Doosan Infracore

65.99897-8098A

Operation and Maintenance Manual

Diesel Engine

DV11

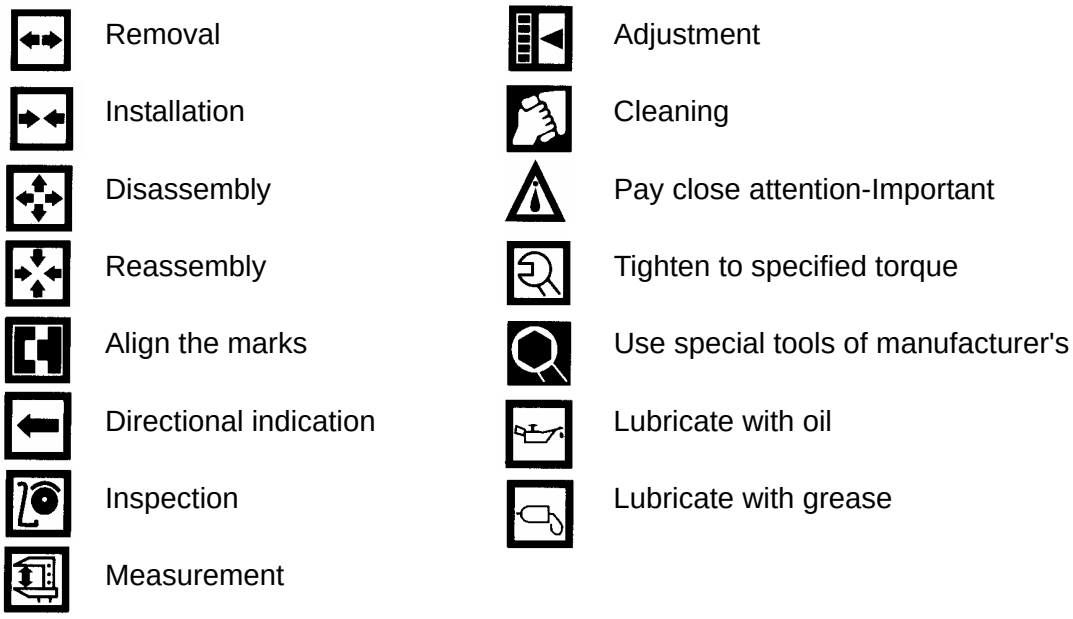
FOREWORD

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 **DV11** 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.

Apr. 2005

CONTENTS

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		DV11
Engine type		Water-cooled, 4 cycle V-type 90°, Turbo charged & intercooled
Combustion chamber type		Direct injection type
Cylinder liner type		Wet type
Timing gear system		Gear driven type
No. of piston ring		2 compression ring, 1 oil ring
No. of cylinder-bore x stroke (mm)		6 – 128 × 142
Total piston displacement (cc)		10,964
Compression ratio		17.1 : 1
Engine dimension (length x width x height) (mm)		1,206 x 1,031 x 1,070
Engine weight (kg)		904
Rotating direction (from flywheel)		Counter clockwise
Firing order		1 – 4 – 2 – 5 – 3 - 6
Fuel high pressure pump type		Bosch CP3.4 fuel high pressure pump type
Engine control type		Electric control type(ECU)
Injector type		Multi-hole(8 x ϕ0.197 Bosch DLLA146)
Fuel injection pressure (kg/cm^2)		250bar (operating pressure 1,600bar)
Valve clearance	Intake valve	0.4
	Exhaust valve	0.5
	Jake brake	1.5
Intake valve	Open at	24° (B.T.D.C)
	Close at	30° (A.B.D.C)
Exhaust valve	Open at	52.5° (B.B.D.C)
	Close at	14.5° (A.T.D.C)
Fuel filter type		Full-flow (cartridge)
Oil pressure (kg/cm^2)	at idle speed	1.0 ~ 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		Full-flow, paper element type(double)
Lubricating oil capacity (max./min.) (lit)		Bus : 34/ 26 , Truck : 32/ 26
Oil cooler type		Water cooled
Oil pressure indicator		Oil pressure unit
Water pump		Belt driven centrifugal type
Cooling method		Pressurized circulation
Cooling water capacity(engine only) (lit)		14.3

Items \ Engine model		DV11
Thermostat	Type	Wax pallet type (79 ~ 94 °C)
	Open at (°C)	83 °C
	Open wide at (°C)	95 °C
	Valve lift (mm)	8
Water temperature indicator		Water temperature sensor mounted
Air compressor	Type	Water cooled
	Capacity (cc/rev)	550 (275 × 2 each)
	Revolution ratio	1 : 1.265 (Engine speed : Air compressor speed)
Power steering pump	Type	Gear driven, vane type
	Capacity (l/min)	16 / 18 / 25
	Adjusting pressure (kg/cm^2)	125 / 150
	Revolution ratio	1 : 1.265 (engine speed : pump speed)
Turbo charger		Exhaust gas driven type (waste gate)
Engine stop system		Fuel feeding shut-off by ECU
Engine brake		Control by ECU
Alternator (voltage – capacity) (V - A)		24 - 60 or 24 – 150
Starting motor(voltage – output) (V-kW)		24 – 6.0
Air heater capacity (V – A)		24V – 2.64 kW
Battery capacity (V - AH)		20 - 150

1.3. Engine Power

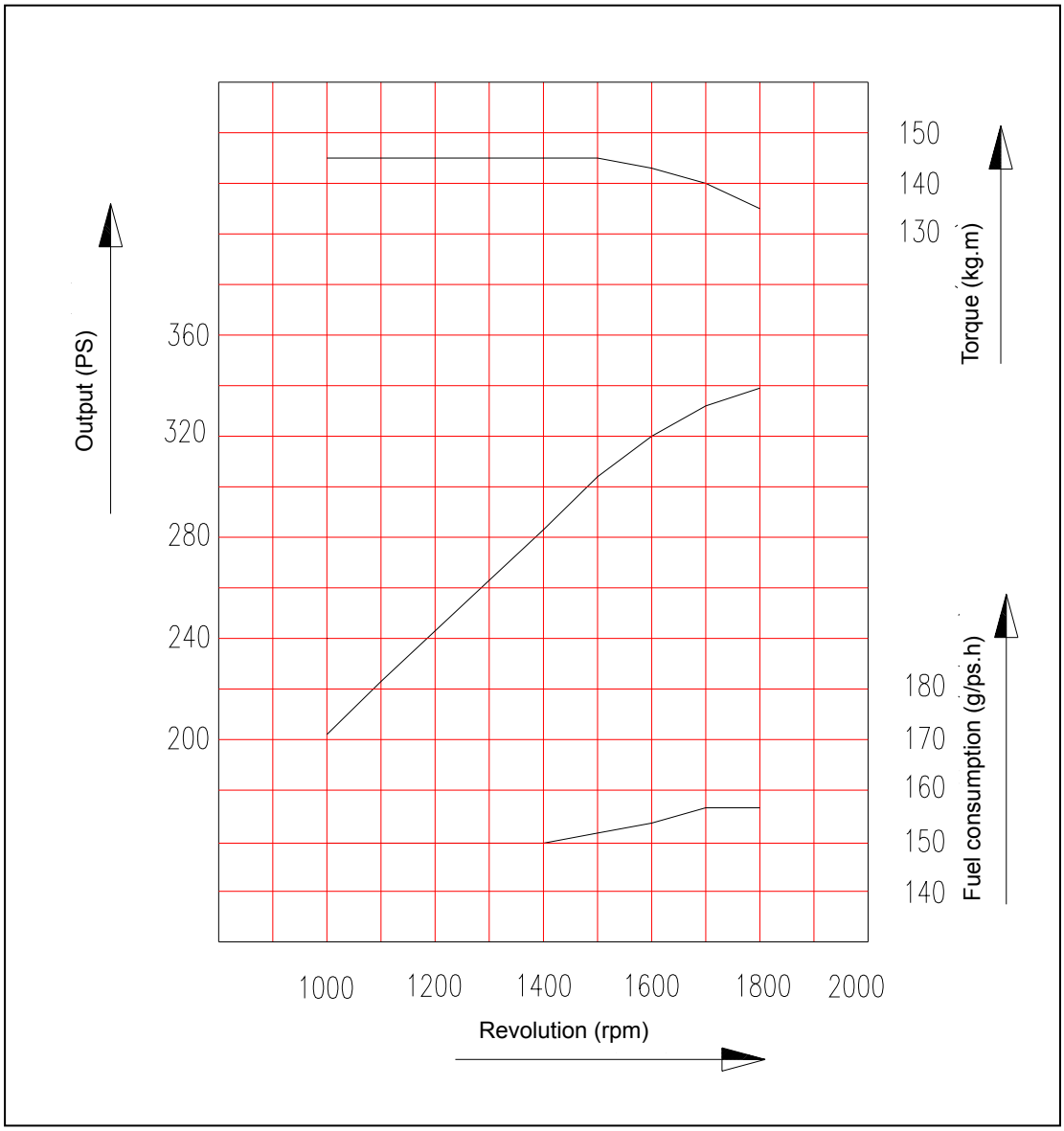
tolerance : ±5%

Engine model		Performance				Remark
Model	Suffix	**Power** (PS / rpm)	**Torque** (kg.m / rpm)	**Low idle** (rpm)	**High idle** (rpm)	
DV11	EUJBA	380 / 1,800	173 / 1,200	600	2,120↓	W/ Jake brake
	EUJBE					W/o Jake brake
	EUJBB	340 / 1,800	145 / 1,200	600	2,120↓	W/ Jake brake
	EUJBF					W/o Jake brake
	EUJBC	360 / 1,800	160 / 1,200	600	2,120↓	W/ Jake brake
	EUJBG					W/o Jake brake
	EUJBD	400 / 1,800	173 / 1,200	600	2,120↓	W/ Jake brake
	EUJBH					W/o Jake brake
	EUJBL					W/ Retarder
	EUJBI	420 / 1,800	187 / 1,200	600	2,120↓	W/ Retarder
	EUJBJ					W/ Jake brake
	EUJBK					W/o Jake brake
	EUJCA EUJCB	420 / 1,800	187 / 1,200	600	2,120↓	W/ Jake brake
	EUJCC	380 / 1,800	160 / 1,200	600	2,120↓	W/o Jake brake
	EUJCI					W/ Jake brake
	EUJCD	345 / 1,800	145 / 1,200	600	2,120↓	W/o Jake brake
	EUJCJ					W/ Jake brake
	EUJCF	420 / 1,800	187 / 1,200	600	2,120↓	W/ Jake brake
	EUJCH					W/ Jake brake
	EUJXA	380 / 1,800	160 / 1,200	600	2,120↓	W/o Jake brake
	EUJXB					W/ Jake brake

