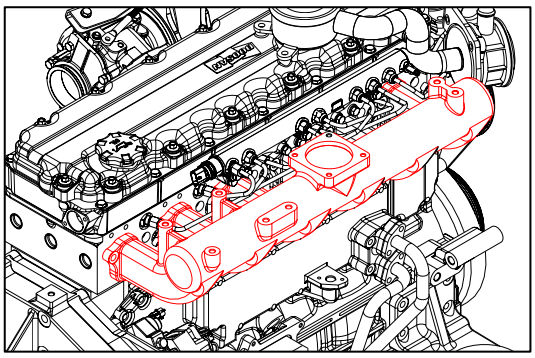

### 3.1.18. Exhaust manifold

- Unscrew the exhaust manifold fixing nuts and remove the heat shield from the exhaust manifold.
- Then disassemble the exhaust manifold and gasket.
- Scrap the used gasket.



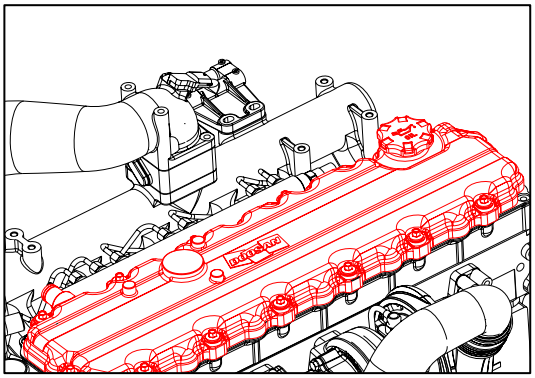
### 3.1.19. Intake manifold

- Unscrew the intake manifold fixing bolts and remove the intake manifold from the cylinder head.
- Disassemble the intake manifold gasket and clean the installed face using the scrapper.



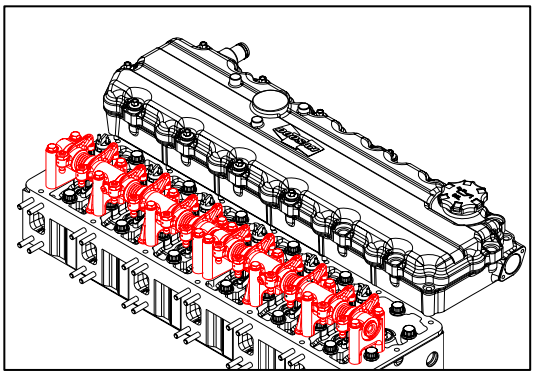
### 3.1.20. Cylinder head cover

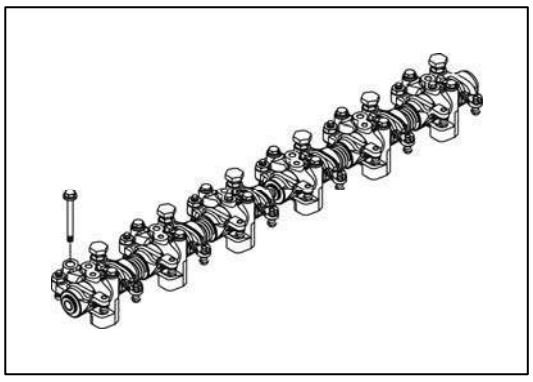
- Remove the head cover fixing bolts and lift the cylinder head cover.



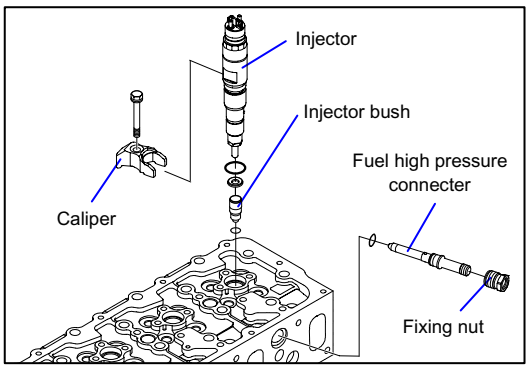
### 3.1.21. Rocker arm

- Remove the rocker arm bracket fixing bolts in reverse order of assembling and disassemble the rocker arm.
- Take out the push rod.





### 3.1.22. Injector



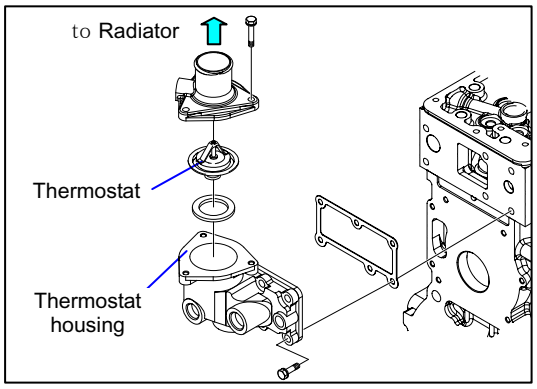

- Remove the fuel high pressure connecter fixing nuts and take off the fuel high pressure connecter.
- Remove the harness connected to injector, then remove injector fixing bracket bolts and take off the injector.
- Be careful about damage of the nozzle when take off the injector.
- Take out the sealing 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 nuts, 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.**

### 3.1.23. Cooling water pipe

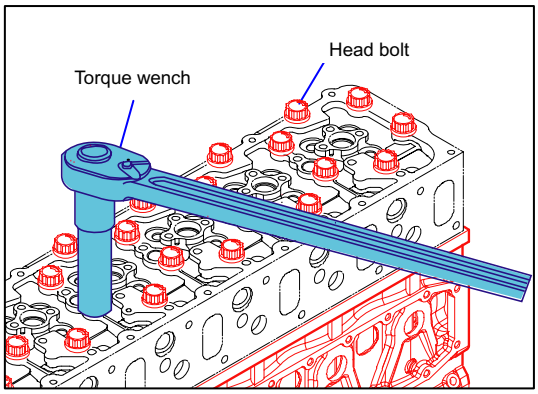



- Unscrew the cooling water pipe fixing bolts and remove the cooling water pipe from the thermostat ho using.
- Remove the cooling water pipe gasket and finish the surface with a scraper.

**CAUTION :**

**Be sure that piece of the gasket do not come into the cooling water passage.**

### 3.1.24. Cylinder head

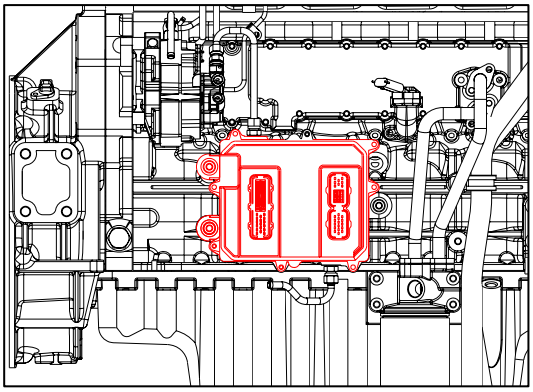



- Remove the cylinder head bolts in the reverse order of tightening but remove it step by step.

**1) First step : Loosen 1 ~ 2 threads**
**2) Second step : Remove by loosening fully.**

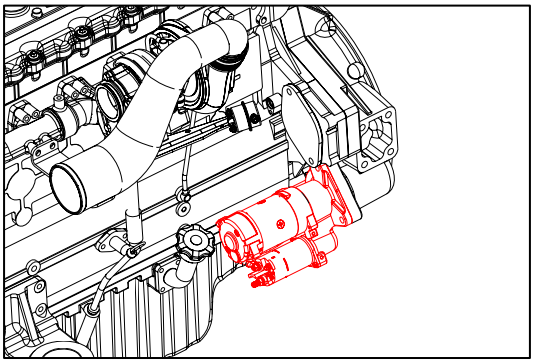
- Remove the total bolts simultaneously by the step of 1) and 2).
- Lay the removed bolts orderly not to damage the threads at all and store.
- Prevent a collision between the bolt thread each other.
- Take out the cylinder head gasket and scrap it.
- Remove the foreign residues from the cylinder head surface and block surface.
- Try not to make any damage on the contact surfaces.

### 3.1.25. Electric control unit



- Remove the electric control unit fixing bolts, then take off the electric control unit and bracket.

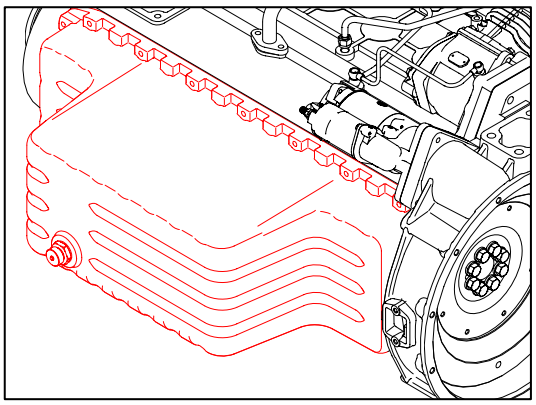
### 3.1.26. Starting motor



- Unscrew the starter fixing nuts and remove the starter being careful not to damage its gears.

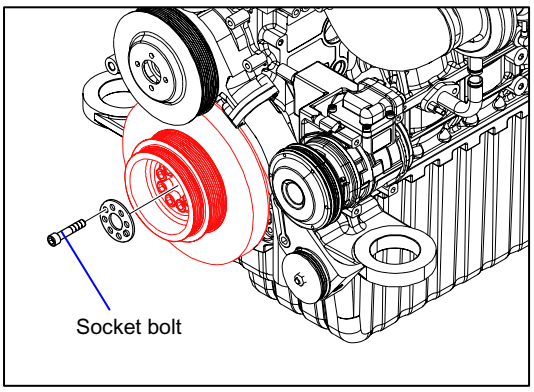
### 3.1.27. Oil pan

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



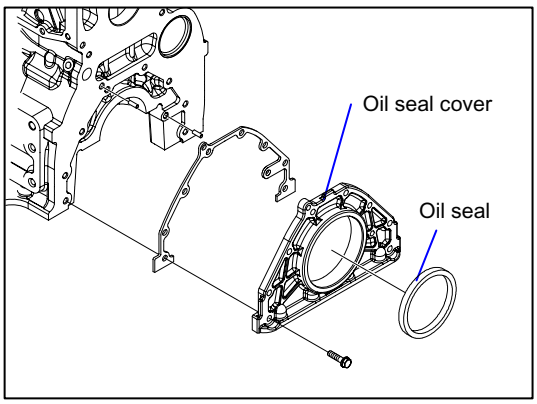
### 3.1.28. Vibration damper

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



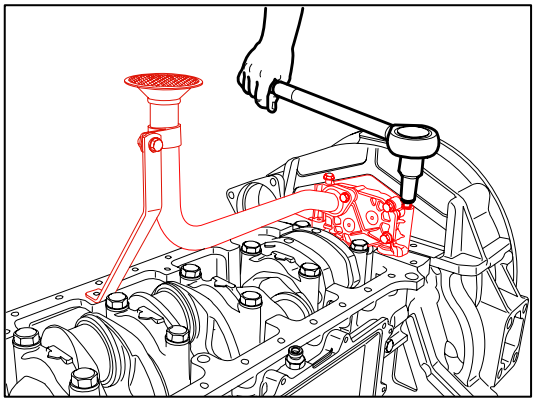

### 3.1.29. Front oil seal cover

- Disassemble the oil seal using an oil seal removing jig.
- Remove the cover fixing bolts and disassemble the cover from the timing gear case.



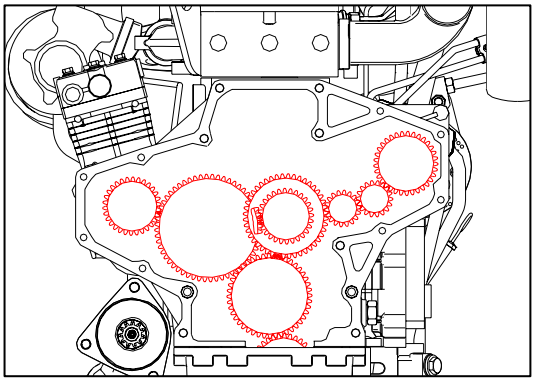
### 3.1.30. Oil pump

- Unscrew the bracket fixing bolts of the oil suction pipe.
- Unscrew the pipe fixing bolts of oil pump and disassemble the oil suction pipe.
- Unscrew the oil pump fixing bolts, and disassemble the oil pump.



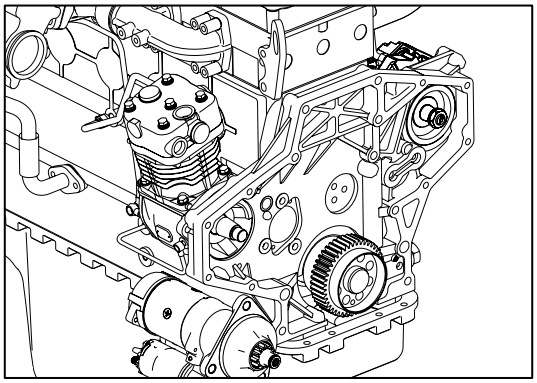
### 3.1.31. Cam gear & idle gear

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

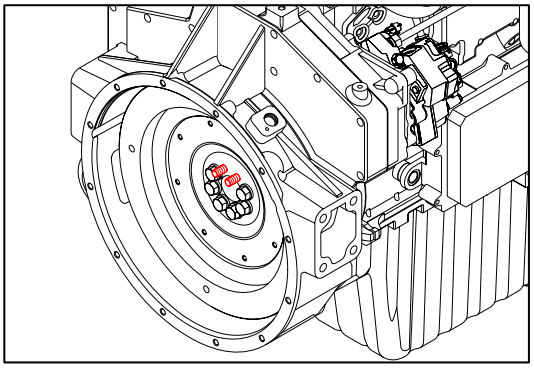


### 3.1.32. Timing gear case

- Remove the timing gear case assembling bolts.
- By tapping lightly with a urethane hammer the right and left back of timing gear case's connecting part, disassemble the timing gear case.

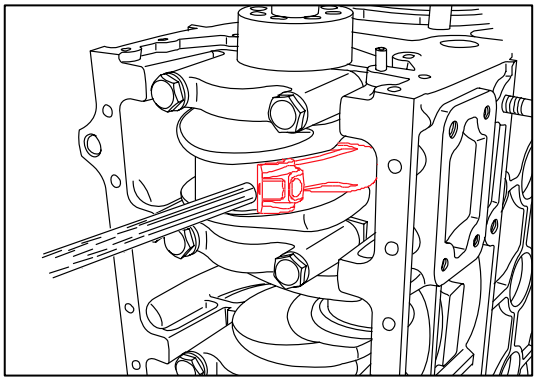


### 3.1.33. Fly wheel



- Remove the flywheel fixing bolts, install the guide bolts and disassemble it.
- The bolt removal is done by the reverse order of assembling and by the steps.

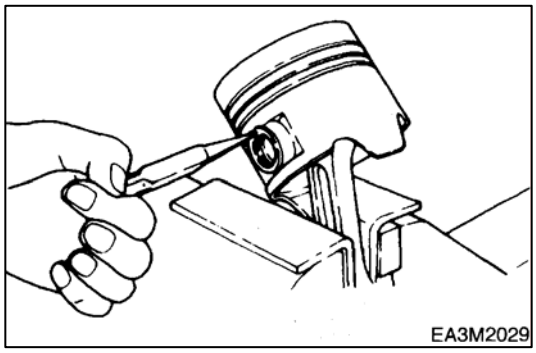
### 3.1.34. Piston



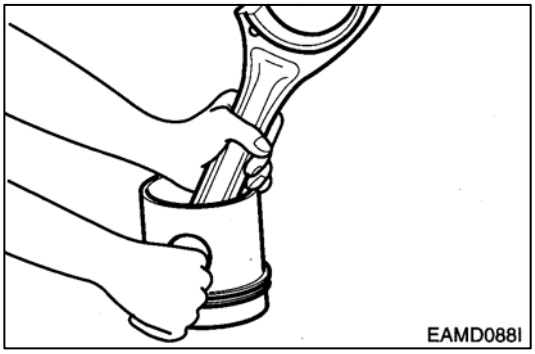
- Remove the connecting rod cap bolts in the reverse order of assembling but do by the step of 1 and 2 same as the cylinder head bolt removal.
- Disassemble the upper/lower of connecting rod caps by tapping lightly with urethane hammer, and remove the bearing
- By pushing the connecting rod with wooden bar from the direction of oil pan toward cylinder head, disassemble the piston assembly.
- The disassembled piston assembly should be handled to prevent bumping each other, and stored as the cylinder's order.
- In order for connecting rod cap not to be swapped, temporarily assemble to the corresponding connecting rod.

**<Disassembly of piston >**

(1) Remove the snap rings by means of the pliers.

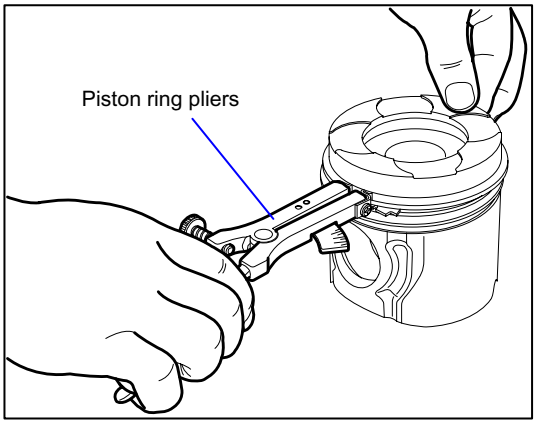



(2) Take out the piston pin from the piston as tapping it with a round wooden bar.



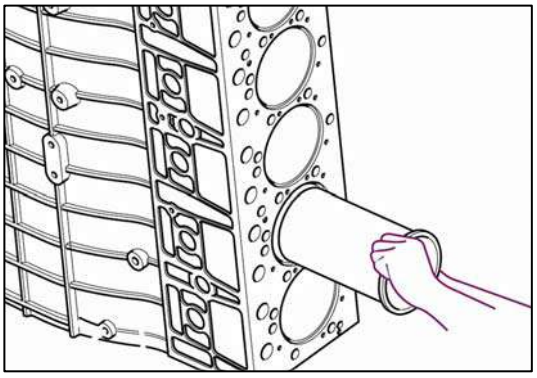

(3) Remove the piston ring with the pliers.

(4) Clean the piston thoroughly.



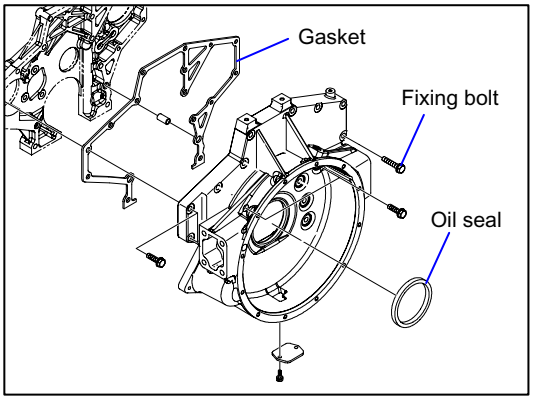

### 3.1.35. Cylinder liner

- Be careful not to generate any damage at cylinder block.
- Disassemble the cylinder liner with a special tool or hand.



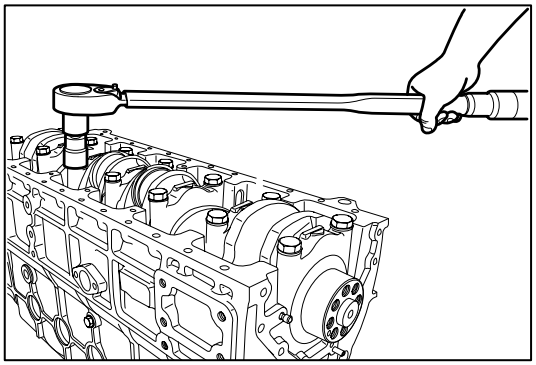
### 3.1.36. Flywheel housing

- Remove the flywheel housing fixing bolts and disassemble the flywheel housing.
- Disassemble the oil seal of flywheel housing.



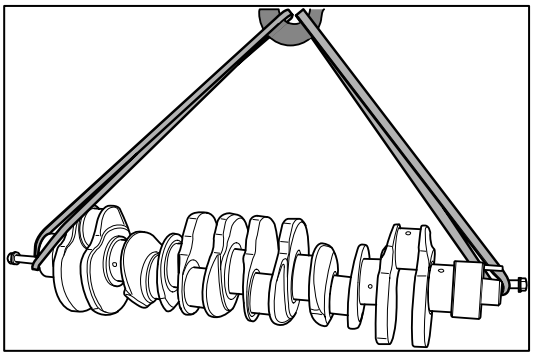

### 3.1.37. Bearing cap

- Remove the bearing cap assembling bolts by the step in the reverse order of assembling, and disassemble the bearing cap. (Remove by the same way as the cylinder head bolts' removal.)
- Disassembled bearing caps are kept laid in order.



### 3.1.38. Crank shaft

- Assemble the bolts on the both side of crankshaft temporarily.
- Connect the rope to the bolts and lift the crankshaft by means of crane being careful not to give any damage on it.
- In order for the disassembled crankshaft to be prevented from bends or damage, put it on the special lathe and store.
- Disassemble the metal bearings in turn and store them.

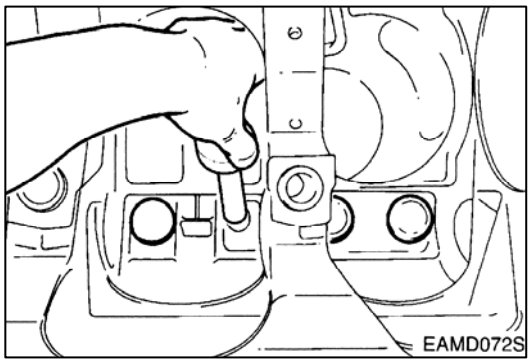


**NOTES :**

**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.**

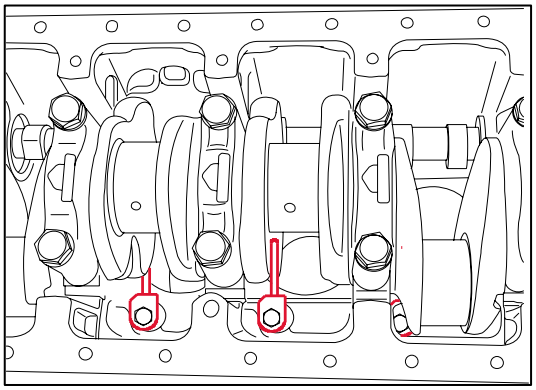
### 3.1.39. Cam shaft & tappet

- In order for camshaft not to be damaged, disassemble turning it.
- In order for the disassembled camshaft to be prevented from bends or damage, put it on the special lathe and store.
- Pull out the tappet.
- Check for damage, scratch, wearing state and if abnormal, tear down.




### 3.1.40. Oil spray nozzle

- Remove the valve screws of oil spray nozzle and disassemble it.



## 3.2. Inspection and Measurement on Major Parts

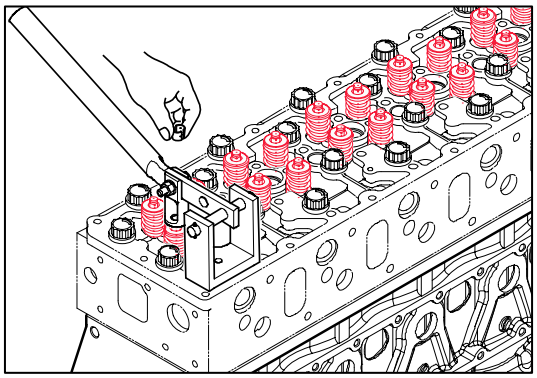
### 3.2.1. Cylinder block

- Clean the cylinder block thoroughly, and check for any crack or damage.
- If there is any crack or severe damage, replace it and if there is minor one, correct it.
- Check for any clogging or corrosion in the oil passage and water passage.
- Carry out a leakage test for any crack or air leaking. (Hydraulic test)
- Plug each cylinder block's water and oil discharge ports, and apply the air pressure of about 4kg/cm$^2$ to intake port and soak it in water for about 1 minute to check if there is any leakage. (Water temperature : 70°C)

### 3.2.2. Cylinder head

#### (1) Disassembly

1) Disassemble the cylinder assembly, and put it on the shelf for assembly or clean lathe.
2) Prevent any damage to gasket's contact surface of the cylinder head.
3) Disassemble the cotter pin, spring, spring seat pushing valve spring by a special tool.
4) Pull out the intake and exhaust valves.
5) The disassembled parts are kept laid in turn.



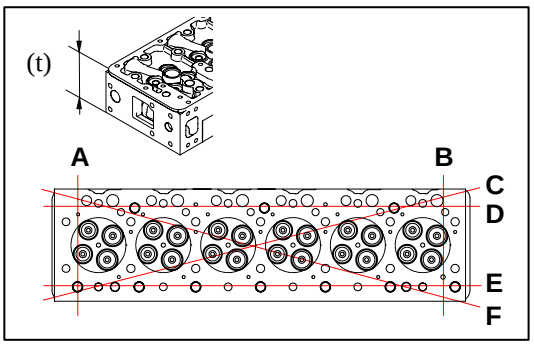
#### (2) Inspection of cylinder head

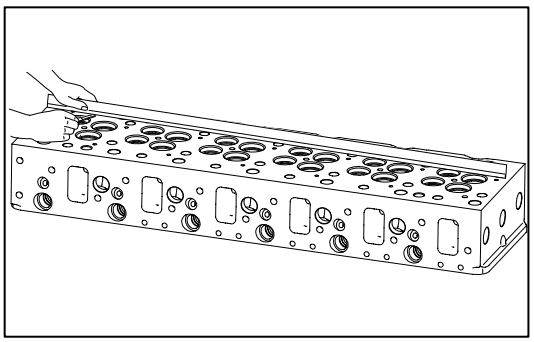
**1) Check for the cylinder head.**

- Remove carbon from the cylinder head lower surface, and then should be careful not to scratch the surface.
- Check any crack or damage that can not found by naked eyes through the hydraulic or magnetic particle test.

### 2) Distortion of lower surface

- 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 height >**

| | Standard | Limit |
|---|---|---|
| Warpage | 0.08 mm or less | 0.15 mm |
| Thickness : t (reference) | 104.9 ~105.1mm | 104.4mm |

### 3) Flatness

- Check the flatness of the installing surface of cylinder head's intake and exhaust manifolds with horizontal ruler and clearance gauge.

| Standard | Limit |
|---|---|
| 0.15 mm | 0.3 mm |

### 4) The hydraulic test

- The hydraulic test of cylinder head is same as the cylinder block test.

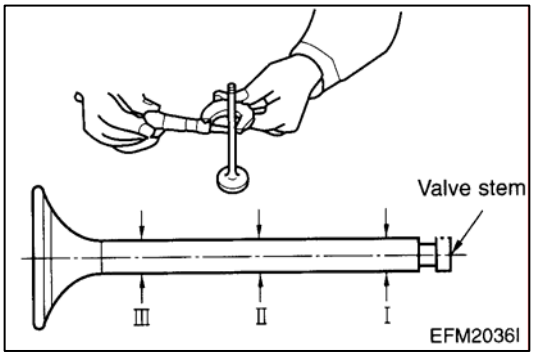
### (3) Inspection of valve and valve guide

#### 1) Valve

- After cleaning valve with fuel, check it.

- **Valve stem outer diameter**

  Measure the valve stem outer diameter at 3 positions (top, middle, and bottom), and check for any wear and if beyond the limit value, replace the valve.



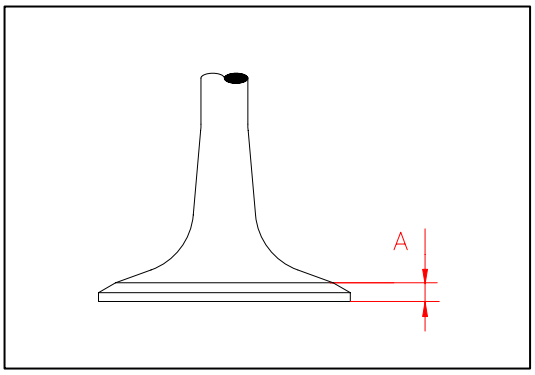

| Dimension / Description | Standard | Limit |
|---|---|---|
| Intake valve stem | ϕ6.963~ϕ6.977mm | ϕ6.93 mm |
| Exhaust valve stem | ϕ6.950~ϕ6.964mm | ϕ6.91 mm |

- **Valve seat contacting faces**

  Check the valve seat contact surface for any crack and wear, and if necessary, correct with grinding paper, and if excessive, replace it.

- **Valve head thickness**

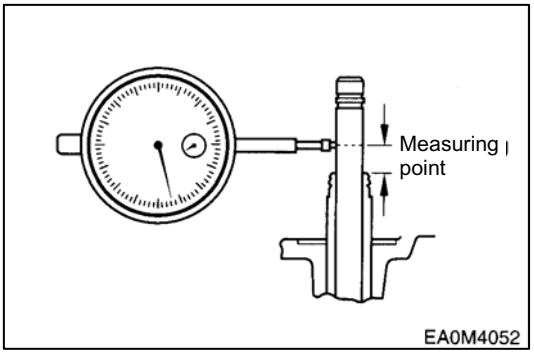
  Measure the thickness of valve head and if beyond the limit value, replace the valve.




| | Standard | Limit |
|---|---|---|
| Intake valve **(A)** | 3.3~3.7 mm | 1 mm or less |
| Exhaust valve **(A)** | 3.3~3.7 mm | 1 mm or less |

### 2) Valve guide

- Insert a valve into cylinder head and measure the clearance between valve guide and valve by valve movement.
- If the clearance is excessive, replace the valve.



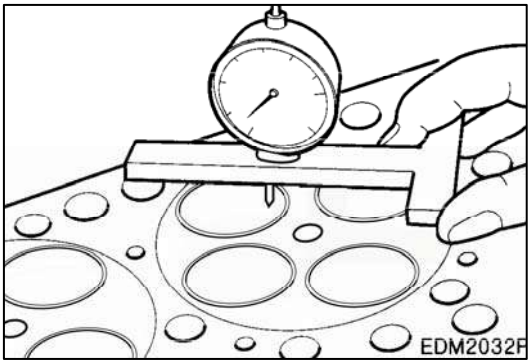

- **Valve stem clearance**

| | Standard | Limit |
|---|---|---|
| Intake valve | 0.023~0.052mm | 0.1 mm |
| Exhaust valve | 0.036~0.065mm | 0.15 mm |

- Assemble the valve to cylinder head's valve guide and see if it is centered with the valve seat using a special tool.

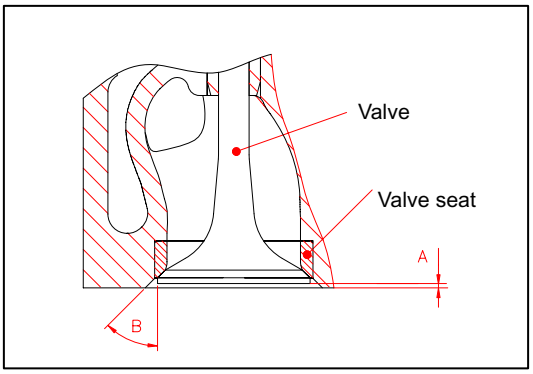
### 3) Valve seat

- As for the valve seat's wear, measure the width of the contact surface with intake valve seat and exhaust valve seat. If beyond the limit value, replace the valve seat.
- Assemble the valve at the valve seat of the cylinder head, and check the amount of depression of the valve from the lower portion of the cylinder head using a dial gauge.



**< Valve depression >**

| | Standard | Limit |
|---|---|---|
| Intake **(A)** | 0.35 ~ 0.65 mm | 0.85 mm |
| Exhaust **(A)** | 0.35 ~ 0.65 mm | 0.85 mm |



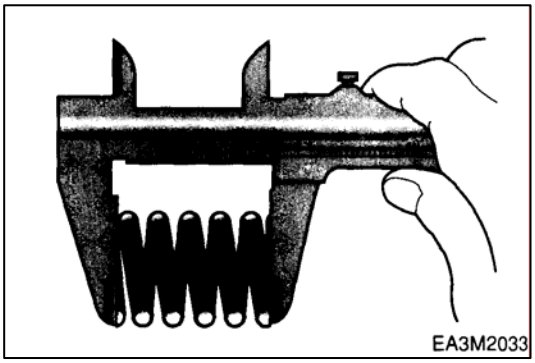

**< Valve angle >**

| Intake valve **(B)** | Exhaust valve **(B)** |
|---|---|
| $60^{O}$ | $45^{O}$ |

- It is necessary to work boring of inner diameter of it when replace the valve seat.
- Apply valve lapping compound to the valve head seating face on the valve seat and lap the valve seat by turning it until it is seated in position, then wipe out the lapping compound.

### 4) Valve spring

- **Visual check**
  Check the appearance of valve spring and if necessary replace the spring.



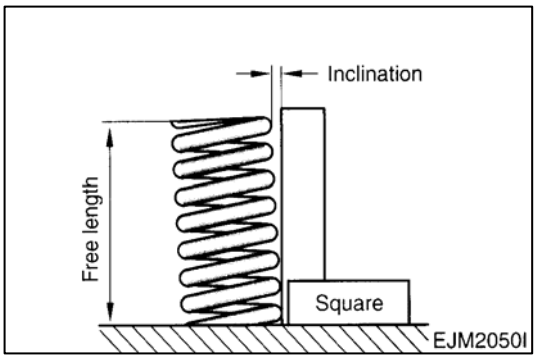

- **Valve spring free length**
  Use a vernier caliper to measure the valve spring free length. If the measured value is less than the specified limit, the valve spring must be replaced.

| Spring free length | Standard |
|---|---|
| Intake valve & Exhaust valve | 53.4 mm |

- **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.

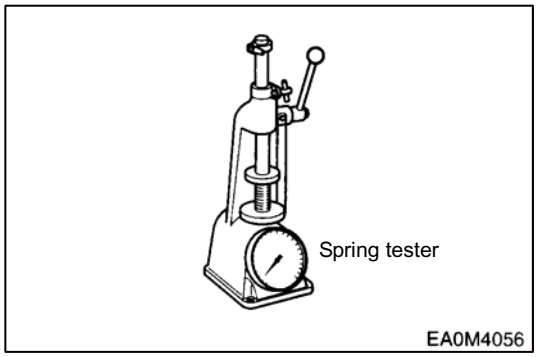



| | Standard | Limit |
|---|---|---|
| Valve spring inclination | 1.4 mm or less | 2.0 mm |

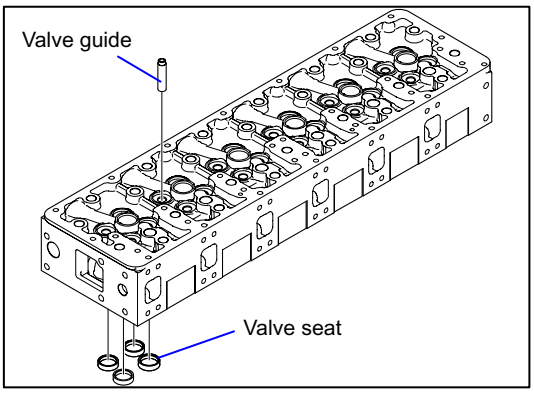
- **Valve spring tension**

Use a spring tester to measure the valve spring tension if the measured value is less than the specified limit, the valve spring must be replaced.

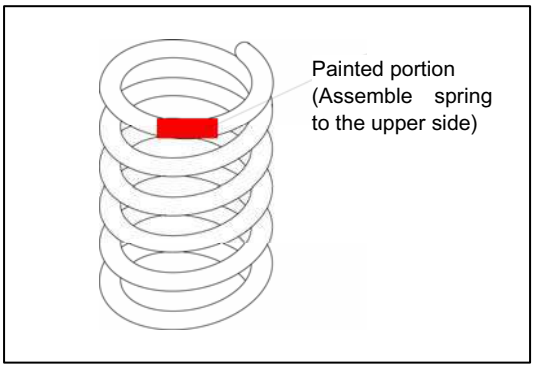
| | Set Length | Spring force | Limit |
|---|---|---|---|
| Intake and exhaust valve | 39.4 mm | 28.8 kg | ±2 kg |
| | 29.67 mm | 50 kg | ±2 kg |



**5)** Assembling cylinder head



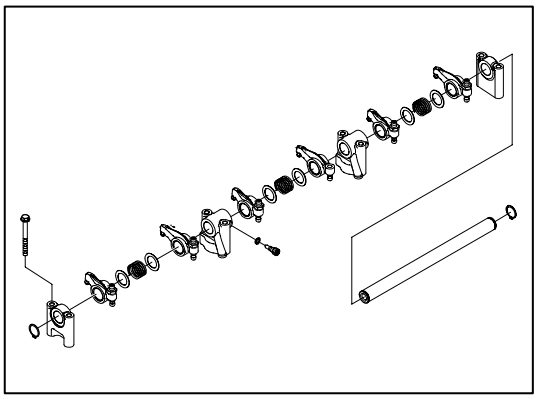

- Clean the cylinder head thoroughly. Replace the valve stem seal with new one, and by means of a special tool, press the stem seal into the valve guide of cylinder head.
- Coat engine oil to valve stem and valve guide and assemble the valve. However, be careful for the damage of valve stem seal.
- Install the lower seat of valve spring to the valve guide of cylinder head.
- After putting inner, outer springs, install the spring upper seat on it.
- Assemble the valve by inserting the valve cotter pressing the valve spring with a special tool.
- After installing the valve, check whether the valve is correctly installed or not tapping it lightly with urethane hammer.




### 3.2.3. Rocker arm

#### (1) Disassembly

1) Disassemble the snap rings that are located at one end of rocker arm shaft by the pliers.
2) Disassemble in the order of washer, rocker arm, rocker arm bracket, rocker arm spring.



### (2) Inspection of rocker arm assembly

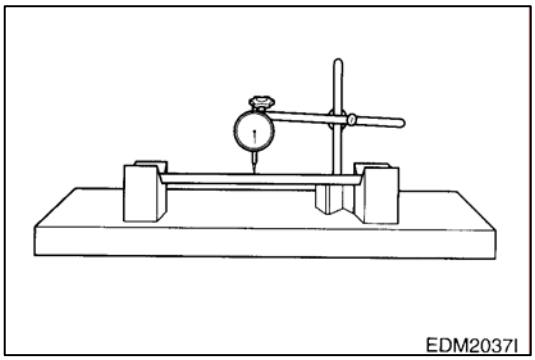
#### 1) Rocker arm shaft

- **Rocker arm shaft run-out**

Place the rocker arm shaft on two V-blocks and inspect the shaft for bend using a dial gauge.

If the amount of this run-out is small, press the shaft with a bench press to correct the run-out.

Replace the shaft if the measured value exceeds the limit.

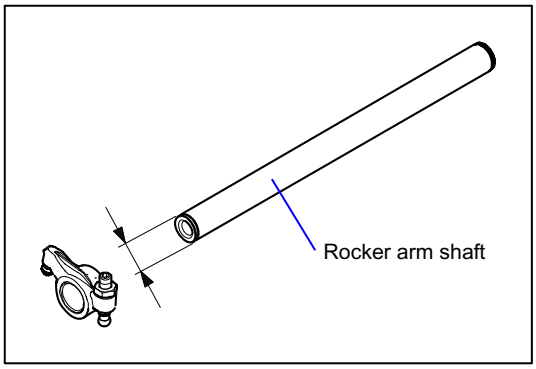



| Limit | 0.1 mm |
|---|---|

- **Rocker arm shaft diameter**

With an outside micrometer, measure the rocker arm shaft diameter at the point where the rocker arms have been installed.

Replace the rocker arm if the amount of wear is beyond the specified limit.




| Standard | Limit |
|---|---|
| ϕ24.939 ~ ϕ24.960 mm | ϕ24.90 mm |

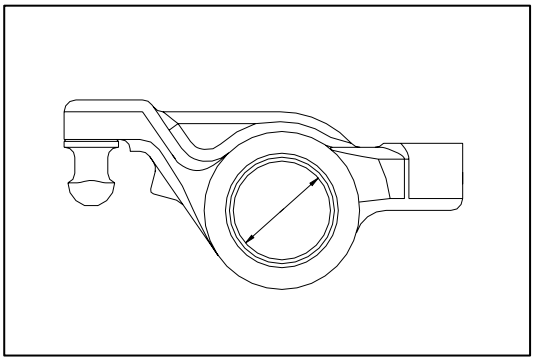
### 2) Rocker arm

- **Visual check**

Visually check the face of the rocker arm in contact with the valve stem end for scores and step wear. If the wear is small, correct it with an oil stone or grinding paper of fine grain size. Rocker arm with a considerable amount of step wear should be replaced.