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

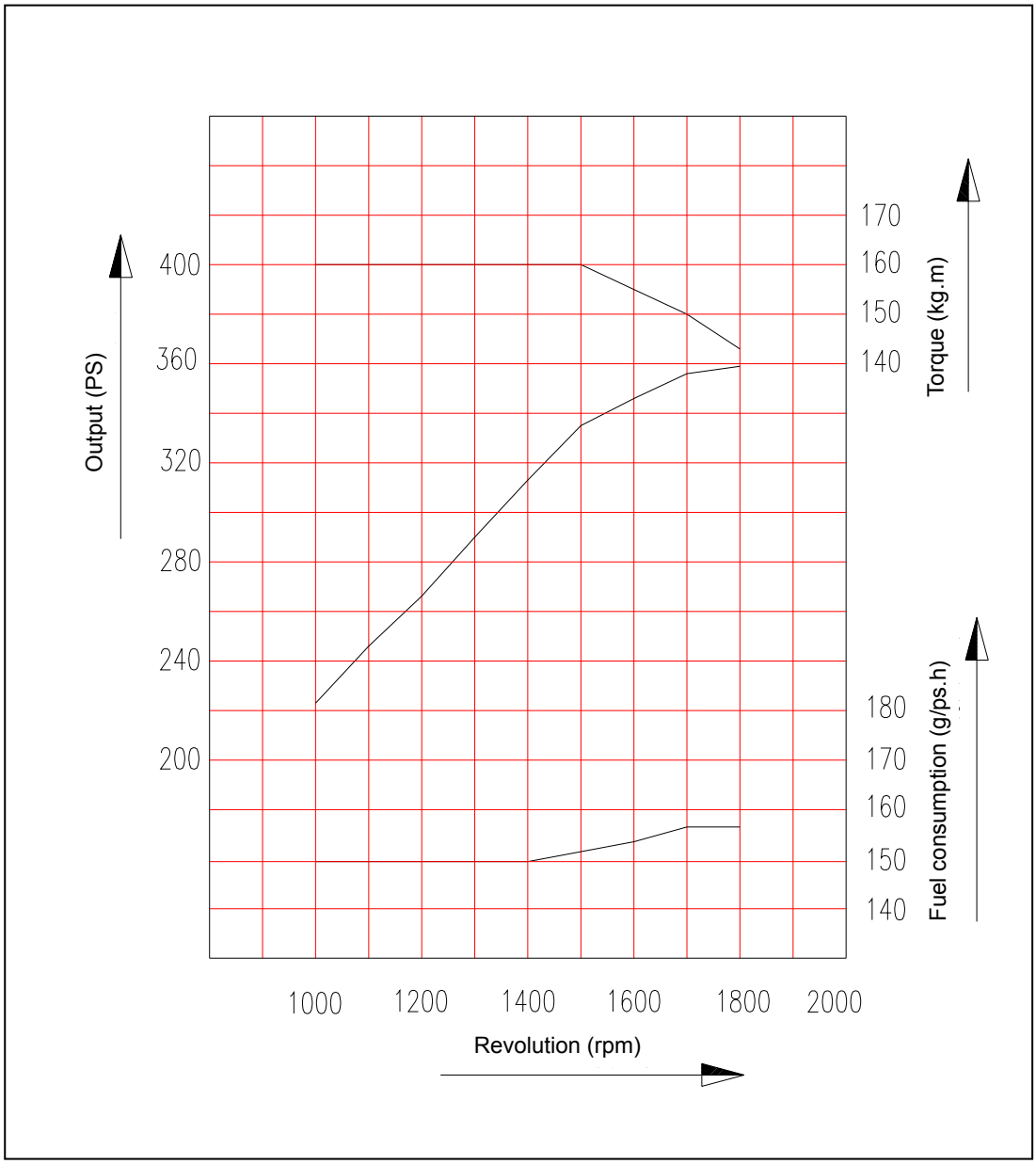
1.4. Engine Performance Curve

1.4.1. Performance curve (340PS)



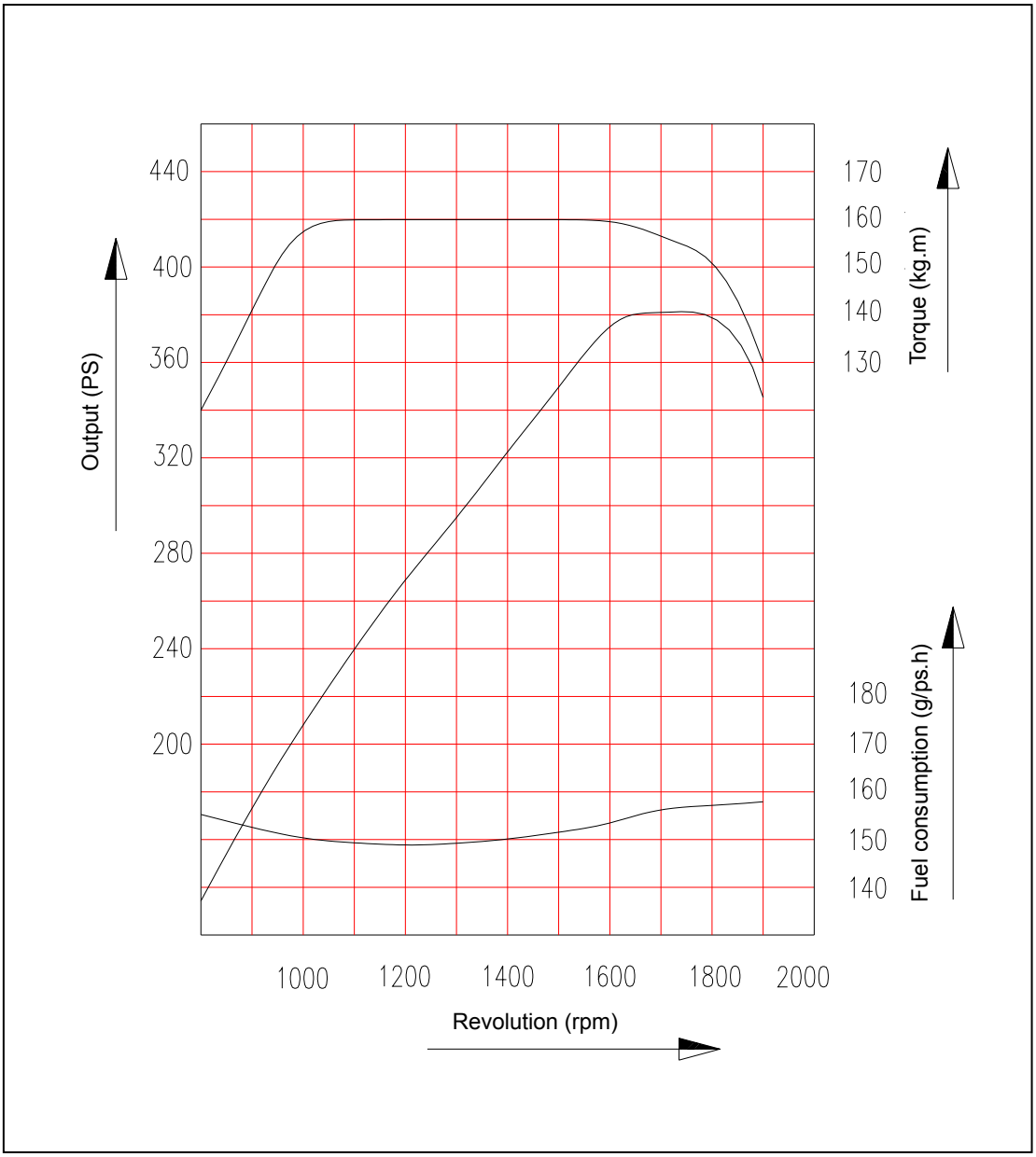
Performance	ISO 1585 (SAE J1349)
Output (max.)	250 kW (340PS) / 1,800 rpm
Torque (max)	1,423 N.m (145 kg.m) / 1,200 rpm
Fuel consumption (min.)	203 g/kW.h (149 g / PS.h)

1.4.2. Performance curve (360PS)



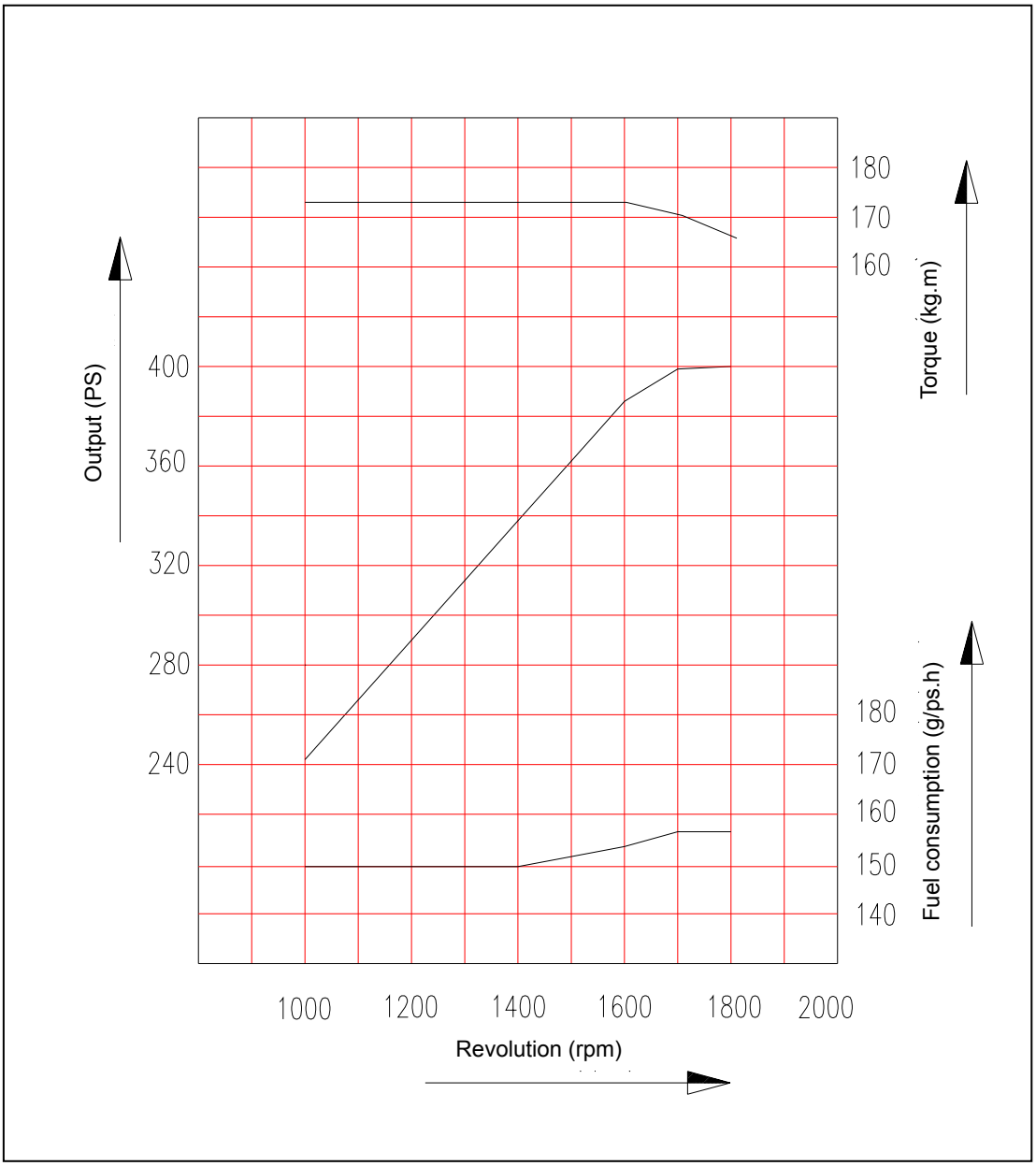
Performance	ISO 1585 (SAE J1349)
Output (max.)	265 kW (360PS) / 1,800 rpm
Torque (max)	1,570 N.m (160 kg.m) / 1,200 rpm
Fuel consumption (min.)	203 g/kW.h (149 g / PS.h)