- **Rocker arm bushing diameter**

Measure the inside diameter of the rocker arm bushing with an inside micrometer or vernier calipers, and compare the measured values with the rocker arm shaft diameter. If the clearance exceeds the limit, replace either bushing or shaft, whichever worn more.



| Standard | Limit |
|---|---|
| ϕ24.991 ~ ϕ25.012 mm | ϕ25.04 mm |

| | Standard | Limit |
|---|---|---|
| Rocker arm and shaft clearance | 0.031~0.073 mm | 0.14 mm or less |

### 3) Tappet and push rod

- **Clearance**

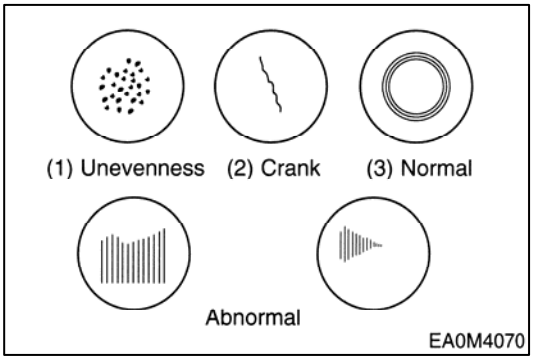
Measure the clearance of the tappet and tappet holes of the cylinder block. If the value is beyond the specified limit, replace tappets.

| Standard | Limit |
|---|---|
| 0.028 ~ 0.069 mm | 0.13 mm |

- **Visual check of tappet**

Visually check the face of the tappets in contact with the cam for pitting, scores or cracks, and replace if severely damaged.

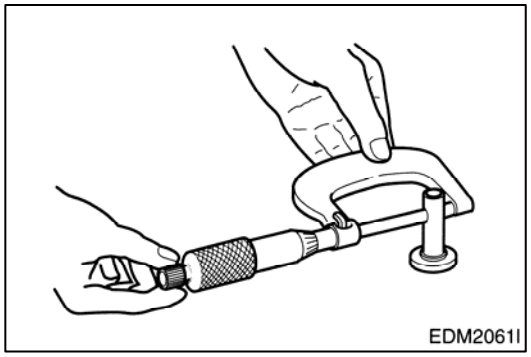
If the amount of cracks or pitting is small, correct with an oil stone or grinding paper.




- **Outside diameter of tappet**

With an outside micrometer, measure the tappet outside diameter if the measured value is beyond the limit, replace tappets.

| Standard | ϕ27.962 ~ ϕ27.982 mm |
|---|---|

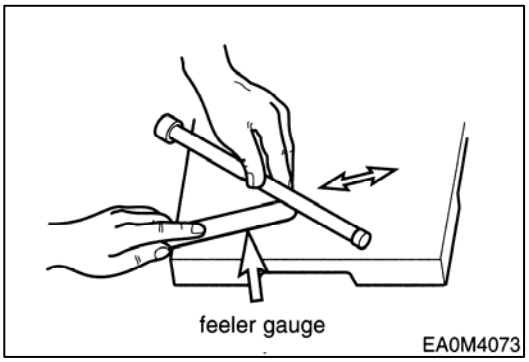



- **Push rod run-out**

Use a feeler gauge to measure the push rod run-out.

Roll the push rod along a smooth flat surface as shown in the figure.

| Limit | 0.25 mm or less |
|---|---|
| Push rod length | 344 mm |



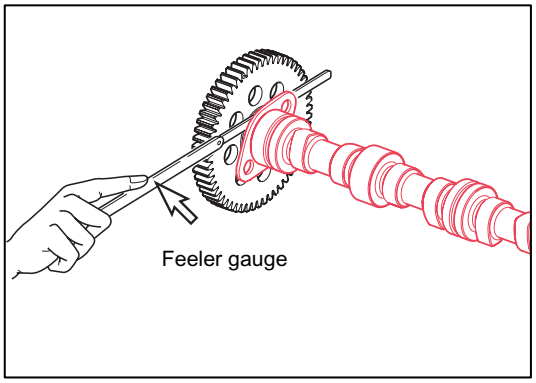
#### 4) Rocker arm assembly

- Reassembling can be done in the reverse order of disassembling and following things should be heeded.
- Check the oil supply hole of rocker arm shaft for any clog and clean thoroughly.
- Be careful, not to occur any swap of position and reverse assembly.

### 3.2.4. Camshaft

#### (1) Camshaft end play

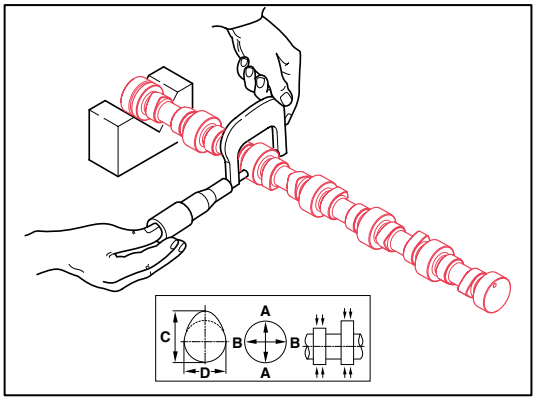
- Push the camshaft gear toward the opposite cylinder block.
- With a feeler gauge, measure the clearance between the thrust plate and camshaft gear.
- If the end play is excessive, replace the thrust plate.




| Standard | Limit |
|---|---|
| 0.280 ~ 0.430 mm | 0.5 mm |

#### (2) Cam

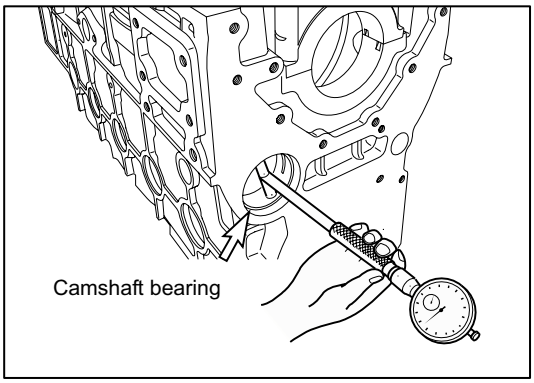
- Use a micrometer to measure the cam lobe height and journal diameter.
- If the measured number is less than the specified limit, the camshaft must be replaced.




| | | Standard | Limit |
|---|---|---|---|
| Cam lobe height (C) | Intake | 46.025 mm | 45.73 mm |
| | Exhaust | 47.782 mm | 47.48 mm |
| Cam journal diameter (A,B) | | ϕ55.92~ϕ55.95mm | ϕ55.65 mm |

- Inspect the cam face for scratch or damage.
- Slight step wear or damage on the cam face may be corrected with oil stone or oiled grinding paper. But, replace if severely damaged.

### (3) Between camshaft journal and camshaft bush



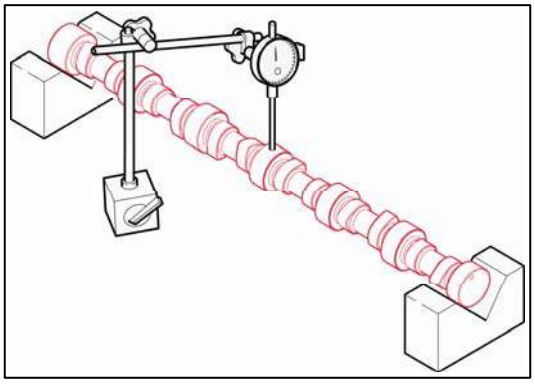

- With an outside micrometer, measure the camshaft journal diameter.
- Measure the inside diameter of the camshaft bushing on the cylinder block using a cylinder bore indicator, and compare the measured value with the camshaft outside diameter to determine the clearance.

**< Clearance >**

| Standard | Limit |
|---|---|
| 0.03 ~ 0.09 mm | 0.18 mm |

- Replace the bushing if the measured value is beyond the specified limit.

### (4) Cam shaft run-out



- Support the camshaft on two V-blocks and check for run-out using a dial indicator. Correct or replace the cam shaft if the amount of run-out is beyond the value indicating need for servicing.

| Standard | Limit |
|---|---|
| 0.05 mm | 0.15 mm |

### 3.2.5. Crankshaft

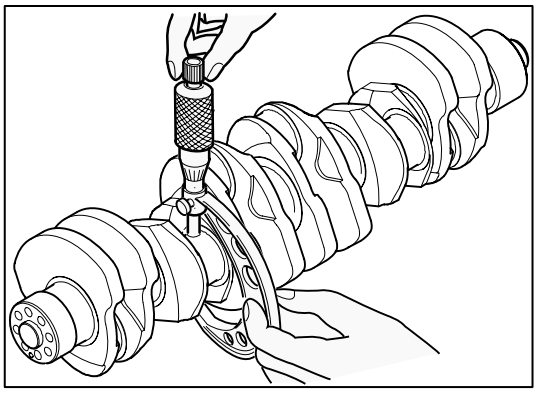
#### (1) Inspection of crankshaft

##### 1) Defect check

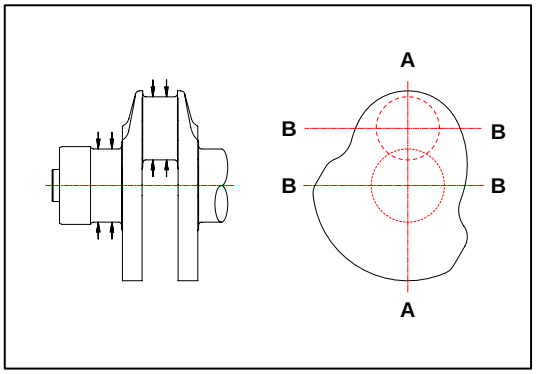
- By naked eyes, check for any scratch or damage on the crankshaft journal and crank pin.
- By means of magnetic particle test and color check, check the crankshaft for any crack and if found, replace it.

##### 2) Wear measuring

- With an outside micrometer measure the diameter of the crankshaft journals and pins in the directions as shown, and compare the measured values to determine the amount of wear.

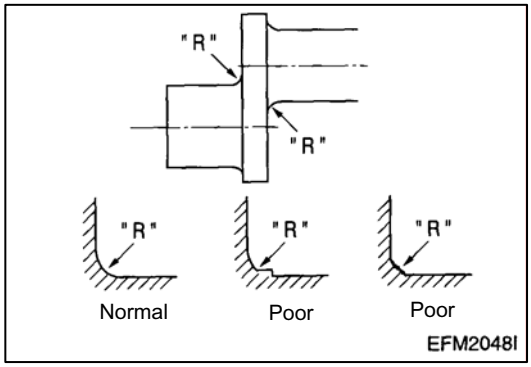


- If the amount of wear is beyond the limit, have the crankshaft ground and install undersize bearings. However, if the amount of wear is within the limit, you can correct the wear using an oil stone or oiled grinding paper of fine grain size. (Be sure to use grinding paper which has been immersed in oil.)



| | Standard | Limit |
|---|---|---|
| Journal diameter | ϕ79.905~ϕ79.925mm | ϕ78.905 mm |
| Pin diameter | ϕ68.924~ϕ68.944mm | ϕ67.924 mm |

- In case that pin's wear is more than the limit value, grind the crankshaft journal and crank pin, and use the undersized bearings.
- Be sure to use grinding paper which has been immersed in oil.




"R" part's specified value
① Crank pin's "R" : 3.3~3.7
② Crank Journal "R" : 3.3~3.7

**< Undersize bearings available >**

- ◆ Standard
- ◆ 0.25 (Inside diameter is 0.25 mm lesser than the standard size)
- ◆ 0.50 (Inside diameter is 0.50 mm lesser than the standard size)
- ◆ 0.75 (Inside diameter is 0.75 mm lesser than the standard size)
- ◆ 1.00 (Inside diameter is 1.00 mm lesser than the standard size)

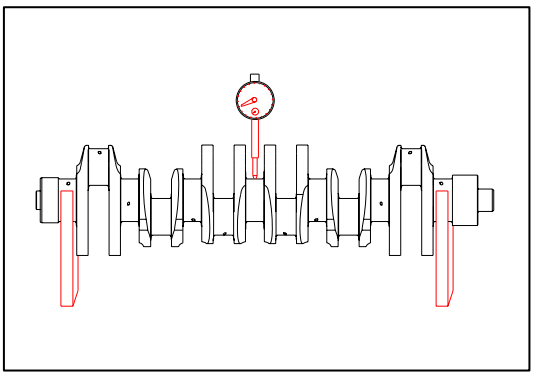
Undersize bearings are available in 4 different sizes as indicated above, and the crankshaft can be reused through the regrinding as described above.

**CAUTION :**

**In case of regrinding, the grinding the "R" part of bearing end should be correctly done and avoid sharp corners or insufficient fillet.**

### 3) Crankshaft run-out

- Support the crankshaft on V-blocks.
- Turn the crankshaft with a dial indicator placed on the surface plate and take the amount of crankshaft run-out.



| Standard | Limit |
|---|---|
| 0.06 mm | Less than 0.15 mm |

## (2) Crankshaft bearing and connecting rod

### 1) Visual check

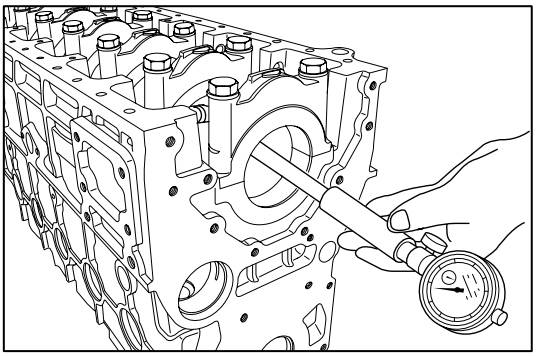
- Visually check the crankshaft bearing and connecting rod bearing for scratch, uneven wear or damage.

### 2) Oil clearance between crankshaft and bearing

**(Method 1 : dial gauge)**

- **Main bearing clearance**

Install the main bearing in the cylinder block, tighten the bearing cap to specified torque, then measure the inside diameter



| Torque | 30±2 kg.m |
|---|---|

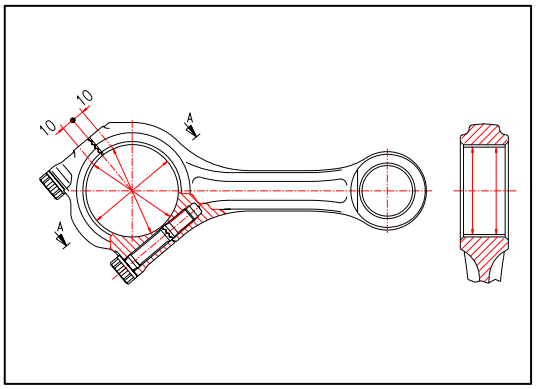
Compare the two values obtained through measurement of main bearing inside diameter with the outside diameters of crankshaft journals to determine the oil clearance.

**<Main bearing oil clearance>**

| Standard | Limit |
|---|---|
| 0.045 ~ 0.110 mm | 0.15 mm |

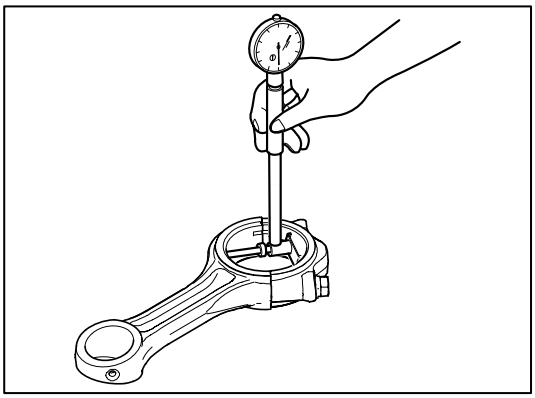
- **Connecting rod bearing clearance**

Install the connecting rod bearing in the connecting rod bearing cap, tighten the connecting rod cap bolts to the specified torque, then measure the inside diameter.




| Torque | 9.75±0.25kg.m |
|---|---|

- Compare the two values obtained through measurement of connecting rod bearing inside diameter with the outside diameters of crankshaft pins to determine the oil clearance.



| Standard | Limit |
|---|---|
| 0.030 ~ 0.081 mm | 0.15 mm |

- If the clearance deviates from the specified range, have the crankshaft journals and pins ground and install undersize bearings.

### 3) Oil clearance between crankshaft and bearing

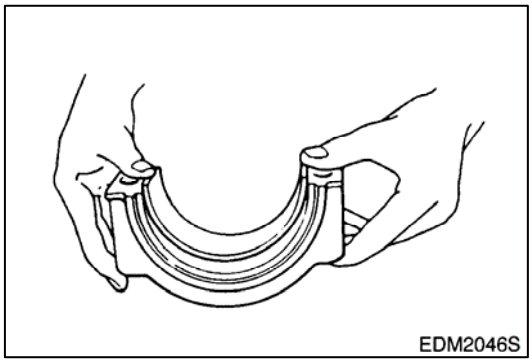
**(Method 2 : plastic gauge)**

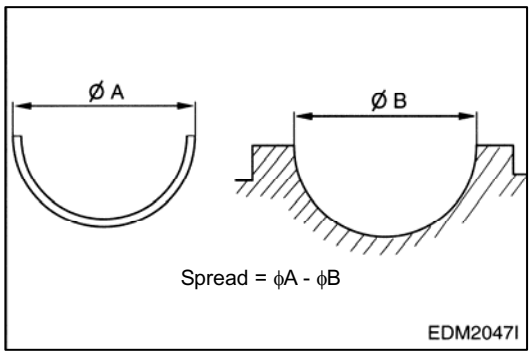
- Assemble the crankshaft on the cylinder block and put plastic gauge on the journal and pin of crankshaft and then after assembling bearing cap, tighten the bolts at the specific torque.
- Again after disassembling the bearing cap by removing the bolts, take out the flatted plastic gauge and measure the width of plastic gauge by means of plastic gauge measuring scale. This is the oil clearance.

### 4) Bearing spread and crush

- **Inspection**

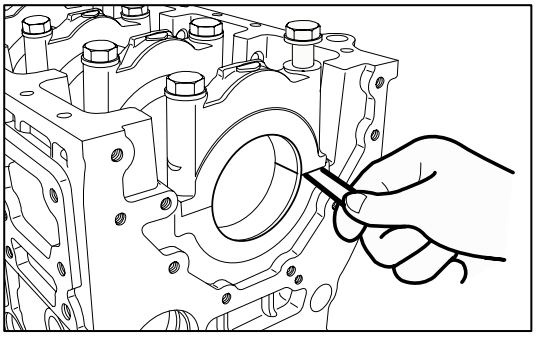
  Check to see that the bearing requires a considerable amount of finger pressure at reassembly operation.



- **Crankshaft bearing crush**

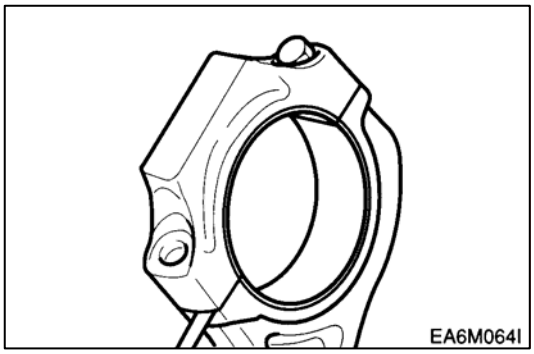
Install the bearing and cap in the cylinder block, retighten the bolts to specified torque, unscrew out one bolt completely, then measure the clearance between the bearing cap and cylinder block using a feeler gauge.



| | |
|---|---|
| Standard | 0.065 ~ 0.105 mm |

- **Connecting rod bearing crush**

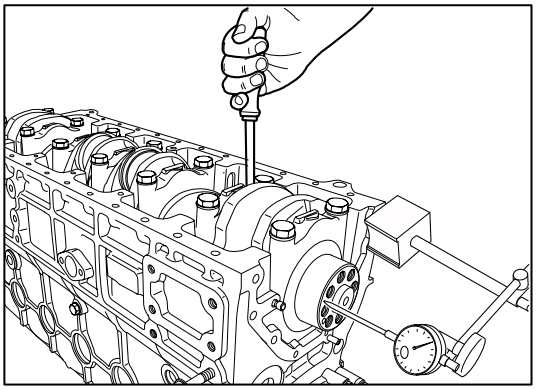
Install the bearing and cap in the connecting rod big end, retighten the bolts to specified torque, unscrew out one bolt completely, then measure the clearance between the bearing cap and connecting rod big end using a feeler gauge.




| | |
|---|---|
| Standard | 0.085 ~ 0.125 mm |

**5) Crank shaft end play**

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



| Standard | Limit |
|---|---|
| 0.14 ~ 0.33 mm | 0.4 mm |

### 3.2.6. Maintenance of cylinder liner and piston

#### (1) Piston inspection

##### 1) Disassembly of piston assembly

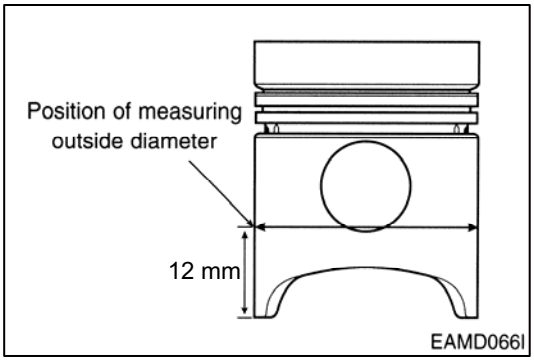
Disassemble piston according to the disassembly process.

##### 2) Visual check

Visually check the pistons for cracks, scuff or wear, paying particular attention to the ring groove.

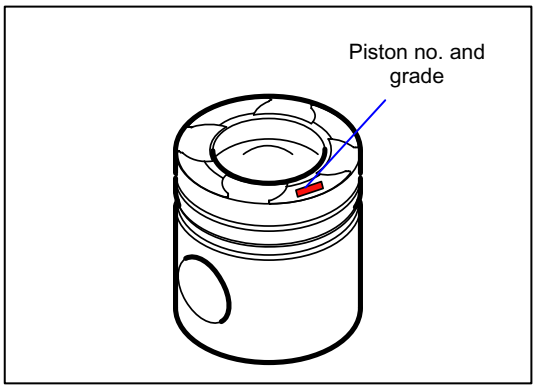
##### 3) Piston outside diameter

- With an outside micrometer, measure the piston outside diameter at a point 12 mm away from the lower end of piston skirt in a direction at a right angle to the piston pin hole.



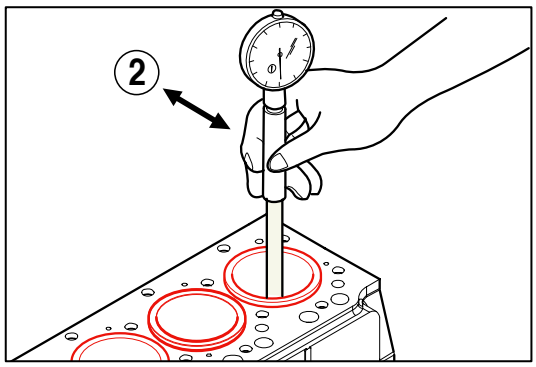

- **Grade selection of piston**

| Standard | Grade marks |
|---|---|
| ϕ99.93 ~ ϕ99.941 mm | A |
| ϕ99.941 ~ ϕ99.952 mm | B |



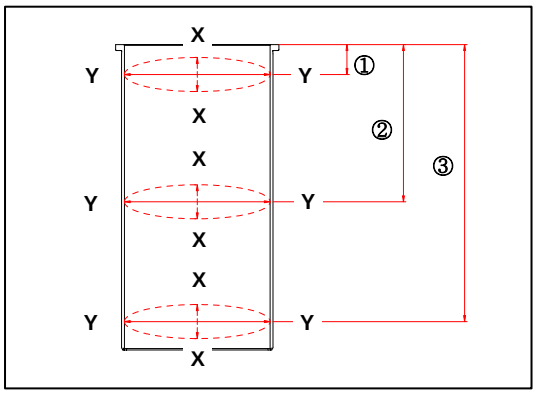

a) ”Piston grade” refers to the piston diameter and the cylinder liner bore combination.
b) Selection of the proper piston grade will ensure efficient engine operation, free from cylinder liner and piston problems.
c) Determine the appropriate piston grade after measuring cylinder liner bore.

### (2) Cylinder liner bore measurement




- Measure cylinder liner bore at measuring points ①, ② and ③ two different directions (X-Y and Y-Y).

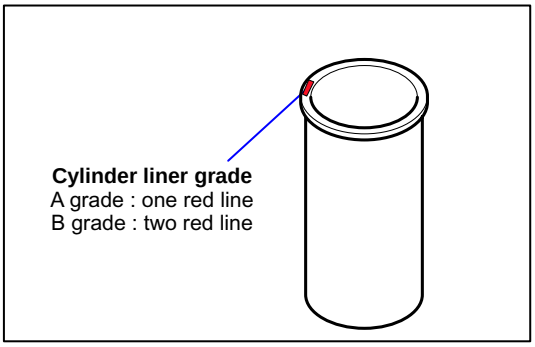
- **Measure points:**
  - ① 20 mm
  - ② 105 mm
  - ③ 185 mm




- Take the mean value with the largest and smallest values excepted.
- Calculate the average value of 6 measurements to determine the correct cylinder liner grade.

- **Grade selection of cylinder liner**

| Standard | Grade marks |
|---|---|
| ϕ100.020 ~ ϕ100.031 mm | One red line (A) |
| ϕ100.031 ~ ϕ100.042 mm | Two red line (B) |




- **Clearance between piston and liner**

| | |
|---|---|
| Standard | 0.079 ~ 0.101 mm |

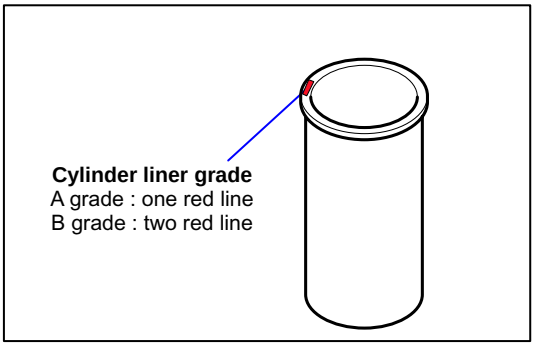
### (3) Maintenance of cylinder liner and piston

To maintain the engine in optimum condition and retain maximum performance for a long time, cylinder liner and piston which have the same grade marking number (the same size tolerance) should be assembled. The marking number (the part's grade) and marking position is as follows.

#### 1) Cylinder liner grade

Marking position; Cylinder liner upper surface

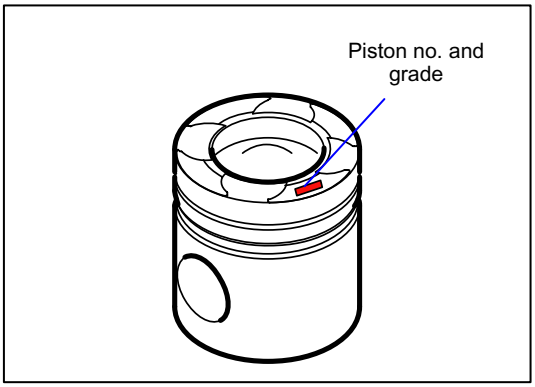
- **A** grade cylinder : one red line
  (Can used the piston **A** grade)
- **B** grade cylinder : two red line
  (Can used the piston **B** grade)




#### 2) Piston grade

Marking position; side of the piston upper surface

- **A** grade piston; **A** mark
  (Can used the cylinder liner **A** grade)
- **B** grade piston; **B** mark
  (Can used the cylinder liner **B** grade)




#### 3) Assembly process of cylinder liner and piston

(1) Check the marking number (**A** or **B**) of cylinder liner. (Top of upper surface)

(2) Assemble the piston whose marking is just same with the digit (**A** or **B**) of the assembled cylinder liner's marking.

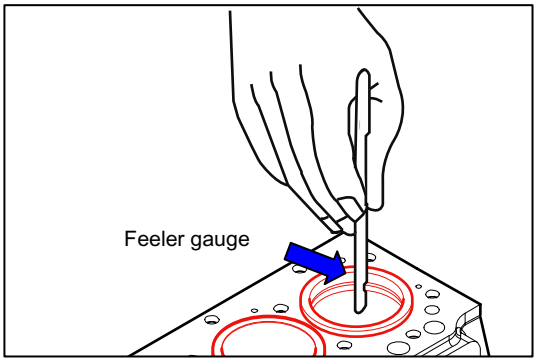
### (3) Piston rings

#### 1) Visual check

- Replace the piston rings with new ones if detected worn or broken when the engine is overhauled.

#### 2) Piston ring gap

- Insert the piston ring into the upper portion of the cylinder liner bore so that it is held at a right angle to the cylinder liner wall.
- Measure the piston ring gap with a feeler gauge.

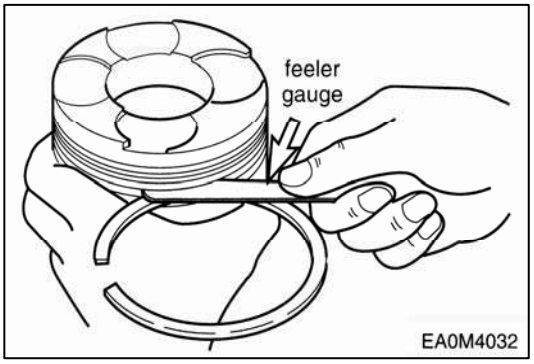



| | Standard | Limit |
|---|---|---|
| 1st ring | 0.30 ~ 0.45 mm | 1.5 mm |
| 2nd ring | 0.60 ~ 0.80 mm | 1.5 mm |
| Oil ring | 0.25 ~ 0.45 mm | 1.5 mm |

- Replace piston rings with new ones if the gap is beyond the limit.

#### 3) Piston ring side clearance

- Fit the compression ring and oil ring in the piston ring groove.
- With a feeler gauge, measure side clearance of each ring, and replace either the ring or piston if the measured value is beyond the specified limit.




| | Standard | Limit |
|---|---|---|
| 1st ring | - | - |
| 2nd ring | 0. 05 ~ 0.09 mm | 0.15 mm |
| Oil ring | 0.03 ~ 0.07 mm | 0.15 mm |

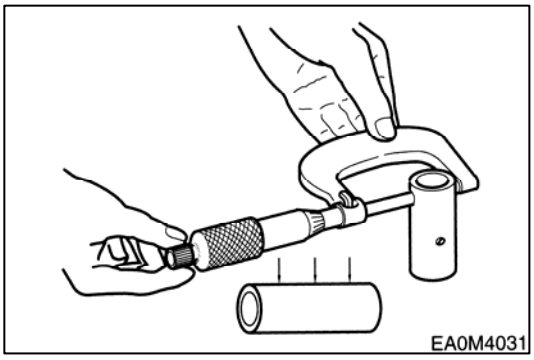
### 4) Piston ring tension

- With a tension tester, measure piston ring tension. Replace the piston ring if the measured value is beyond the limit.

| | Standard |
|---|---|
| 1st ring | 1.47 ~ 2.21 kg |
| 2nd ring | 1.49 ~ 2.23 kg |
| Oil ring | 4.08 ~ 5.52 kg |

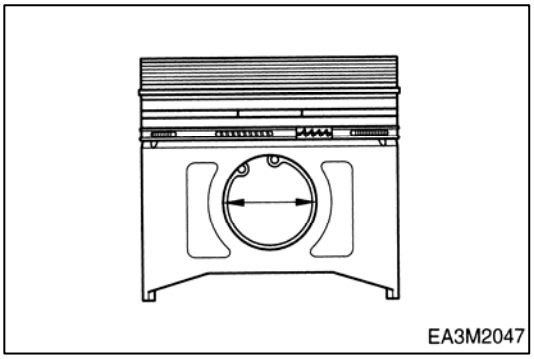
## (4) Piston pin inspection

- Measure the amount of wear on the piston pin at the points as shown.
- The measured values are beyond the limit (0.08 mm or greater), replace the piston pin.




| Standard | Limit |
|---|---|
| ϕ39.994 ~ ϕ 40.000 mm | ϕ 39.94 mm |

- Measure the clearance between the piston pin and connecting rod bushing, and replace either of them, whichever damaged more, if the measured value is beyond the limit.




| Standard | Limit |
|---|---|
| 0.006 ~ 0.020 mm | 0.08 mm |

- When replacing the piston, be sure to replace the piston pin together.

### (5) Connecting rod inspection

#### 1) Distortion

- Check the connecting rod for distortion. As shown in the figure below, install the connecting rod to the connecting rod tester, and check for distortion using a feeler gauge.
- If the connecting rod is found distorted, never re-use it but replace with a new one.

#### 2) Holes alignment (parallelism)

- Measure the alignment of the connecting rod piston pin bushing holes with connecting rod big end holes.

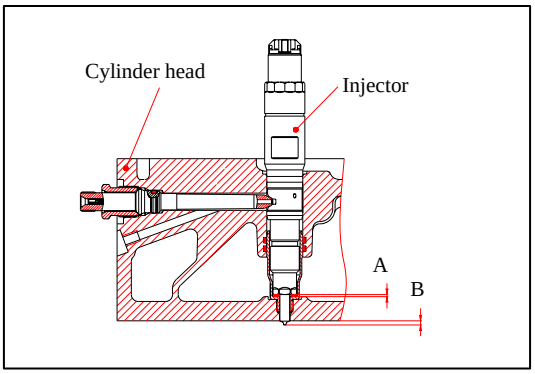
| Standard | Limit |
|---|---|
| 0.02 mm | 0.1 mm or less |

#### 3) Wear

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

| Standard | Limit |
|---|---|
| 0.170 ~ 0.30 | 0.50 mm |

### 3.2.7. Projection of injector




- Insert a seal ring on the cylinder head and assemble the injector. (Refer to 3.3 chapter for assembly order)
- Measure the clearance between the cylinder head bottom and injector tip. If the measured valves are beyond the limit, replace the seal ring.

| | |
|---|---|
| **A**<br>(Thickness of seal ring) | 2.0 mm |
| **B**<br>(Projection of nozzle) | 3.0 mm |

## 3.3. Engine Reassembly

### 3.3.1. General precautions

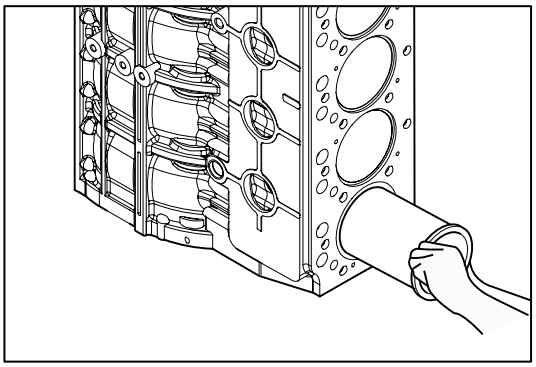
- Clean all the disassembled parts, particularly oil and water ports, using compressed air, then check that they are free from restrictions.
- Arrange the general and special tools in order for engine assembly operation.
- To wet each sliding part, prepare the clean engine oil.
- Prepare service materials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

### 3.3.2. Cylinder block

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

### 3.3.3. . Cylinder liner

- Stand the cylinder block so that the flywheel faces downward.
- Thoroughly clean the liner flange fitting surface and bore inside with compressed air to prevent the entry of foreign substances.

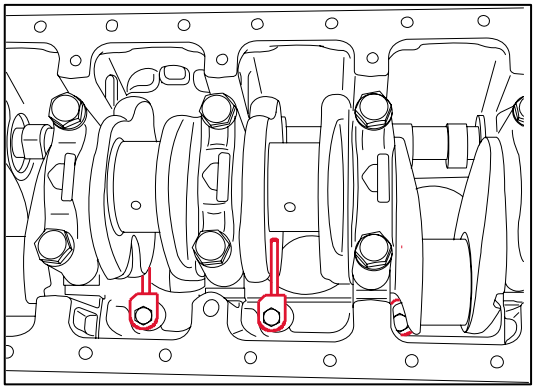


- After the cleaning operation, make the cylinder liner dried up and push it into the cylinder block by hand.
- Wet the liner inside diameter with engine oil.

### 3.3.4. Oil spray nozzle

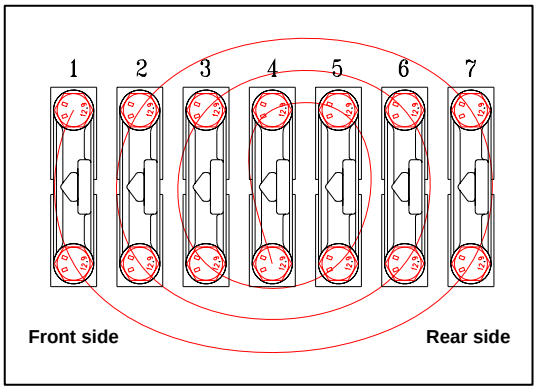
- Assemble the oil spray nozzle on the cylinder block with relief valve.

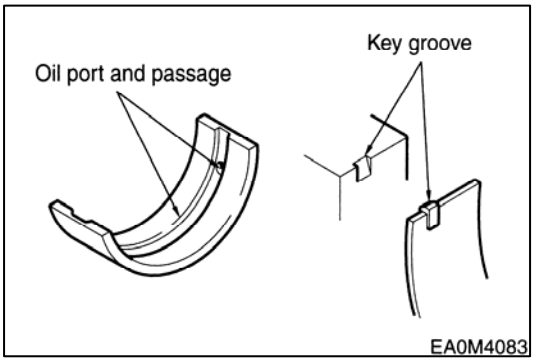
| | |
|---|---|
| Torque | 2.1+0.5 kg.m |



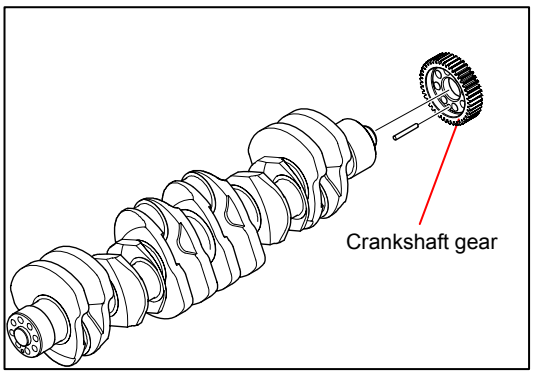
### 3.3.5. Crankshaft

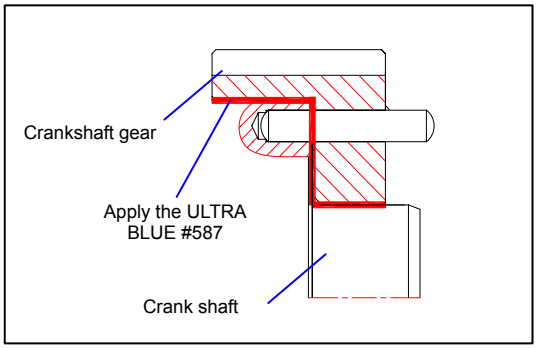
- Install the main bearing (refer to assemble sequence : right figure) machined with two holes in the cylinder block so that the key is aligned with the key groove, then apply oil to the bearing surface.



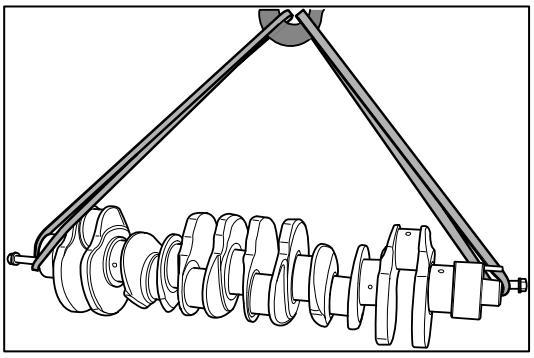



- Put the crankshaft gear into the heater to heat it up to 150°C level for 10 minutes, push it over the crankshaft by means of a jig.

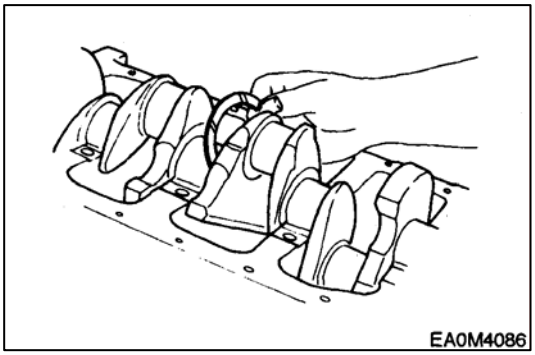


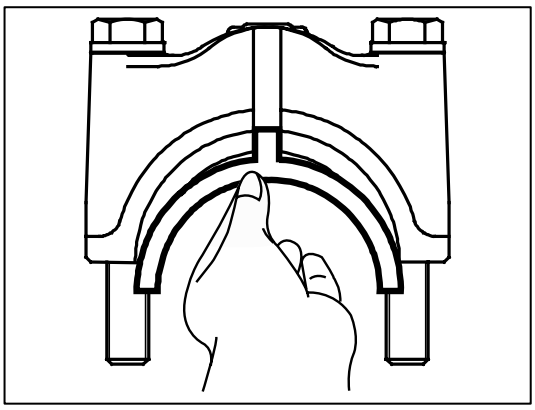

- Semi-tighten bolts at both sides of the crankshaft, apply engine oil to journals and pins, then assemble the crankshaft with the cylinder block by tightening the fixing bolts.
- Coat engine oil to the pin and journal of crankshaft.



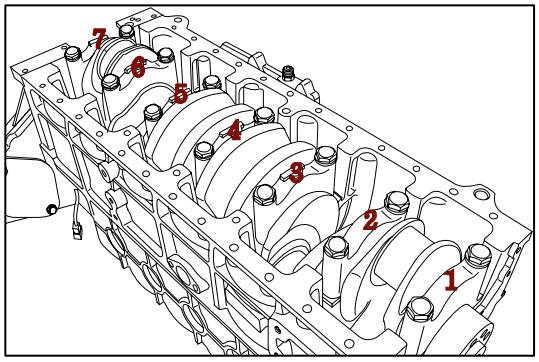
- Install the oiled thrust washers with the oil groove facing outward.



- Install the bearing and thrust washers to the bearing cap and apply oil to the bearing and thrust washers.

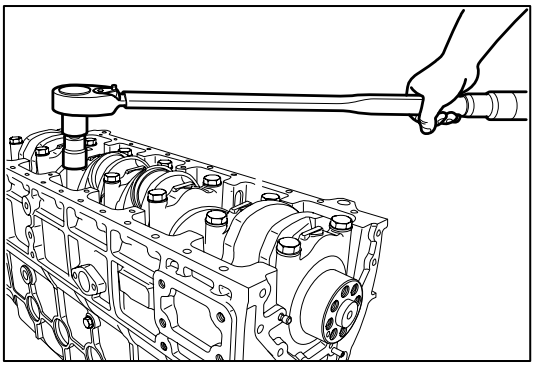


- Install the bearing cap by matching the cylinder block No. with the bearing cap No.



- Apply oil to the entire part of the bearing cap bolts, then tighten in tightening sequence to specified torque.

| | |
|---|---|
| Torque | 30±2 kg.m |



- After semi-tightening both bolts evenly, tighten them diagonally to the specified torque using a torque wrench as follows.

**<Tightening Order>**

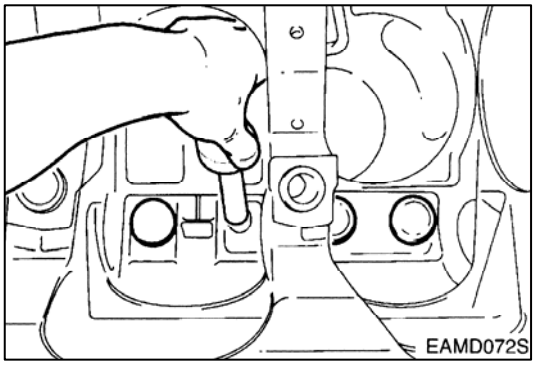
**(1) First stage : Coat the cap bolts with engine oil**
**(2) Second stage : Temporary bolt screwing about 1 ~ 2 threads**
**(3) Third stage : With impact wrench, tighten up to about 15 kg.m**
**(4) Fourth stage : With torque wrench, tighten up to about 25 kg.m**
**(5) Fifth stage : By means of torque wrench, tighten finally in the specified**

**torque. (30±2 kg.m).**

- Tighten the bearing cap in the sequence of **4 – 3 – 5 – 2 – 6 – 1 - 7**.
- Check to see that the assembled crankshaft turns smoothly with hand.

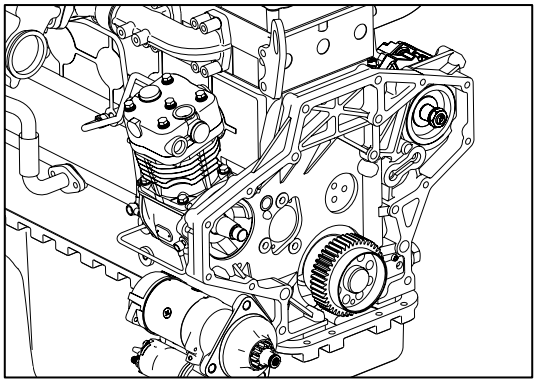
### 3.3.6. Tappet & cam shaft

- Undercool a new bush with dry ice for about 2 hours and press it into position in the cylinder block using a bench press. After the pressing operation, measure the inside diameter of the cam bush to check if it is not deformed.
- Apply engine oil to the entire face of the tappets and slide them into the tappet holes on the cylinder block.

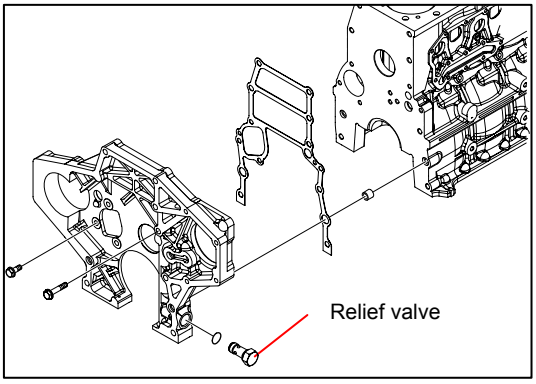



### 3.3.7. Timing gear case

- Mount a new gasket using dowel pin on the cylinder block.
- Put the time gear case to the cylinder block by aligning the dowel pin hole of timing gear case with its pin, and then assemble it by tapping lightly with an urethane hammer to the right and left. (Particularly around dowel pin)



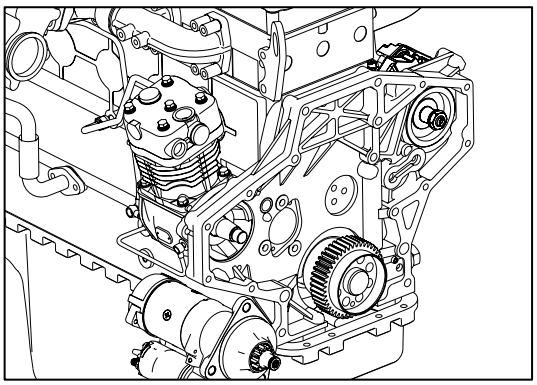
- Tighten the bolts for assembling to the specified torque.
- However, in case of tightening the bolts, tighten primarily the bolts of both end parts and then do the rest.



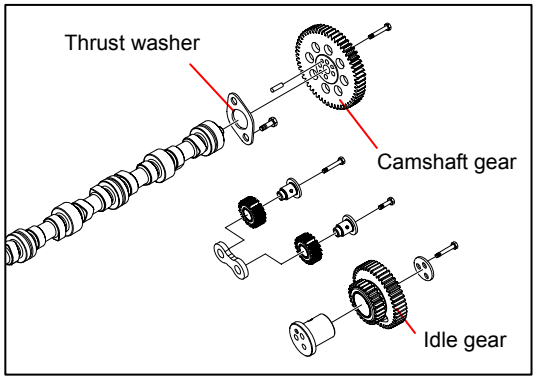

| | |
|---|---|
| Relief valve | 2.6 +0.5 kg.m |
| Timing gear case fixing bolt | 4.4 +0.5 kg.m |

### 3.3.8. Gear system

- Install a thrust washer over the camshaft and assemble the cam gear by aligning it with camshaft dowel pin.
- Tighten the cam gear fixing bolts to the specified torque.

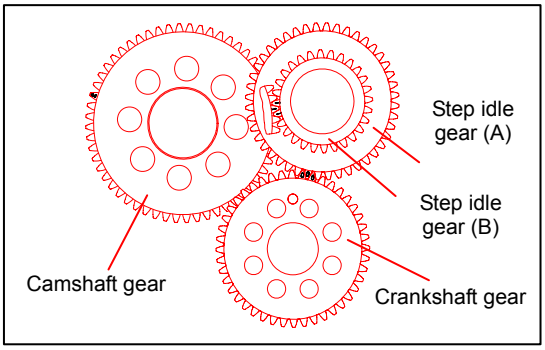


| | |
|---|---|
| Camshaft thrust washer | 1.0 +0.1 kg.m |
| Camshaft gear fixing bolt | 3.1 +0.5 kg.m |




- Assemble in order that camshaft gear → step idle gear → high pressure pump idle gear → high pressure pump gear

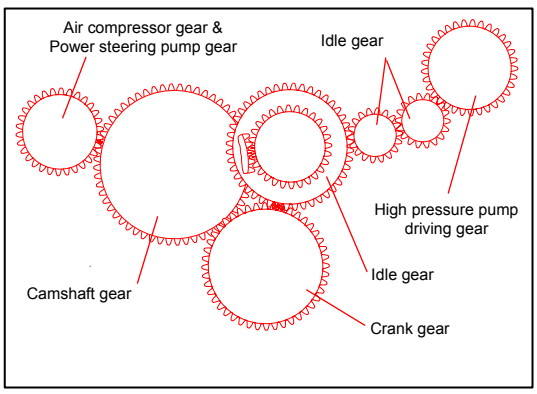
- Install the idle gear by aligning the marks impressed on the crankshaft gear and camshaft gear.
- When install the step idle gear pin, align the oil port of step gear pin toward lower side.




**<Gear aligned mark>**

| | |
|---|---|
| Crankshaft gear and step idle gear (A) | **"0" and "0"** |
| Step idle gear (B) and Camshaft gear | **"1" and "1"** |

| | |
|---|---|
| Step idle gear | 6.2 +0.5 kg.m |
| High pressure idle gear | 6.2 +0.5 kg.m |



- Check the amount of backlash between gears using a feeler gauge.

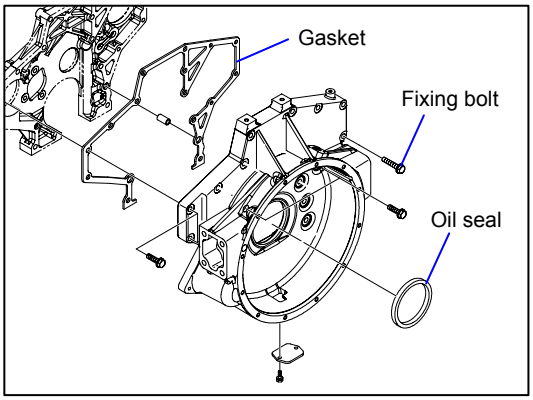
**< Back lash >**

| Measuring position | Standard |
|---|---|
| Cam shaft gear & idle gear | 0.074 ~ 0.163 mm |
| Fuel high pressure pump gear & idle gear | 0.103 ~ 0.182 mm |
| Crankshaft gear & oil pump driving gear | 0.073 ~ 0.239 |
| Air compressor driving gear & cam gear | 0.074 ~ 0.163 |

**< End play >**

| Measuring position | Standard |
|---|---|
| Cam shaft gear | 0.280 ~ 0.430 mm |
| Step idle gear | 0.107 ~ 0.183 mm |
| Fuel high pressure pump idle gear | 0.078 ~ 0.140 mm |

### 3.3.9. Flywheel housing



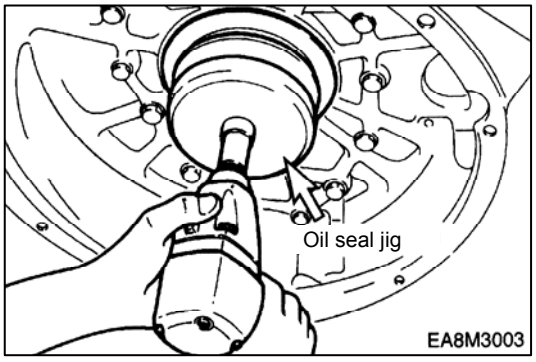

- Temporarily install the guide bar on the cylinder block.
- Apply gasket to the cylinder block.
- Using the dowel pin and guide bar, install the flywheel housing and tighten the fixing bolts in a diagonal sequence to specified torque. (Zigzag method)

| Torque | 11.2 +1.0 kg.m |
|---|---|

- When the bolts are tightened, remove the guide bar.
- Apply lubricating oil to the inside, outside of the oil seal and insert it to the flywheel housing using a press.

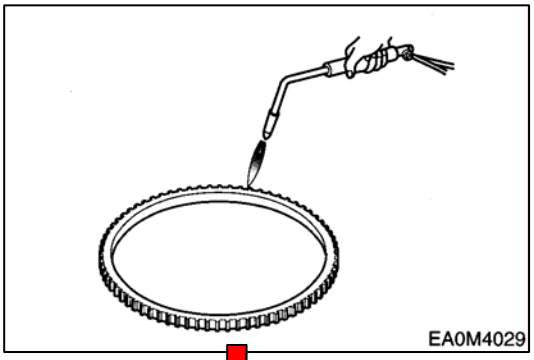
### 3.3.10. Oil seal (Rear side)

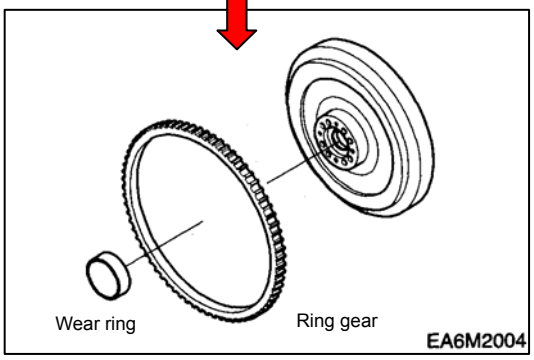
- Apply lubricating oil to the outside of the oil seal and flywheel housing inside diameter and fit them over the crank shaft, then assemble the oil seal using an oil seal fitting jig.

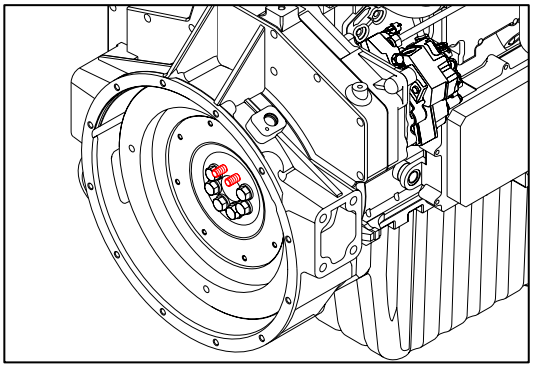



### 3.3.11. Fly wheel

- 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.
- Heat the wear ring at the 150°C in the heater and assemble the wear ring using an assembly jig after coat the loctite #262 on it.
- At the time assembling the wear ring, the direction of the cutting face of the circumference is the forward side.
- Install a guide bar into a bolt hole on the crank shaft, and lift the flywheel to align the dowel pin with the pin hole on the flywheel for temporary assembly operation.
- Coat the adhesive (#587 Loctite) over the fixing bolts and install bolts in the remaining holes. After that take out the guide bar, then install a bolt in the hole where the guide bar had been inserted.

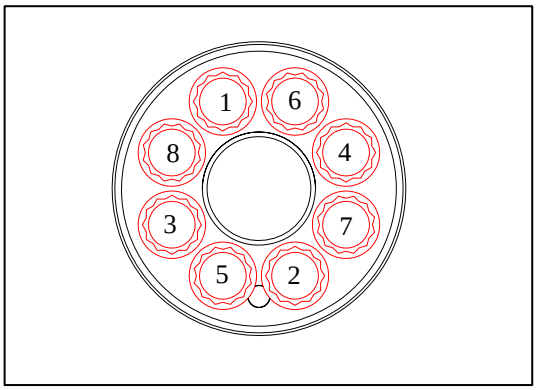


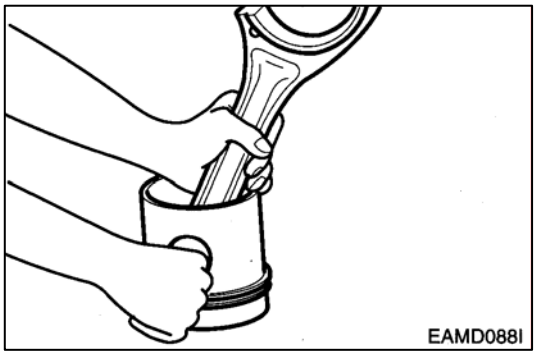
- According to the order of tightening tighten it using a torque wrench to specified torque.

| | |
|---|---|
| Bolt specification | M14 x 1.5 |
| Torque | 20 +2.0 kg.m |

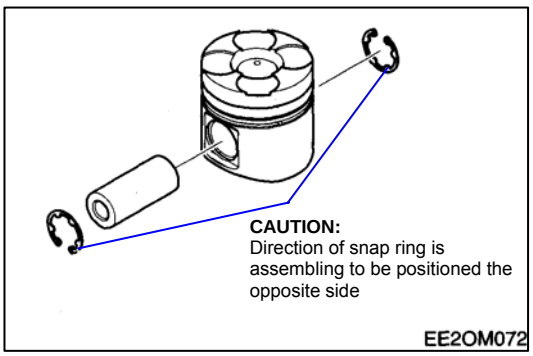



### 3.3.12. Piston & connecting rod

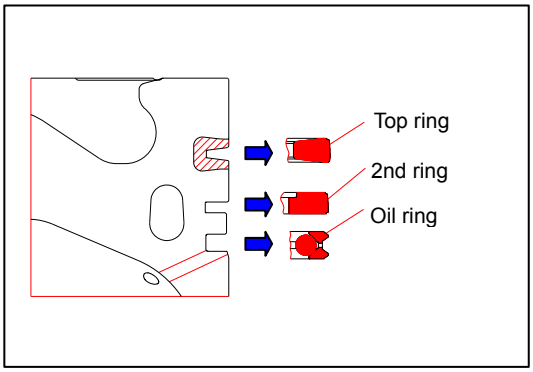
- In case of assembling the piston and connecting rod, assemble in align that the oil inlet hole side of the connecting rod small end is in the opposite direction from the oil gallery port side (big end) of the piston.

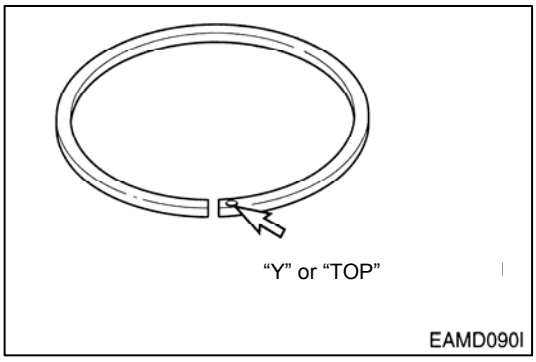



- Align the piston pin hole with the oiled connecting rod small end and press the piston pin (by lightly tapping with a rubber hammer) to assemble the connecting rod with the piston.
- Assemble in order that up side and down side of the open side for assembling of the snap ring is in the opposite direction each other.
- Install the snap rings and check to see that it is securely assembled.

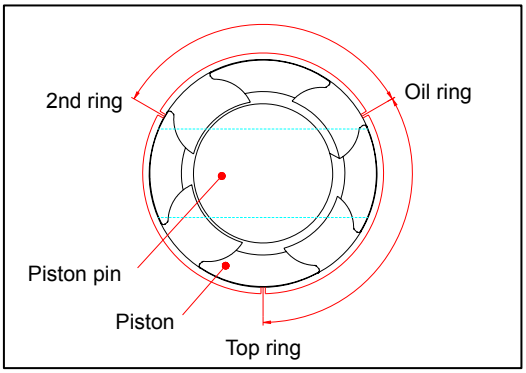


- Install the piston ring in the piston using piston ring pliers.
- Identify the mark "**Y**" or "**TOP**" on the ring end to prevent the top and bottom of the piston ring from being interchanged and make the marked portion face upward.

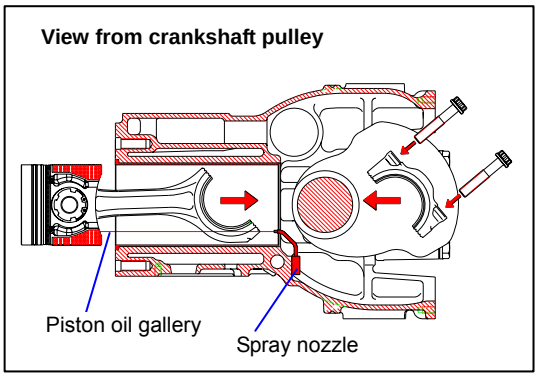


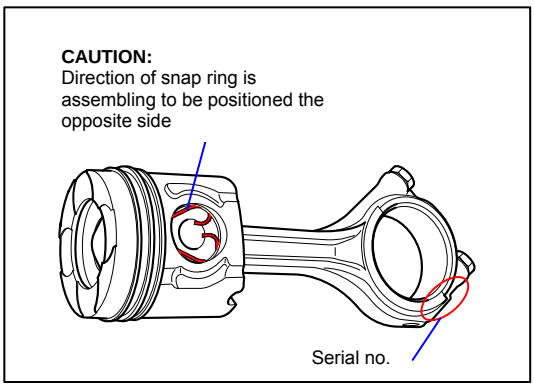

- Adjust the angle among individual piston ring gaps to 90° and fit a piston assembling jig onto the piston, use care not to match the ring gaps with the pin direction.
- Install the bearing by aligning it with the connecting rod key groove and apply oil to the bearing and piston.
- Insert the piston by aligning the oil gallery port with the direction of the spray nozzle.
- Use care not to damage the cylinder liner and piston, and slightly lift and insert the piston into the cylinder so that the ring may not be damaged by the fillet of the liner.



- Install the bearing in the connecting rod cap and apply oil.




- Make sure that the manufacture serial numbers impressed on the connecting rod cap and connecting rod big end are identical, and install the connecting rod cap by aligning it with dowel pin.
- Wet the fixing bolts with engine oil, semi-tighten them with hand, tighten them to the specified torque using a torque wrench as follows.

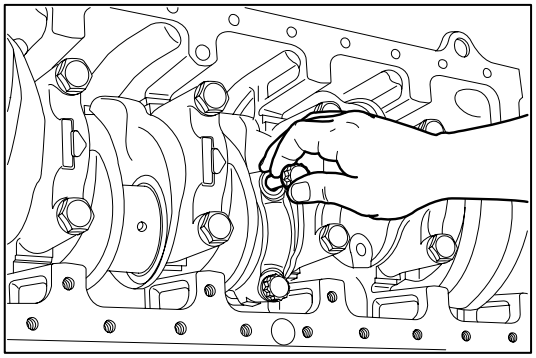



**<Tightening order>**

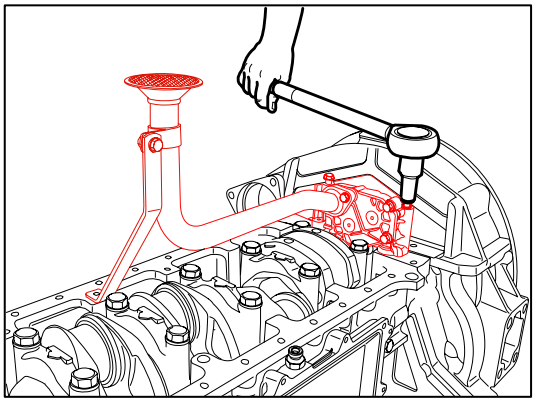
**(1) First stage : Coat engine oil over bolts.**
**(2) Second stage : Temporary bolt screwing about 1~2 threads**
**(3) Third stage : With torque wrench, tighten up to about 4 ~ 6 kg.m**
**(4) Fifth stage : With torque wrench, tighten finally up to 9.75+0.5 kg.m.**

| | |
|---|---|
| Torque | 9.75+0.25 kg.m |

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



### 3.3.13. Oil pump and oil pipe

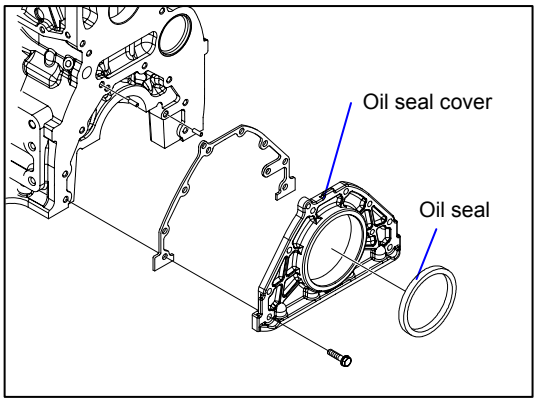


- Install a dowel pin in the oil seal holder, then assemble the oil pump by tapping lightly with urethane hammer.
- Tighten the fixing bolts with specified torque.

| | | |
|---|---|---|
| Torque | M8 | 2.2+0.5 kg.m |
| | M10 | 4.4+0.5 kg.m |

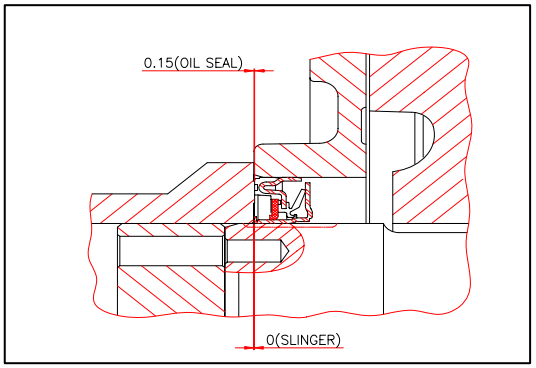
- Assemble the oil suction pipe with the delivery pipe to oil pump by the bolts.

### 3.3.14. Oil seal




- Apply lubricating oil to the outside of the oil seal and the oil seal hole of the timing gear case cover.
- Put the new oil seal on the oil seal hole of timing gear case cover aligning the center of them, then assemble the oil seal using an oil seal fitting jig.

| | |
|---|---|
| Torque | 2.2+0.5 kg.m |

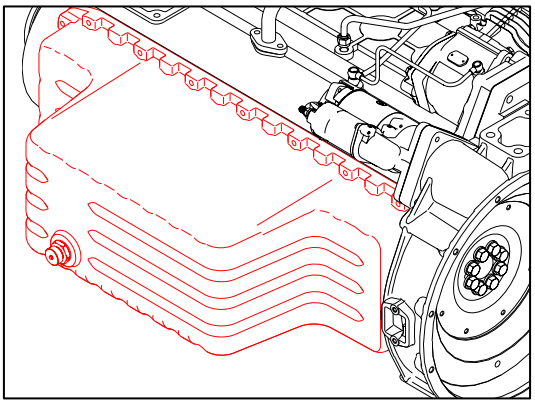


### 3.3.15. Oil pan

- Remove the gaskets thoroughly that project at the timing gear case, case cover of cylinder block, and the contacting part of flywheel housing by means of a scraper.

**CAUTION :**
**Be careful for the gasket pieces not fall into the engine during the work.**

- Coat the silicone at the gasket part that was removed (Contacting part), and attach the new oil pan gasket.
- Assemble the oil pan by tightening the oil pan fixing bolts, and when tightening bolts, primarily tighten the bolts (4ea) at the both ends and then tighten the rest bolts to specified torque.



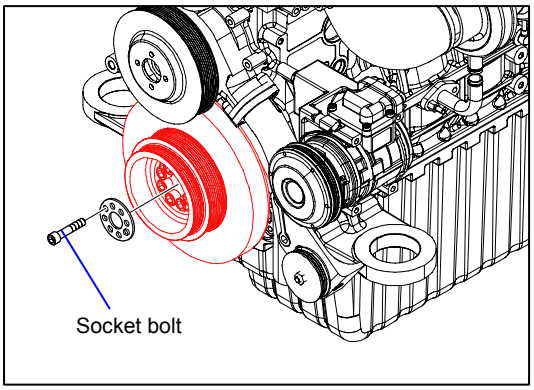
| | | |
|---|---|---|
| Torque | Oil pan | 2.2+0.5 kg.m |
| | Drain plug | 10+1.0 kg.m |

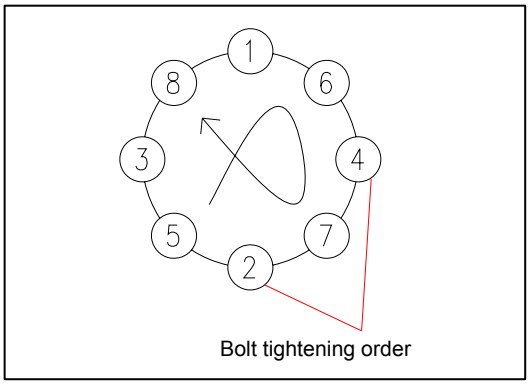
- Align the bolt holes with gasket holes to prevent damage to the gasket and tighten.

### 3.3.16. Crankshaft pulley & vibration damper

- Insert the vibration damper to the crankshaft, and assemble by tightening the assembling bolts at the specified tightening torque according to bolt tightening order.

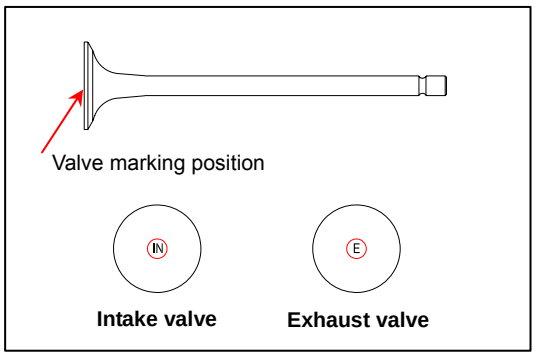
| | | |
|---|---|---|
| Torque | Damper | 6.2+0.5 kg.m |
| | Crankshaft pulley | 20+2.0 kg.m |



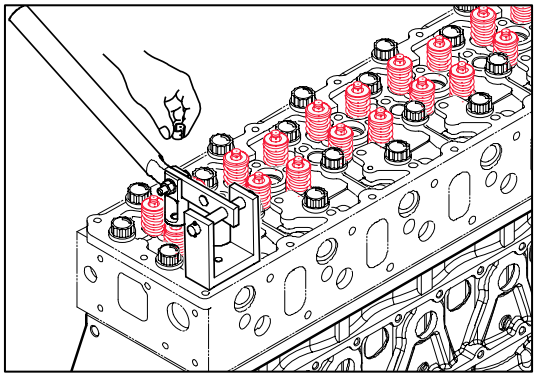




### 3.3.17. Intake and exhaust valves

- Identify the marks of "**IN**" and "**E**" 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.

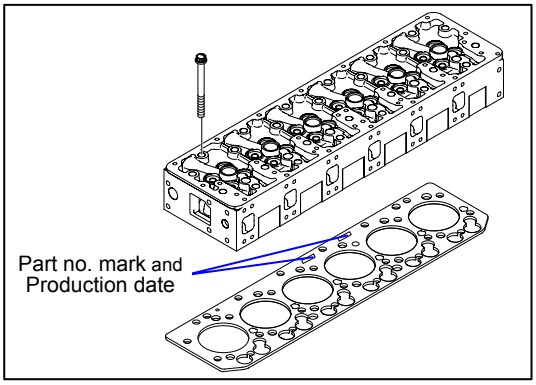



- After installing valve springs and spring retainer, press the retainer with a jig, then install the cotter pin.
- Tap the valve stem lightly with a rubber hammer to check that the valve is assembled correctly.

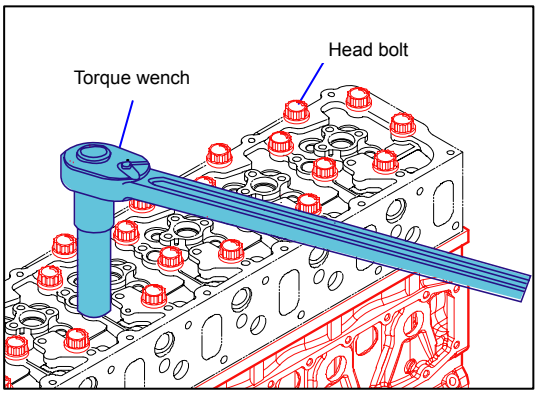


### 3.3.18. Cylinder head

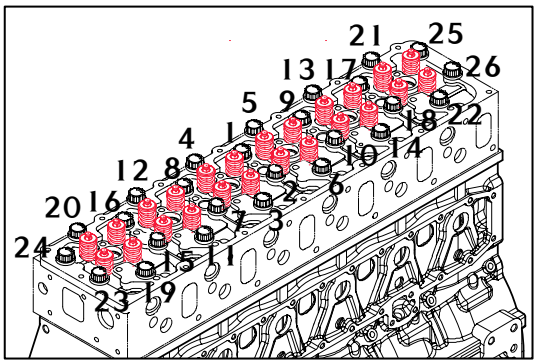
- Blow the bolt holes of cylinder block with a compressed air and remove the foreign matter.
- Clean the head gasket contact surface thoroughly. However, be careful for the foreign material not to enter into the combustion chamber.




- Assemble the new head gasket by aligning the holes with dowel pins of cylinder block with the right‘s mark facing upward.
- Check the inside of combustion chamber for foreign substances, and carefully mount the cylinder head in the block by aligning the dowel pin with the dowel pin hole.




- Be careful not to damage the cylinder head gasket. If the dowel pin is not in alignment, lift the cylinder head again and then remount it**.**
- After tightening the cylinder head bolts, even at disassembling, the cylinder head gasket should be changed a new one.
- Coat the cylinder head bolts with engine oil, and tighten in proper sequence to the specified torque according to bolt tightening order.



**< Cylinder head bolts >**

| | |
|---|---|
| Specification | M13×1.5×140 |
| Torque | 1st Tightening : 5 kg.m<br>2nd Tightening : 90°<br>3rd Tightening : 90°<br>Final tightening : 90° |

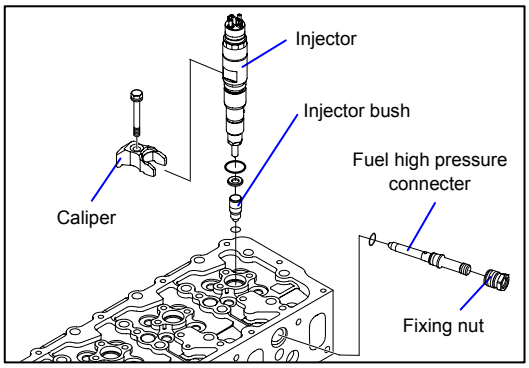
**< Tightening order of bolts by steps >**

**(1) First stage : Coat the bolts with engine oil.**
**(2) Second stage : Tighten 1 ~ 2 threads with hands.**
**(3) Third stage : Tighten about 5 kg.m with a wrench.**
**(4) Fourth stage : Tighten at rotating angle method 90° with a wrench.**
**(5) Fifth stage : Tighten at rotating angle method 90° with a wrench.**
**(6) Sixth stage : Finally, tighten at rotating angle method 90° with a torque wrench.**

- All bolts are tightened simultaneously by above steps.
- Coat the push rod with engine oil and insert it into the push rod hole.

### 3.3.19. Injector

- The injector should be assembled correctly by the following order.
- Put the O-ring into the injector and coat the circumference face of it with engine oil.
- The sealing set to injector hole of cylinder head, then the injector insert. (The side groove face of injector set to the fuel high pressure connector.)
- The injector set to injector fixing bracket with the fixing bolt, then assemble temporarily it.




| | | |
|---|---|---|
| Temporarily torque | Injector fixing bracket | Fuel high pressure connector fixing nut |
| | 0.3 kg.m | 0.25 kg.m |

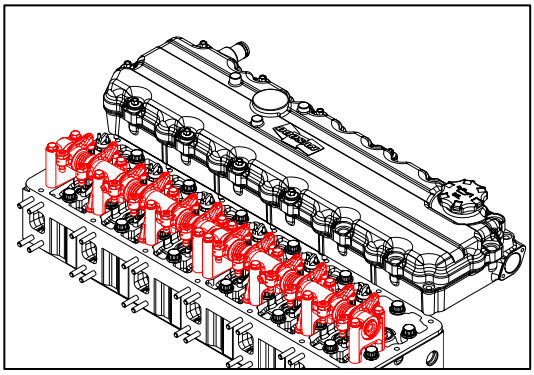
- Assemble the injector fixing bracket bolt with specified torque, and assemble the fuel high pressure connector fixing nut.

| | | |
|---|---|---|
| Torque | Injector fixing bracket bolt | 3.1+0.3 kg.m |
| | Fuel high pressure connector fixing nut | 5+0.5 kg.m |
| | Injector harness fixing nut | 0.15+0.01 kg.m |
| | Fuel over flow pipe fixing nut | 0.8 ~ 0.9 kg.m |

### 3.3.20. Rocker arm

- Apply lubricating oil to the rocker arm bush and shaft, and assemble the intermediate bracket with the rocker arm (rocker arm assembly) on the cylinder head using fixing bolts.

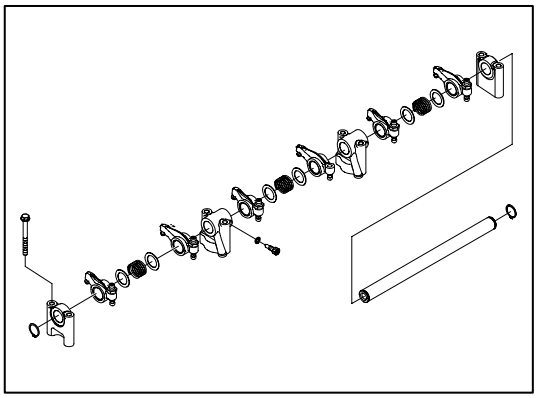
- In tightening the bolts, it must be done at the specified value using zigzag method.



| | |
|---|---|
| Torque | 3.7+0.5 kg.m |

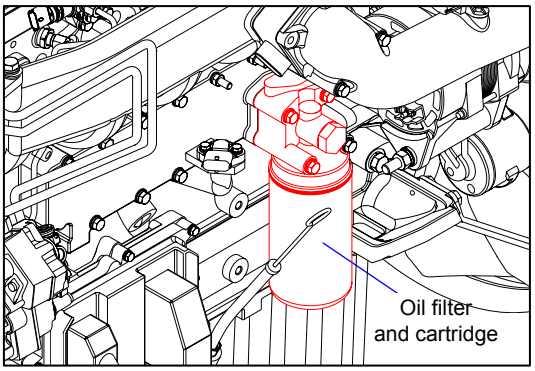
- Semi-install valve clearance adjusting bolts onto the rocker arm.
- Install the spring, washer, rocker arm, rocker bracket and snap ring in the described sequence.

- Install the rocker arm and bracket in the same direction.



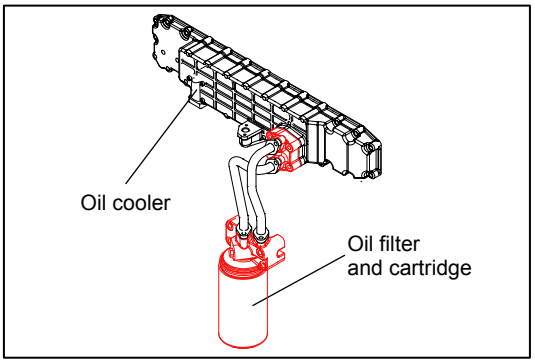
### 3.3.21. Oil cooler & oil filter

- Install the oil cooler assembly and gasket onto the cylinder block, and tighten the fixing bolts.
- Be careful not to be changed of the direction of assembling the gasket.




| | | |
|---|---|---|
| Torque | Oil cooler | 2.2+0.5 kg.m |
| | Oil filter | 4.4+0.5 kg.m |
| | Oil pipe | 2.2+0.5 kg.m |

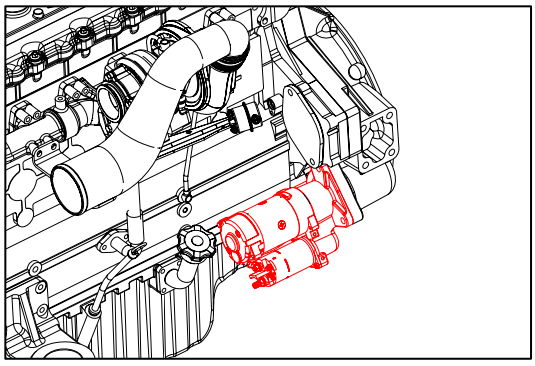
- Apply engine oil to the oil filter cartridge o-ring and assemble the cartridge using a filter wrench.