1.4.3. Performance curve (380PS)



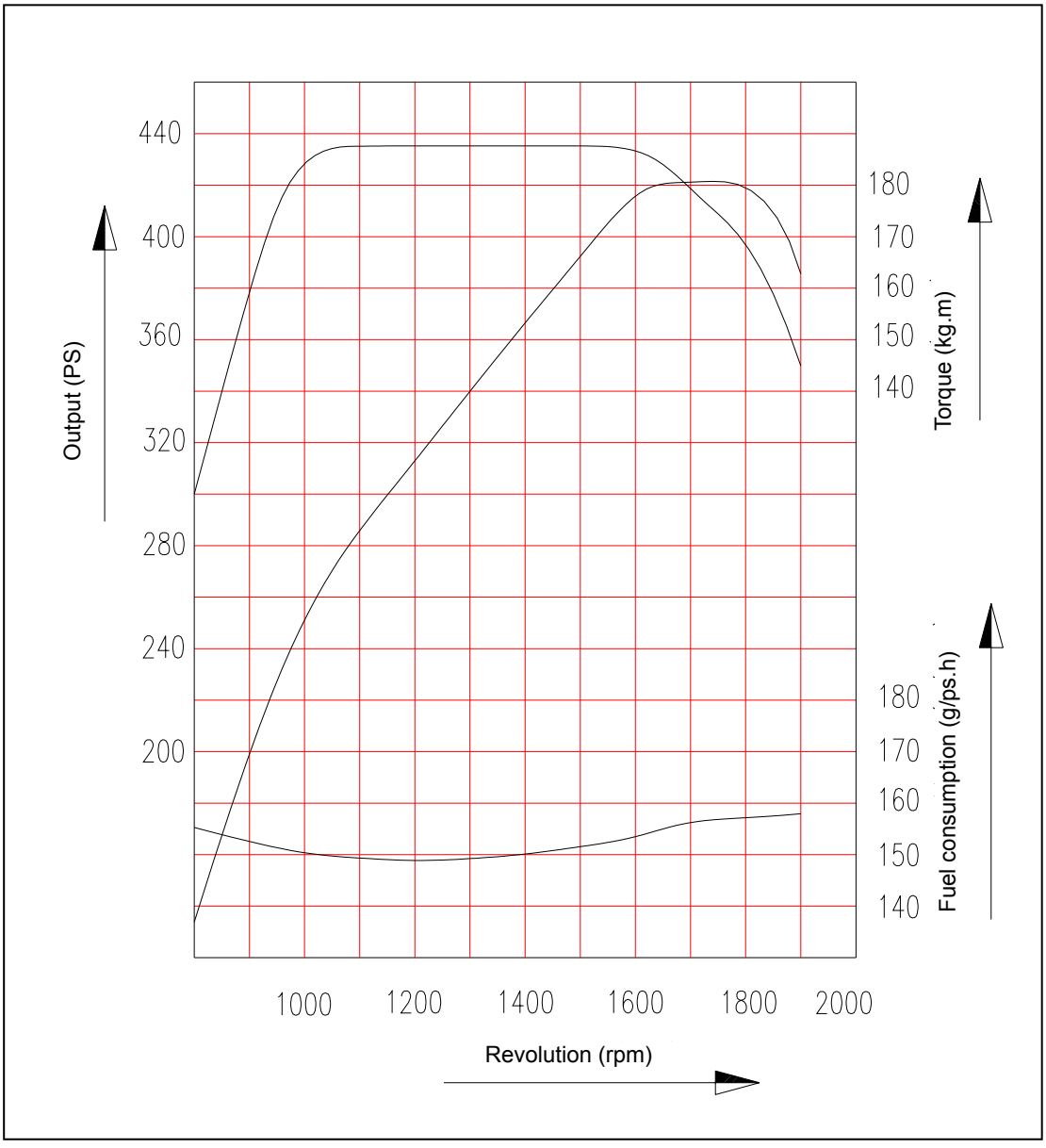
Performance	ISO 1585 (SAE J1349)
Output (max.)	280 kW (380PS) / 1,800 rpm
Torque (max)	1,570 N.m (160 kg.m) / 1,200 rpm
Fuel consumption (min.)	203 g/kW.h (149 g / PS.h)

1.4.4. Performance curve (400PS)



Performance	ISO 1585 (SAE J1349)
Output (max.)	294 kW (400PS) / 1,800 rpm
Torque (max)	1,697 N.m (173 kg.m) / 1,200 rpm
Fuel consumption (min.)	203 g/kW.h (149 g / PS.h)

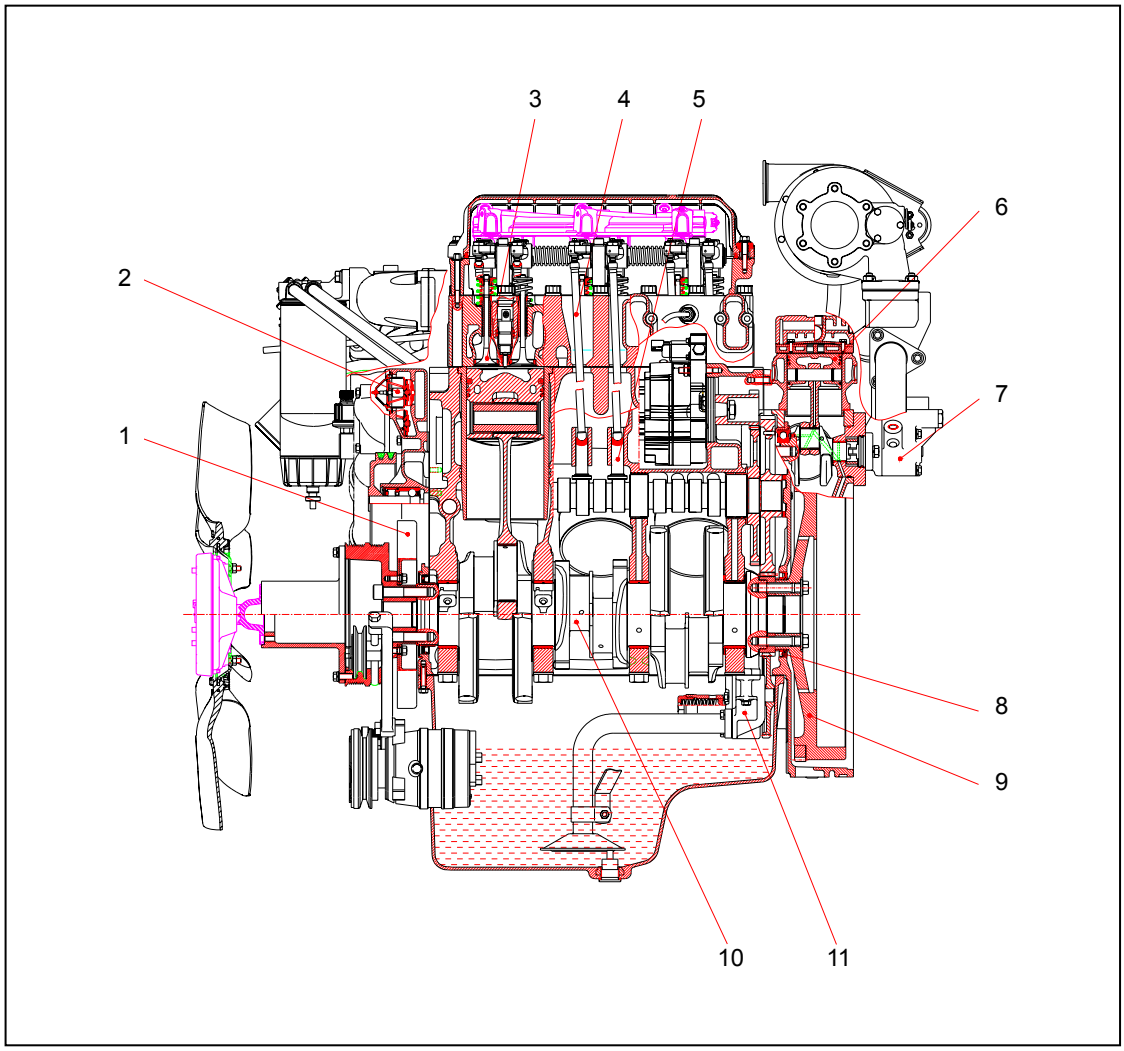
1.4.5. Performance curve (420PS)



Performance	ISO 1585 (SAE J1349)
Output (max.)	309 kW (420PS) / 1,800 rpm
Torque (max)	1,834 N.m (187 kg.m) / 1,200 rpm
Fuel consumption (min.)	203 g/kW.h (149 g / PS.h)

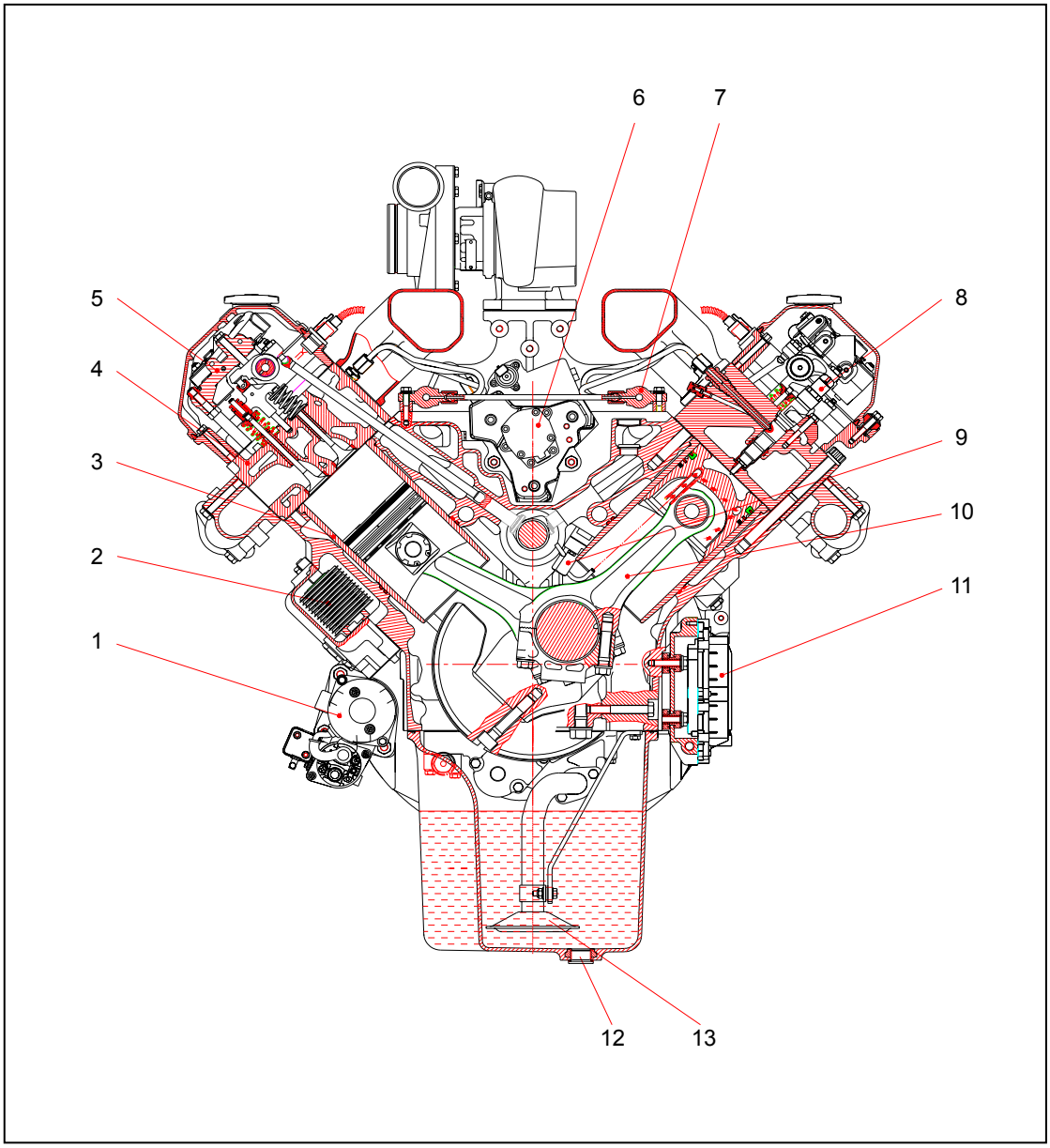
1.5. Engine Assembly

1.5.1. Engine sectional view (longitudinal)



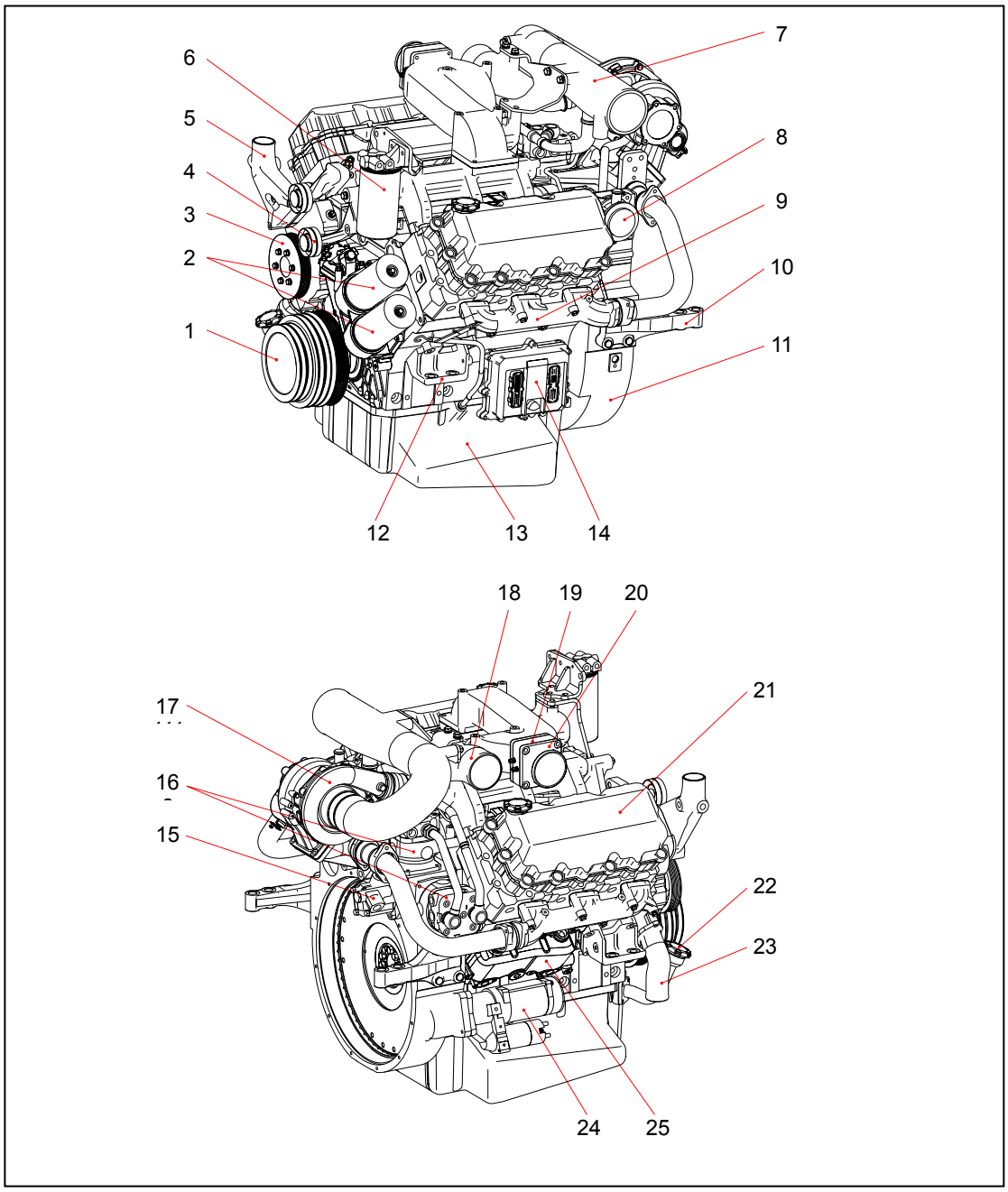
1	Vibration damper	7	Power steering pump
2	Thermostat	8	Oil seal
3	Exhaust valve	9	Fly wheel
4	Push rod	10	Crank shaft
5	Tappet	11	Oil pump
6	Air compressor		

1.5.2. Engine sectional view (cross)



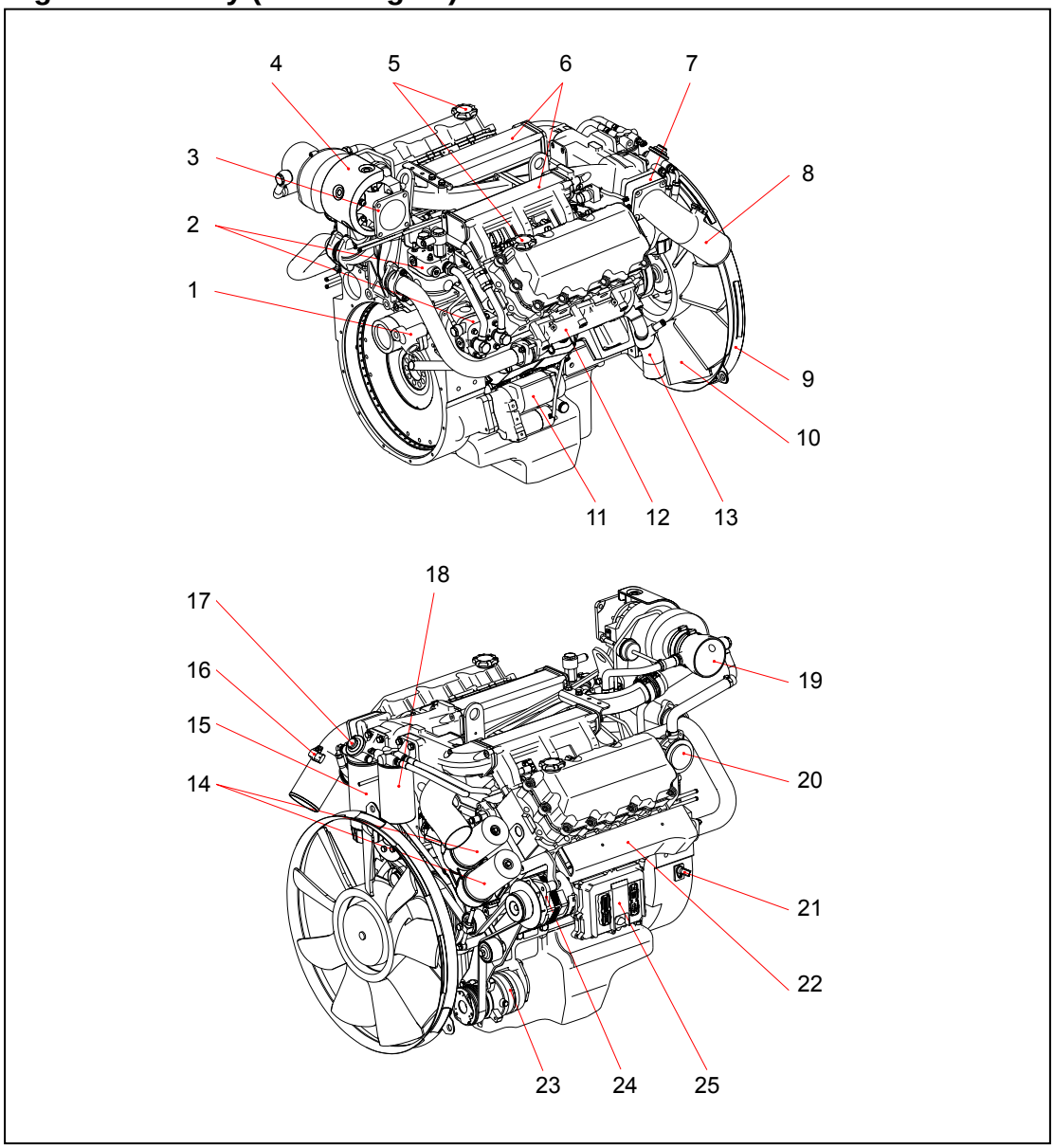
1	Starting motor	8	Injector
2	Oil cooler	9	Oil spray nozzle
3	Cylinder block	10	Connecting rod
4	Cylinder head	11	Electric control unit (E.C.U)
5	Engine brake	12	Oil drain plug
6	Fuel high pressure pump	13	Oil suction pipe
7	Common rail		

1.5.3. Engine assembly (Bus engine)



1	Crank shaft pulley	9	Exhaust manifold	18	Air pipe
2	Oil filter	10	Mounting bracket (rear)		(turbocharger to intercooler
3	Water pump pulley	11	Flywheel housing	19	Air heater
4	Idle pulley	12	Mounting bracket (front)	20	Air pipe
5	Water outlet	13	Oil pan	21	Cylinder head cover
6	Fuel filter	14	Electric control unit (ECU)	22	Oil filler cap
7	Air pipe	15	Power steering pump	23	Water inlet
	(Air cleaner to turbocharger)	16	Air compressor	24	Starting motor
8	Breather	17	Turbocharger	25	Oil cooler