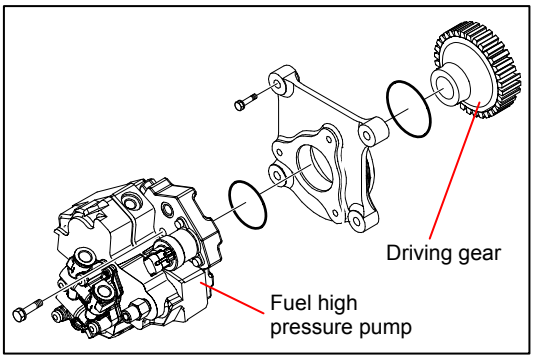

### 3.3.22. Starting motor

- Insert the starter into the flywheel housing and tighten the fixing nuts.

| | |
|---|---|
| Torque | 8.0+1.0 kg.m |



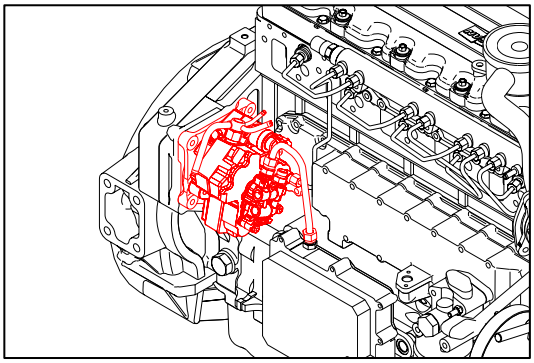
### 3.3.23. Fuel high pressure pump




- Assemble the gear of the fuel high pressure pump by using specified tool.

| | |
|---|---|
| Gear nut torque | 11±0.5 kg.m |
| Flange fixing bolt | 4.4±0.5 kg.m |

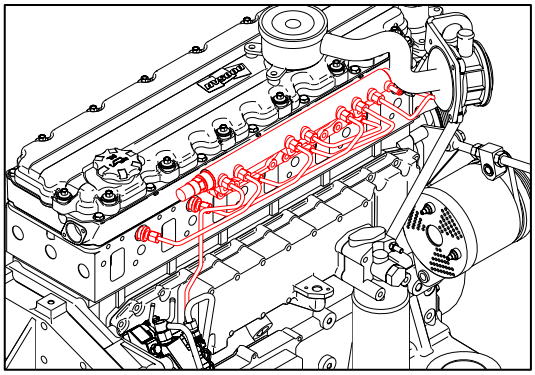
- Fill 60cc fuel at the fuel inlet before reassemble.
- Install the fuel high pressure pump on the backside of the fly wheel housing.



- Assemble the fixing bolts according to the sequence of assemble with specified torque.

| | | |
|---|---|---|
| Torque | Hollow screw | 3.0+0.5 kg.m |
| | Nipple | 4.4+0.5 kg.m |

### 3.3.24. Common rail & high pressure pipe



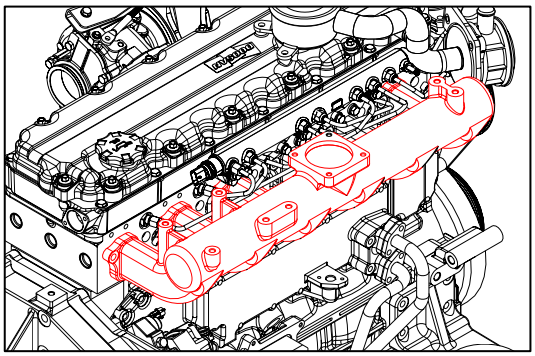
- Install the common rail on the cylinder block.
- Assemble the fuel high pressure pipe between the common rail and the fuel high pressure connector, then tighten the cylinder by cylinder with specified torque.

| | | | |
|---|---|---|---|
| Torque | Fuel high pressure pipe | Side of common rail | 2.5+0.5 kg.m |
| | | Side of fuel high pressure connector | 2.8+0.5 kg.m |
| | | Common rail from fuel high pressure pump | 2.1+0.5 kg.m |
| | Common rail and fixing bolt | | 2.2+0.5 kg.m |

### 3.3.25. Intake manifold

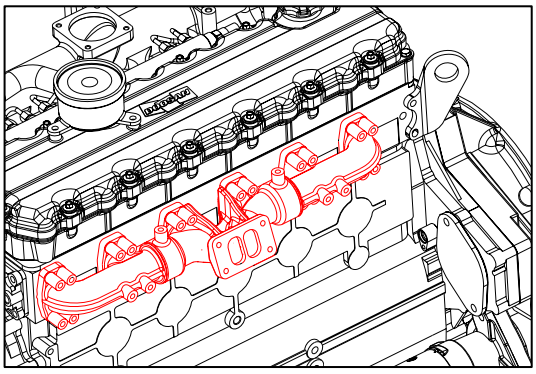
- Put in the new gasket between the cylinder head and manifold, and assemble the intake manifold by tightening the fixing bolts.

| | |
|---|---|
| Torque | 4.4 +0.5 kg.m |

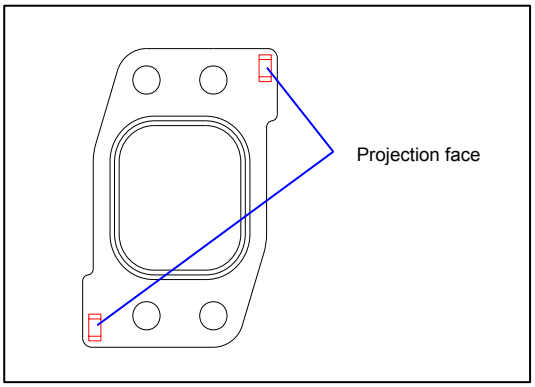


### 3.3.26. Exhaust manifold

- Install the exhaust manifold gasket over the stud bolts by aligning the gasket with the exhaust port on the cylinder head so that the face and back of the gasket can be positioned correctly.

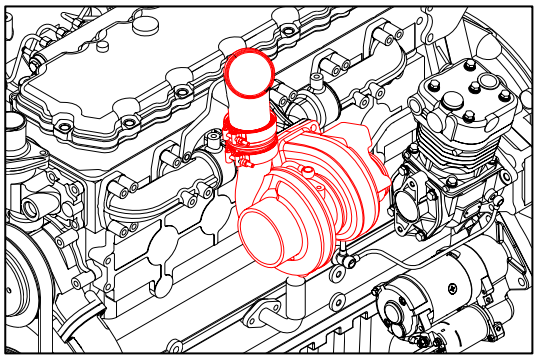


- Install the exhaust manifold gasket. The projection face must be facing the exhaust manifold.
- Assemble the exhaust manifold and the heat resisting plate, the tightening order of bolts is from the middle to left and right alternately.




| | |
|---|---|
| Torque | 5.0+0.5 kg.m |

### 3.3.27. Turbo charger

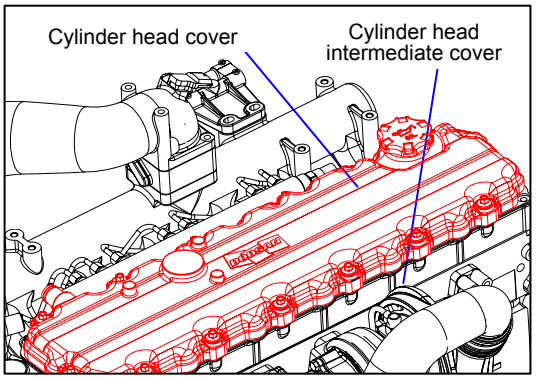


- Fit a new gasket over the stud bolts of the exhaust manifold before tightening those turbocharger fixing nuts.

| | | |
|---|---|---|
| Torque | Turbo fixing nut | 8.0+1.0 kg.m |
| | Hose clamp | 0.5 kg.m |

- Install the oil supply pipe and return pipe.
- Tighten the clamps of rubber hose that is connected air pipe to the turbocharger.

### 3.3.28. Cylinder head cover

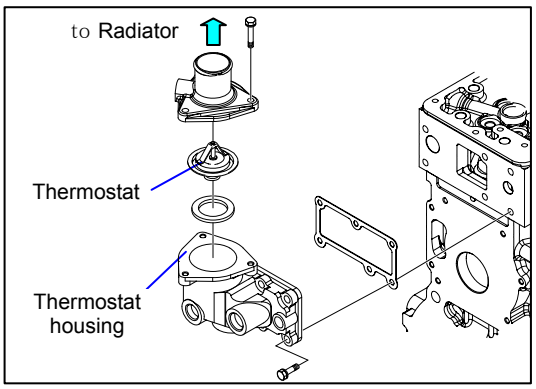



- Attach a new gasket on the cylinder head cover, assemble the cylinder head intermediate cover to the cylinder head, tighten the fixing bolts to the specified torque.

| | | |
|---|---|---|
| Torque | Head cover | 2.2+0.5 kg.m |
| | Intermediate cover | 3.1+0.5 kg.m |

- Fit the oil filler cap on the cylinder head cover.

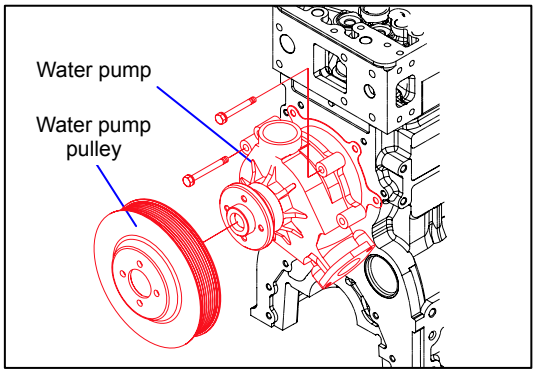
### 3.3.29. Thermostat




- Attach the gasket to the cylinder head, assemble the thermostat housing.
- Install the gasket and O-ring to the thermostat, assemble the cooling water pipe by tightening the fixing bolts.

| | | |
|---|---|---|
| Torque | Thermostat housing | 4.4+0.5 kg.m |
| | Water outlet | 2.2+0.5 kg.m |

### 3.3.30. Cooling water pump

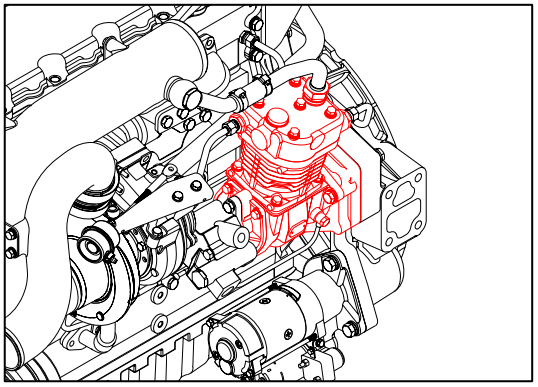



- Mount a new cooling water pump gasket.
- Install the water pump on the cylinder block and tighten the assembling bolts with specified torque.

| | |
|---|---|
| Torque | 2.2+0.5 kg.m |

- Connect water pipes and by-pass pipe to the water pump.

### 3.3.31. Air compressor

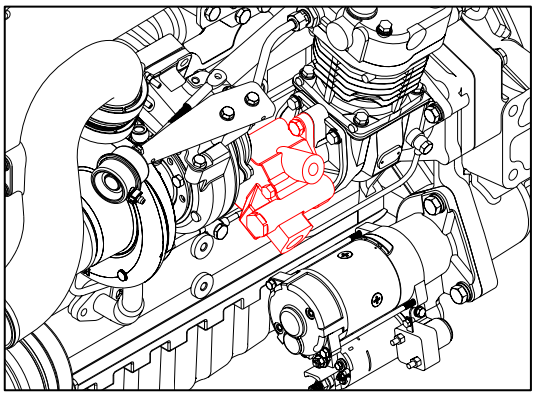


- Coat the oil on the O-ring of attached face of air compressor, install it to the fly wheel housing.
- Assemble the air compressor a'ssy tighten to the specified torque. (Carefully damage the O-ring)

### 3.3.32. Power steering pump

- Insert the driving dog to the air compressor, coat the engine oil on the O-ring of the power steering pump.

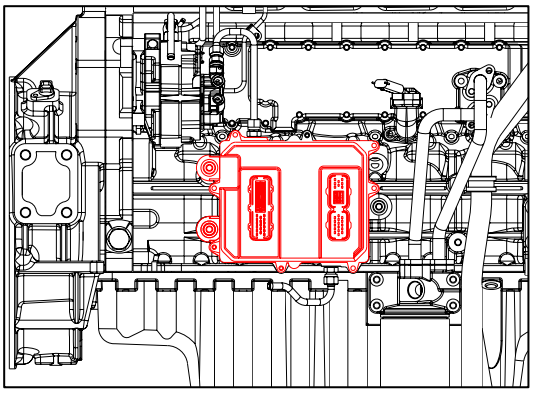
- Tighten the fixing bolts to the specified torque.



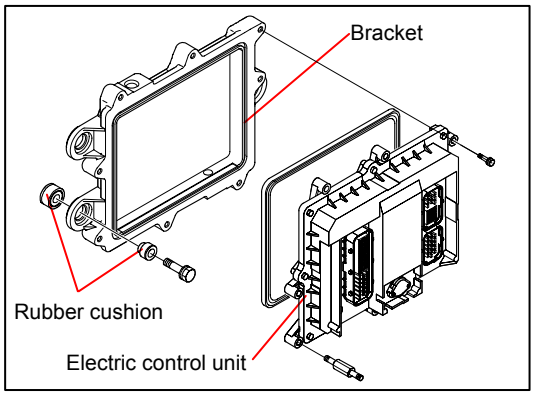
### 3.3.33. Electrical control unit : ECU

- Install the electric control unit fixing bracket on the cylinder block, then assemble the electric control unit.

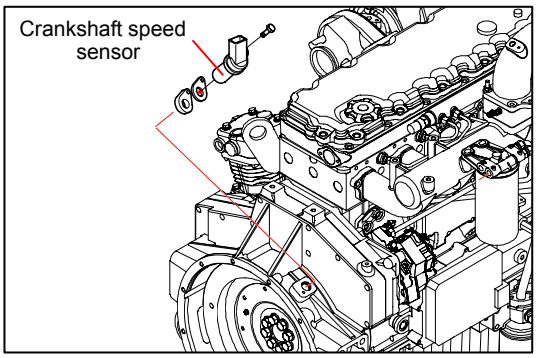
| | | |
|---|---|---|
| Torque | ECU bracket | 4.4 kg.m |
| | ECU fixing bolt | 1.0+0.1 kg.m |



- Assemble the electric control unit (ECU) according to the right figure order.
- Refer to the chapter of 3.4 about relation of the common rail system and the electric control unit.



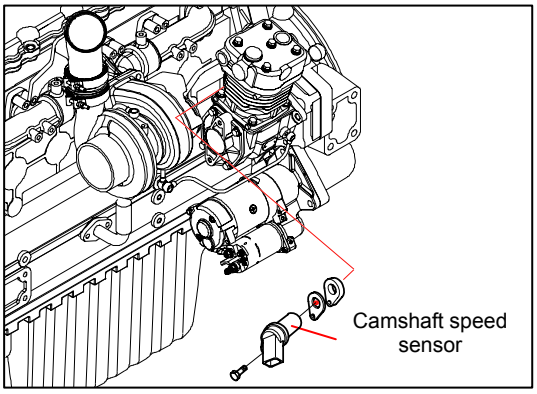
### 3.3.34. Crankshaft speed sensor




- Measure the clearance of the assembling part of the sensor and fly wheel, then assemble it with the shim.

| | |
|---|---|
| clearance | 1. 0 ±0.1mm |
| Torque | 1.0+0.5 kg.m |

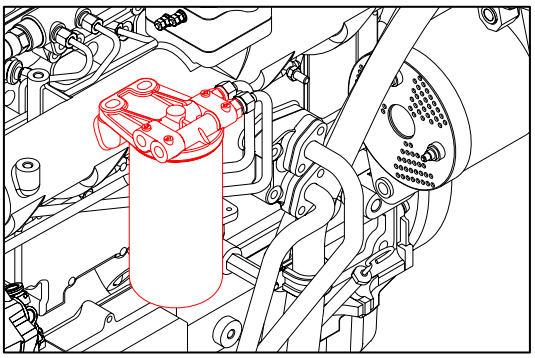
### 3.3.35. Camshaft speed sensor




- Measure the clearance of the assembling part of the sensor and timing gear, then assemble it with the shim.

| | |
|---|---|
| Clearance | 1. 0 ±0.1mm |
| Torque | 1.0 +0.5 kg.m |

### 3.3.36. Fuel filter

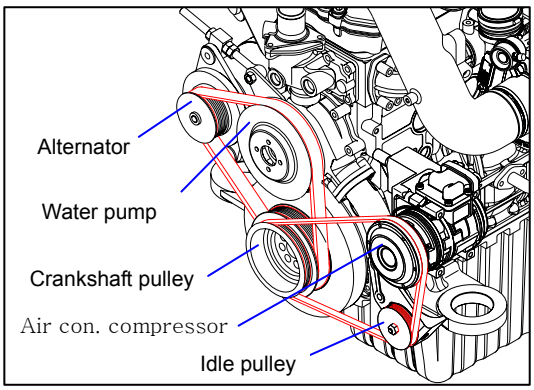


- Assemble the fuel filter on the intake manifold.
- Assemble the fuel filter after fill the fuel into inside of the cartridge when replace the new fuel filter.
- Assemble the fuel feed pipe according to the direction of an arrow impressed on the fuel filter head so that fuel can be fed in the sequence of **Fuel feed pump → Fuel filter → Fuel high pressure pump → Common rail.**

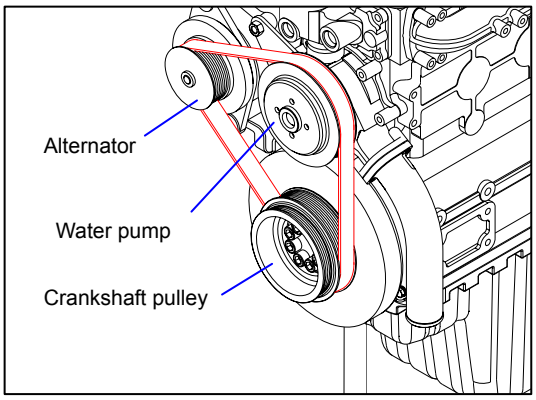
| | | |
|---|---|---|
| Torque | Fuel pipe | 3.0+0.5 kg.m |
| | Fuel temp sensor | 2.2+0.5 kg.m |
| | Fixing bracket | 4.4+0.5 kg.m |

### 3.3.37. Alternator & belt

- Install the alternator and the air con bracket using the fixing bolts.
- Assemble the alternator, the air-conditioner and idle pulley.
- Adjust the belt tension by adjusting bolt.

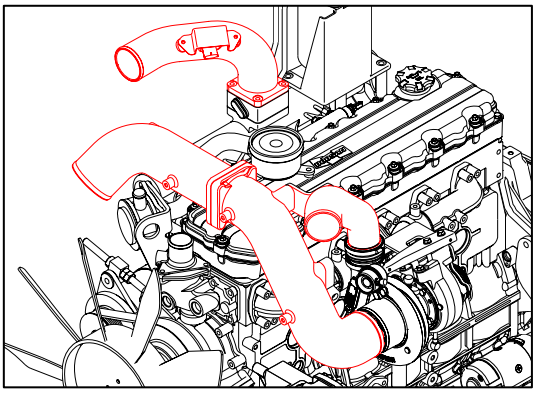



| | | |
|---|---|---|
| Torque | Alternator fixing bolt (M12x1.5) | 7.7+0.5 kg.m |
| | Eye bolt (M12x1.5) | 5.0+0.5 kg.m |

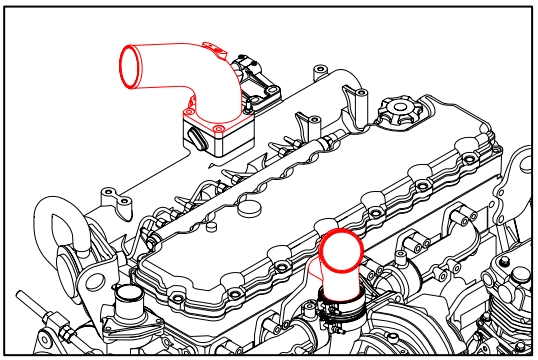



### 3.3.38. Air pipe & air heater

- Assemble the air pipe and air heater using the fixing bolts.
- Be careful not to mix into the inner side of the turbocharger.



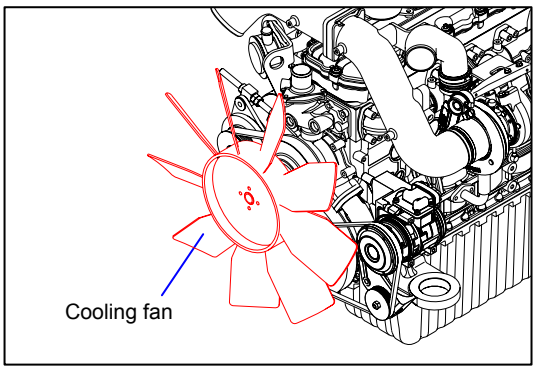
| | | |
|---|---|---|
| Torque | V-clamp | 0.5+0.5 kg.m |
| | Air pipe | 2.2+0.5 kg.m |
| | Fixing bracket | 4.4+0.5 kg.m |



### 3.3.39. Cooling fan

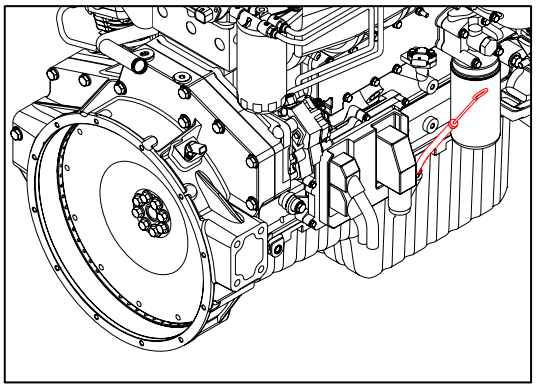
- Install the flange to the crankshaft pulley, then assemble the cooling fan and the fan flange.

| | |
|---|---|
| Torque of cooling fan | 2.2+0.5 kg.m |




### 3.3.40. Oil level gauge

- Apply sealant (Loctite #271) to the bottom side of the guide tube.
- Assemble the guide tube and oil level gauge on the oil pan.



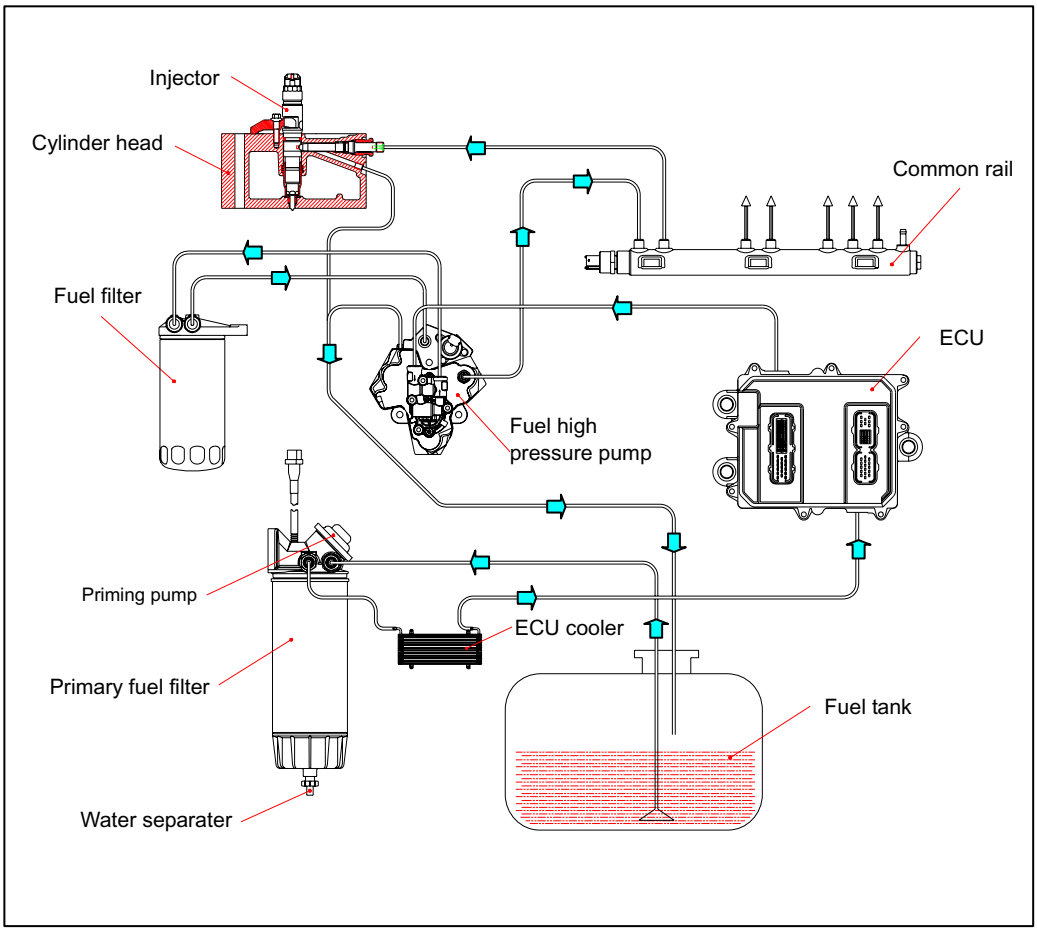
### 3.3.41. Others

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

## 3.4. Fuel injection System

### 3.4.1. Common rail fuel-injection system

- Pressure generation and fuel injection are completely decoupled from each other in the common rail injection system. The electric control unit(ECU) determine the fuel quantity, injection timing, and injection pressure in order to show the optimum performance on the condition for operation of the engine, then inject the fuel in the cylinder.




- The fuel is stored under pressure in the common rail ready for injection. The injected fuel quantity is defined by the driver, and the start of injection and injection pressure are calculated by the ECU on the basis of the stored map. The ECU then triggers the solenoid valves that the injector at each engine cylinder injects accordingly.

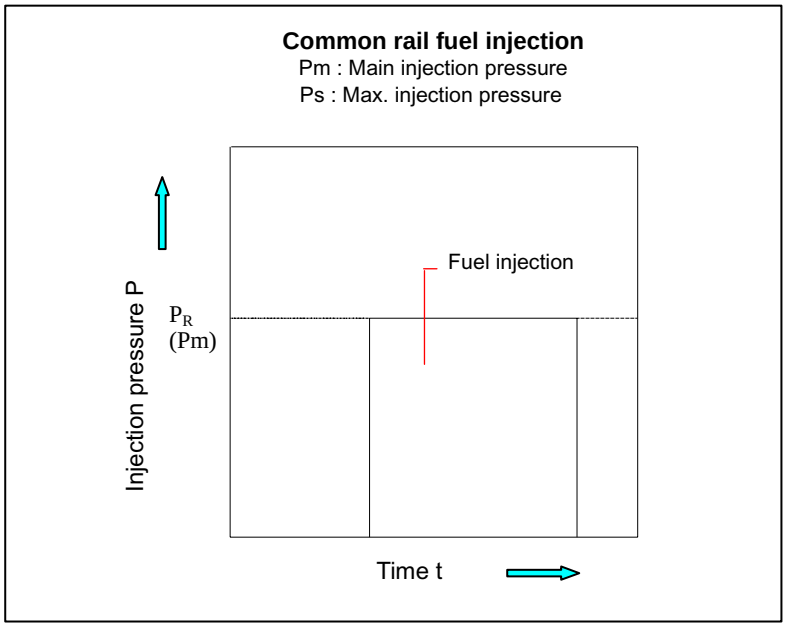
### 3.4.2. Major components of the common rail system

1) Electric control unit(ECU)
2) Crankshaft speed sensor
3) Camshaft speed sensor
4) Accelerator pedal sensor
5) Fuel temperature sensor
6) Boost pressure and temperature sensor
7) Common rail pressure sensor
8) Coolant temperature sensor
9) Oil pressure and temperature sensor

- Using the input signals from the above sensors, the ECU registers the driver's requirements(accelerator pedal setting) and defines the instantaneous operating performance of the engine and the vehicle as a whole. On the basis of this information, it can then intervene with open and closed-loop controlling action at the vehicle and particularly at the engine.
- The engine speed is measured by the crankshaft speed sensor, and the camshaft speed sensor determines the firing sequence (phase length). The electrical signal generated across a potentiometer in the accelerator pedal module informs the ECU about how far the driver has depressed the pedal, the engine is equipped with a turbocharger and boost pressure control, the boost pressure sensor also measures boost pressure.
- At low outside temperatures and with the engine cold, the ECU applies the data from the coolant temperature and air temperature sensors to adapt the set point values for start of the particular operating conditions.

### 3.4.3. Injection characteristics with common rail

- Injection characteristics with common rail, compared to conventional injection characteristics, the following demands are made up on an ideal injection characteristic, Independently of each other, injected fuel quantity and injection pressure should be definable for each and every engine operating condition.




- At the beginning of the injection process, the injected fuel quantity should be as low as possible (that is, during the ignition lag between the start of injection and the start of combustion)
- The common rail system is a modular system, and essentially the following components are responsible for the injection characteristic.
  - Solenoid valve controlled injectors which are screwed into the cylinder head
  - Common rail
  - Fuel high pressure pump
  - Electric control unit(ECU)
  - Crankshaft speed sensor
  - Camshaft speed sensor

### 3.4.4. Fuel high pressure pump

- A radial-piston pump is used as the high pressure pump for pressure generation. Pressure is generated independently of the injection process. The speed of the high pressure pump is coupled directly to the engine speed with a non-variable transmission ratio. In comparison with conventional injection systems, the fact that delivery is practically uniform.
- The injectors are connected to the common rail by high pressure pipe, comprise a nozzle, and a solenoid valve which is energized by the ECU to switch it on (start of injection), When the solenoid valve is switched off injection ceases.

- The required high-speed solenoid switching is achieved by using high voltages and currents. This means that the solenoid valve triggering stage in the ECU must be designed accordingly. The start of injection is controlled by the angle-time control system of the EDC(Electronic Diesel Control).This uses a sensor on the crankshaft to register engine speed, and a sensor on the camshaft for phase detection(working cycle).

### 3.4.5. Fuel system

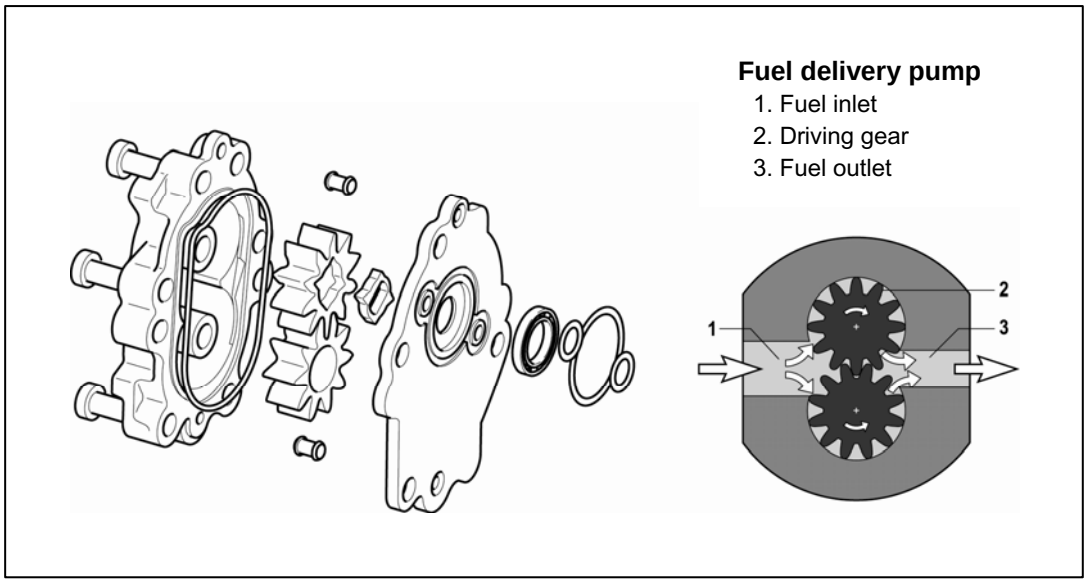
- The common rail fuel injection system comprises a low pressure stage for the low pressure delivery of fuel, a high pressure stage for the high pressure delivery, and the ECU.

### 3.4.6. Fuel tank

- The fuel tank must be of non-corroding material, and must remain free from leaks at double the operating pressure, and in any case at 0.3 bar.

### 3.4.7. Fuel delivery pump

- The fuel delivery pump is installed on back side of the fuel high pressure pump, is a gear type fuel pump. The pump draws the fuel from the fuel tank and continually delivers the required quantity of fuel in the direction of the high pressure pump.



### 3.4.8. Fuel filter

- Fuel filter inadequate filtering can lead to damage at the pump components, delivery valves, and injector nozzles. The fuel filter cleans the fuel before it reaches the high pressure pump, and thereby prevents premature wear at the pump's sensitive components.

### 3.4.9. High pressure fuel delivery

- The high pressure stage of the fuel system in a common rail installation comprises.
  - High pressure pump with pressure control valve
  - High pressure fuel lines
  - The common rail as the high pressure accumulator
  - Rail pressure sensor.
  - Pressure limiting valve.
  - Injectors
  - Fuel return lines

### 3.4.10. High pressure system components

- **Fuel high pressure pump**

  The high-pressure pump pressurizes the fuel to a system pressure of up to 1,600bar. This pressurized fuel then passes through a high-pressure line and into the tubular high pressure fuel accumulator (common rail).

- **Common rail**

  Even after an injector has taken fuel from the common rail in order to inject it, the fuel pressure inside the rail remains practically constant. Fuel pressure is measured by the rail pressure sensor and maintained at the desired level by the pressure control valve. It is the job of the pressure limiter valve to limit the fuel pressure in the rail to maximum 1,600 bar.

- **Injector**

  The nozzles of these injectors open when the solenoid valve is triggered and permit the flow of fuel. They inject the fuel directly into the engine's combustion chamber, The excess fuel which was needed for opening the injector nozzles flows back to the tank through a collector line. The return fuel from the pressure control valve and from the low pressure stage is also led into this collector line together with the fuel used to lubricate the high pressure pump.

- **Fuel high pressure pipe**

  These fuel high pressure pipes carry the high pressure fuel of up to 1600bar. They must therefore be able to permanently withstand the maximum system pressure and, during the pauses in injection, the sometimes high frequency pressure fluctuations which occur. They are therefore manufactured from the high pressure pipe. They have an outside diameter of 8.0 mm and an internal diameter of 3.0 mm. The fuel high pressure pipe lines between the common rail and the injectors must all be of the same length, should be kept as short as possible.

### 3.4.11. Construction of the fuel high pressure pump

#### 1) Function

The high pressure pump is the interface between the low-pressure and the high pressure stages. Under all operating conditions, it is responsible for providing adequate high pressure fuel throughout the vehicle's complete service life. This also includes the provision of extra fuel as needed for rapid starting and for rapid build-up of pressure in the rail. The high pressure pump continually generates the system pressure as needed in the common rail.

#### 2) Construction of the fuel high pressure pump

The fuel is compressed with three radially arranged pump pistons which are at an angle of 120° to each other. Since three delivery strokes take place for every revolution, only low peak drive torques are generated so that the stress on the pump drive remains uniform. The driving torque of the common rail is only about 1/9 of torques to drive existing pump system.

#### 3) Method of operation

The fuel supply pump fuel from the tank to the high pressure pump through the fuel inlet and the safety valve. It forces the fuel through the safety valve into the high pressure pump. The driveshaft with its eccentric cams moves the piston of the pump up and down in accordance with the shape of the cam.

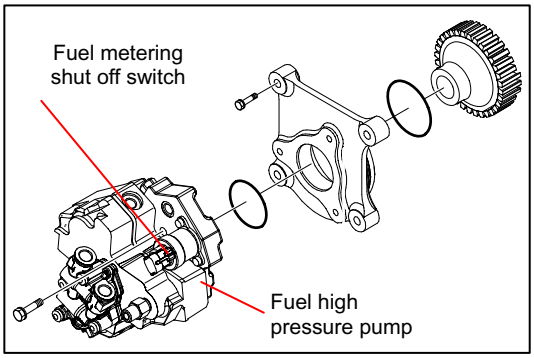
As soon as the delivery pressure exceeds the safety valve's opening pressure (0.5 ~ 0.5 bar), the fuel supply pump can force fuel through the high pressure pump's inlet valve into the pumping-element chamber whose pump piston is moving downwards(suction stroke). The inlet valve closes when the pump piston passes through the bottom dead center (BDC) and, since it is impossible for the

fuel in the pumping-element chamber to escape, it can now be compressed beyond the delivery pressure. The increasing pressure opens the outlet valve as soon as the rail pressure is reached, and the compressed fuel enters the high pressure circuit. The pump piston continues to deliver fuel until it reaches TDC, after which the pressure collapses so that the outlet valve closes. The fuel remaining in the pumping-element chamber relaxes and the pump piston moves downwards again. As soon as the pressure in the pumping-element chamber drops below the presupply pump pressure, the inlet valve opens and the pumping process starts again.

**4) Fuel delivery rate**

Since the high-pressure pump is designed for large delivery quantities, excess high-pressure fuel is delivered during idle and part load operation. This excess fuel is returned to the tank via the pressure control valve.

**5) Fuel metering shut off valve**

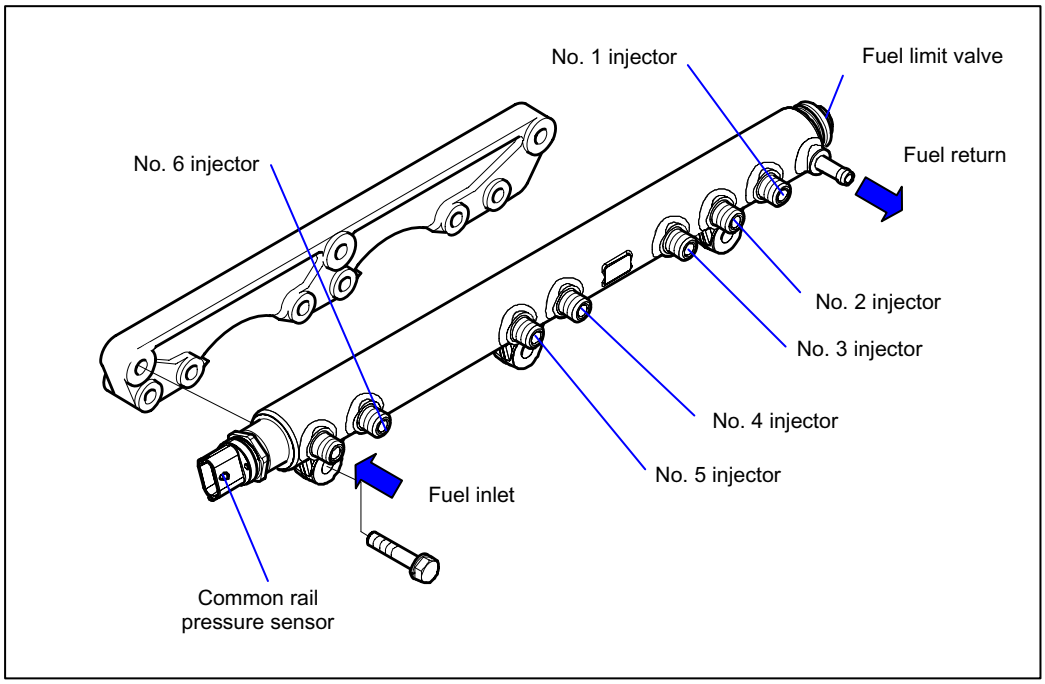



When one of the pumping elements is switched off, this leads to a reduction of the amount of fuel which is pumped into the common rail. Switch off involves the suction valve remaining open permanently. When the solenoid valve of the pumping-element switch off is triggered, a pin attached to its armature continually holds the inlet valve open. The result is that the fuel drawn into this pumping element cannot be compressed during the delivery stroke. No pressure is generated in the element chamber since the fuel flows back into the low-pressure passage again. With one of its pumping elements switched off when less power is needed, the high-pressure pump no longer delivers the fuel continuously but rather with brief interruptions in delivery.

**6) Common rail**

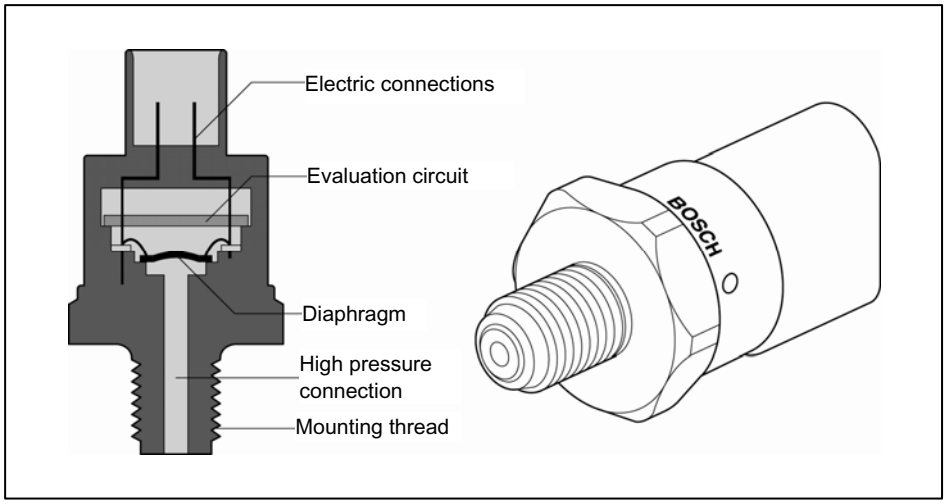
The common rail stores the fuel at high pressure. At the same time, the pressure oscillations which are generated due to the high pressure pump delivery and the injection of fuel are damped by the rail volume. After the injector use the fuel from the common rail for fuel injection, the pressure oscillation of the common rail is

maintained constantly by the common rail volume. The fuel pressure is calculated by the pressure sensor of the common rail, is maintained with required value by the pressure control valve. The fuel pressure is controlled at max. 1,600 bar in the common rail.



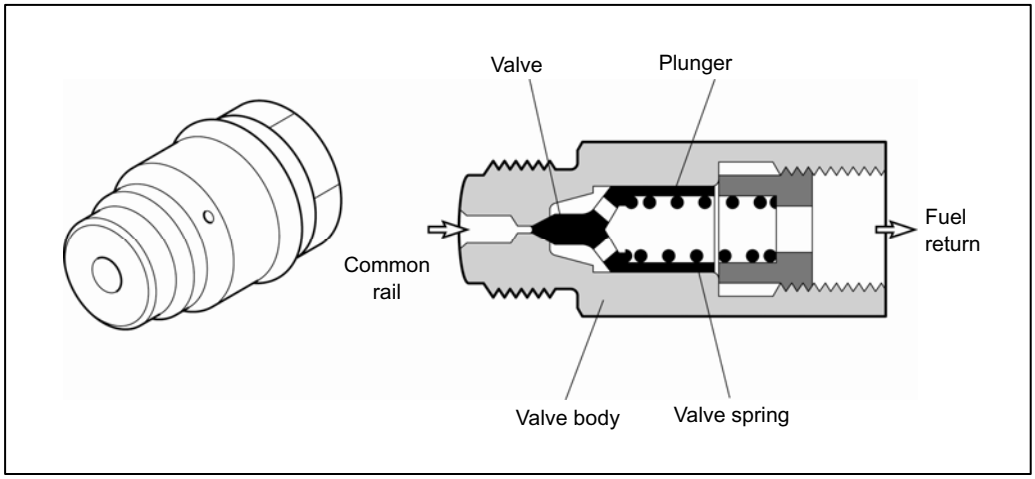

### 7) Common rail pressure sensor

The fuel flows to the rail pressure sensor through an opening in the common rail, the end of which is sealed off by the sensor diaphragm. Pressurized fuel reaches the sensor's diaphragm through a blind hole. The sensor element for converting the pressure to an electric signal is mounted on this diaphragm. The signal generated by the sensor is inputted to an evaluation circuit which amplifies the measuring signal and sends it to the ECU.



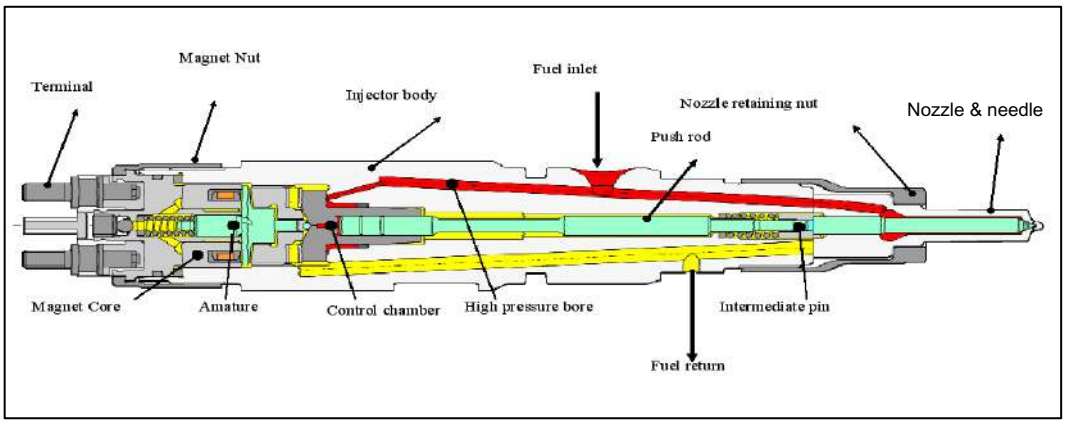
### 3.4.12. Pressure limiter valve

- The pressure limiter valve is at the connection end to the common rail, is closed by the cone shaped end of the plunger valve against inside of the valve body. At normal operating pressures (1600bar), a spring forces the plunger against the seat and the common rail remains closed.
- As soon as the operating pressure is exceeded, the plunger is forced by the rail pressure against the force of the spring, the fuel pressure is maintained with the normal pressure, and the escape fuel return to the fuel tank through the return pipe.




### 3.4.13. Injector

- The start of injection and the injected fuel quantity are adjusted by the solenoid valve of the injector. These injectors supersede the nozzle and nozzle holder of the existing engine. The fuel is fed from the high pressure connector, to the nozzle through the passage, and to the control chamber through the feed orifice.
- The control chamber is connected to the fuel return via a bleed orifice which is opened by the solenoid valve. With the bleed orifice closed, the hydraulic force applied to the valve control plunger exceeds that at the nozzle needle pressure shoulder. As a result, the needle is forced into its seat and seals off the high pressure passage from the combustion chamber.
- When the injector's solenoid valve is triggered, the bleed orifice is opened. This leads to a drop in control-chamber pressure and, as a result, the hydraulic pressure on the plunger also drops. As soon as the hydraulic force drops below the force on the nozzle-needle pressure shoulder, the nozzle needle opens and fuel is injected through the spray holes into the combustion chamber.




- This indirect control of the nozzle needle using a hydraulic force-amplification system is applied because the forces which are necessary for opening the needle very quickly cannot be directly generated by the solenoid valve. The so-called control quantity needed for opening the nozzle needle is in addition to the fuel quantity which is actually injected, and it is led back to the fuel-return line via the control chamber's orifices. In addition to the control quantity, fuel is also lost at the nozzle-needle and valve plunger guides. These control and leak-off fuel quantities are returned to the fuel tank via the fuel return and the collector line to which overflow valve, high pressure pump, and pressure control valve are also connected.

**1) Method of operation**

The injector's operation can be subdivided into four operating states with the engine running and the high pressure pump generating pressure.

- Injector closed (with high pressure applied)
- Injector opens (start of injection)
- Injector opened fully, and
- Injector closes (end of injection)

These operating states result from the distribution of the forces applied to the injector's components. With the engine at standstill and no pressure in the rail, the nozzle spring closes the injector.

**2) Injector closed (at rest status)**

In the at rest state, the solenoid valve is not energized and is therefore closed. With the bleed orifice closed, the valves spring forces the armature's ball onto the bleed-orifice seat. The rail's high pressure builds up in the control valve, and the same pressure is also present in the nozzle's chamber volume. The rail pressure applied at the control plunger's end face, together with the force of the nozzle spring, maintain the nozzle in the closed position against the opening forces applied to its pressure stage.

**3) Injector opens (start of injection)**

The injector is in its at-rest position. The solenoid valve is energized with the pick-up current which serves to ensure that it opens quickly. The force exerted by the triggered solenoid now exceeds that of the valve spring and the armature opens the bleed orifice. Almost immediately, the high-level pick-up current is reduced to the lower holding current required for the electromagnet. This is possible due to the magnetic circuit's air gap now being smaller. When the bleed orifice opens, fuel can flow from the valve-control chamber into the cavity situated above it, and from there via the fuel return to the fuel tank. The bleed orifice prevents complete pressure balance, and the pressure in the valve control chamber sinks as a result. This leads to the pressure in the valve-control chamber being lower than that in the nozzle's chamber volume which is still at the same pressure level as the rail. The reduced pressure in the valve-control chamber causes a reduction in the force exerted on the control plunger, the nozzle needle opens as a result, and injection starts.

The nozzle needle's opening speed is determined by the difference in the flow rate through the bleed and feed orifices. The control plunger reaches its upper stop where it remains supported by a cushion of fuel which is generated by the flow of fuel between the bleed and feed orifices. The injector nozzle has now opened fully, and fuel is injected into the combustion chamber at a pressure almost equal to that in the fuel rail. Force distribution in the injector is similar to that during the opening phase.

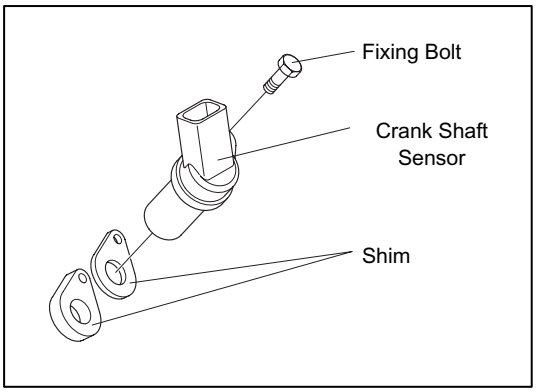
#### 4) Injector closes (end of injection)

As soon as the solenoid valve is no longer triggered, the valve spring forces the armature downwards and the ball closes the bleed orifice. The armature is a 2-piece design. Here, although the armature plate is guided by a driver shoulder in its downward movement, it can "over spring" with the return spring so that it exerts no downwards-acting forces on the armature and the ball.

The closing of the bleed orifice leads to pressure buildup in the control chamber via the input from the feed orifice. This pressure is the same as that in the rail and exerts an increased force on the control plunger through its end face. This force, together with that of the spring, now exceeds the force exerted by the chamber volume and the nozzle needle closes.

The nozzle needle's closing speed is determined by the flow through the feed orifice. Injection ceases as soon as the nozzle needle comes up against its bottom stop again.

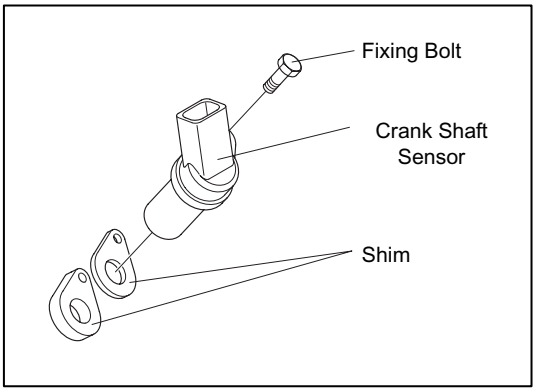
### 3.4.14. Crank shaft speed sensor




- The piston position in the combustion chamber is decisive in defining the start of injection. All the engine's pistons are connected to the crankshaft by connecting rods. A sensor on the crankshaft can therefore provide information on the position of all the pistons.

The rotational speed defines the number of crankshaft rotations per minute. This important input variable is calculated in the ECU using the signal from the inductive crankshaft speed sensor.

### 3.4.15. Cam shaft speed sensor

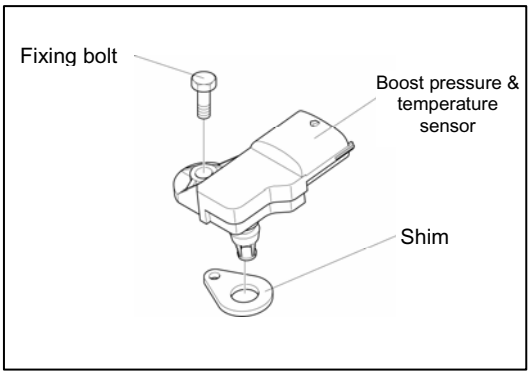



- The camshaft controls the engine's intake and exhaust valves. It turns at half the speed of the crankshaft. When a piston travels in the direction of TDC, the camshaft position determines whether it is in the compression phase with subsequent ignition, or in the exhaust phase. This information cannot be generated from the crankshaft position during the starting phase. During normal engine operation on the other hand, the information generated by the crankshaft sensor suffices to define the engine status. In other words, this means that if the camshaft sensor should fail while the vehicle is being driven, the ECU still receives information on the engine status from the crankshaft sensor.

### 3.4.16. Accelerator pedal sensor

- The accelerator pedal sensor transmitted the driver’s acceleration input to the ECU.
- A voltage is generated across the potentiometer in the accelerator-pedal sensor as a function of the accelerator-pedal setting. Using a programmed characteristic curve, the pedal's position is then calculated from this voltage.

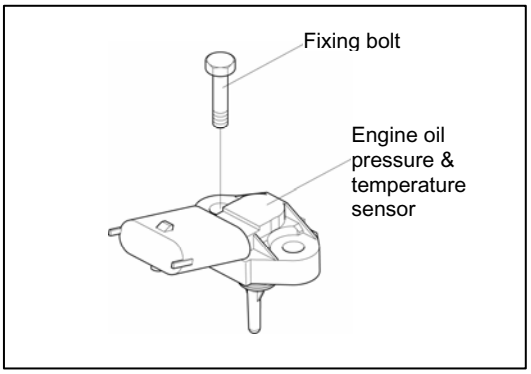
### 3.4.17. Boost pressure & temperature sensor




- The boost pressure & temperature sensor are connected to the intake manifold by the O-ring and measures the intake manifold's absolute pressure and temperature.
- The output signal is inputted to the ECU where, with the help of a programmed characteristic curve, it is used for calculating the boost pressure.

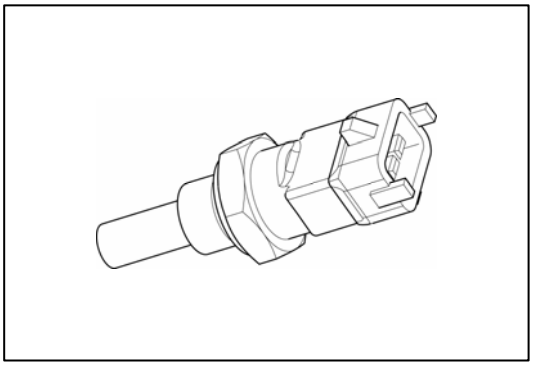
### 3.4.18. Engine oil pressure & temperature sensor

- The engine oil pressure and oil temperature sensor measure in the engine lube oil and measuring data is inputted into ECU.



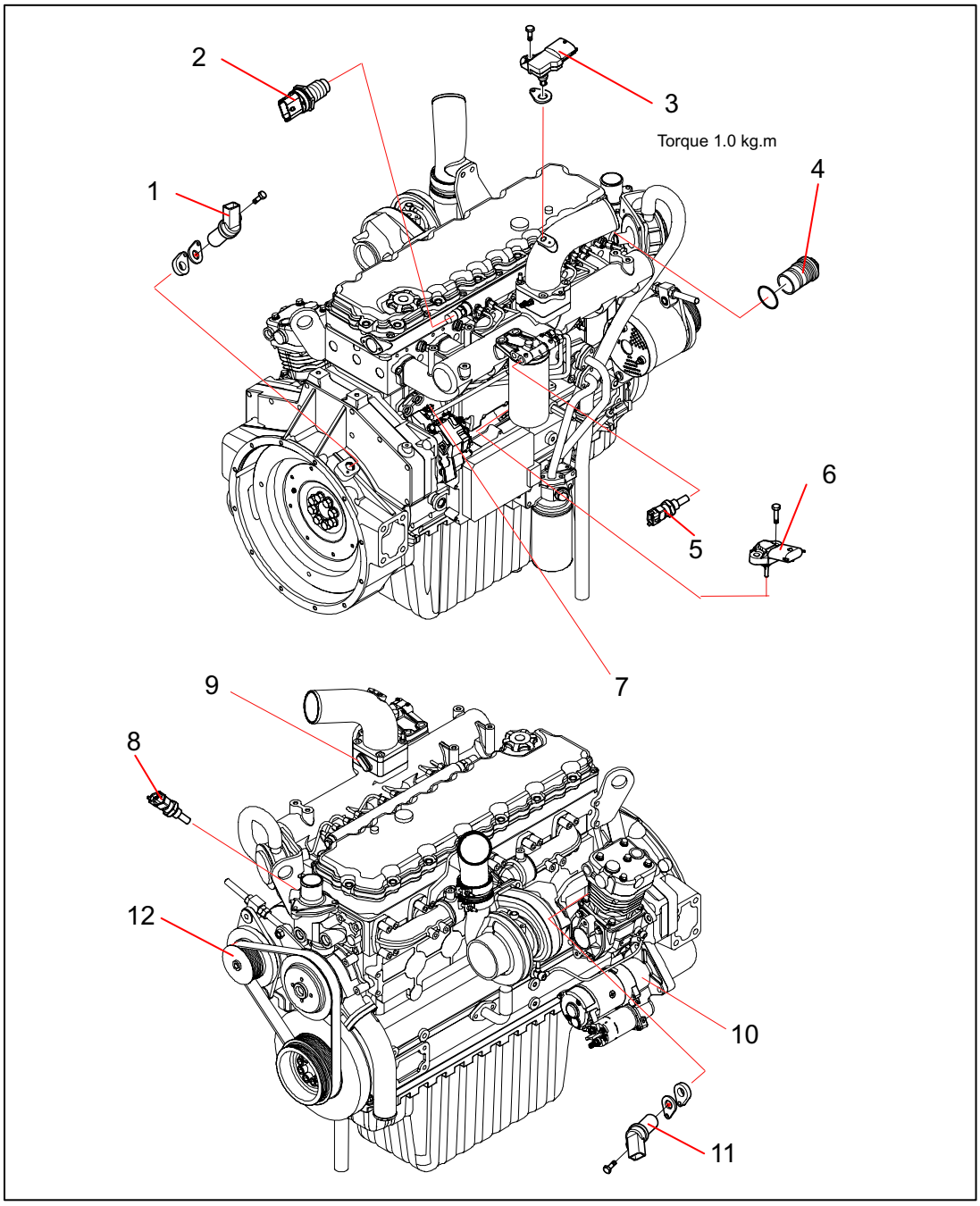

### 3.4.19. Engine coolant temperature sensor

- The engine coolant temperature sensor measure in the engine coolant circuit and measuring data is inputted into ECU.



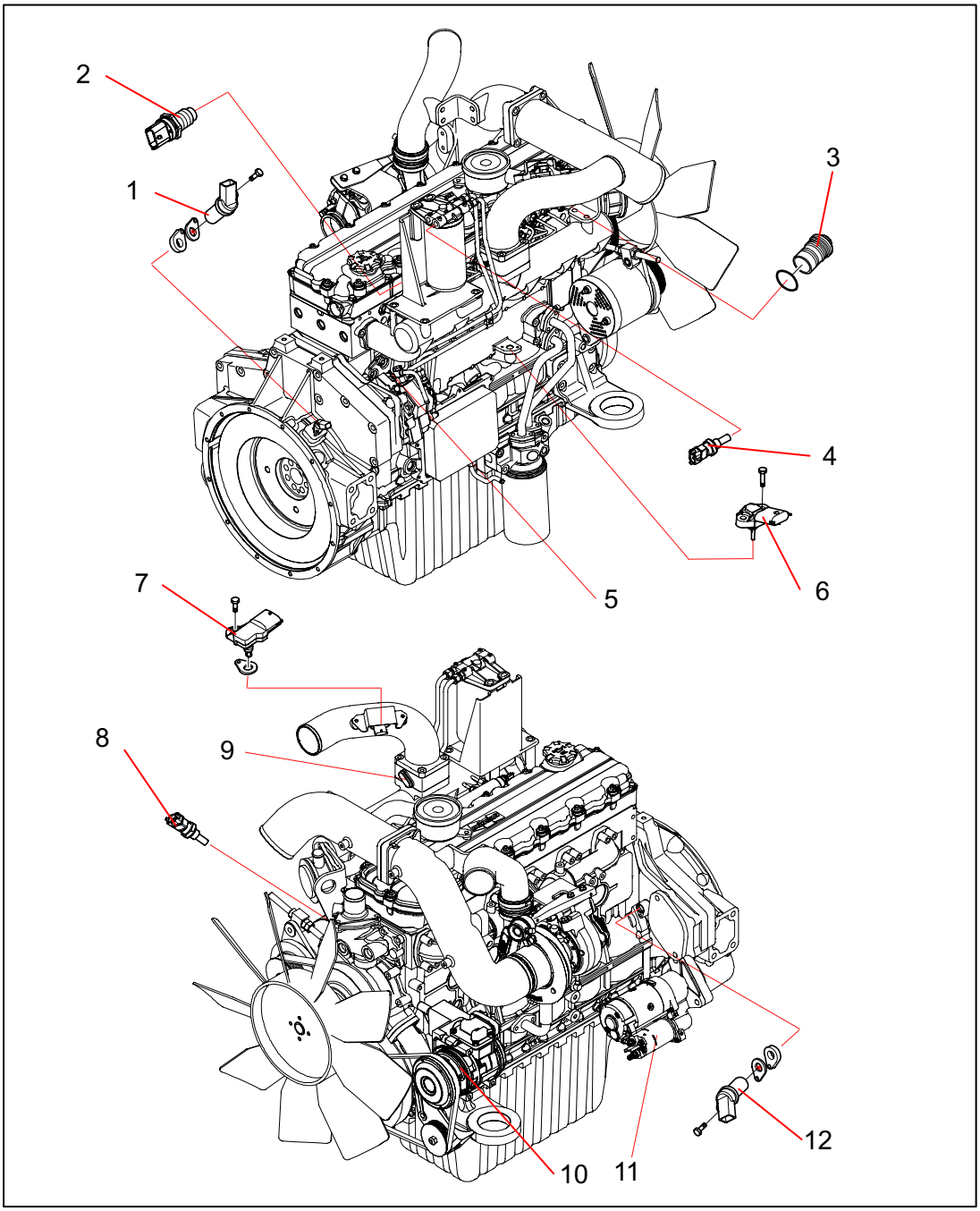
## 3.5. Electrical System

### 3.5.1. Electric parts – Fork lift




| | | | |
|---|---|---|---|
| 1 | Crankshaft speed sensor | 7 | Fuel metering shut off switch |
| 2 | Common rail pressure sensor | 8 | Coolant temperature sensor |
| 3 | Boost pressure & temperature sensor | 9 | Air heater |
| 4 | Fuel pressure limit valve | 10 | Starter |
| 5 | Fuel temperature sensor | 11 | Camshaft speed sensor |
| 6 | Engine oil pressure & temperature sensor | 12 | Alternator |

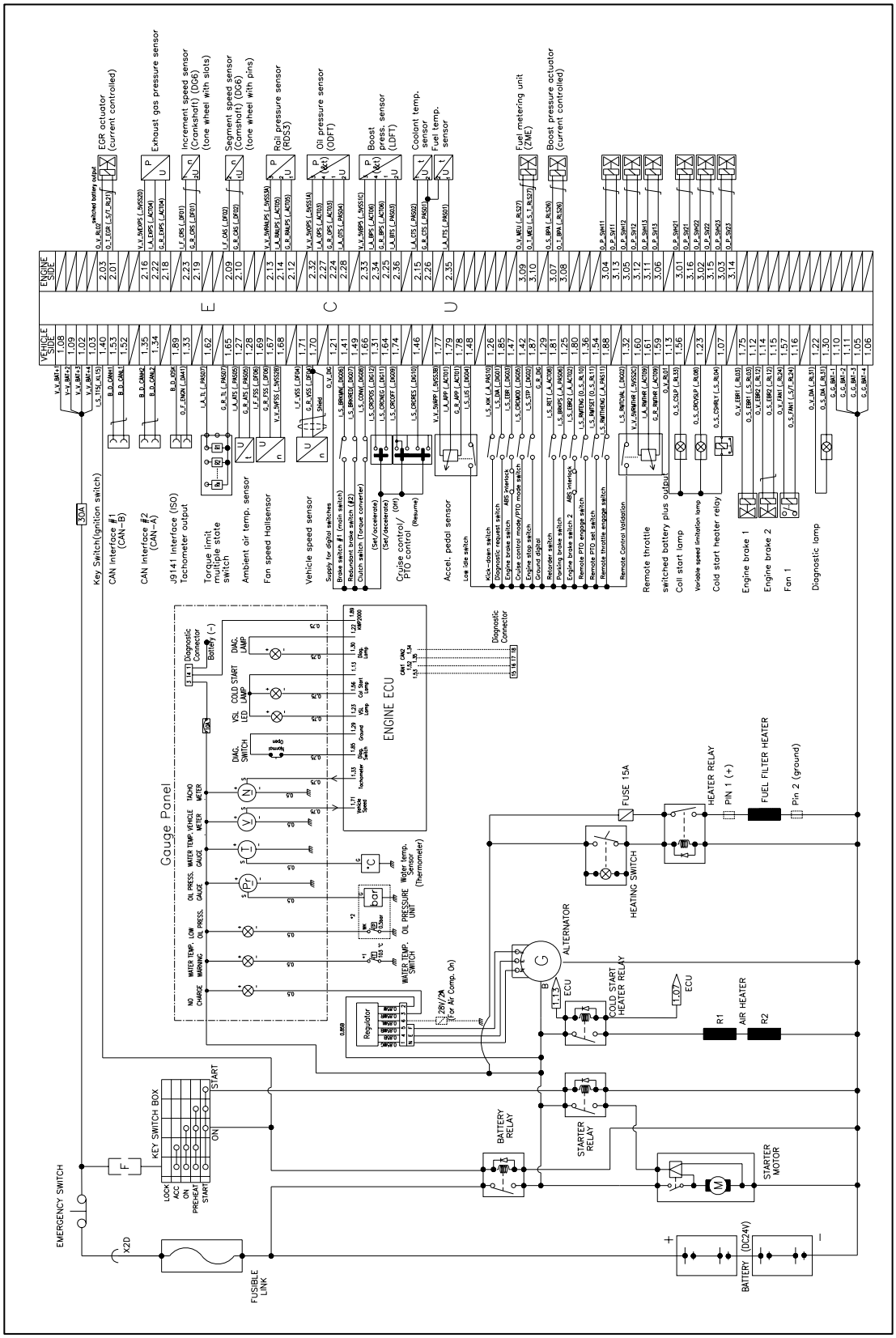
### 3.5.2. Electric parts – Excavator



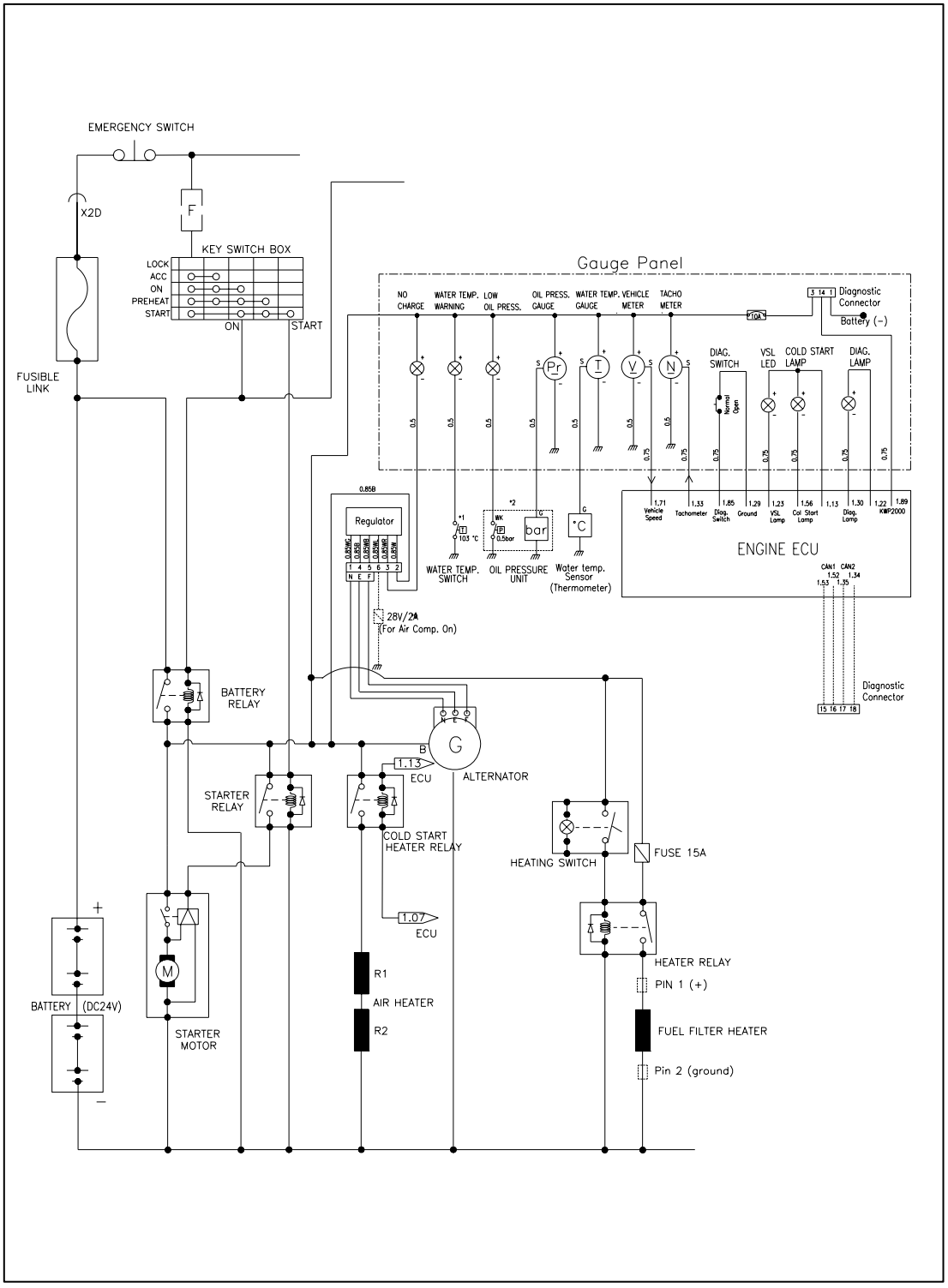

| | | | |
|---|---|---|---|
| 1 | Crankshaft speed sensor | 7 | Boost pressure & temperature sensor |
| 2 | Common rail pressure sensor | 8 | Coolant temperature sensor |
| 3 | Fuel pressure limit valve | 9 | Air heater |
| 4 | Fuel temperature sensor | 10 | Air con. compressor |
| 5 | Fuel metering shut off switch | 11 | Starter |
| 6 | Engine oil pressure & temperature sensor | 12 | Camshaft speed sensor |

### 3.5.3. Harness of electrical control unit

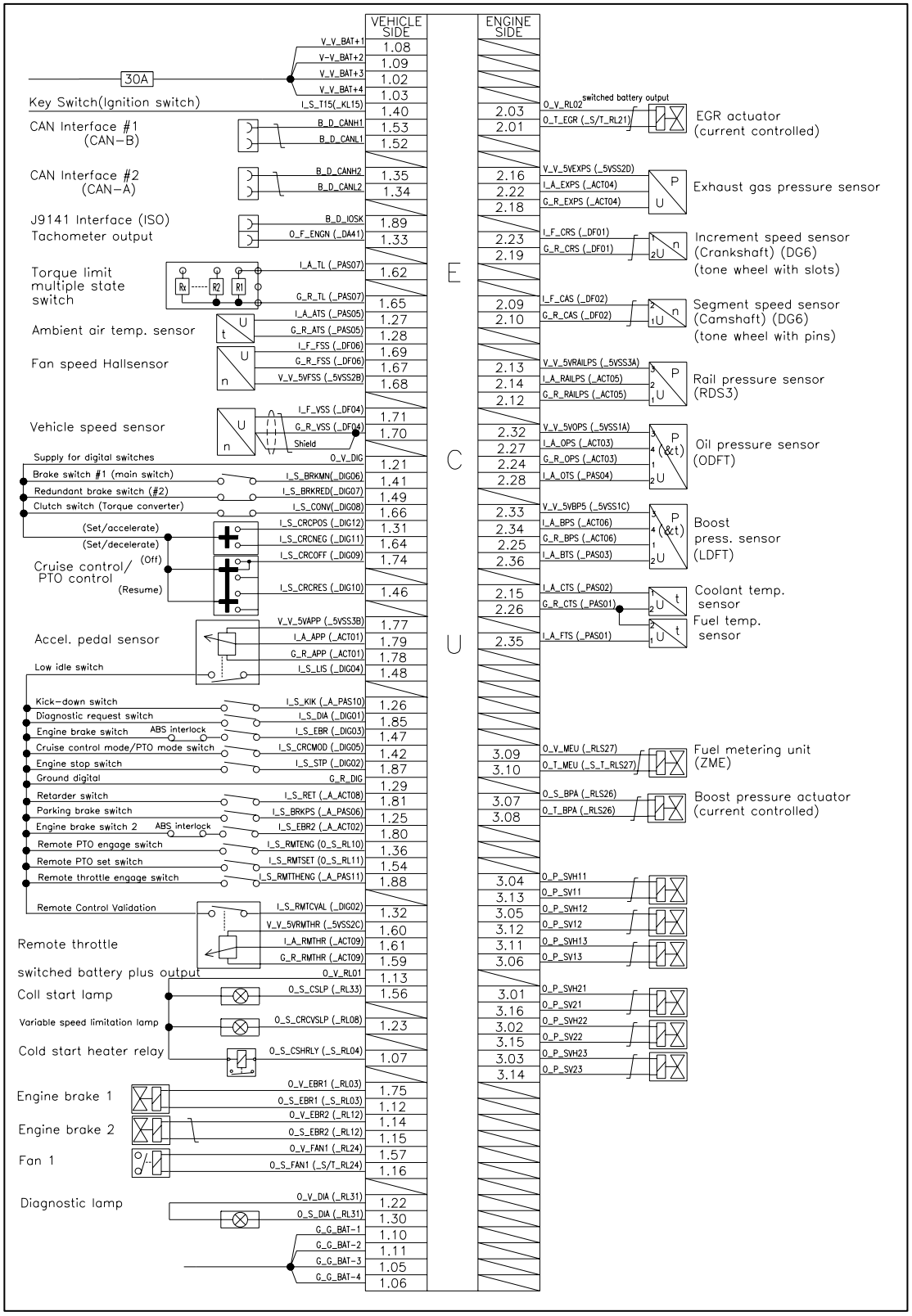
#### a) Harness of electrical control unit (A)



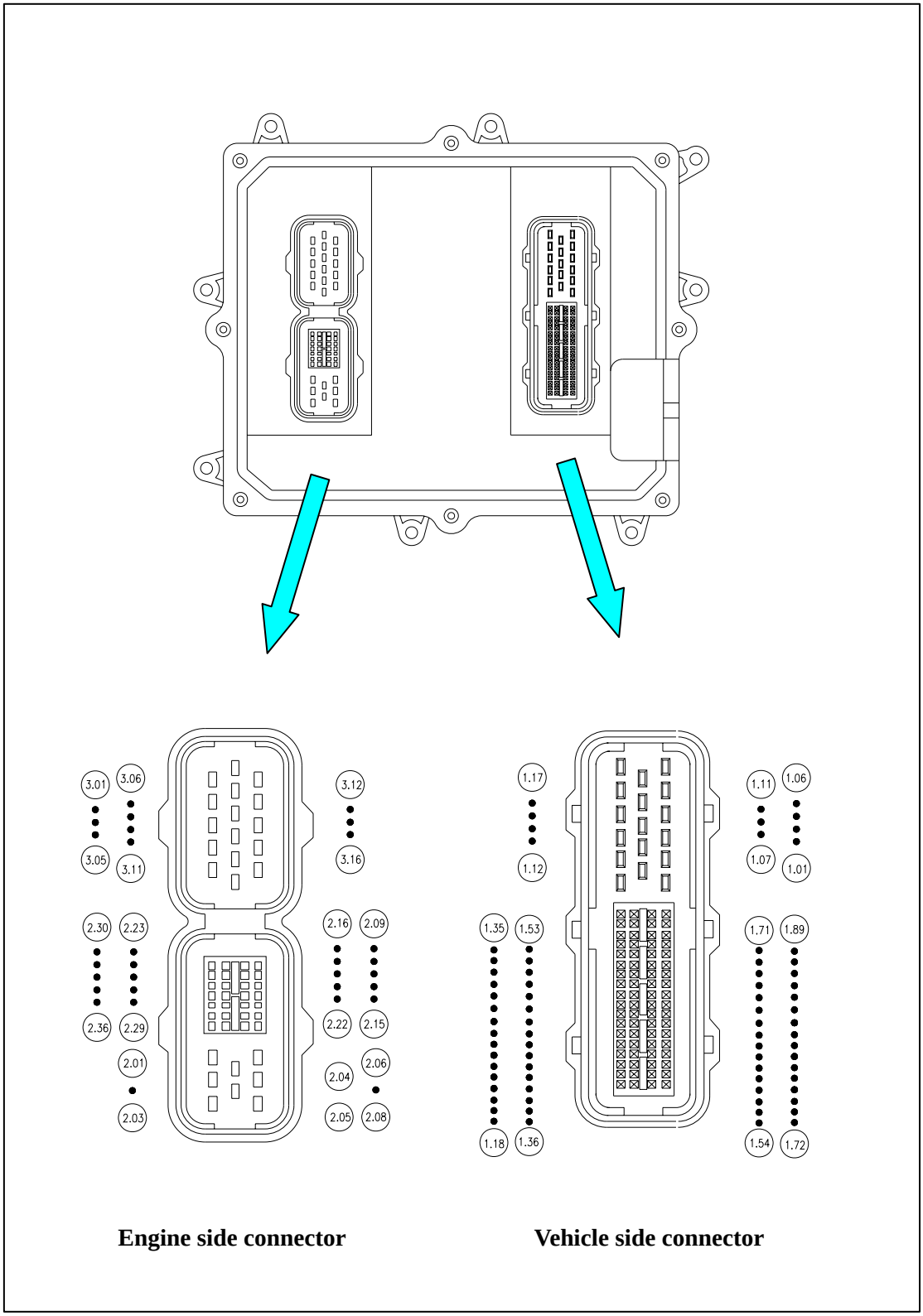
## b) Harness of electrical control unit (B)