1.5.4. Engine assembly (Truck engine)

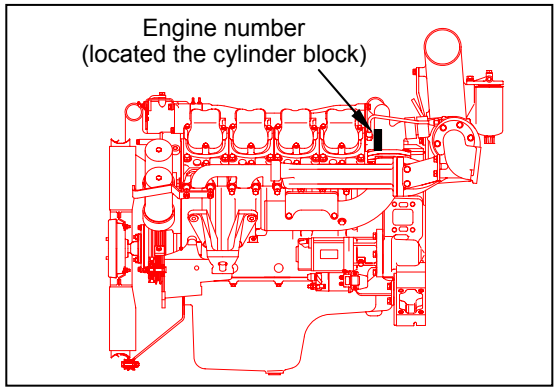


1	Power steering pump	9	Fan guide	18	2nd fuel filter
2	Air compressor	10	Cooling fan	19	Air pipe
3	Exhaust outlet	11	Starter		(Air filter to intake manifold)
4	Turbo charger	12	Exhaust manifold	20	Breather
5	Oil filler cap	13	Water inlet	21	Crank shaft speed sensor
6	Intake manifold	14	Oil filter	22	Exhaust manifold
7	Air heater	15	Primary fuel filter	23	Air con compressor
8	Air pipe	16	Boost pressure sensor	24	Alternator
	(Air cleaner to Turbocharger)	17	Fuel priming pump	25	Electric control unit(ECU)

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 : DV11)**

DV11 5 00001 BA

- **Engine model suffix (EUJBA)**
- **Serial no.**
- **Production year (2005)**
- **Engine model**

- **Engine serial No. (example 2 : DV11)**

DV11 5 00001 CA

- **Engine model suffix (EUJCA)**
- **Serial no.**
- **Production year (2005)**
- **Engine model**

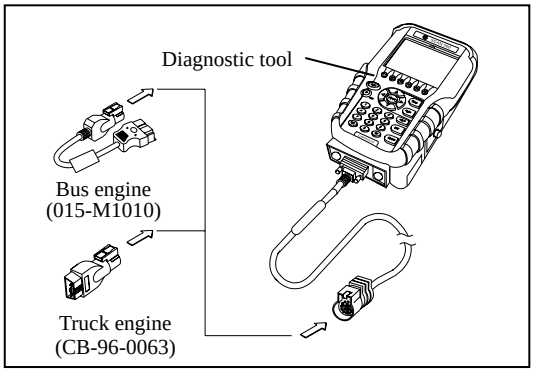
2.2. Diagnostic tool (SCAN-200)

The SCAN-200 is a powerful tool to support the service personal diagnosing and repairing of electric system for vehicle with installed DV11 engine.

< SCAN-200 tool>

- High resolution digital type display.
- Soft touch key-board.

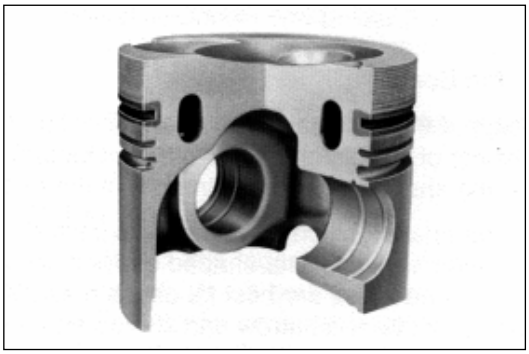
- Diagnosis trouble code or sensor data operation via help.
- Large memory expansion ROM pack data storage area for flight recorded data.



NOTE:
Inspect the electrical parts problem with SCAN-200 and refer diagnostic manual.

2.3. Engine Character

- DOOSAN ‘s DV11 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

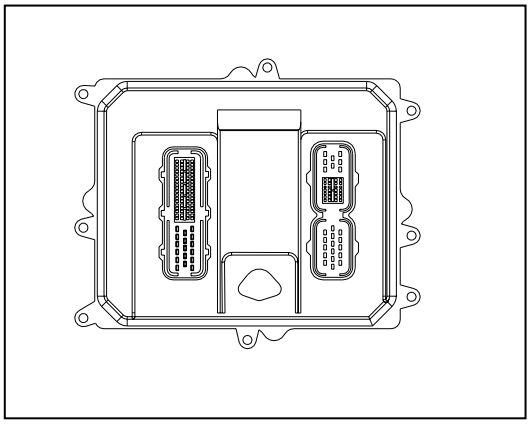
- The cylinder block is a single piece of alloy cast iron. To increase its stiffness, it is extended to a level below the crankshaft center line. The engine has replaceable wet cylinder liners and individual cylinder heads.

2.3.2. Piston/ Connecting rod/ Crank assembly

- The forged crankshaft has screwed-on the balance weights. Radial seals with replaceable wearing rings on crankshaft and flywheel are provided to seal the crankcase penetrations.
- The connecting rods are die-forged, diagonally split and can be removed through the top of the cylinders together with the pistons. Crankshaft and connecting rods run in steel-backed lead bronze ready-to fit type bearings.

2.3.3. 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.

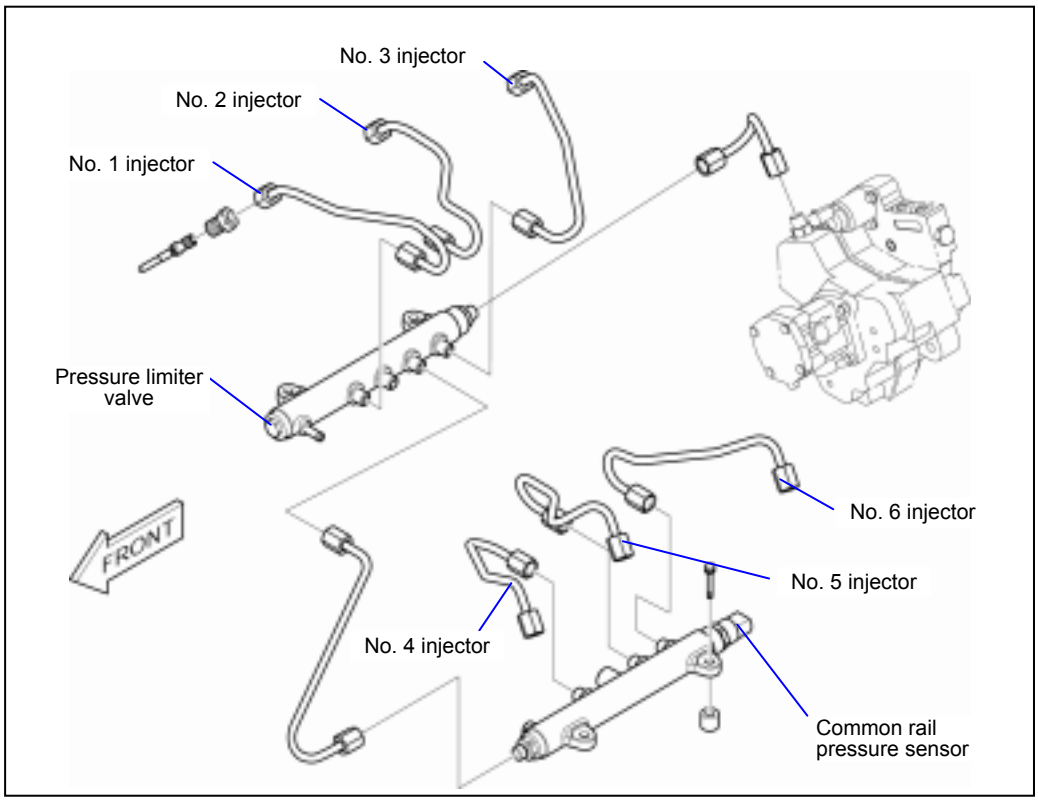


CAUTION:

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.

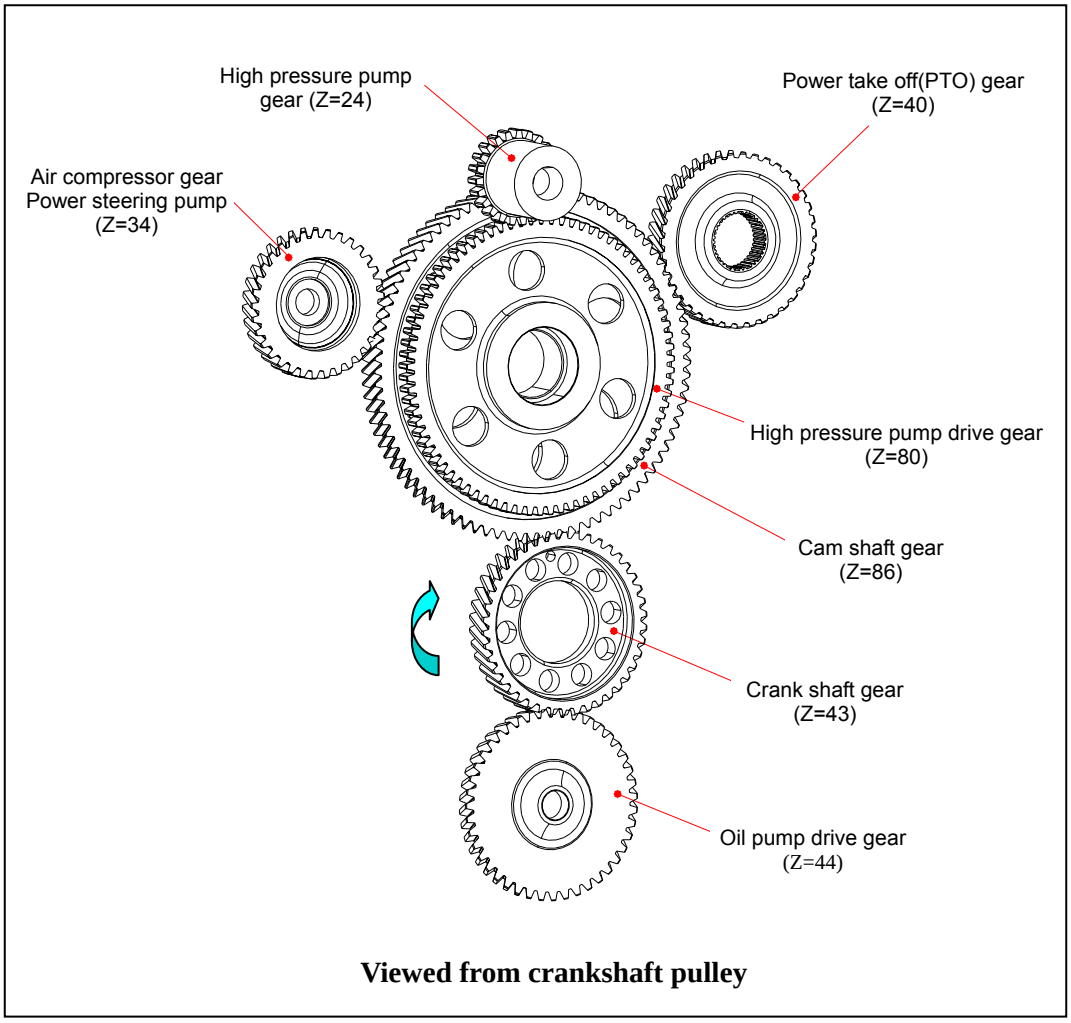
2.3.4. Common rail system

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



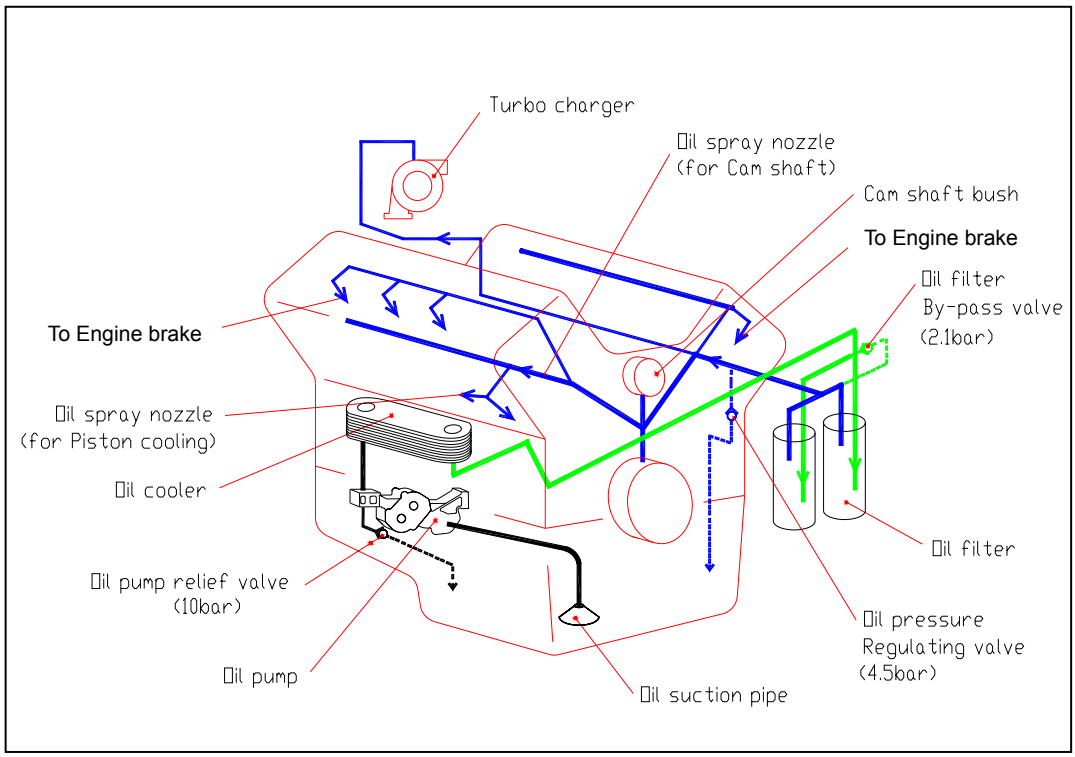
Viewed from crankshaft pulley

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 operating

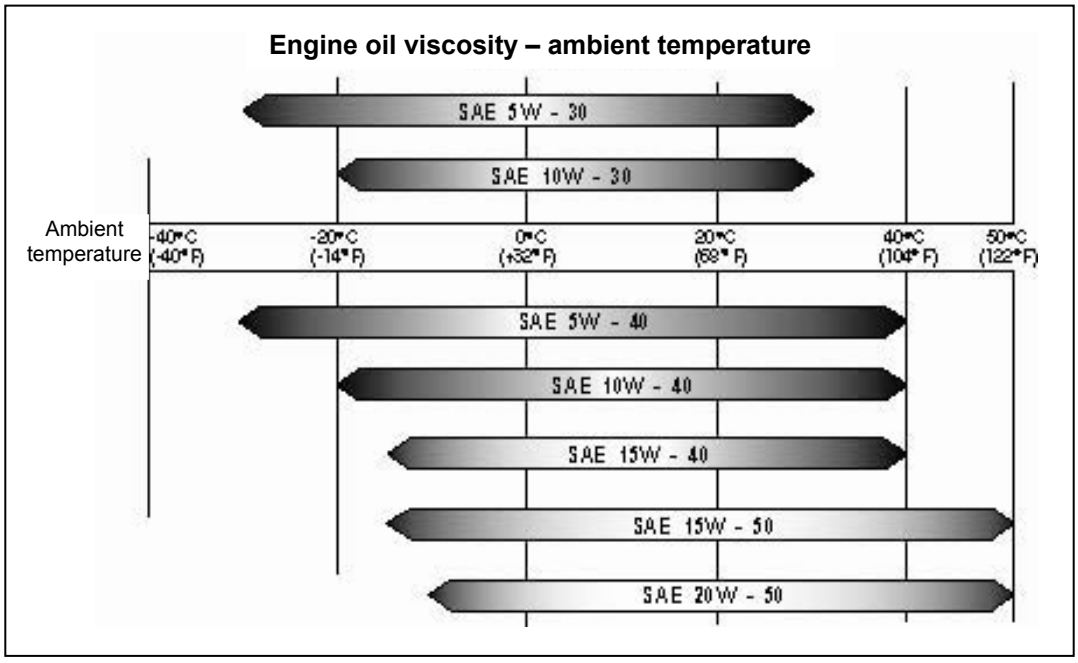
First oil change	After 5,000km operating
1 day operating distance 500km less (Bus, truck)	After once replenishment, every 40,000km
1 day operating distance 500km more (Bus, truck)	After once replenishment, every 60,000km

- The following oils are also recommended.

Engine oil	**SAE No.**	**API No.**
DV11	SAE 10W40	ACEA-E5 (API CI-4)

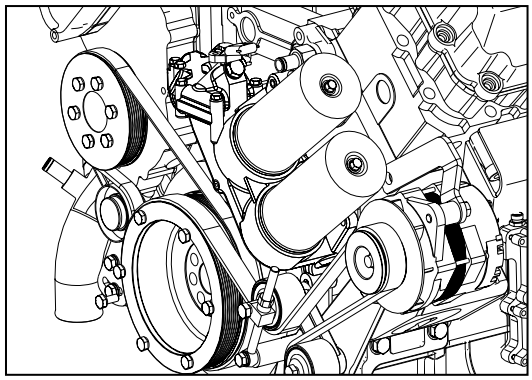
- **Engine oil capacity**

Engine oil capacity				
Engine model		**Oil pan inside**		**Total (lit)**
		Max. (lit)	**Min. (lit)**	
DV11	**Bus**	34	26	37
	Truck	32	26	35



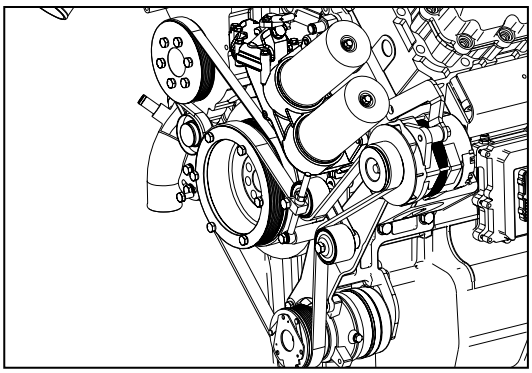
2.3.9. Oil filter

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



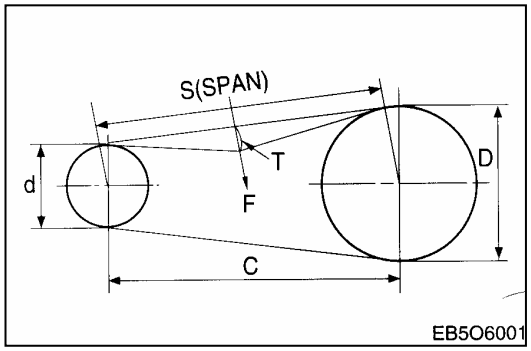
2.3.10. Fan belt

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



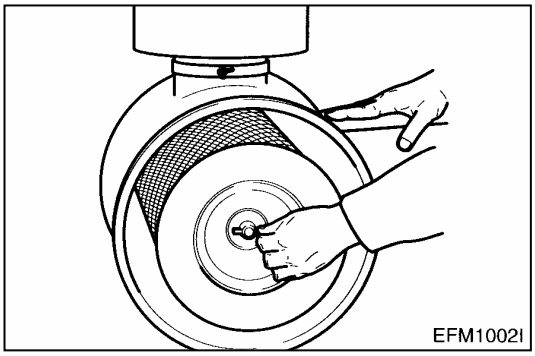
- Adjust the tension of poly belt when pressed down with specified force (F kg):

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



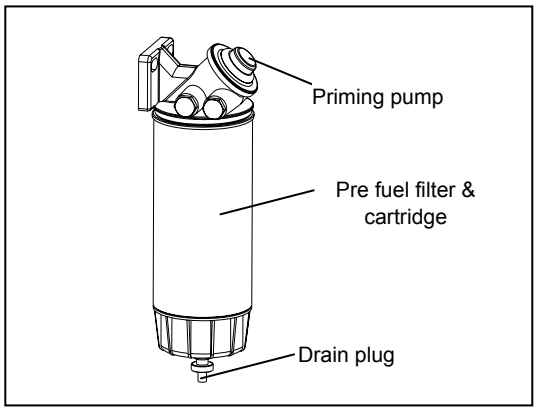
2.3.11. Air cleaner

- 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.



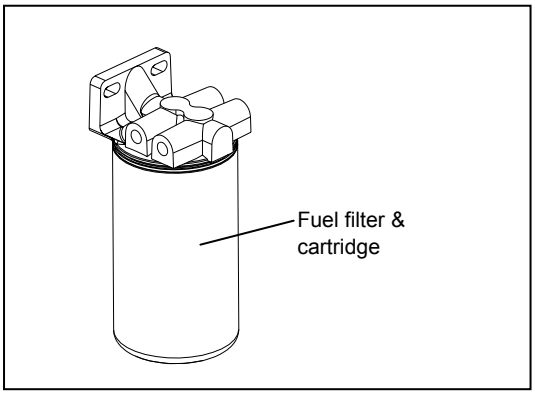
2.3.12. Pre fuel filter

- Drain water in cartridge with loosening the drain plug 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.