## c) Harness of electrical control unit (C)



### 3.5.4. Connector of electrical control unit (ECU)




**Engine side connector** **Vehicle side connector**

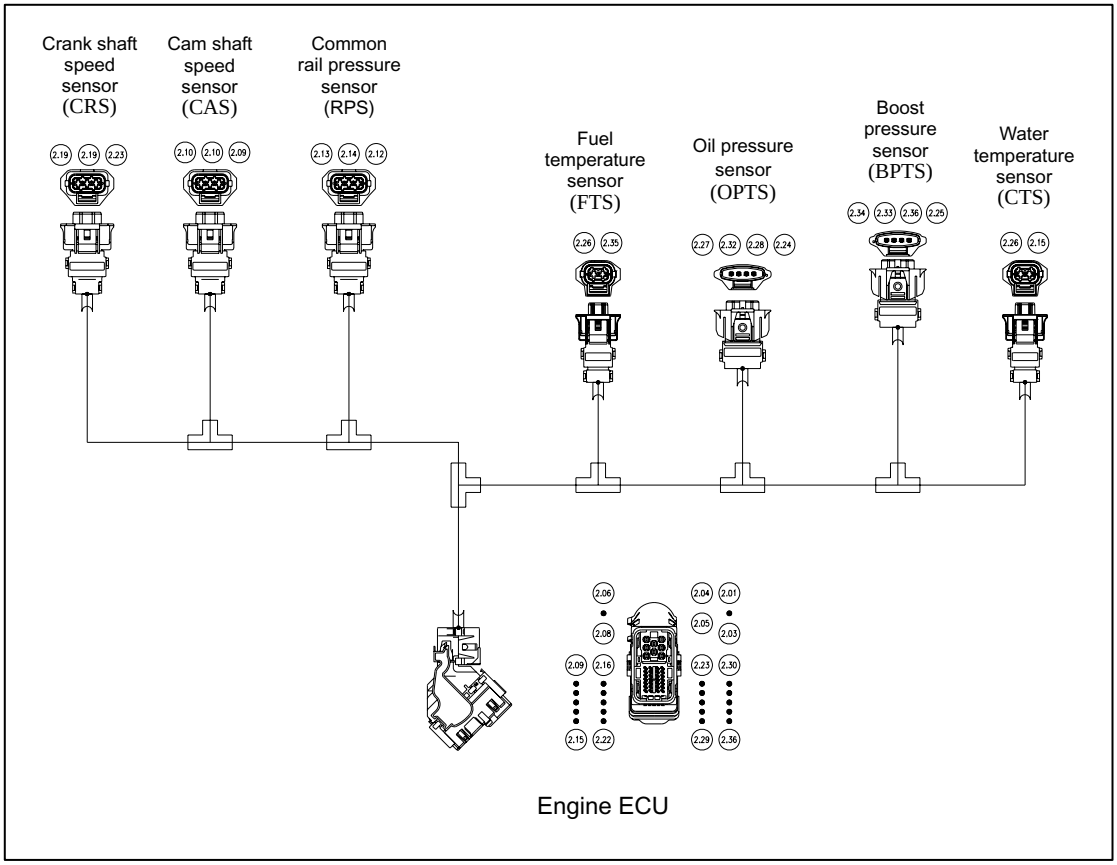
### 3.5.5. Electrical Control Unit

| Pin no. | Abbreviation | | Part name |
|---|---|---|---|
| | BOSCH | DOOSAN | |
| 1.02 | V_V_BAT+3 | V_V_BAT+3 | Battery plus 3 |
| 1.03 | V_V_BAT+4 | V_V_BAT+4 | Battery plus 4 |
| 1.05 | G_G_BAT-3 | G_G_BAT-3 | Battery minus 3 |
| 1.06 | G_G_BAT-4 | G_G_BAT-4 | Battery minus 4 |
| 1.07 | O_S_CHRLY | O_S_RL04 | Cold starter heater relay |
| 1.08 | V_V_BAT+1 | V_V_BAT+1 | Battery plus 1 |
| 1.09 | V_V_BAT+2 | V_V_BAT+2 | Battery plus |
| 1.10 | G_G_BAT-1 | G_G_BAT-1 | Battery minus 1 |
| 1.11 | G_G_BAT-2 | G_G_BAT-2 | Battery minus 2 |
| 1.12 | O_S_EBR1 | O_S_RL03 | Engine brake 1 |
| 1.13 | O_V_RL01 | O_V_RL01 | Switched battery plus output 1 (low side driver) |
| 1.14 | O_V_EBR2 | O_V_RL12 | Engine brake 2 supply (BAT+) |
| 1.15 | O_S_EBR2 | O_S_RL12 | Engine brake 2 power output |
| 1.16 | O_S_FAN1 | O_S/T_RL24 | Motor fan relay 1 |
| 1.21 | O_V_DIG | O_V_DIG | Supply for digital switches |
| 1.22 | O_V_DIA | O_V_RL31 | Diagnostic lamp supply (BAT+ ) |
| 1.23 | O_S_CRCVSLP | O_S_RL08 | Variable speed limitation lamp |
| 1.25 | I_S_BRKPS | I_A_PAS06 | Parking brake signal |
| 1.26 | I_S_KIK | I_A_PAS10 | Kick-down input signal |
| 1.27 | I_A_ATS | I_A_PAS05 | Ambient temperature sensor signal |
| 1.28 | G_R_ATS | G_R_PAS05 | Ambient temperature sensor ground |
| 1.29 | G_R_DIG | G_R_DIG | Ground digital |
| 1.30 | O_S_DIA | O_S_RL31 | Diagnostic lamp |
| 1.31 | I_S_CRCPOS | I_S_DIG12 | Cruise control activator / PTO, "Set / accelerate" |
| 1.32 | I_S_RMTSCVAL | I_S_DIG02 | Remote control validation |
| 1.33 | O_F_ENGN | O_F_DA41 | Engine speed sensor output signal |
| 1.34 | B_D_CANL2 | B_D_CANL2 | Controller area network 2, low |
| 1.35 | B_D_CANH2 | B_D_CANH2 | Controller area network 2, high |
| 1.36 | I_S_RMTENG | O_S_RL10 | Remote PTO engage |
| 1.40 | I_S_T15 | I_S_KL15 | Terminal 15 (switched BAT+) |
| 1.41 | I_S_BRKMN | I_S_DIG06 | Brake main switch signal |
| 1.42 | I_S_CRCMOD | I_S_DIG05 | Variable speed limitation input signal(Programmable) |
| 1.46 | I_S_CRCRES | I_S_DIG10 | Cruise control activator / PTO, "Resume" |
| 1.47 | I_S_EBR | I_S_DIG03 | Engine brake switch signal |
| 1.48 | I_S_LIS | I_S_DIG04 | Low idle position switch input signal |
| 1.49 | I_S_BRKRED | I_S_DIG07 | Redundant brake switch signal |
| 1.52 | B_D_CANL1 | B_D_CANL1 | Controller area network 1, low |
| 1.53 | B_D_CANH1 | B_D_CANH1 | Controller area network 1, high |
| 1.54 | I_S_RMTSET | O_S_RL11 | Remote PTO set |
| 1.56 | O_S_CSLP | O_S_RL33 | Cold start lamp |
| 1.57 | O_V_FAN1 | O_V_RL24 | Motor fan relay 1 supply (BAT+ ) |

| Pin no. | Abbreviation | | Part name |
|---|---|---|---|
| | BOSCH | DOOSAN | |
| 1.59 | G_R_RMTHR | G_R_ACT09 | Remote throttle ground |
| 1.60 | V_V_5VRMTHR | V_V_5VSS2C | Remote throttle, supply |
| 1.61 | I_A_RMTHR | I_A_ACT09 | Remote throttle input signal |
| 1.62 | I_A_TL | I_A_PAS07 | Torque limitation signal |
| 1.64 | I_S_CRCNEG | I_S_DIG11 | Cruise control activator/PTO,"Set / decelerate" |
| 1.65 | G_R_TL | G_R_PAS07 | Torque limitation ground |
| 1.66 | I_S_CONV | I_S_DIG08 | Clutch switch signal (Torque converter) |
| 1.67 | G_R_FSS | G_R_DF06 | Fan speed sensor ground |
| 1.68 | V_V_5VFSS | V_V_5VSS2B | Fan speed sensor supply |
| 1.69 | I_F_FSS | I_F_DF06 | Fan speed sensor signal |
| 1.70 | G_R_VSS | G_R_DF04 | Vehicle speed sensor ground |
| 1.71 | I_F_VSS | I_F_DF04 | Vehicle speed sensor input signal |
| 1.74 | I_S_CRCOFF | I_S_DIG09 | Cruise control activator / PTO, "Off" |
| 1.75 | O_V_EBR1 | O_V_RL03 | Engine brake1 |
| 1.77 | V_V_5VAPP | V_V_5VSS3B | Accelerator pedal position sensor supply |
| 1.78 | G_R_APP | G_R_ACT01 | Accelerator pedal position sensor ground |
| 1.79 | I_A_APP | I_A_ACT01 | Accelerator pedal position sensor signal |
| 1.80 | I_S_EBR2 | I_A_ACT02 | Engine brake switch 2 signal |
| 1.81 | I_S_RET | I_A_ACT08 | Retarder switch signal |
| 1.85 | I_S_DIA | I_S_DIG01 | Error memory read signal<br>/ Diagnostic request switch |
| 1.87 | I_S_STP | I_S_DA42 | Engine stop switch signal |
| 1.88 | I_S_RMTTHENG | I_F_DA43 | Remote throttle engage switch |
| 1.89 | B_D_ISOK | B_D_ISOK | ISO-K Interface |
| 2.01 | O_T_EGR | O_S/T_RLS21 | EGR actuator, current controlled |
| 2.03 | O_V_RL02 | O_V_RL02 | Switched battery plus output 2 (low side driver) |
| 2.09 | I_F_CAS | I_F_DF02 | Segment (camshaft) speed sensor signal |
| 2.10 | G_R_CAS | G_R_DF02 | Segment (camshaft) speed sensor ground |
| 2.12 | G_R_RAILPS | G_R_ACT05 | Rail pressure sensor ground |
| 2.13 | V_V_5VRAILPS | V_V_5VSS3A | Rail pressure sensor supply |
| 2.14 | I_A_RAILPS | I_A_ACT05 | Rail pressure sensor signal |
| 2.15 | I_A_CTS | I_A_PAS02 | Coolant temperature sensor signal |
| 2.16 | V_V_5VEXPS | V_V_5VSS2D | Exhaust gas back-pressure sensor supply |
| 2.18 | G_R_EXPS | G_R_ACT04 | Exhaust gas back-pressure sensor ground<br>(and FTS) |
| 2.19 | G_R_CRS | G_R_DF01 | Crankshaft speed sensor ground |
| 2.22 | I_A_EXPS | I_A_ACT04 | Exhaust gas back-pressure sensor signal |
| 2.23 | I_F_CRS | I_F_DF01 | Crankshaft speed sensor signal |
| 2.24 | G_R_OPS | G_R_ACT03 | Oil pressure sensor ground |
| 2.25 | G_R_BPS | G_R_ACT06 | Boost pressure sensor ground |
| 2.26 | G_R_CTS | G_R_PAS01 | Coolant temperature sensor ground |
| 2.27 | I_A_OPS | I_A_ACT03 | Oil pressure sensor input signal |
| 2.28 | I_A_OTS | I_A_PAS04 | Oil temperature sensor signal |

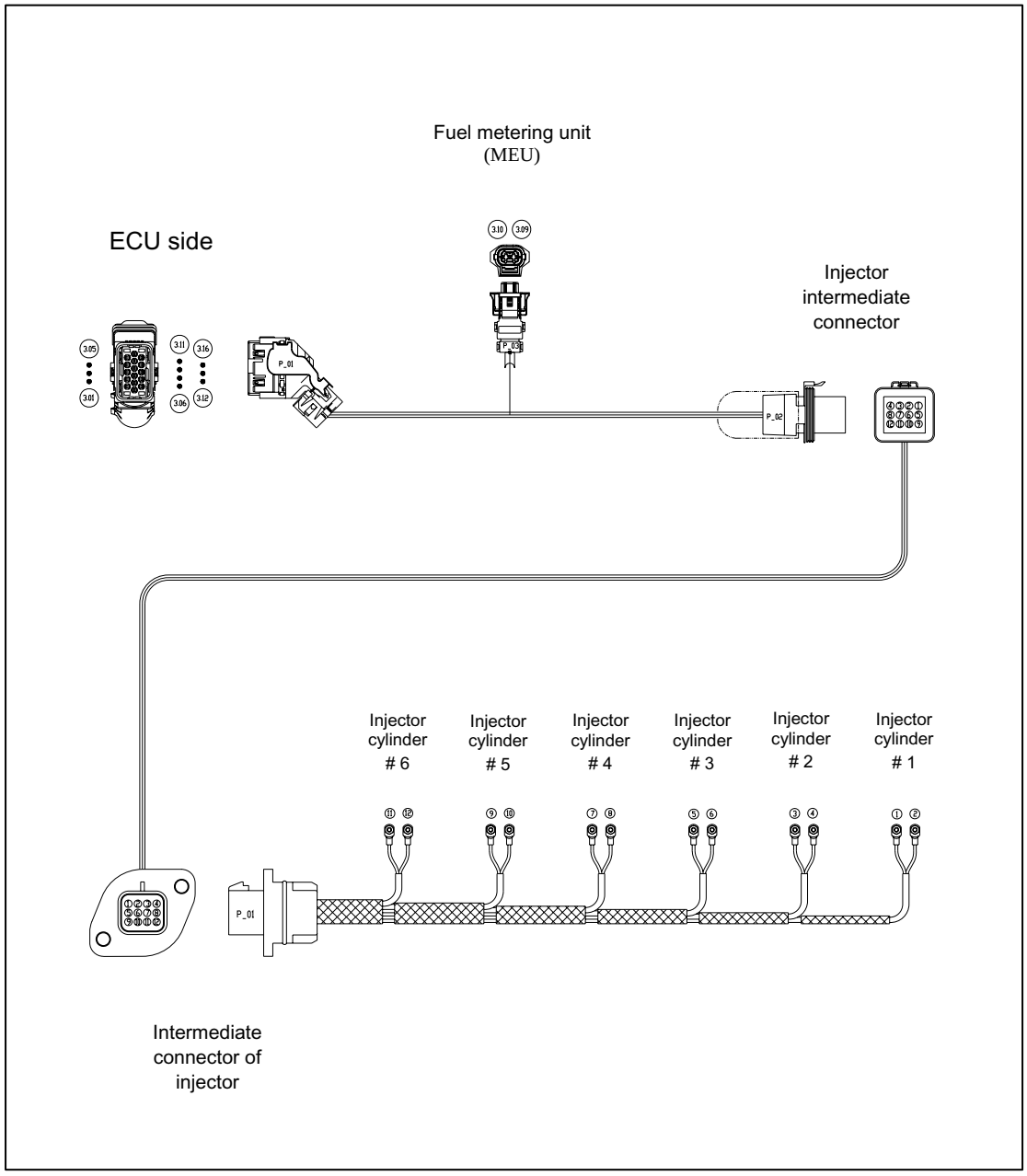
| Pin no. | Abbreviation | | Part name |
|---|---|---|---|
| | BOSCH | DOOSAN | |
| 2.32 | V_V_5VOPS | V_V_5VSS1A | Oil pressure sensor supply |
| 2.33 | V_V_5VBPS | V_V_5VSS1C | Boost pressure sensor supply |
| 2.34 | I_A_BPS | I_A_ACT06 | Boost pressure sensor signal |
| 2.35 | I_A_FTS | I_A_PAS01 | Fuel temperature sensor signal |
| 2.36 | I_A_BTS | I_A_PAS03 | Boost pressure temperature sensor signal |
| 3.01 | O_P_SVH21 | O_P_SVH21 | Injector 5 “High Bank 2” ; Cylinder no. 5 |
| 3.02 | O_P_SVH22 | O_P_SVH22 | Injector 6 “High Bank 2” ; Cylinder no. 6 |
| 3.03 | O_P_SVH23 | O_P_SVH23 | Injector 4 “High Bank 2” ; Cylinder no. 4 |
| 3.04 | O_P_SVH11 | O_P_SVH11 | Injector 1 “High Bank 1” ; Cylinder no. 1 |
| 3.05 | O_P_SVH12 | O_P_SVH12 | Injector 3 “High Bank 1” ; Cylinder no. 3 |
| 3.06 | O_P_SV13 | O_P_SV13 | Injector 2 “High Bank 1” ; Cylinder no. 2 |
| 3.07 | O_V_BPA | O_V_RLS26 | Boost pressure actuator supply (BAT+ ) |
| 3.08 | O_T_BPA | O_T_RLS26 | Boost pressure actuator (EPW) |
| 3.09 | O_V_MEU | O_V_RLS27 | Fuel metering unit supply (BAT+ ) |
| 3.10 | O_T_MEU | O_S/T_RLS27 | Fuel metering unit |
| 3.11 | O_P_SVH13 | O_P_SVH13 | Injector 2 “High Bank 1” ; Cylinder no. 2 |
| 3.12 | O_P_SV12 | O_P_SV12 | Injector 3 “High Bank 1” ; Cylinder no. 3 |
| 3.13 | O_P_SV11 | O_P_SV11 | Injector 1 “High Bank 2” ; Cylinder no. 1 |
| 3.14 | O_P_SV23 | O_P_SV23 | Injector 4 “High Bank 2” ; Cylinder no. 4 |
| 3.15 | O_P_SV22 | O_P_SV22 | Injector 6 “High Bank 2” ; Cylinder no. 6 |
| 3.16 | O_P_SV21 | O_P_SV21 | Injector 5 “High Bank 2” ; Cylinder no. 5 |

## 3.5.6. Engine harness - 1

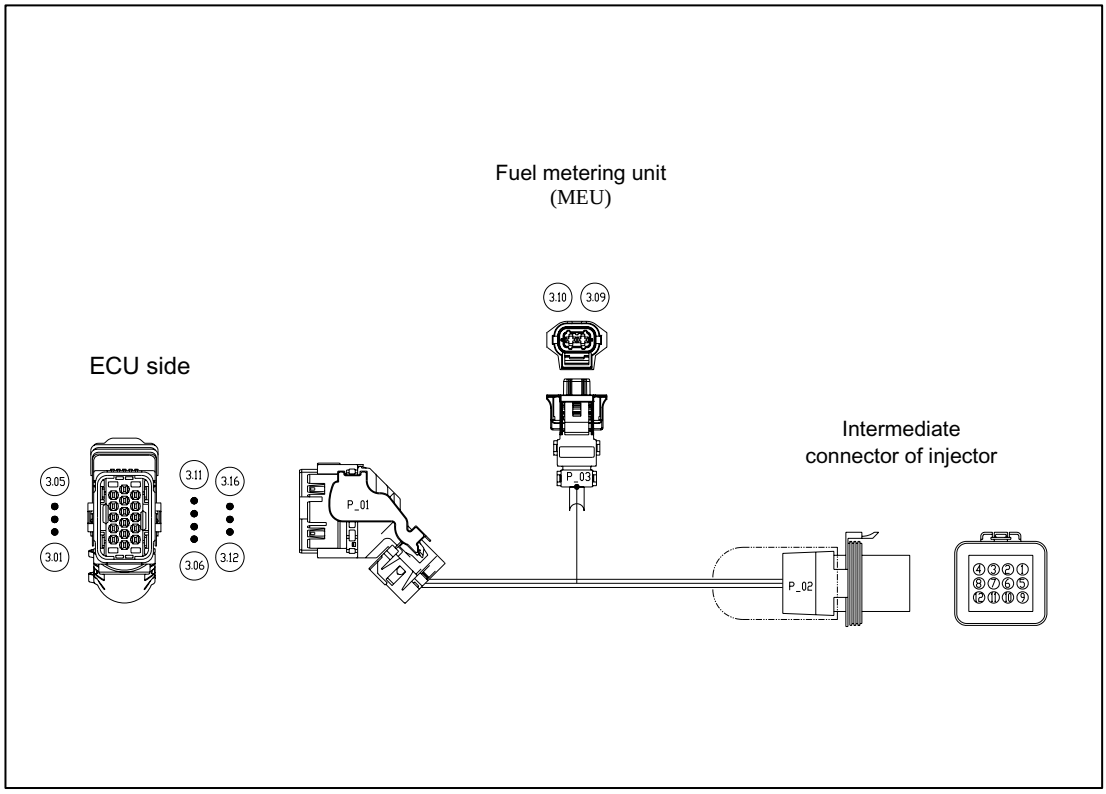



| Sensor pin no. | Signal | Pin position | | Wire color | Circuit name |
|---|---|---|---|---|---|
| | | ECU pin no. | Connecting pin no. | | |
| 2.23 | CRS | ECU no. 23 | Crankshaft sensor no.1 | White | Speed sensor signal |
| 2.19 | | ECU no. 19 | Crankshaft sensor no.2 | Black | Speed sensor ground(-) |
| 2.09 | CAS | ECU no. 09 | Camshaft sensor no.1 | White | Speed sensor signal |
| 2.10 | | ECU no. 10 | Camshaft sensor no.2 | Black | Speed sensor ground (-) |
| 2.24 | OPTS | ECU no. 24 | Oil pressure sensor no.1 | Black | Oil pressure sensor ground (-) |
| 2.28 | | ECU no. 28 | Oil temperature sensor no.2 | White | Oil temperature sensor signal |
| 2.32 | | ECU no. 32 | Oil pressure sensor no.3 | White | Oil pressure sensor power supply (5V) |
| 2.27 | | ECU no. 27 | Oil pressure sensor no.4 | White | Oil pressure sensor signal |
| 2.25 | BPTS | ECU no. 25 | Boost pressure sensor no.1 | Black | Boost pressure sensor ground(-) |
| 2.36 | | ECU no. 36 | Boost temperature sensor no.2 | White | Boost temperature sensor signal |
| 2.33 | | ECU no. 33 | Boost pressure sensor no.3 | White | Boost pressure sensor power supply (5V) |
| 2.34 | | ECU no. 34 | Boost pressure sensor no.4 | White | Boost pressure sensor signal |
| 2.12 | RPS | ECU no. 12 | Rail pressure sensor no.1 | Black | Rail pressure sensor ground (-) |
| 2.14 | | ECU no. 14 | Rail pressure sensor no.2 | White | Rail pressure sensor signal |
| 2.13 | | ECU no. 13 | Rail pressure sensor no.3 | White | Rail pressure sensor power supply (5V) |
| 2.15 | CTS | ECU no. 15 | Coolant temperature sensor 1 | White | Coolant temperature sensor signal |
| 2.26 | | ECU no. 26 | Coolant temperature sensor 2 | Black | Coolant temperature sensor ground(-) |
| 2.35 | FTS | ECU no. 35 | Fuel temperature sensor no.1 | White | Fuel temperature sensor signal |
| 2.26 | | ECU no. 26 | Fuel temperature sensor no.2 | Black | Fuel temperature sensor ground(-) |

### 3.5.7. Engine harness – 2

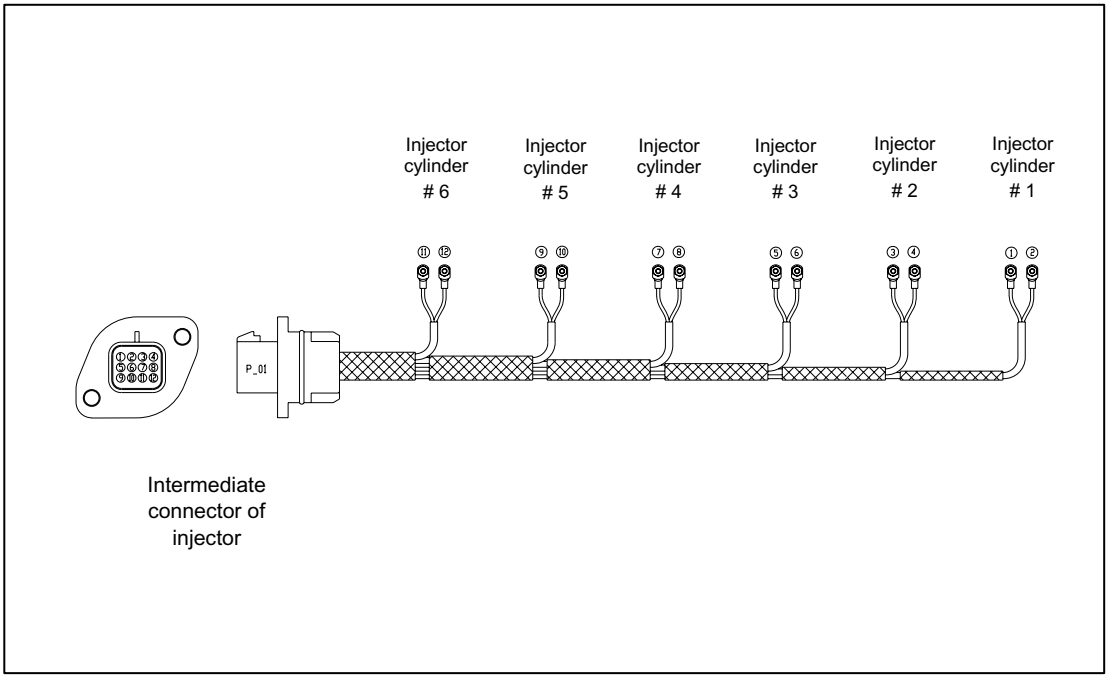


### 1) Injector harness (outside)




| Side of ECU | | Destination | | Wire color | Circuit name |
|---|---|---|---|---|---|
| Connector no. | Pin no. | Connector no. | Pin no. | | |
| P_01<br><br>Y462 U03 027<br>(1 928 404 202)<br>(BOSCH) | 3.04 | P_02<br>211 PC<br>0123S0003<br>(FCI) | 1 | White | High side of injector 1 |
| | 3.13 | | 2 | White | Low side of injector 1 |
| | 3.11 | | 3 | White | High side of injector 2 |
| | 3.06 | | 4 | White | Low side of injector 2 |
| | 3.05 | | 5 | White | High side of injector 3 |
| | 3.12 | | 6 | White | Low side of injector 3 |
| | 3.03 | | 7 | White | High side of injector 4 |
| | 3.14 | | 8 | White | Low side of injector 4 |
| | 3.01 | | 9 | White | High side of injector 5 |
| | 3.16 | | 10 | White | Low side of injector 5 |
| | 3.02 | | 11 | White | High side of injector 6 |
| | 3.15 | | 12 | White | Low side of injector 6 |
| | 3.09 | P_03<br>936059-1<br>(AMP) | 1 | White | Fuel metering unit(high side) |
| | 3.10 | | 2 | Black | Fuel metering unit(low side) |

## 2) Injector harness (Inside)




| Side of ECU harness | | Destination | | Wire color | Circuit name |
|---|---|---|---|---|---|
| Connector no. | Pin no. | Connector no. | Pin no. | | |
| P_01<br><br>65.26810-5011<br><br>99013-00102 (AMP) | 1 | C-1599298 (AMP) | 1 | White | High side of injector 1 |
| | 2 | | 2 | | Low side of injector 1 |
| | 3 | | 3 | | High side of injector 2 |
| | 4 | | 4 | | Low side of injector 2 |
| | 5 | | 5 | | High side of injector 3 |
| | 6 | | 6 | | Low side of injector 3 |
| | 7 | | 7 | | High side of injector 4 |
| | 8 | | 8 | | Low side of injector 4 |
| | 9 | | 9 | | High side of injector 5 |
| | 10 | | 10 | | Low side of injector 5 |
| | 11 | | 11 | | High side of injector 6 |
| | 12 | | 12 | | Low side of injector 6 |

## 3.6. Engine Diagnostic

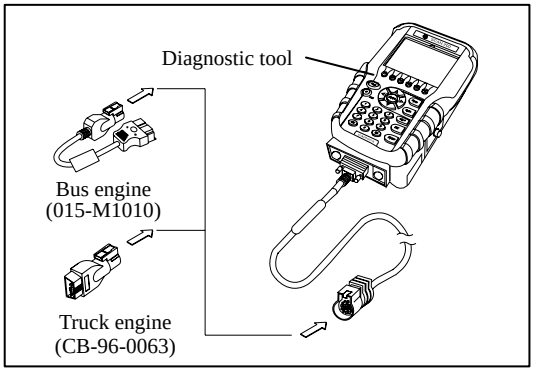
### 3.6.1. Method of confirmation for the fault code

The method of performing the DL06 engine diagnostic are method by using the diagnostic tool and method of confirming the indicator code using the blinking times of the vehicle's engine indicator lamp.

DOOSAN recommend the using the diagnostic tool, because it can be worked speedy and correctly.

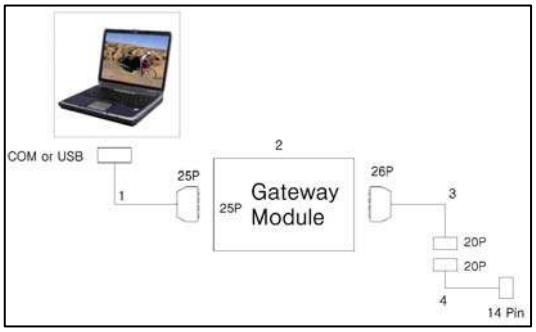
### 3.6.2. Diagnostic by SCAN-200

- SCAN-200 is designed to serve to the maintenance with adding the function of the graphic and oscilloscope to be used for the diagnosis and maintenance of present vehicle system.




### 3.6.3. Diagnostic by notebook computer

- Please know well the user's manual to shorten the time and to apply the diagnostic tool before use the diagnostic tool. At the time of using the diagnostic tool, if use together diagnostic manual and maintenance manual for the maintenance, the effect should be increased more and more.



### 3.6.4. Engine fault code and occurring condition

| Fault code | Contents of trouble | Lamp | Condition of occurring |
|---|---|---|---|
| 1.1 | Relation to coolant temperature sensor is abnormal | C | * Sensor / harness is abnormal<br>* Coolant temperature is too high |
| 1.2 | Relation to fuel temperature sensor is abnormal | C | * Sensor / harness is abnormal<br>* Fuel temperature is too high |
| 1.3 | Relation to boost air temperature sensor is abnormal | C | * Sensor / harness is abnormal<br>* Intake temperature is excessive after intercooler<br>* Engine / turbocharger / intercooler is abnormal |
| 1.4 | Relation to boost air pressure sensor is abnormal | C | * Sensor / harness is abnormal<br>* Intake pressure is excessive after intercooler<br>* Engine / turbocharger / intercooler is abnormal |
| 1.5 | Ambient air temperature sensor is abnormal | N | * Not use<br>* Sensor / harness is abnormal |
| 1.6 | Ambient air pressure sensor is abnormal | C | *Ambient air pressure sensor attached to ECU is abnormal ECU |
| 1.7 | Relation to oil temperature sensor is abnormal | N | * Sensor / harness is abnormal<br>* Oil temperature is too high |
| 1.8 | Relation to oil pressure sensor is abnormal | C | * Sensor/harness is abnormal<br>* Oil pressure is abnormal (Leakage etc.) |
| 1.9 | Multiple state switch is abnormal | C | * Switch abnormal<br>- SRC upper limitation<br>- SRC lower limitation |
| 2.1 | Battery voltage is abnormal | C | * Battery / alternator / ECU is abnormal |
| 2.2 | Relation to fuel pressure sensor is abnormal | B | * Sensor / harness is abnormal |
| 2.3 | Relation to accelerator pedal is abnormal | B | * Accelerator pedal sensor / switch / harness is abnormal |
| 2.4 | Relation to accelerator pedal is abnormal | C | * Accelerator pedal error related on service brake switch fail.<br>* Not use for Industrial vehicles<br>* Service brake & accelerator pedal switch / harness is abnormal |
| 2.5 | Vehicle speed is abnormal | C | * Not use for industrial vehicles<br>* Vehicle speed sensor, tachometer or harness is abnormal |
| 2.6 | Air mass sensor is abnormal | N | * Not use |
| 2.7 | Clutch pedal switch is abnormal | C | * Not use for industrial vehicles<br>* Clutch pedal switch / harness is abnormal |
| 2.8 | Service brake switch is abnormal | C | * Not use for industrial vehicles<br>* Foot brake switch / harness is abnormal |
| 2.9 | Relation to cruise control switch is abnormal | N | * Switch or harness is abnormal |
| 3.1 | Monitoring of wear damage of the injection system | N | * Not use |
| 3.2 | Common rail pressure excessive fluctuation | B | * Common rail pressure is abnormal |
| 3.3 | Boost pressure regulation is abnormal | N | * Not use |
| 3.4 | Exhaust gas regulation is abnormal | N | * Not use |
| 3.5 | Transmission control is abnormal | N | * Auto transmission control unit message error |
| 3.6 | Automatic traction control is abnormal | N | * Not use for Industrial vehicles<br>* Auto traction control unit message error |
| 3.7 | CAN-B line is abnormal | C | * Transmit and receive message communicating line thru CAN (ASR, Auto transmission, etc)<br>- CAN bus off<br>- SRC low or DPRAM error<br>- No signal or error passive time |
| 3.8 | Warning which engine speed is excessive | C | * Engine over-speed |
| 3.9 | Main relay is short on circuit to ground | B | * ECU inner main relay is abnormal<br>* Power supplying is abnormal<br>* When the main relay is shorted to ground, depending on whether the main relay is 1,2 or 3 |

| Fault code | Contents of trouble | Lamp | Condition of occurring |
|---|---|---|---|
| 4.1 | Abnormality by abnormal stopping of engine | B | * Abnormal engine stopping |
| 4.2 | Relation to crank shaft speed sensor is abnormal | C | * Sensor / harness is abnormal<br>* Sensor gap is abnormal |
| 4.3 | Relation to cam shaft speed sensor is abnormal | C | * Sensor / harness is abnormal<br>* Sensor gap is abnormal |
| 4.4 | Engine speed sensor is abnormal | C | * Motivation of cam shaft / crank shaft speed sensor signal is abnormal |
| 4.5 | Dater storage of EEPROM in ECU is abnormal | C | * Error is occurred during storing important data of operating in ECU to EEPROM when engine stop. |
| 4.6 | Initialization is not good after power supply to ECU | C | * ECU initialization is abnormal |
| 4.7 | Pressure limit valve of common rail is opened by excessive rail pressure | B | * Pressure limit value is opened compulsory when rail pressure is occurred at excessive pressure more than rail pressure or high pressure pump |
| 4.8 | Power supplying source is abnormal | C | Battery voltage is abnormal : ECU, battery and alternator is abnormal |
| 4.9 | Main relay is short on circuit to ground | C | * When the main relay is shorted to Battery, depending on whether the main relay is 1,2 or 3 |
| 5.1 | Main relay ECU | C | * After the final switch-off command is given to ECU if the ECU is not switched OFF within the time then a fault is assumed to have occurred |
| 5.2 | Cylinder balancing cylinder 1 | N | * Not use |
| 5.3 | Cylinder balancing cylinder 2 | N | * Not use |
| 5.4 | Cylinder balancing cylinder 3 | N | * Not use |
| 5.5 | Cylinder balancing cylinder 4 | N | * Not use |
| 5.6 | Cylinder balancing cylinder 5 | N | * Not use |
| 5.7 | Cylinder balancing cylinder 6 | N | * Not use |
| 5.8 | Relation to connecting of injector # 1 harness is abnormal | B | * Injector cable / connector is abnormal |
| 5.9 | Relation to connecting of injector # 2 harness is abnormal | B | |
| 6.1 | Relation to connecting of injector # 3 harness is abnormal | B | |
| 6.2 | Relation to connecting of injector # 4 harness is abnormal | B | |
| 6.3 | Relation to connecting of injector # 5 harness is abnormal | B | |
| 6.4 | Relation to connecting of injector # 6 harness is abnormal | B | |
| 6.5 | Low side power stage 1 | C | * CP3 Pump<br>* Metering unit / cable / connector is abnormal |
| 6.6 | Low side Power stage 2 | N | * Not use |
| 6.7 | Low side Power stage 3 | N | * Not use |
| 6.8 | Low side power stage 13 | C | * Cold starter heater relay<br>* Relay unit / cable / connector is abnormal |
| 6.9 | Low side Power stage 12 | N | * Engine brake 1<br>* Brake 1 unit / cable / connector is abnormal |
| 7.1 | Low side Power stage 6 | N | * Not use |
| 7.2 | Low side Power stage 7 | N | * Not use |
| 7.3 | Low side Power stage 8 | N | * Not use |
| 7.4 | Low side Power stage 9 | N | * Not use |
| 7.5 | Low side Power stage 10 | N | * variable speed limit |

| Fault code | Contents of trouble | Lamp | Condition of occurring |
|---|---|---|---|
| 7.6 | Low side Power stage 11 | N | * Not use |
| 7.7 | Low side Power stage 5 | N | * Not use |
| 7.8 | Low side Power stage 4 | N | * Not use |
| 7.9 | Low side Power stage 14 | N | * Engine brake 2<br>* Brake 2 unit / cable / connector is abnormal |
| 8.1 | Low side Power stage 15 | N | * Not use |
| 8.2 | Low side Power stage 16 | N | * Not use |
| 8.3 | Low side power stage 17 | N | * Cold start lamp<br>* Lamp unit / cable / connector is abnormal |
| 8.4 | Low side Power stage 18 | N | * Not use |
| 8.5 | Low side Power stage 19 | N | * Not use |
| 8.6 | Low side power stage 20 | N | * diagnostic lamp<br>* Diagnostic lamp unit / cable / connector is abnormal |
| 8.7 | Low side Power stage 21 | N | * Not use |
| 8.8 | Low side Power stage 22 | N | * Not use |
| 8.9 | Lowside powerstage 23(High side Power stage 1) | N | * Not use |
| 9.1 | Can-A line | C | * Fault message communicating line thru CAN<br>- CAN bus off<br>- SRC low or DPRAM error<br>- No signal or error passive time |
| 9.2 | Lowside powerstage 24(High side Power stage 2) | N | * Not use |
| 9.3 | Lowside powerstage 25(High side Power stage 3) | N | * Not use |
| 9.4 | Low side power stage 26 | N | * Tachometer<br>* Tachometer unit / cable / connector is abnormal |
| 9.5 | Lowside powerstage 27(Small Signal Power stage 2) | N | * Not use |
| 9.6 | Remote Throttle | N | * Not use for industrial vehicles<br>* Only special truck. Same with accelerator pedal (External pedal) |
| 9.7 | Monitoring of misfire cylinder #1 | C | * injector is abnormal, compression pressure is a drop, camshaft, crankshaft speed sensor signal is abnormal |
| 9.8 | Monitoring of misfire cylinder #2 | C | |
| 9.9 | Monitoring of misfire cylinder #3 | C | |
| 10.1 | Monitoring of misfire cylinder #4 | C | |
| 10.2 | Monitoring of misfire cylinder #5 | C | |
| 10.3 | Monitoring of misfire cylinder #6 | C | |
| 10.4 | Monitoring of misfire multiple cylinder | C | |
| 10.5 | Monitoring of overrun | C | * Overrun monitoring of accelerator pedal related on accelerate, service brake, clutch, parking brake, etc |
| 10.6 | Engine speed redundant | C | * The difference between ASW engine speed and redundant engine speed exceeds a threshold.<br>* Segment speed is above threshold and if the interrupt detection status is not in-active. |
| 10.7 | Accelerator pedal unplausibility (APP3) | N | * Not use |
| 10.8 | Smooth running control seg-0 | N | * Not use |
| 10.9 | Smooth running control seg-1 | N | * Not use |

| Fault code | Contents of trouble | Lamp | Condition of occurring |
|---|---|---|---|
| 11.1 | Smooth running control seg-2 | N | * Not use |
| 11.2 | Smooth running control seg-3 | N | * Not use |
| 11.3 | Smooth running control seg-4 | N | * Not use |
| 11.4 | Smooth running control seg-5 | N | * Not use |
| 11.5 | Fan speed sensor | N | * Not use<br>* Fan speed sensor / harness is abnormal |
| 11.6 | EBC1 message timeout | N | * Not use |
| 11.7 | Fuel pressure monitoring MPROPHIGH | B | * Same with fuel pressure monitoring MPROPHIGH. Only, this is critical error. So, engine stalls.<br>* Fuel pressure sensor fail or DBV fail |

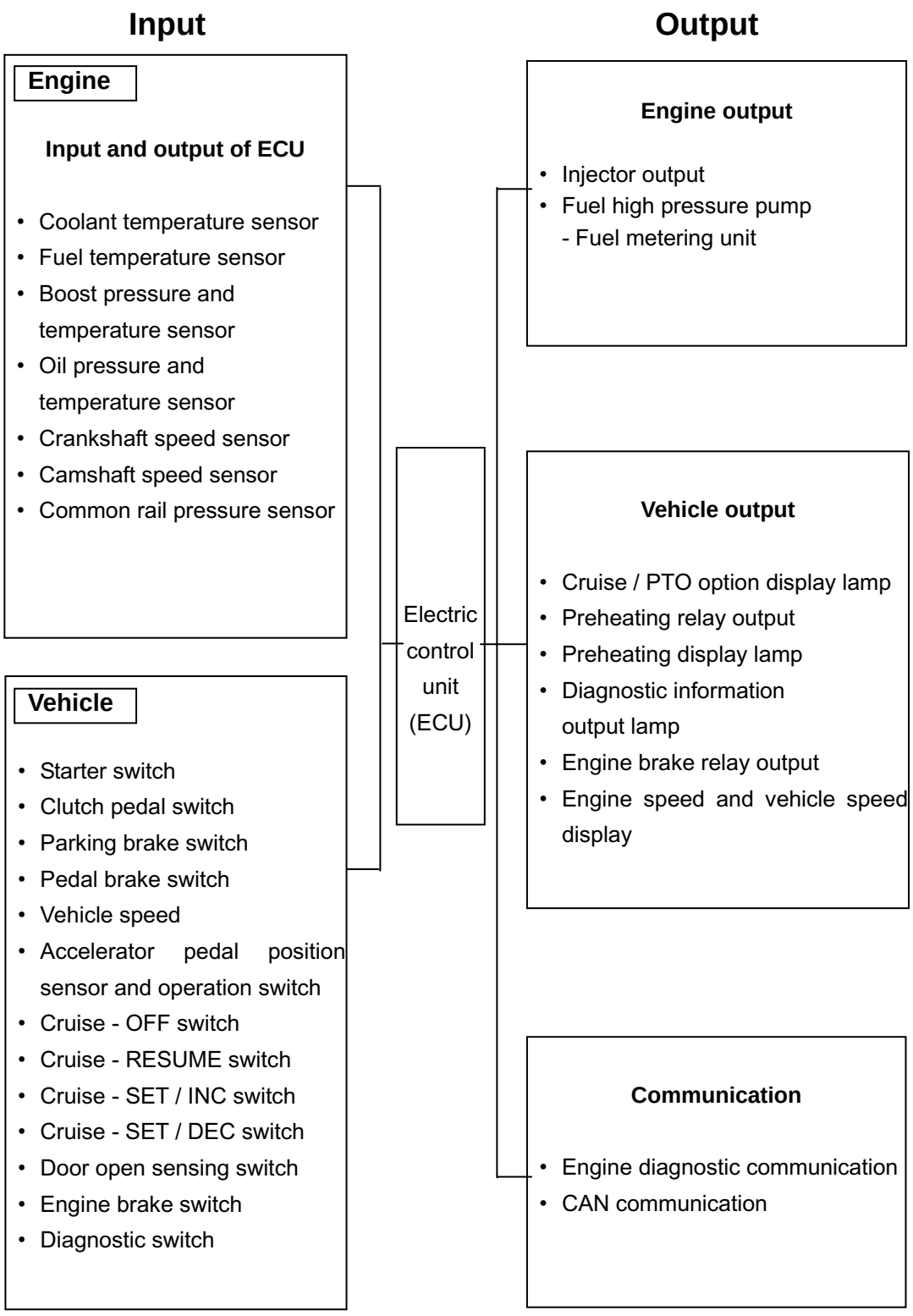
* Check of the lamp's operation

N : Case of no damage to the performance and the engine.