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**

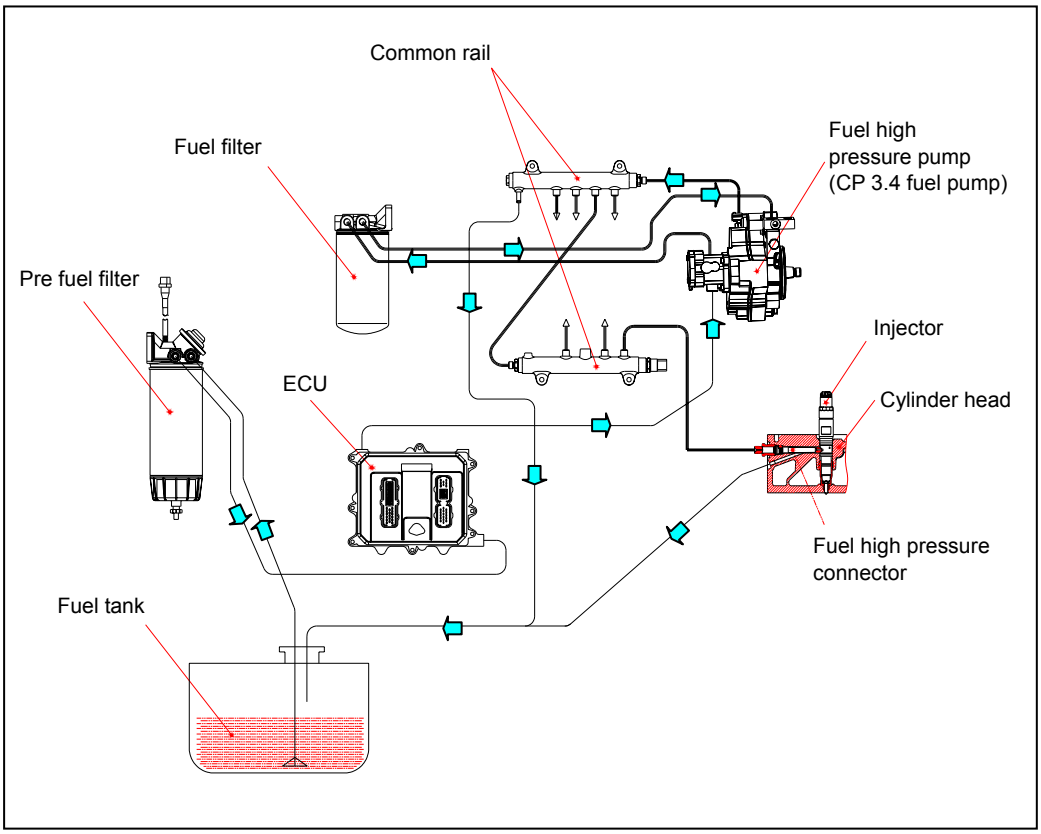
Fuel classification	Unit	DIN EN 590
Cetane number	-	≥ 51
Cetane index	-	≥ 46
Density @ 15°C	kg/m^3	820 ~ 845
Poly aromatic hydrocarbon	% (m/m)	≤ 11
Sulfur content	mg/kg	≤ 0.05
Flash point	°C	≥ 55
Ash content	% (m/m)	≤ 0.01
Water content	mg/kg	≤ 200
Particulate matter content	mg/kg	≤ 24
Copper corrosion 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

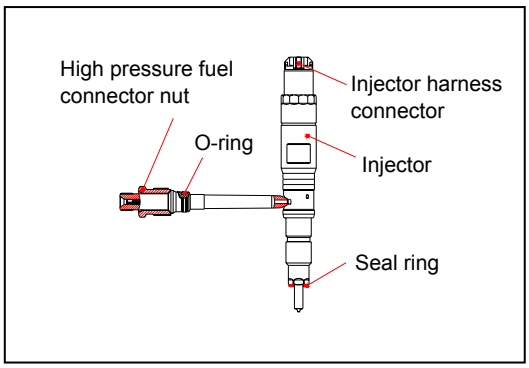
- The fuel is stored under pressure in the common rail ready for injection. The injected fuel quantity is defined by the driver, and the start of injection and injection pressure are calculated by the ECU on the basis of the stored maps. The ECU then triggers the solenoid valves so that the injector (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 is not found, and bleed the system.

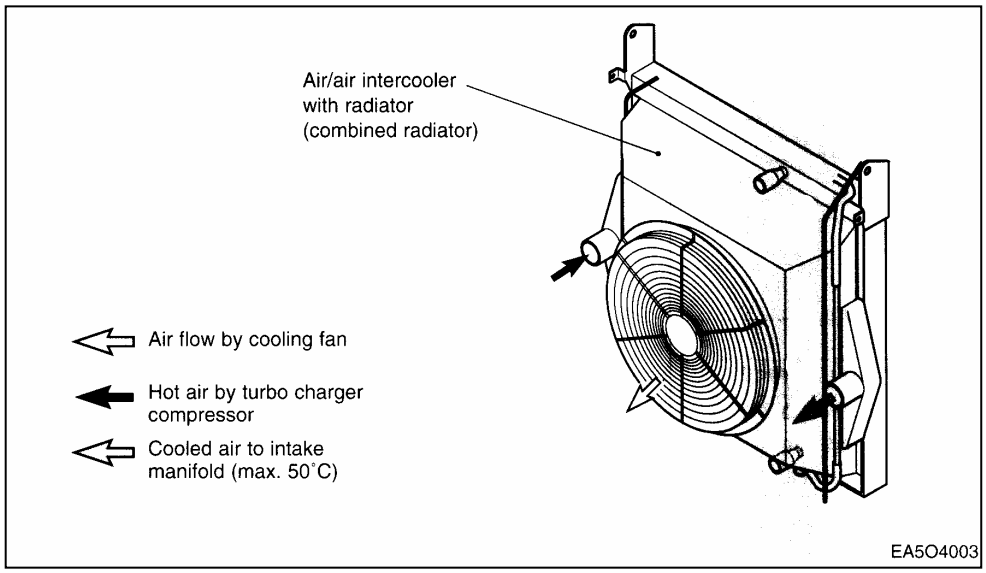
2.3.18. Injector & high pressure connector



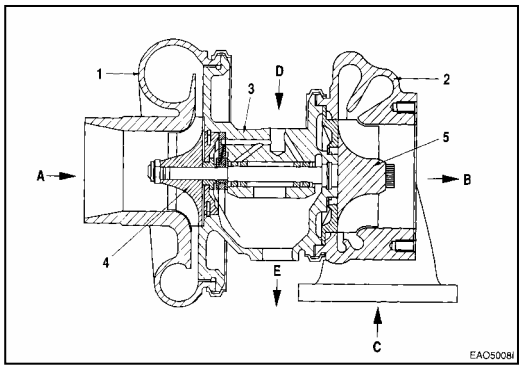
- Be careful to mix the foreign matter into the injector and inside of the connector for connecting the high pressure at disassembly and check.
- O-ring and cupper washer should be changed with new one at reassembly.
- Assemble after coat the oil on the O-ring.
- Assemble after check serial number at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



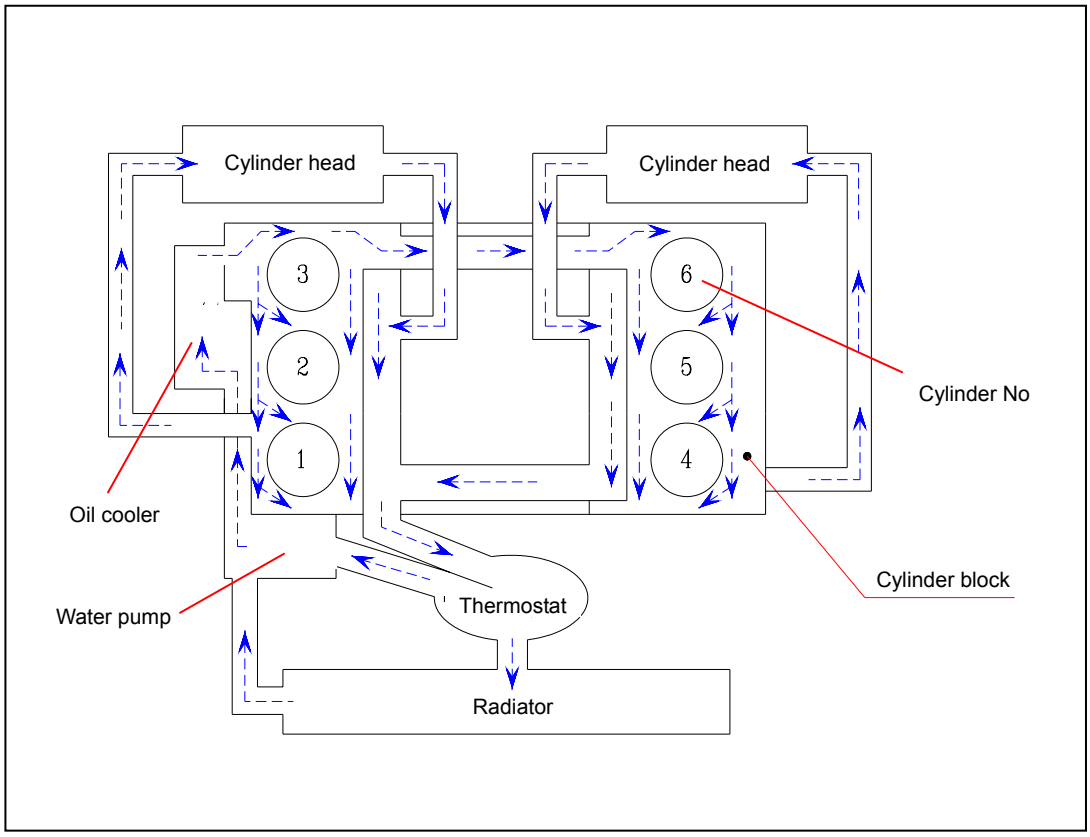
- The turbocharger needs not any specific maintenance.
- Every time of engine replacement, a leakage or clogging of oil pipes should be inspected.
- Air cleaner should be maintained carefully for nut or foreign material not to get in. Periodic inspection should be applied on the compressed air and exhaust 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

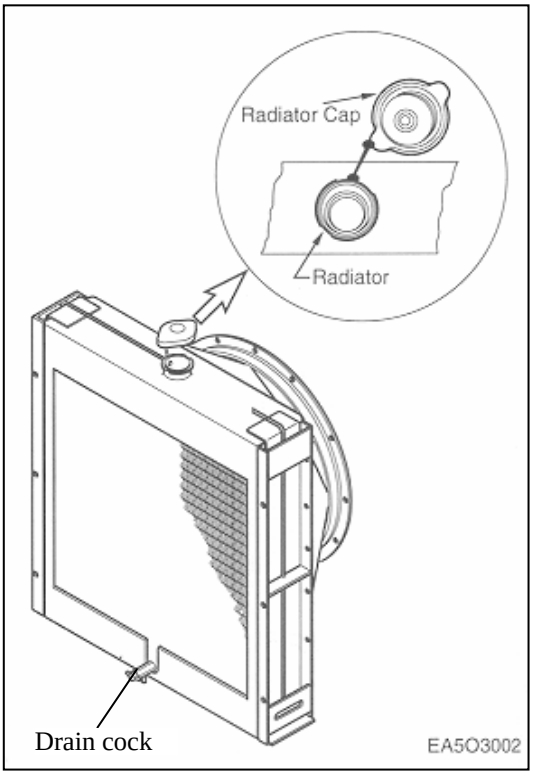
The engine has a liquid-cooling system. The fresh water pump is a maintenance-free by belt from the crankshaft pulley.

- 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.

2.3.23. Cooling water

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

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

- Since **DV11** engine cylinder liner is wet type, particularly the cooling water control should be applied thoroughly.

- The density of anti-freezing solution and additive for rust prevention is able to be confirmed by the cooling water test kit.
  (**Fleetguard CC2602M** or **DOOSAN 60.99901-0038**)

- How to use the cooling water test kit
  (1) When the cooling water temp. of engine is in the range of 10 55 °C, loosen the plug for cooling water discharge and fill the plastic cup about a half.

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

(2) At the state of a test paper soaked in the sampled water, after 3 - 5 seconds past, take the paper out through water agitation, and shake off the water.
(3) Wait for about 45 sec. till the color change of test paper.