C : Case of requirement for the check after running (no emergency check).

B : Case of requirement for the check and measure after running at the low speed at the time of occurring.

### 3.6.5. Input and output of the ECU



## 3.7. Operating condition of the ECU

### 3.7.1. Engine starting

- Setting of a basic temperature for decision of the fuel quantity.
  Set to a basic temperature the minimum value between coolant temperature and fuel temperature and intake air temperature.
- Engine speed sensor signal measurement
  - Using by crankshaft speed sensor.
  - Using by camshaft speed sensor.
  - Supply to the engine after decided properly fuel quantity to starting the engine.

### 3.7.2. Vehicle running

- Essential dater for the running of the vehicle.
  - Accelerator pedal position signal
  - Engine speed
  - Vehicle speed

### 3.7.3. Engine idle adjusting

- Adjusting of engine's idle speed by the necessity of the driver.
- Method of the adjusting is possible by using the cruise control switch.

- **Preparing condition for the adjusting of the idle speed**
  - Cruise control switch : no trouble
  - Pedal brake : no trouble
  - Vehicle speed : stop
  - Coolant temperature : more than limit
  - Engine speed : less than limited scope of the speed

- **Adjusting method of the idle speed**
  - When the brake pedal is depressed.
  - After the cruise [RESUME] switch is depressed for one minute.
    - Engine speed increase : cruise control [SET/INC] switch is depressed.
    - Engine speed decrease: cruise control [SET/DEC] switch is depressed.

- **Storage of the variable of the idle speed**
  - Cruise control [RESUME] switch is depressed after variation of the speed.
  - When the switch [RESUME] is stored at the condition of depressing, the last stored value keep constantly after start the engine.
  - When the engine is stopped at the condition of doing not depressed [RESUME] switch, return to the first value.

### 3.7.4. Maximum speed limit function

- Limit speed : 100 km/h
- 80km/h : mixer, tank-rolley, concrete/high pressure gas transport car, the controller and operation unit and connecting unit should be sealed.
- The ECU control the speed not to exceed the limit defined according to the vehicle class.

### 3.7.5. Safety function when door is opened

- The vehicle limit the accelerating not to start on conditions of opened door.
  - City bus / a seat bus are adapted only
  - When the door is opened at stopping a vehicle.
    - Engine is operated by the idle speed.
    - Engine speed is not increased even though accelerator pedal is depressed.
  - When the door is opened during the vehicle running.
    - Engine speed is reduced to the idle speed and is maintained it.
    - Engine speed is not increased even though accelerator pedal is depressed.
- Opening and closing of the door is sensed automatically by the sensor switch.

### 3.7.6. Engine stop during long time of idling

- Engine is stop automatically when the condition of the idling is maintained for a long time.
  - Regulation for the reduction of the exhaust gas from the vehicle (engine idle revolution prohibition law)
    - Idle revolution limit time : less than 5 minutes
    - If the vehicle is unavoidably need the idle revolution an account of the air heating - cooling for the safety - rest of the passenger - driver, and if atmosphere temperature is more than 25°C or less than 5°C, the idle revolution is done within 10 minutes before start first.
- The ECU is operated by automatic sensing.

- **Operation condition**
  - State of vehicle speed sensor : normal
  - Vehicle speed : state of stop
  - Engine speed : idle speed
  - Parking brake : state of operation

- **Full disabled condition**
  - State of vehicle speed sensor : occurrence of trouble
  - Vehicle speed : running
  - Engine speed : change of speed more than idle speed
  - Parking brake : disabled

- **Temporarily disabled method**
  - Pedal brake is depressed, clutch pedal is depressed, or accelerator pedal is depressed.

### 3.7.7. Limp home function

- The limp home is a function which the vehicle can be operated to the maintenance shop with minimum condition for traveling on the condition of taking safety when the defect code is occurred.

- **Application condition**
  - **Accelerator pedal is trouble :** The vehicle is operated by constant engine speed no relation to depressing of the accelerator pedal.
  - **Sensor is trouble :** The vehicle is operated with constant transfer value when the trouble of all kinds sensors is occurred.
  - **Fuel quantity is limited :** The fuel quantity supplied into the engine is limited according to kind of the defect. (is applied by division into 4 stages)
  - **Diagnostic information output lamp :** The safety driving is leaded to the driver by proposal of information about status of occurred faults.

### 3.7.8. Diagnostic

- Diagnostic information output lamp (CEL: Check engine lamp) is operated when the trouble is occurred.

- **Operation of CEL and level of importance of faults**
  - **Defect of slight level :** lamp is not lighted.
    - ➢ No influence on performance
  - **Defect of middle level :** lamp is lighted continuously.
    - ➢ Little influence on performance, but the check is needed.
  - **Defect of serious level :** lamp is blinked.
    - ➢ Engine power is dropped
    - ➢ Engine power is not dropped, but the check is needed unavoidably after low speed operating.

- Method of confirmation of the fault code by using the CEL
  - The fault code is displayed one by one every time switch of the CEL is depressed.

- Diagnostic by the SCAN-200
  - Diagnostic is executed by the connection SCAN-200 to the connector in the relay box.

### 3.7.9. Vehicle operating record

- The vehicle information related to the operating is recorded in the electric control unit (ECU).
  - The measurement of the operating record is possible after the accumulated value or the switch『reset』is depressed.

- **The contents recorded in the electric control unit**
  - Fuel quantity according to the division : total, idle state, PTO
  - Fuel consumption rate.
  - operating mileage.
  - Engine operating time, ECU using time.

- The monitoring is possible by using diagnostic tool.

# 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 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 5,000 km(50 Hr), 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 5,000km (50Hr)**

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

| SAE no. | Oil grade |
|---|---|
| 10W40 | ACEA-E5<br>(API CI-4) |

- **Engine oil capacity**

| Engine oil capacity | | | | |
|---|---|---|---|---|
| Engine model | | Oil pan inside | | Total (lit) |
| Use | Suffix | Max (lit) | Min (lit) | |
| Truck | EUTCA | 19 | 15 | 21 |
| Excavator | EUTEA/C/F/G/H/I | 27 | 17 | 29 |
| | EUTEB/D/J/K/L | 22 | 16 | 24 |
| | EUTLA/B/C/D | 27 | 20 | 29 |
| Fork lift | EUTFA/B/C/D | 27 | 17 | 29 |

### 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 5,000km 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 1.5 ~ 3 kg/cm$^2$ at idling and 3.0 ~ 5.5 kg/cm$^2$ 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. Over-speed control

The electric control unit (ECU) have a system of preventing the engine over-speed among many system. This system involve many function of fuel flow control, ignition time delay, fuel shut off, and ignition shut off etc.

These values are set up in advance in the memory of the ECU, and should not be revised by user.

This engine with ECU should not be run at the over-speed rating speed for a regular time, if the vehicle is speeded, the fuel and ignition is shut off until the engine speed is up to the proper level.

## 4.4. Operation in winter time

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

### 4.4.1. Operation in winter time

**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 20 seconds When the pilot lamp is extinguished, do operation 2.

**Behavior** - When the coolant temperature is below 9°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 automatically.

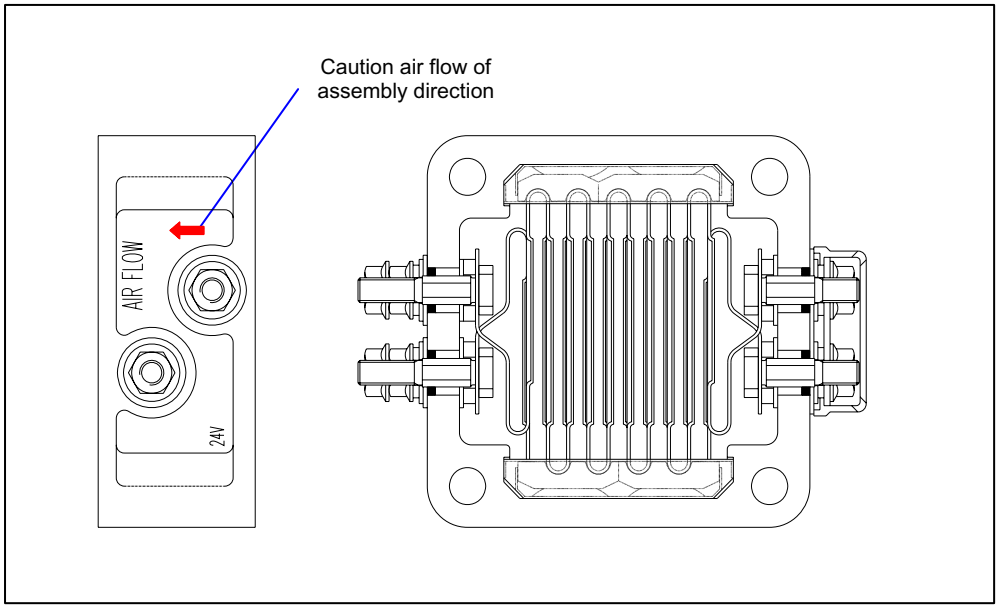
- If the coolant temperature is above 10°C, air eater needs not be heated.

**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 180 seconds (3 minute after-heating) to reduce and to element quickly white smoke.

- **Air heater major specification**

| | |
|---|---|
| Rated voltage | DC 22V (95A ±10%) |
| Rated current | 2.1 kW |




### 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 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

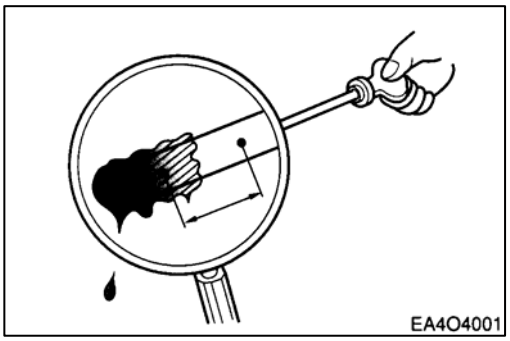
In order to insure maximum, trouble-free engine performance at all times, regular inspection, adjustment and maintenance are vital.

### 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

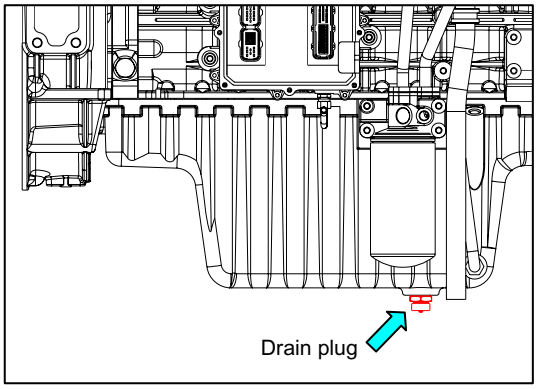



- Check the oil level in the engine sump daily with a oil level gauge.
- The notches in oil level gauge must indicate the oil level between the max.
- The oil level should be checked with the engine horizontal and only after it has been shut down for about 5 minutes.
- Examining the viscosity and the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

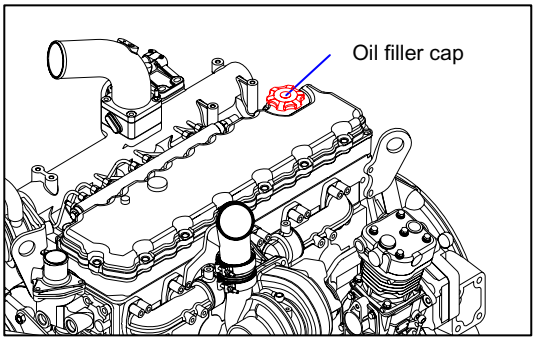
**CAUTION:**
**Do not add so much engine oil that the oil level rises above the max. marking on the oil level gauge. Over lifting will result in damage to the engine.**

### 4.6.4. Oil exchange procedure

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



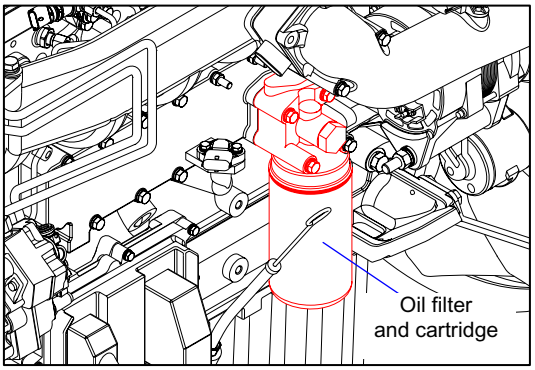

- Take out the oil level gauge.
- Remove the drain plug from oil pan, then drain out the engine oil into a container.




- 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.

### 4.6.5. Replacement of oil filter cartridge

- At the same times of oil exchanges, replace the oil filter cartridge.



**CAUTION :**

**Don't forget tightening the drain plug after having drained engine oil.**

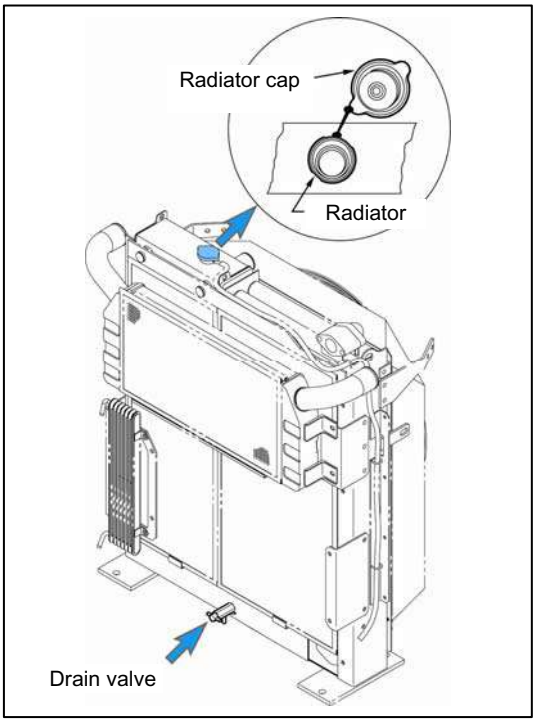
- Loosen the oil filter by turning it counter-clockwise with a filter wrench.
- With a rag wipe clean the fitting face of the filter head and the oil filter cartridge so that new oil filter cartridge can be seated properly.
- Lightly apply oil the O-ring and turn the oil filter until sealing face is fitted against the O-ring. Turn 3/4 ~ 1 turns further with the filter wrench.

**CAUTION :**

**It is strongly advisable to use DOOSAN genuine oil filter cartridge for replacement**.

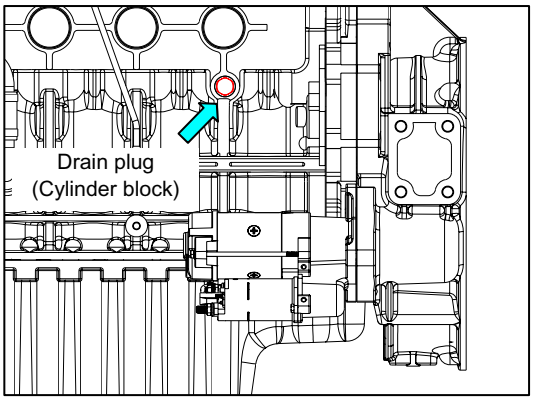
## 4.7. Cooling System

The coolant must be changed at intervals of 40,000km (1,200 Hr) 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.




**CAUTION :**

**When removing the pressure 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.**

### 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:**

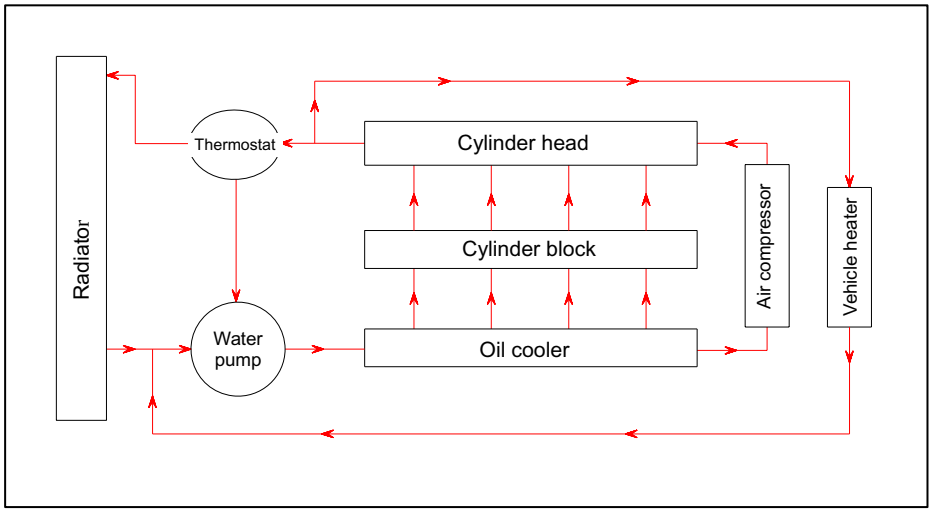
**Periodically clean the circuit interior with a cleaner.**

# 5. Maintenance of Major Components

## 5.1. Cooling System

### 5.1.1. General descriptions and main data

- 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



### 5.1.2. Specification

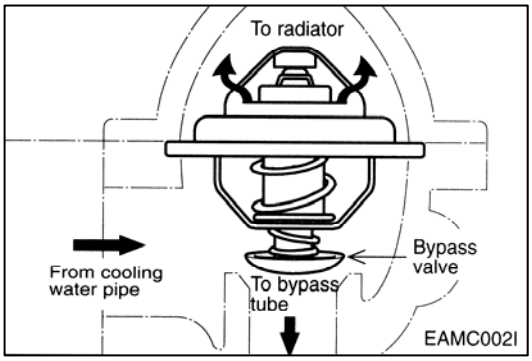
| Item | | Specification | |
|---|---|---|---|
| 1. Water pump | Type | Centrifugal type | |
| | Pumping speed | 2,500 rpm | |
| | Delivery | about 200 liter/min or more | |
| | Pump head | 7.0 m | |
| | Pumping back pressure | Bellow 0.5 bar | |
| 2. Thermostat | Operating temperature | 71°C type | 82°C type |
| | Valve lift | 10mm or more (at 90°C) | 10mm or more (at 95°C) |
| | Operating temperature | 71 ~ 90°C | 82 ~ 95°C |
| 3. Cooling fan and belt | | | |
| Fan diameter – Number of blades | | Truck : Ø620mm – 10 | |

### 5.1.3. Thermostat

- **General descriptions and main data**

The thermostat maintains a constant temperature of coolant (82 ~ 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.

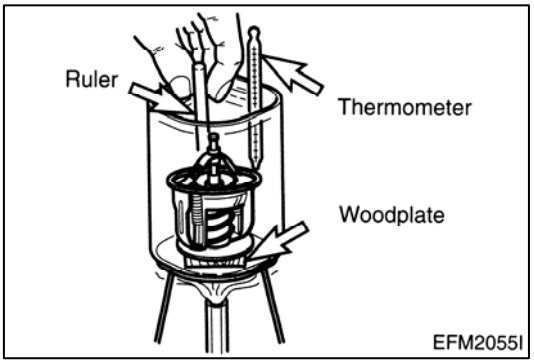



| Item | In moderate climates | In tropical climates |
|---|---|---|
| Type | Wax-pallet type | |
| Open at | 82 °C | 71 °C |
| Open wide at | 95 °C | 90 °C |
| Valve lift | 10 mm or more | 10 mm or more |

- **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 82 °C and 10 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 over-speed it immediately after engine starting.

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

(3) Replacing thermostat

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

### 5.1.4 Diagnostics and troubleshooting

| Complaints | Possible causes | Corrections |
|---|---|---|
| 1. Engine overheating | ● Lack of coolant<br>● Radiator cap pressure valve spring weakened<br>● Fan belt loosened or broken<br>● Fan belt fouled with oil<br>● Thermostat inoperative<br>● Water pump defective<br>● Restrictions in water passages due to deposit of scales<br>● Injection timing incorrect<br>● Restriction in radiator core<br>● Gases leaking into water jacket due to broken cylinder head gasket | ● Replenish coolant<br>● Replace cap<br>● Adjust or replace fan belt<br>● Replace fan belt<br>● Replace thermostat<br>● Repair or replace<br>● Clean radiator and water passages<br>● Check injection timing by SCAN-200<br>● Clean exterior of radiator<br>● Replace cylinder head gasket |
| 2. Engine overcooling | ● Thermostat inoperative<br>● Ambient temperature too low | ● Replace thermostat<br>● Install radiator curtain |
| 3. Lack of coolant | ● Radiator leaky<br>● Radiator hoses loosely connected or damaged<br>● Radiator cap valve spring weakened<br>● Water pump leaky<br>● Heater hoses loosely connected or broken<br>● Cylinder head gasket leaky<br>● Cylinder head or cylinder block cracked | ● Correct or replace<br>● Retighten clamps or replace hoses<br>● Replace cap<br>● Repair or replace<br>● Tighten or replace hoses<br>● Replace cylinder head gasket<br>● Replace cylinder head block |
| 4. Cooling system noisy | ● Water pump bearing defective<br>● Fan loosely fitted or bent<br>● Fan out of balance<br>● Fan belt defective | ● Replace bearing<br>● Retighten or replace fan<br>● Replace fan<br>● Replace fan belt |

## 5.2. Lubrication system

### 5.2.1. 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 high pressure 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 cartridge | |
| Relief valve opening pressure | 9 ~10.5 kg/cm$^2$ | Valve opening pressure | 1.9~2.3 kg/cm$^2$ |
| Adjusting valve for spray nozzle | | Bypass main gallery | |
| Opening pressure | 2 ~2.4 kg/cm$^2$ | Relief valve | 5.3~5.7 kg/cm$^2$ |

### 5.2.2. Oil pump

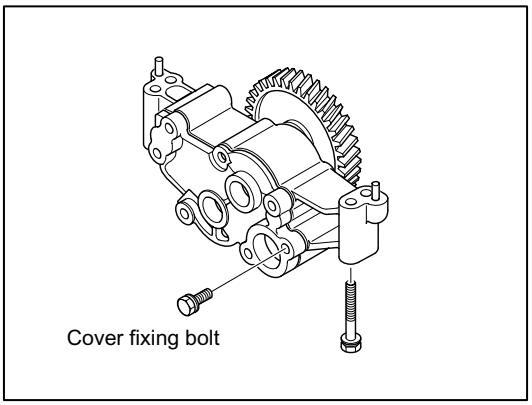
- **Disassembly**

(1) Disassembly of oil pump drive gear

a. Unscrew the screw and disassemble the oil relief valve.

b. Unfold the washer for the oil pump drive gear fixing nut and remove the nut.

c. Disassemble the drive gear.

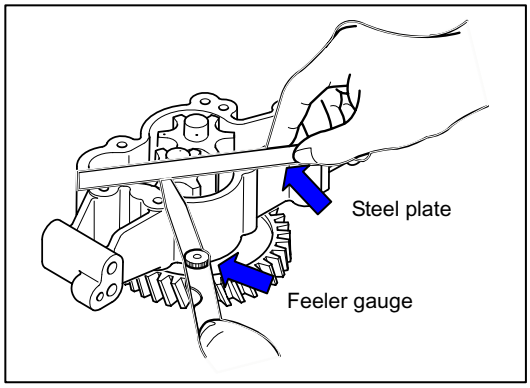



(2) Remove the oil pump cover fixing nuts and disassemble the oil pump cover.
The oil pump cover is fixed with the two dowel pins.

(3) Disassemble the drive gear and driven gear.

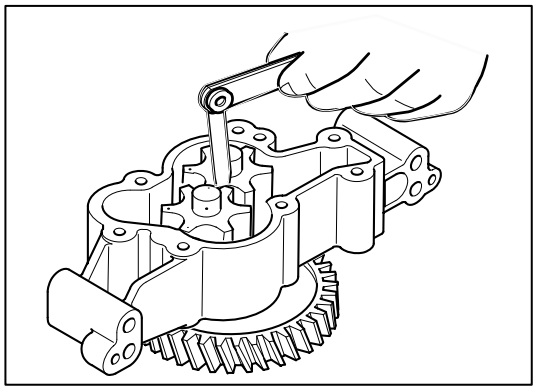
- **Inspection and correction**

(1) With steel rule and feeler gauge, measure the axial end play of the oil pump gear. Replace if the measured value is beyond the limit.




| | |
|---|---|
| End play limit | 0.03 ~ 0.136 mm |

(2) With a feeler gauge, measure the amount of backlash between the oil pump drive gear and driven gear. Replace if the measured value is beyond the limit.



| | |
|---|---|
| Standard | 0.312 ~ 0.476 mm |
| Limit | 0.64 mm |

(3) Measuring clearance between drive shaft and bushing

a. Measure the outside diameters of the drive shaft and driven shaft, and replace if the measured values are less than the limit.

| | |
|---|---|
| Standard | ϕ21.936 ~ ϕ21.95 mm |
| Limit | ϕ21.90 mm |

b. Measure the inside diameter of the pump body bushing to determine the clearance between the bushing and shaft, and compare the measured value with the standard value to determine whether to replace or no.

| | |
|---|---|
| Oil clearance | 0.050 ~ 0.085 mm |

- **Reassembly**

(1) For reassembly, reverse the disassembly sequence.

### 5.2.3. Diagnostics and troubleshooting

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

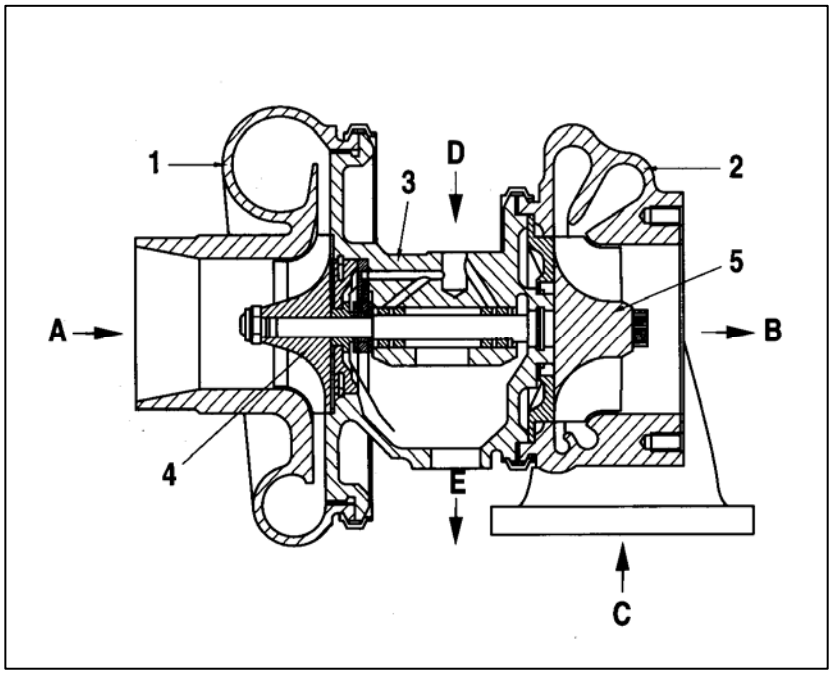
## 5.3. Turbo Charger

### 5.3.1. Specification and construction

#### 1) Main data and specification

| Specification | | DL06 |
|---|---|---|
| Model | | Holset HX35, HX35W<br>Honeywel GT35W |
| At maximum output | Air pressure at compressor outlet | Approx. 1.9 kgr/cm$^2$ |
| | Air suction of turbine revolution | Approx. 15.9 m$^3$/min |
| | Speed of turbine revolution | Approx. 120,000 rpm |
| Maximum allowable speed | | 140,000 rpm |
| Maximum allowable temperature of exhaust gas at turbine inlet | | 750 °C |
| Lubricating system | | External oil supply |
| Weight | | Approx 11 kg |

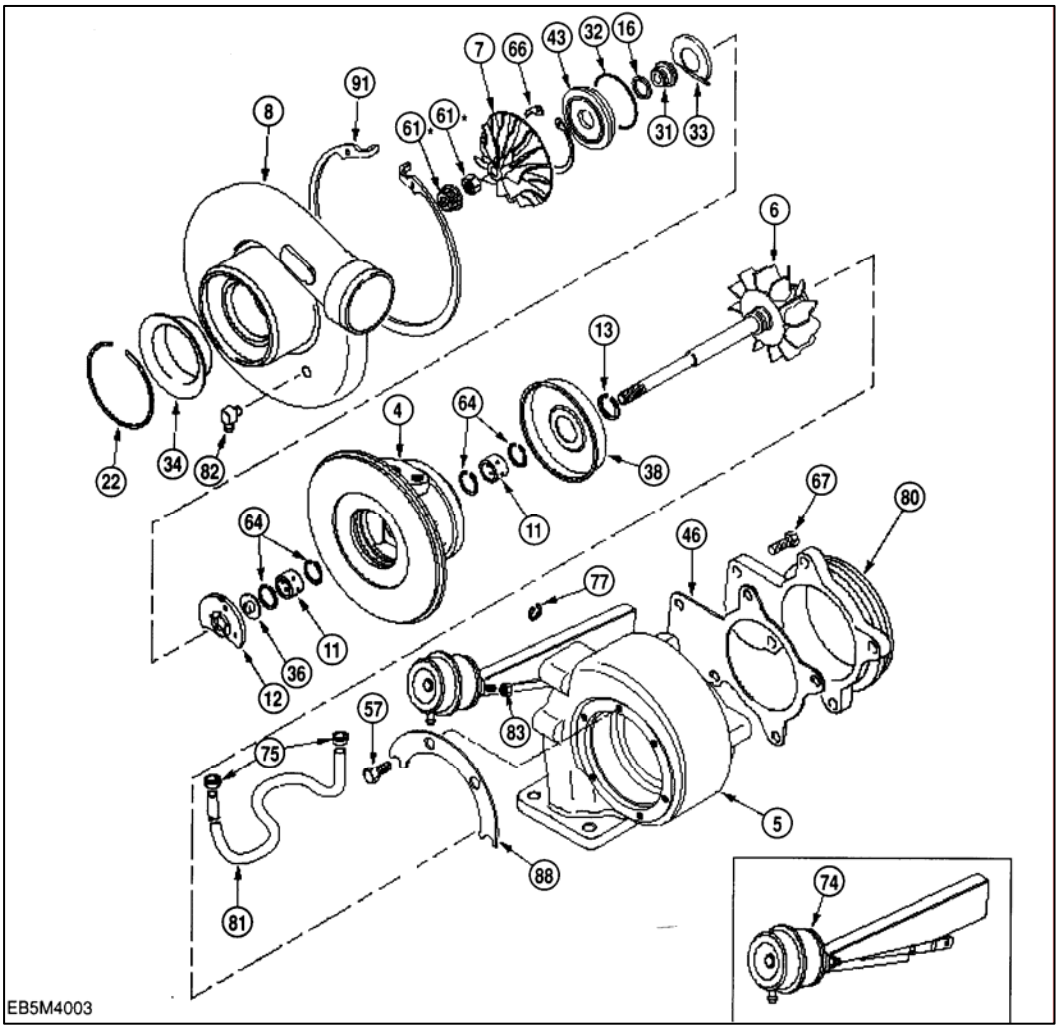
#### 2) Construction




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

### 3) Components of turbocharger

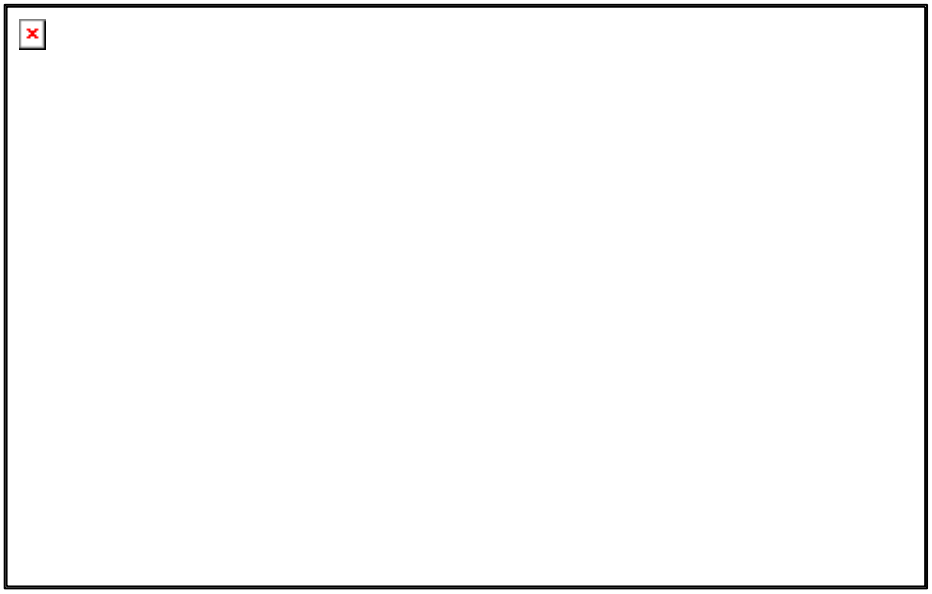
- Make sure that servicing should be performed at the professional maintenance shop as authorized by Holset and Honeywel Company.




| | | | | | |
|---|---|---|---|---|---|
| 4 | Bearing housing | 32 | O - ring | 67 | Hex bolt |
| 5 | Turbine housing | 33 | Oil baffle | 74 | Actuator ass'y |
| 6 | Turbine wheel ass'y | 34 | Inlet baffle | 75 | Hose clamp |
| 7 | Compressor wheel | 36 | Thrust collar | 77 | Actuator clip |
| 8 | Compressor housing | 38 | Heat protector cover | 80 | Cover plate |
| 11 | Journal bearing | 43 | Oil seal plate | 81 | Hose |
| 12 | Thrust bearing | 46 | Gasket | 82 | Elbow |
| 13 | Piston ring seal (turbine) | 57 | Hex bolt | 83 | Hex nut |
| 16 | Piston ring seal | 61 | Lock nut | 88 | Clamp plate |
| 22 | Retaining ring | 64 | Snap ring | 91 | Retaining ring |
| 31 | Oil stopper | | | | |

#### 4) Operating principle

The turbocharger is a system designed to make use of the engine exhaust gas energy to charge high-density air into the cylinders, thereby to increase the engine output.



### 5.3.2. 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.

### 5.3.3. 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 protector.

**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**

(1) Thrust bearing

Thrust bearing force is applied to the turbine wheel and an arrangement is made for the shaft not to shift.

(2) Journal bearing

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.

### 5.3.4. 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<br>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.<br>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. | 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.<br>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.<br>2) Various inspections must insure that there are no leakage of oil, gas and air. | 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.<br>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. |

| Operation | Caution | Reason |
|---|---|---|
| During operation | Following items must be confirmed.<br>1) Oil pressure<br>At idling : 1.5 ~ 3.0 kg/cm$^2$<br>At full load : 3.0 ~ 5.5 kg/cm$^2$<br><br>2) When abnormal noises and vibration are generated, slow down the revolution and must stop it to investigate the causes. | 1) If the pressure is too low, abnormal wear or stuck may be caused. Or if too high, the oil leak may be generated.<br>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 5 min. 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. |

### 5.3.5. 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 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) 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. Suggested engine oils for the turbocharger-mounted engine are as follows:

| Engine model | Recommended oil | |
|---|---|---|
| | SAE no. | API no. |
| DL06 | SAE 10W40 | ACEA-E5<br>(API CI-4) |

## 5.3.6. Periodical servicing

Make it a rule to check the turbocharger assembly for condition and contamination periodically.

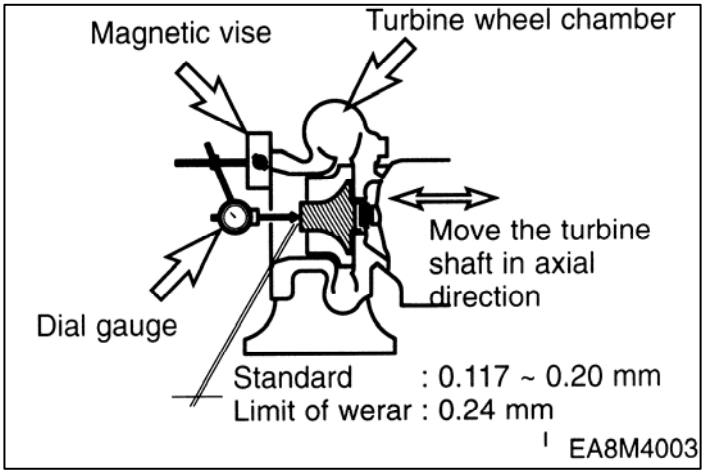
### 1) Guide for checking the rotor for rotating condition

The inspection of the rotor assembly for rotating condition should be performed by the degree of unusual sound. If a sound detecting bar is used, install its tip on the turbocharger housing and increase the engine revolutions slowly. If a high-pitch sound is heard continuously, it means that the rotor assembly is not normal. In this case, as the metal bearing and rotor are likely to be in abnormal conditions, the turbocharger should be replaced or repaired.

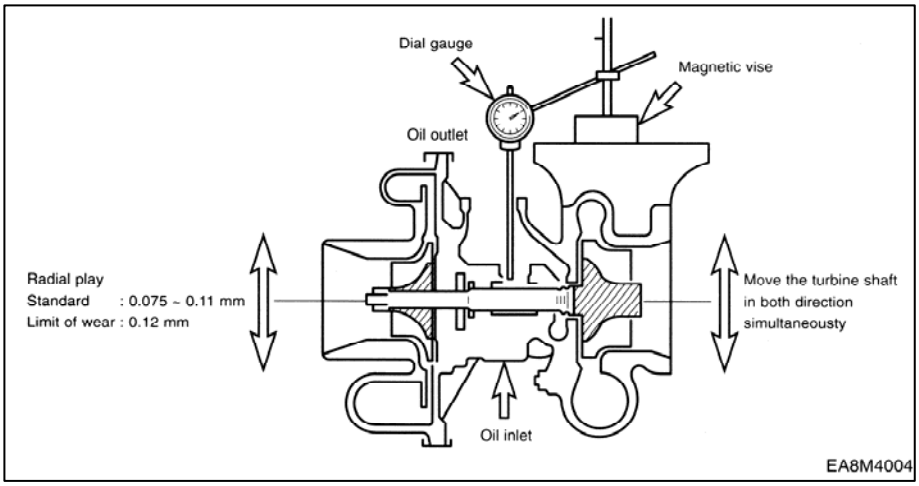
### 2) Guide for checking rotor end play

Disassemble the turbocharger from the engine, then check the rotor axial play and radial play. When disassembling the turbocharger, be sure to plug the oil inlet and outlet ports with taps, etc

(1) **Rotor axial direction end play**




(2) **Rotor radial direction end play**




(3) If the measured axial and radial end plays are beyond the limit of wear, replace or repair the turbocharger.

**3) Guide for disassembling/cleaning and checking the turbocharger**

First, disassemble the turbocharger from the engine and clean/check it with the oil inlet and outlet plugged with tape and so on

**4) Precautions for reassembling the turbocharger onto the engine**

For reassembly of the turbocharger or handling it after reassembly operation, be sure to observe the following precautions.

Especially, exercise extreme care to prevent foreign matters from entering the inside of the turbocharger.

**(1) Lubricating system**

- Before reassembling the turbocharger onto the engine, inject new oil in the oil inlet port and lubricate the journal and thrust bearings by rotating them with hand.
- Clean not only the pipes installed between the engine and oil inlet port but also the oil outlet pipe and check them for damage or foreign matters.
- Assemble each joint on oil pipes securely to prevent oil leaks.

**(2) Air intake system**

- Check the inside of the intake system for foreign matters.
- Assemble each joint on the intake duct and air cleaner securely to prevent air leaks.

**(3) Exhaust system**

- Check the inside of the exhaust system for foreign matters.
- Be sure to use heat resisting steel bolts and nuts. Do not interchange them with ordinary steel bolts and nuts when performing reassembly operation. Apply anti-seizure coating to the bolts and nuts.
- Assemble each joint on the exhaust pipes securely to prevent gas leaks.

### 5.3.7. Diagnostics and troubleshooting

| Complaints | Possible causes | Corrections |
|---|---|---|
| 1. Excessive black smoke | 1) Air cleaner element clogged | Replace or clean |
| | 2) Restrictions in air duct | Check and correct |
| | 3) Leakage at intake manifold | Check and correct |
| | 4) Turbocharger seized up and not rotating | Disassemble/repair or replace |
| | 5) Turbine blades and compressor blades coming in contact with each other or damaged | Disassemble/repair or replace |
| | 6) Exhaust piping deformed or clogged | Check and correct |
| 2. Excessive white smoke | 1) Oil leak into turbine and compressor | Disassemble/repair or replace |
| | 2) Worn or damaged seal ring due to excessive wear of bearing | Disassemble/repair or replace |
| 3. Low engine output | 1) Gas leak at each part of exhaust system | Check and correct |
| | 2) Air cleaner element restricted | Replace or clean |
| | 3) Turbocharger fouled or damaged | Disassemble/repair or replace |
| | 4) Leakage at discharge port on compressor side | Check and correct |
| 4. Unusual sound or vibration | 1) Rotor assembly coming in contact | Disassemble/repair or replace |
| | 2) Unbalanced rotation of rotor | Disassemble/repair or replace |
| | 3) Seized up | Disassemble/repair or replace |
| | 4) Each joint loosened | Check and correct |

## 5.4. Air cleaner

### 5.4.1. Maintenance of air cleaner

**(Only when engine is switched off)**

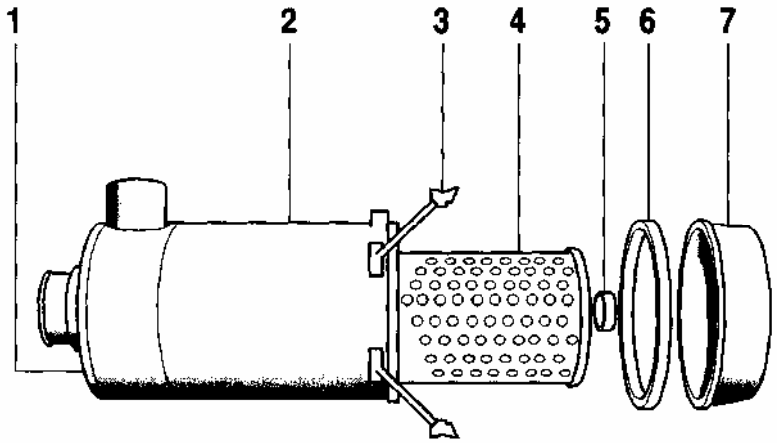
Empty the dust bowl (7) regularly. The bowl should never be filled more than halfway with dust.

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.

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

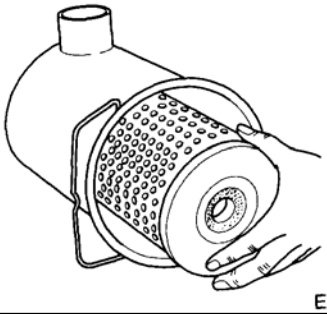



EA6O5012

### 5.4.2. Changing air cleaner element

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

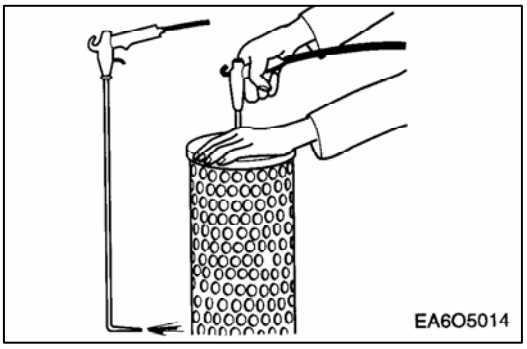
- On removing the hexagon nut, take out the dirty cartridge and renew or clean.
- Wipe the cleaner housing with a damp cloth, in particular the sealing surface for the element.



EA6O5013

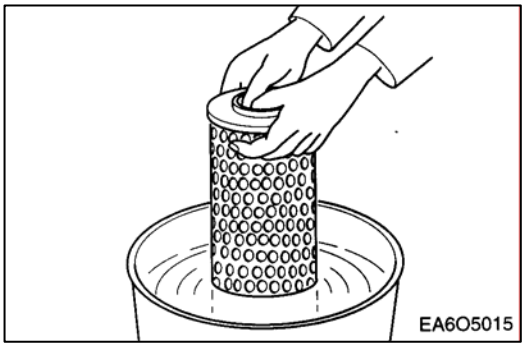
### 5.4.3. Cleaning air cleaner elements

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



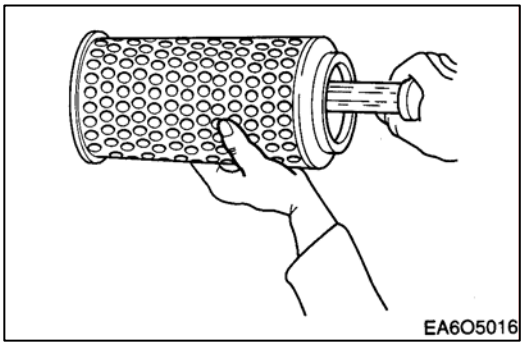

  - For the purpose, the air gun should be fitted with a nozzle extension which is bent 90° at the discharge end and which is long enough to reach down inside to the bottom of the element.
  - Moving the air gun up and down, blow out the element from the inside (maximum 5 bar) until no more dust comes out of the air cleaner 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 fro 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 air cleaner 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 air cleaner 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.
  - Damaged cartridges should not be reused under any circumstances. In cases of doubt, discard the cartridge and install a new one.

## 5.5. Belt

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

**(1) Change the belts if necessary**

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

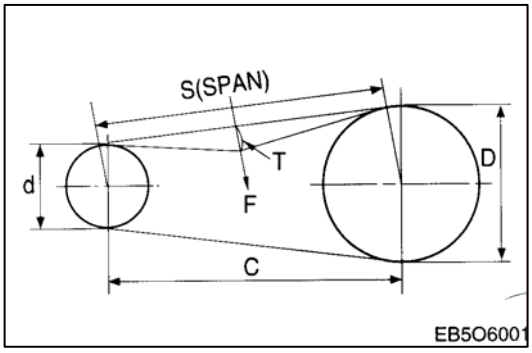
**(2) Checking condition**

Check belts for cracks, oil, overheating and wear

**(3) Testing by hand**

- **Poly belt**

  Poly belt will be properly tensioned if the deflection force "F" is applied mid-way between the belt's tangent points with the pulley.



(T) = 0.015 x S (about 1.5mm per 100mm).

T = 0.015 x *S (mm)
(T : Deflection, S : Span)

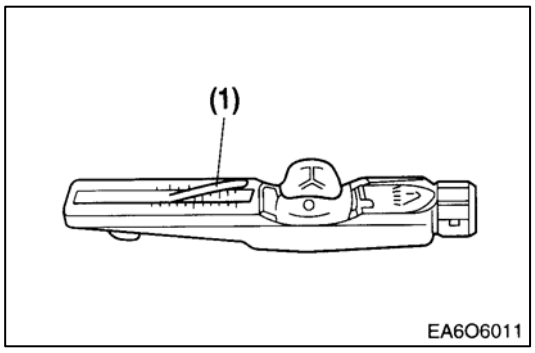
$$^{*}S = \sqrt{C^2 - \frac{(D-d)^2}{2}} \text{ (mm)}$$

C : Distance of pulleys (mm)
D : Large pulley diameter (mm)
d : Small pulley diameter (mm)

**(4) Measuring tension**

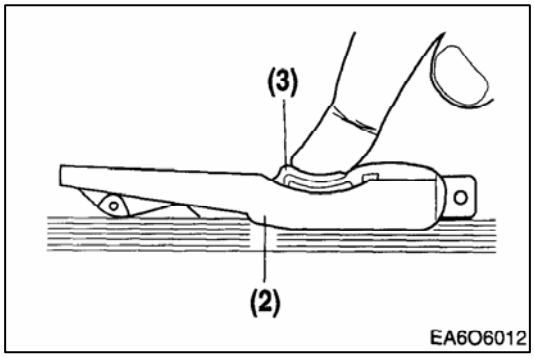
① Lower indicator arm (1) into the scale

- 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.



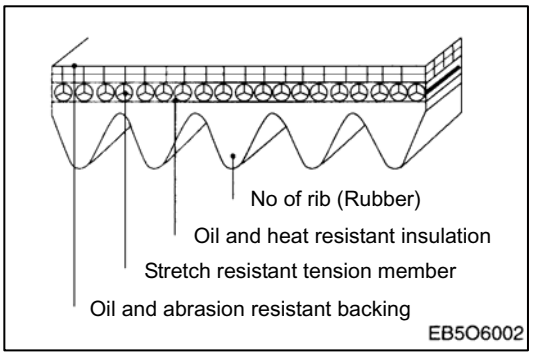
② Reading of tension

- 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.

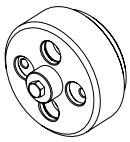
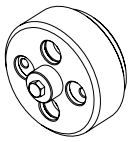
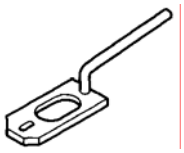
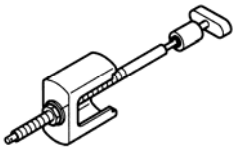
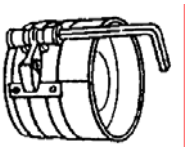
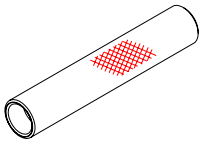


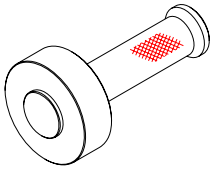
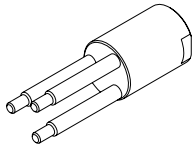
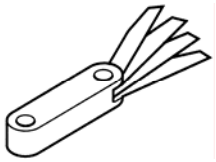
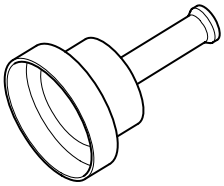
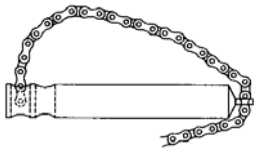
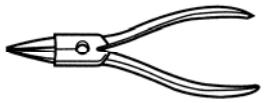

- **Poly belt tension**

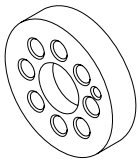
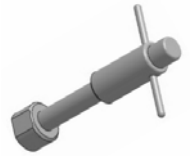
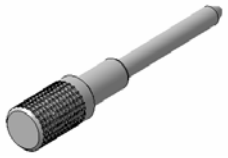
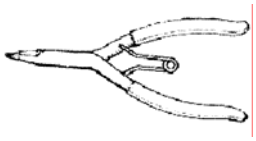
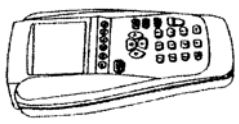
| No of rib (PK type) | Force (kgf) |
|---|---|
| 3 | 20 - 27 |
| 4 | 27 - 36 |
| 5 | 34 – 45 |
| 6 | 41 – 57 |
| 7 | 48 – 66 |
| 8 | 59 - 73 |



# 6. Special Tool List

| No | Part no. | Figure | Tool name | Remark |
|---|---|---|---|---|
| 1 | EF.121-299 |  | Oil seal insert assembly (Front) | |
| 2 | EF.121-300 |  | Oil seal insert assembly jig (Rear) | |
| 3 | EF.123-065 |  | Valve spring compression | |
| 4 | EF.123-365A |  | Cylinder liner puller | |
| 5 | EF.121-250 | | Piston insert | Only DL06 engine |
| | EF.120-208 |  | | All engine |
| 6 | EF.121-253 |  | Valve stem seal punch | |

| No | Part no. | Figure | Tool name | Remark |
|---|---|---|---|---|
| 7 | EF.121-181 |  | Cam shaft hole cover punch | |
| 8 | EF.121-252 |  | Step idle gear pin assembly | |
| 9 | EF.120-239 | | Slave piston disassembly & assembly (Engine brake) | |
| 10 | 60.99901-0027 |  | Filler gauge | |
| 11 | EF.121-260 |  | Wear ring punch(rear) | |
| 12 | 65.98801-0001 |  | Filter wrench | |
| 13 | T7610001E |  | Snap ring plier | |

| No | Part no. | Figure | Tool name | Remark |
|---|---|---|---|---|
| 14 | EF.121-259 |  | Crankshaft gear insert jig | |
| 15 | EF.120-277 |  | Injector insert jig | |
| 16 | EF.120-278 |  | High pressure connector dummy | |
| 17 | T7621010E |  | Piston ring plier | |
| 18 | EF.123-322 |  | SCAN-200 Diagnostic tool | Memory card |

# Appendix

## Tightening torque for major parts

| Major parts | Screw (Diameter x pitch) | Tightening torque |
|---|---|---|
| Cylinder block bearing cap | M16 x 2.0 | 30±2 kg.m |
| Oil spray nozzle | M10 x 1.25 | 2.1+0.5 kg.m |
| Flywheel housing | M12 x 1.5 | 11.2 +1.0 kg.m |
| Crankshaft pulley | M14 x 1.5 | 20+0.2 kg.m |
| Vibration damper | M10 x 1.5 | 6.2+0.5 kg.m |
| Flywheel | M14 x 1.5 | 20 +2.0 kg.m |
| Connecting rod cap | M12 x 1.5 | 9.75+0.25 kg.m |
| Cylinder head | M13 x 1.5 | 5kg.m + 90°+ 90°+ 90° |
| Cylinder head cover | M8 | 2.2 +0.5 kg.m |
| Injector cable | M4 | 0.15+0.01 kg.m |
| Rocker arm bracket | M8 x 1.25 | 3.7+0.5 kg.m |
| Rocker arm adjusting nut | M10 x 1.0 | 3.0 +0.5 kg.m |
| Oil pump cover | M8 | 2.2+0.5 kg.m |
| Oil pump mounting | M10 x 1.5 | 4.4+0.5 kg.m |
| Oil cooler | M8 | 2.2+0.5 kg.m |
| Oil pan | M8 | 2.2+0.5 kg.m |
| Oil pan drain plug | M30 x 1.5 | 10+1.0 kg.m |
| Exhaust manifold fixing nut | M8 | 5.0 +0.5 kg.m |
| Intake manifold | M10 x 1.5 | 4.4 +0.5 kg.m |
| Starting motor | M12 x 1.5 | 8.0+1.0 kg.m |
| Alternator bracket | M12 x 1.5 | 7.7+0.5 kg.m |
| Cooling water temperature sensor | M12 x 1.5 | 2.2 kg.m (max. 2.5 kg.m) |
| Engine mounting bracket | M10 x 1.5 | 6.2+0.5 kg.m |

## Tightening torque for fuel injection system

| | | |
|---|---|---|
| Fuel high pressure pump gear | M18 x 1.5 | 11 kg.m ± 0.5 kg.m |
| Fuel injector fixing bolt | M8 | 3.1 kg.m |
| Fuel high pressure pump | M8 | 4.4+0.5 kg.m |
| Fuel high pressure connector | M22 x 1.5 | 5+0.5 kg.m |
| Common rail | M8 | 2.2+0.5 kg.m |
| Fuel high pressure pipe – Connector | M14 x 1.5 | 2.8+0.5 kg.m |
| Fuel high pressure pipe – Common rail | M14 x 1.5 | 2.5+0.5 kg.m |
| Fuel high pressure pipe – Pump | M14 x 1.5 | 2.1+0.5 kg.m |
| Fuel filter | M10 | 4.4+0.5 kg.m |

## Standard bolt tightening torque table

Refer to the following table for bolts other then described above

| Diameter x pitch (mm) | Degree of strength | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3.6 | 4.6 | 4.8 | 5.6 | 5.8 | 6.6 | 6.8 | 6.9 | 8.8 | 10.9 | 12.9 |
| | (4A) | (4D) | (4S) | (5D) | (5S) | (6D) | (6S) | (6G) | (8G) | (10K) | (12K) |
| | Limit value for elasticity (kg/mm$^2$) | | | | | | | | | | |
| | 20 | 24 | 32 | 30 | 40 | 36 | 48 | 54 | 64 | 90 | 108 |
| | Tightening torque (kg.m) | | | | | | | | | | |
| M5 | 0.15 | 0.16 | 0.25 | 0.22 | 0.31 | 0.28 | 0.43 | 0.48 | 0.5 | 0.75 | 0.9 |
| M6 | 0.28 | 0.30 | 0.45 | 0.4 | 0.55 | 0.47 | 0.77 | 0.85 | 0.9 | 1.25 | 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 |
| M8x1 | 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 |
| M10x1 | 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 |
| M12x1.5 | 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 |
| M14x1.5 | 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 |
| M16x1.5 | 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 |
| M18x1.5 | 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 |
| M20x1.5 | 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 |
| M22x1.5 | 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 |
| M24x1.5 | 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

## ● Engine assembly tolerance

(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 | | ϕ104.9~ϕ105.1 | ϕ104.4 | Replace liner | Measure unworn portion beneath the rim of the upper side |
| | | Amount of liner projection | | 0.03 ~ 0.08 | - | | From top of cylinder |
| | | The flatness of upper surface of cylinder block | | 0.08 | - | Correct with a surface grinder | Referenced length 200mm |
| | | Hydraulic test for 1 Minute (kg/cm$^2$) | | 4 | - | Replace if leaky | |
| | Cylinder head & valve | Valve seat depression | Intake | 0.35 ~ 0.65 | 0.85 | | Depression of valve from lower face of cylinder head |
| | | | Exhaust | 0.35 ~ 0.65 | 0.85 | | |
| | | Cylinder head height | | 104.9~105.1 | 104.4 | Replace cylinder head | |
| | | The flatness of lower surface of cylinder head | | 0.15 | 0.3 | Replace cylinder head | |
| | | Thick of cylinder head gasket(at assembly status) | | 1.215~1.285 | - | | |
| | | Hydraulic test for 1 minute (bar) | | 4 | - | Replace if leaky | Water temperature 70°C |
| Major moving parts | Piston | Outer diameter of piston | | ϕ99.93~ϕ99.952 | - | Replace liner | Measure at 8 mm away from piston head(long diameter) |
| | | Clearance between piston and liner | | 0.079 ~ 0.101 | 0.3 | Replace one worn more | |
| | | Inner diameter of piston pin side | | ϕ40.006~ϕ40.014 | - | | |
| | | Width of piston ring grooves | Top ring | - | - | Replace piston if groove width is beyond specified | Measure at ϕ100mm of top ring groove |
| | | | 2nd ring | 2.54~2.56 | - | | |
| | | | Oil ring | 4.02~4.04 | - | | |
| | | Piston projection from cylinder block upper surface | | 0.206 ~ 0.558 | - | | Measure unworn portion beneath the rim of the upper side |
| | | Permissible weight difference of each piston | | 30g | 30g↓ | Replace piston | |
| | Piston ring | Width of piston ring | Top ring | - | - | Replace ring | |
| | | | 2nd ring | 2.47~2.49 | - | | |
| | | | Oil ring | 3.97~3.99 | - | | |
| | | Piston ring gap | Top ring | 0.30~0.45 | 1.5 | Replace ring | Standard gauge inside diameter: ϕ100 |
| | | | 2nd ring | 0.60~0.80 | 1.5 | | |
| | | | Oil ring | 0.25~0.45 | 1.5 | | |
| | Piston | Piston | Top ring | - | - | Replace ring or | Limit for use is if |

| Group | Part | Inspection item | | Stand value for assembly | Limit for use | Correction | Remark |
|---|---|---|---|---|---|---|---|
| | | ring side clearance | 2nd ring | 0.05~0.09 | 0.15 | piston | for standard clearance. |
| | | | Oil ring | 0.03~0.07 | 0.15 | | |
| | | Direction of ring gap | | - | - | Cross Install by 120° | |
| | Piston pin | Outer diameter of piston pin | | ϕ39.994~ϕ40.000 | ϕ39.94 | Replace piston pin | |
| | | Clearance between piston pin and its bush | | 0.006~0.020 | 0.08 | Replace one worn more | |

(Unit : mm)

| Group | Part | Inspection item | Stand value for assembly | Limit for use | Correction | Remark |
|---|---|---|---|---|---|---|
| Major moving parts | Crank shaft | Radial run-out of journal and pin | - | 0.01 | Correct with a grinder | Horizontal and vertical directions |
| | | Outside diameter of journal | ϕ79.905~ϕ79.925 | ϕ78.905 | Use under sized bearings respectively (0.25, 0.5, 0.75, 1.0) | |
| | | Outside diameter of pin | ϕ68.924~ϕ68.944 | ϕ67.924 | | |
| | | With of thrust journal | 33.99 ~ 34.03 | 33.94 | | |
| | | Ellipticity of journal and pin | 0.007 | 0.025 | | |
| | | Concentricity of journal and pin | 0.02 | 0.03 | | |
| | | Taper of journal and pin | 0.02 | 0.03 | | |
| | | Run-out of crankshaft | 0.06↓ | 0.1↓ | Adjust by a press | Measure #4 journal (journal #1, #7 support) |
| | | Clearance between crankshaft and bearing | 0.045~0.110 | 0.15 | Replace bearings | Measure at crown part |
| | | End play of crankshaft | 0.14~0.33 | 0.4 | Replace thrust bearing | Measure at crown part |
| | | Balance of Crankshaft (g.cm) | 60 ↓ | 60 or less | Check dynamic balance | Measure at 400 rpm |
| | | Torque of Journal bearing cap bolt (kg.m) | 30±2 | - | Coat the bolt with engine oil | Clean out foreign objects on joining surface. |
| | | Crush of journal diameter | 0.065 ~ 0.105 | - | | Measure after tightening metal cap and releasing one bolt |
| | | Oil seal for wear (crank shaft rear) | - | - | Replace oil seal if oil leaking | |
| | Connecting rod | Inner diameter of small-end | ϕ40.03 ~ ϕ40.04 | - | | |
| | | Inner diameter of big-end | ϕ73.000~ϕ73.015 | - | | |
| | | End play of con-rod | 0.170 ~ 0.30 | 0.50 | | |
| | | Clearance between con-rod bearing and crank pin | 0.030 ~ 0.081 | 0.15 | Replace con-rod | |
| | | Clearance between small end bush & piston pin | 0.03 ~ 0.046 | 0.08 | Replace bearing | |
| | | Crush height of con-rod bearing | 0.085 ~ 0.125 | - | | Measure after installing the bearing and releasing one bolt |
| | | Perpendicularity of big-end inner diameter | 0.05 | 0.1 | | |
| | | Roundness of big-end inner diameter | 0.007 | 0.25 | | |
| | | Parallelness of small end side and big end | 0.2 | 0.50 | Replace con-rod | |
| | | Allowable weight difference per con-rods | 10g ↓ | - | Replace same degree | Management of con-rod's grade (A ~I) |

| Group | Part | Inspection item | | Stand value for assembly | Limit for use | Correction | Remark |
|---|---|---|---|---|---|---|---|
| | | Con-rod bearing cap bolt (kg.m) | | 9.75+0.25 | - | Coat the bolt with engine oil | Clean out foreign objects on joining surface. |
| | Cam shaft | Inner diameter of hall of cylinder block camshaft | | ϕ56.000 ~ ϕ56.030 | - | | |
| | | Diameter of camshaft journal | | ϕ55.92~ϕ55.95 | ϕ55.65 | | |
| | | Clearance between cam shaft and cam bush | | 0.03 ~ 0.09 | 0.18 | Replace cam bush | |
| | | End play of camshaft | | 0.280 ~ 0.430 | 0.5 | Replace thrust washer | |
| | | Run-out of camshaft | | 0.05 | 0.15 | Correct or replace the cam shaft | |
| | Timing gear | Clearance between idle shaft bush and idle shaft | | 0.025~0.066 | 0.1 | | |
| | | End play of idle gear shaft | | 0.107~0.183 | 0.3 | Correct or replace gear | |
| | Fly wheel | Ring gear assembly part's outer diameter | | ϕ361.5 ~ ϕ361.6 | - | | Heating temperature at wear ring assembly (150°C) |
| | | Ring gear inner diameter | | ϕ361 ~ ϕ361.2 | - | | |
| | | Overlap | | 0.3 ~ 0.6 | - | | |
| | | Heating temperature at ring gear assembly (°C) | | 200 | - | | |
| | | Allowable shaking amount after assembly | | 0.5 | - | | |
| | | Outer diameter after reassembly wear ring | | ϕ99.86 ~ ϕ100.0 | - | | |
| Valve system | Valve and valve guide | Diameter of intake valve stem | | ϕ6.963~ϕ6.977 | ϕ6.93 | Replace Valve & valve guide | When replacing valve guide & seat work simultaneously by special tools. |
| | | Diameter of exhaust valve stem | | ϕ6.950~ϕ6.964 | ϕ6.91 | | |
| | | Clearance between valve stem and valve guide | Intake | 0.023~0.052 | 0.1 | | |
| | | | Exhaust | 0.036~0.065 | 0.15 | | |
| | | Degree of valve seat | Intake | 60° | - | | |
| | | | Exhaust | 45° | - | | |
| | | Diameter of valve head | Intake | ϕ34.9 ~ϕ35.1 | - | | |
| | | | Exhaust | ϕ30.9 ~ ϕ31.1 | - | | |
| | | Thickness of valve head | Intake | 3.3~3.7 | 2.8 or more | | |
| | | | Exhaust | 3.3~3.7 | | | |
| | | Projection amount of valve guide and valve spring seat | Intake | 12.8 ~13.2 | - | Use with assembly jig | To upper side of valve guide from spring seat side of cylinder head |
| | | | Exhaust | 12.8 ~13.2 | - | | |
| | | Valve seat assembly | Intake | ϕ35.800~ϕ35.825 | - | | |

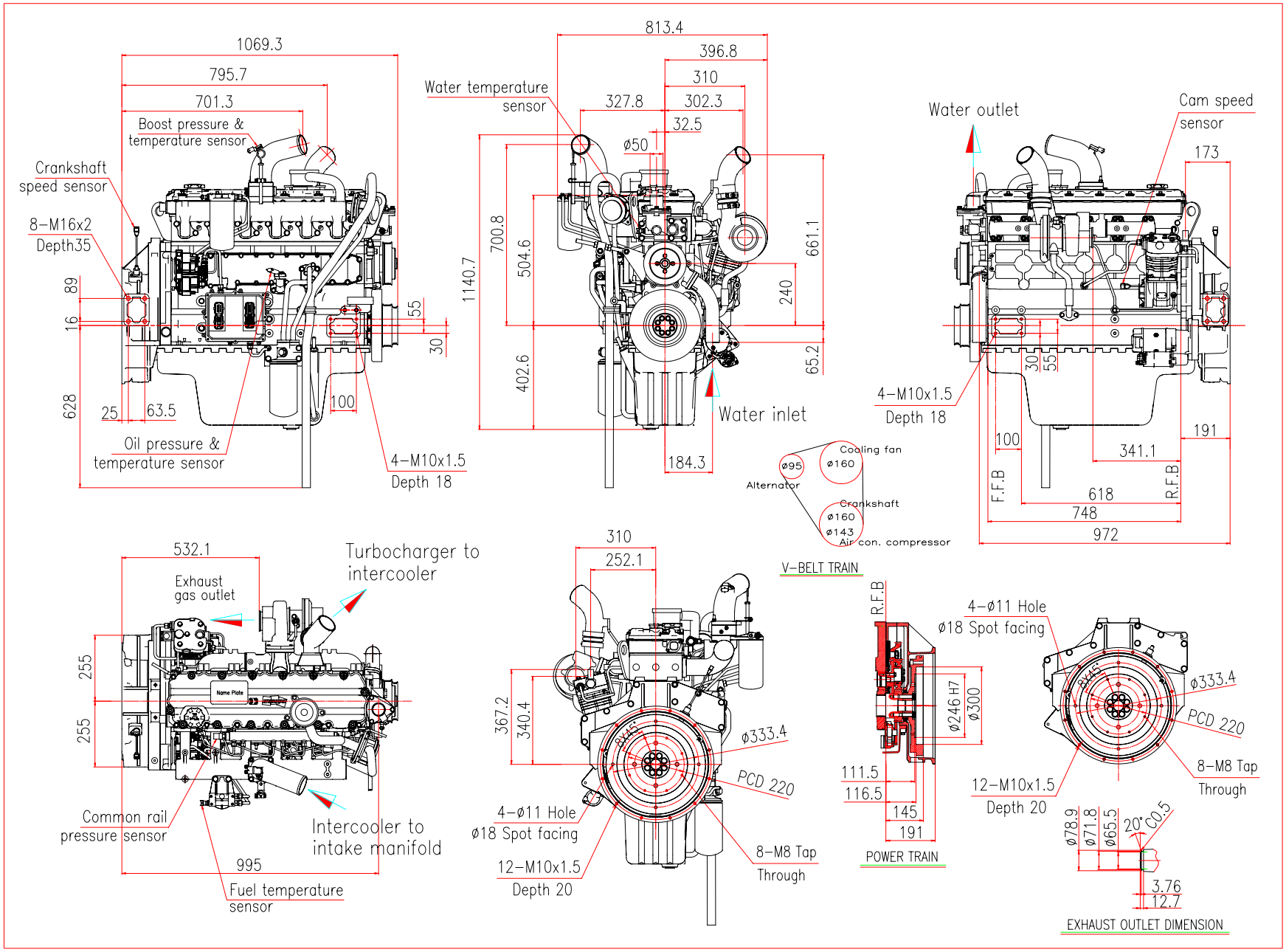
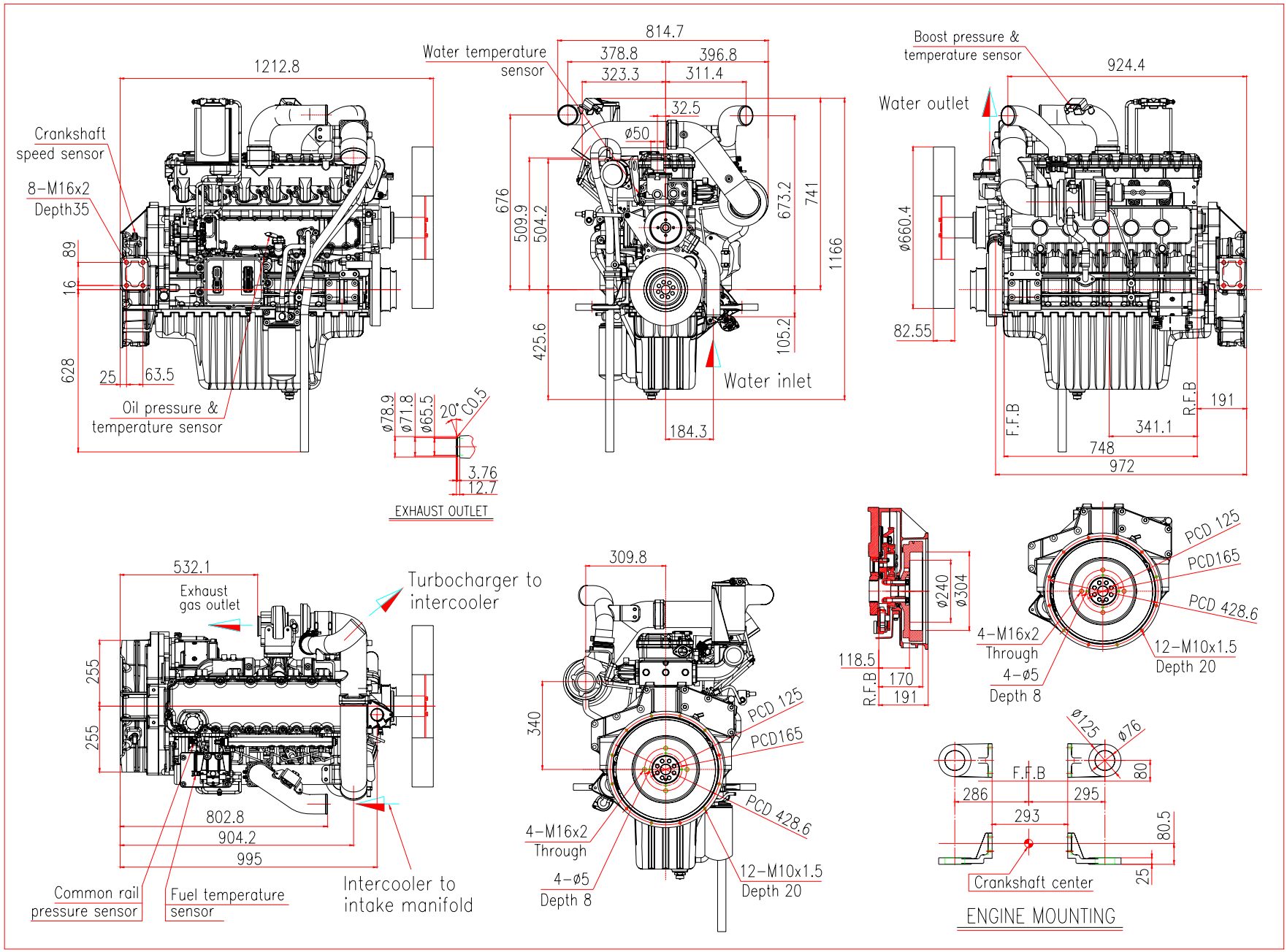
| Group | Part | Inspection item | | Stand value for assembly | Limit for use | Correction | Remark |
|---|---|---|---|---|---|---|---|
| | | part's inner diameter of cylinder head | Exhaust | ϕ32.000~ϕ32.025 | | | |
| | | Outer diameter of valve seat | Intake | ϕ35.848~ϕ35.864 | - | | |
| | | | Exhaust | ϕ32.048~ϕ32.064 | | | |
| | | Valve seat assembly part's depth of cylinder head | | 7.9 ~ 8.1 | - | | |
| | | Inner diameter of valve guide | | ϕ7.000~ϕ7.015 | - | | When replacing valve guide & seat work simultaneously by special tools. |
| | | Valve guide assembly part's inner diameter of cylinder head | | ϕ13.000~ϕ13.018 | - | | |
| | | Diameter of valve guide | | ϕ13.028~ϕ13.039 | - | | |
| | | Clearance between valve guide and cylinder head installing hole | | -0.01 ~ -0.039 | - | | Spread oil over valve guide and press it into the hole |
| | | Concentricity between valve seat and valve guide | | 0.05 | - | | Without spring seat |
| | | Intake and exhaust valve spring | Free length | 53.4 mm | - | Replace valve spring | |
| | | | Tension force (kg) 39.4mm | 28.8 kg | ±2 kg | | |
| | | | Tension force (kg) 29.67mm | 50 kg | ±2 kg | | |
| | | | Squareness (along free length direction) | 1.4 mm | 2.0 | | |
| | Rocker arm and push rod | Valve clearance (at cold) | Intake | 0.3 | - | Adjust | |
| | | | Exhaust | 0.4 | - | | |
| | | Joining surface of valve stem and adjust screw cap of rocker arm | | - | - | Grind or replace if severely pitted on tip of rocker arm and stem | |
| | | Inner diameter of rocker arm bush | | ϕ24.991~ϕ25.012 | ϕ25.04 | | |
| | | Diameter of rocker arm shaft | | ϕ24.939~ϕ24.960 | ϕ24.90 | | |
| | | Clearance between rocker arm shaft & rocker arm bush | | 0.031~0.073 | 0.14 | Replace bush or shaft | |
| | | Run-out of push rod | | 0.25 | 0.25 or less | Replace or correct | |
| | Tappet | Tappet assembly part's inner diameter of cylinder block | | ϕ28.010~ϕ28.031 | - | | |
| | | Diameter of tappet | | ϕ27.962~ϕ27.982 | - | Replace tappet | |
| | | Clearance between tappet & tappet hole of cylinder block | | 0.028~0.069 | 0.13 | Replace if severely worn or deformed | |

| Group | Part | Inspection item | Stand value for assembly | Limit for use | Correction | Remark |
|---|---|---|---|---|---|---|
| | | Tappet face in contact with cam | - | - | Replace if severely worn or deformed | |
| Lubricating system | Engine oil | Oil pressure (at normal speed) kg/cm$^2$ | 3.0 ~ 5.5 | - | Check oil leakage and clearance between each part | |
| | | Oil pressure (idling) kg/cm$^2$ | 1.5 ~ 3.0 | - | Use recommended oil | |
| | | Oil temperature (°C) | - | 105 | | Must not exceed this value |
| | | Permissible oil temperature in short time (°C) | - | 120 | | |
| | | By-pass valve for oil filter (kg/cm$^2$) | 1.9 ~ 2.3 | - | | |
| | | Spray nozzle — Operating pressure | 2.0 ~ 2.2 | | Replace valve | |
| | | Spray nozzle — Nozzle diameter | ϕ1.6 | | | |
| | Oil pump | Delivery volume l/min<br>- Pump speed: 3,333rpm<br>- Oil temperature: 80°C<br>- pressure: 4.0 kg/cm$^2$ | 75 or more | - | Replace gear or cover | |
| | | Width gear assembly part's of oil pump housing | 18.000 ~18.027 | - | | |
| | | Width of oil pump gear | 17.941 ~ 17.968 | - | | |
| | | Relief valve of oil pump (kg/cm$^2$) | 9.0 ~10.5 | - | Replace valve | |
| | | Clearance between drive gear shaft and cover hole | 0.050~0.085 | - | Replace bush or cover | |
| | | Diameter of gear shaft | ϕ21.936~ϕ21.95 | - | Replace gear shaft | |
| | | Diameter of driving gear bush | ϕ22.000~ϕ22.021 | - | Replace bush | |
| | Oil filter | Damage of oil filter cartridge | - | - | Clean or replace | |
| | | Bypass for oil filter (kg/cm$^2$) | 1.9 ~ 2.3 | - | Replace valve | |
| Cooling system | Radiator | Radiator & water pump for corrosion, damage & improper connecting | - | - | Correct or replace | |
| | | Test for leakage (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 | - | | |
| | | Differential pressure for regulating valve | 0.05 | - | | |

| Group | Part | Inspection item | | Stand value for assembly | Limit for use | Correction | Remark |
|---|---|---|---|---|---|---|---|
| | Water pump | Delivery volume l/min<br>- Pump speed 2,500rpm<br>- Water temp. 80°C<br>- Back pressure 0.5 kg/cm$^2$ | | 200 or more | - | Check the water passage | For any restrictions |
| | | Diameter of water pump shaft | Pulley side | ϕ25.048~ϕ25.061 | - | | |
| | | | Impeller side | ϕ16.045~ϕ16.056 | - | | |
| | | Clearance of bearing | | 0.050~0.091 | | | |
| | | Clearance between impeller & housing | | 0.4 ~ 0.8 | - | Replace if impeller & housing are damaged | |
| | | Squareness of pulley | | 0.1 | - | | |
| | | Fan belt depression | | Refer to adjust table | - | Adjust | |
| | Cooling water temp | Operating temperature (permissible temp.) (°C) | | 82 ~ 95 | - | Must not exceed this value | |
| | | Permissible temperature in a short time (°C) | | - | 105 | | |
| | Thermostat | Thermostat opening temperature °C (under atmospheric pressure) | | 82 | - | Replace | |
| | | Full opening temperature (°C) | | 95 | - | Replace if defective Stroke : min. 10 mm | |
| Fuel system | Fuel high pressure pump maker (CP pump) | | | Bosch | - | | |
| | Common rail maker | | | | | | |
| | Fuel injector maker | | | | | | |
| | Piping & others | Fuel pipe, injection pipe & nozzle holder for damage, cracks, improper O-ring | | - | - | Replace | |
| | | Fuel filter cartridge for damage | | - | - | Replace cartridge | |
| | Injection pressure of injector (kg/cm$^2$) | | | Max 1,600 | - | | |
| | Operating pressure of overflow valve (kg/cm$^2$) | | | 10.5 ~13 | - | Replace valve | |
| | Diameter of injector nozzle | | | 8 - ϕ0.136 | | | |
| | Projection height of nozzle from the cylinder head surface(mm) | | | 3.0 | - | Use sealing by option | |
| Air compressor | Air compressor | Inner diameter of cylinder | B grade | ϕ90.000~ϕ90.010 | - | Replace same grade | |
| | | | C grade | ϕ90.010~ϕ90.020 | - | | |
| | | | D grade | ϕ90.020~ϕ90.030 | - | | |
| | | Diameter of piston | B grade | ϕ89.910~ϕ89.920 | - | Replace same grade | |
| | | | C grade | ϕ89.920~ϕ89.930 | - | | |
| | | | D grade | ϕ89.930~ϕ89.940 | - | | |
| | | Piston ring gap | #1, #2 ring | 0.2 ~ 0.45 | - | | |
| | | | #2, #4 ring | 0.2 ~ 0.4 | | | |
| Drive system | Gear back lash | Cam shaft gear & idle gear | | 0.074 ~ 0.163 | - | | |
| | | Fuel high pressure pump gear & idle gear | | 0.103 ~ 0.182 | - | | |

| Group | Part | Inspection item | Stand value for assembly | Limit for use | Correction | Remark |
|---|---|---|---|---|---|---|
| | | Crankshaft gear & oil pump driving gear | 0.073 ~ 0.239 | - | | |
| | | Air compressor driving gear & cam gear | 0.074 ~ 0.163 | - | | |

# 1. Engine assembly DL06 – EUTFC



## 2. Engine assembly DL06 – EUTEG