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

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

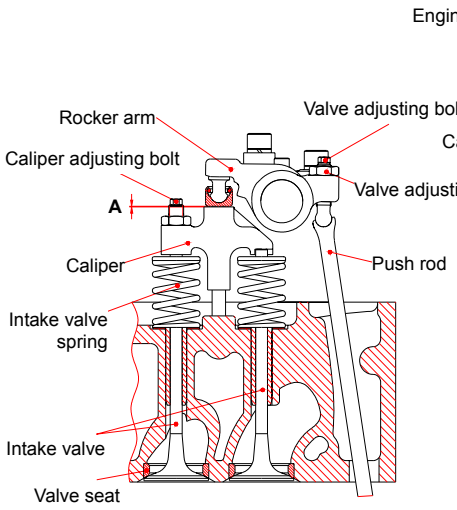
- Amount of Anti-freeze in winter

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

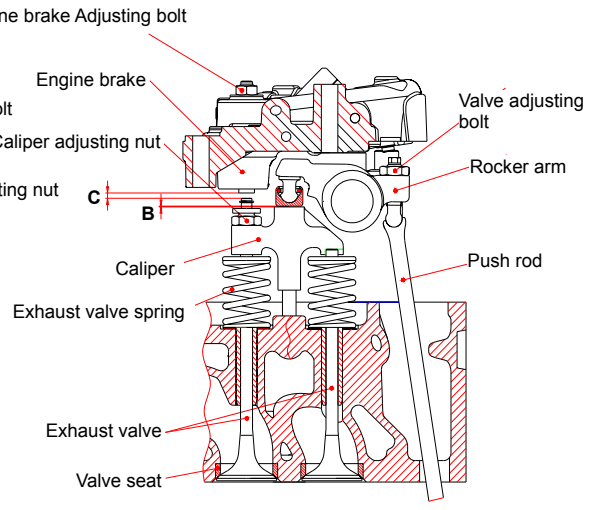
2.3.24. Valve clearance adjust procedure

- 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 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 (A)	Exhaust valve (B)	Engine brake (C)
DV11	0.4 mm	0.5 mm	1.5 mm



Intake valve adjusting

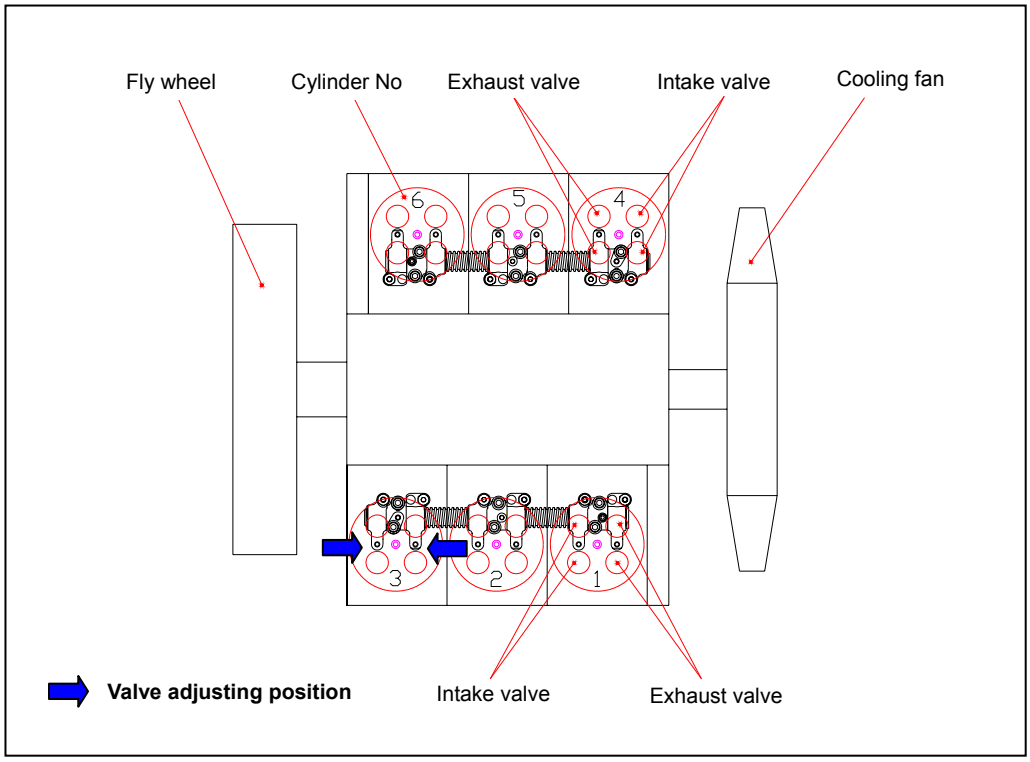


Exhaust valve, engine brake adjusting

< Adjust the valve clearance as following order. >

1) Rotating the engine, let #6 cylinder overlap.
2) In time that #1 cylinder become the state of top dead center, adjust the valve clearance corresponding to " ◎ " of following lists.
3) Rotating the crankshaft by 90° rotation, adjust the valve clearance corresponding to " ⊙ ".
4) Rotating the crankshaft by 1 rotation (360° rotation), let #1 cylinder overlap.
5) In time that #5 cylinder become the state of top dead center, adjust the valve clearance corresponding to " ● " of following lists.
6) Rotating the crankshaft by 450° rotation, adjust the valve clearance corresponding to " ○ ".
7) After rechecking the valve clearance, readjust if necessary.

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



- **Adjusting of valves (Type 1)**

Cylinder No / Valve adjusting	1		2		3		4		5		6	
	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
#1 cylinder top dead center (#5 cylinder valve overlap)	◎	◎	◎					◎			◎	
Crankshaft 90° rotation							⊙					
360° rotation #5 cylinder top dead center (#1 cylinder valve overlap)				●	●				●	●		●
Crank shaft 450° rotation						○						

- **Adjusting of valves (Type 2)**

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

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

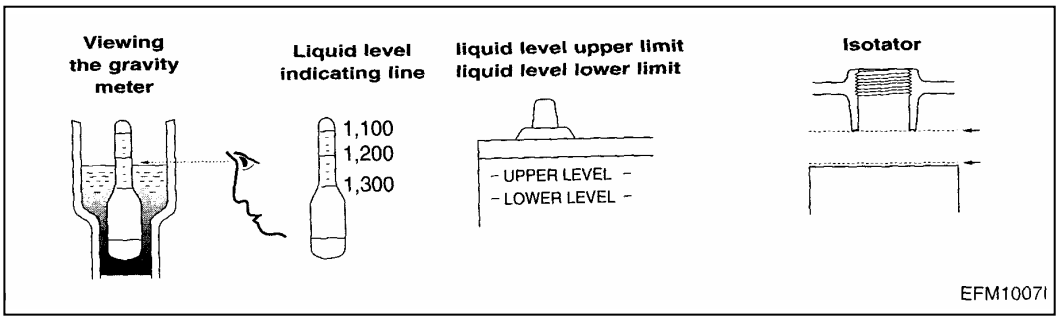
- Adjusting of engine brake (Adjusting of slave piston)

Cylinder no. / Slave piston adjusting	Engine brake slave piston adjusting No.		
#1 cylinder top dead center (#5 cylinder valve overlap)	**1**	**2**	**4**
360° rotation (#1 cylinder valve overlap)	**3**	**5**	**6**

* When adjust slave piston of the engine brake, adjust only exhaust valve correspond to the cylinder number.

2.3.25. Battery

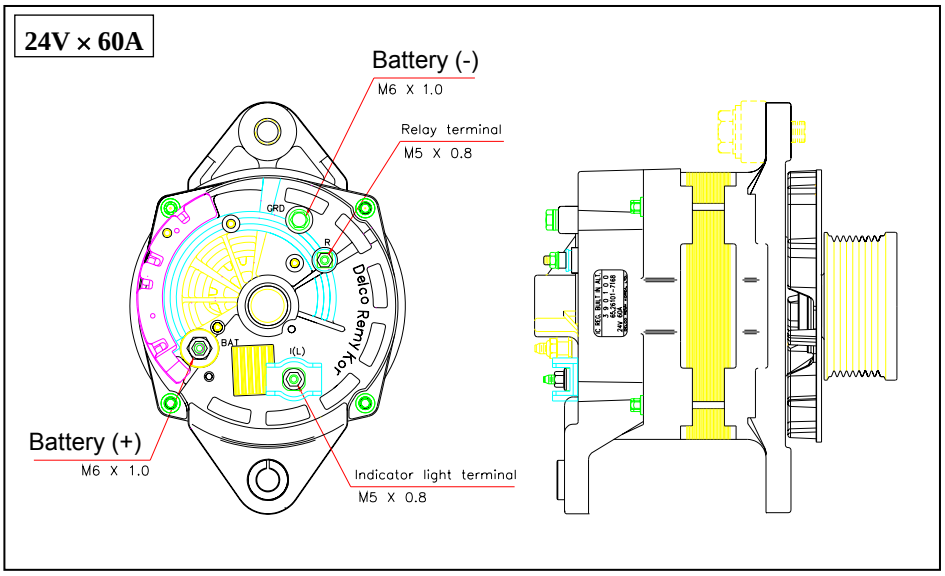
- Inspect for any leakage of electrolytic solution owing to battery crack, and replace the battery in case of poor condition.
- Inspect for amount of electrolytic solution, and replenish if insufficient.
- Measure the gravity of electrolytic solution, if less than specified value (1.12 1.28), replenish.



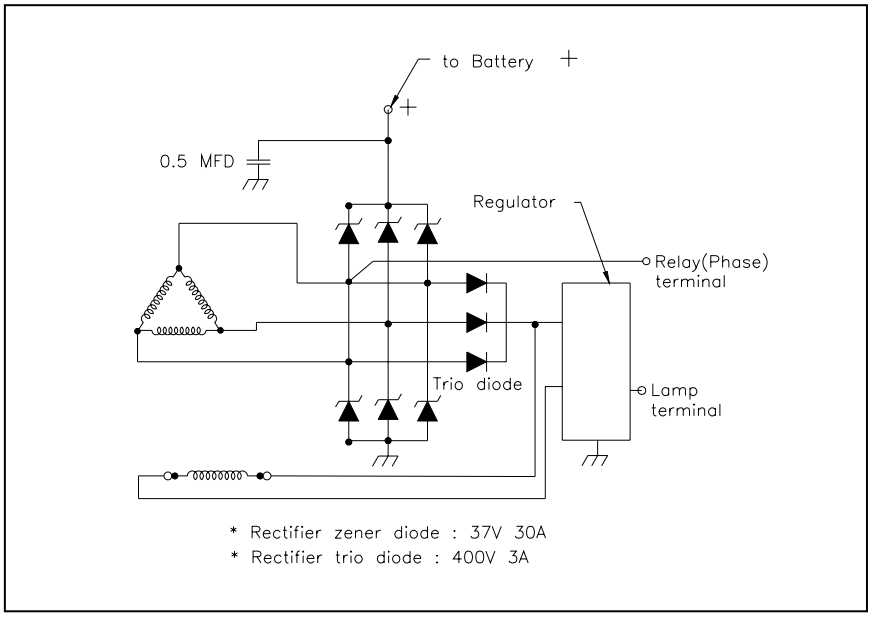
2.3.26. Alternator

a) Alternator (24Vx60A)

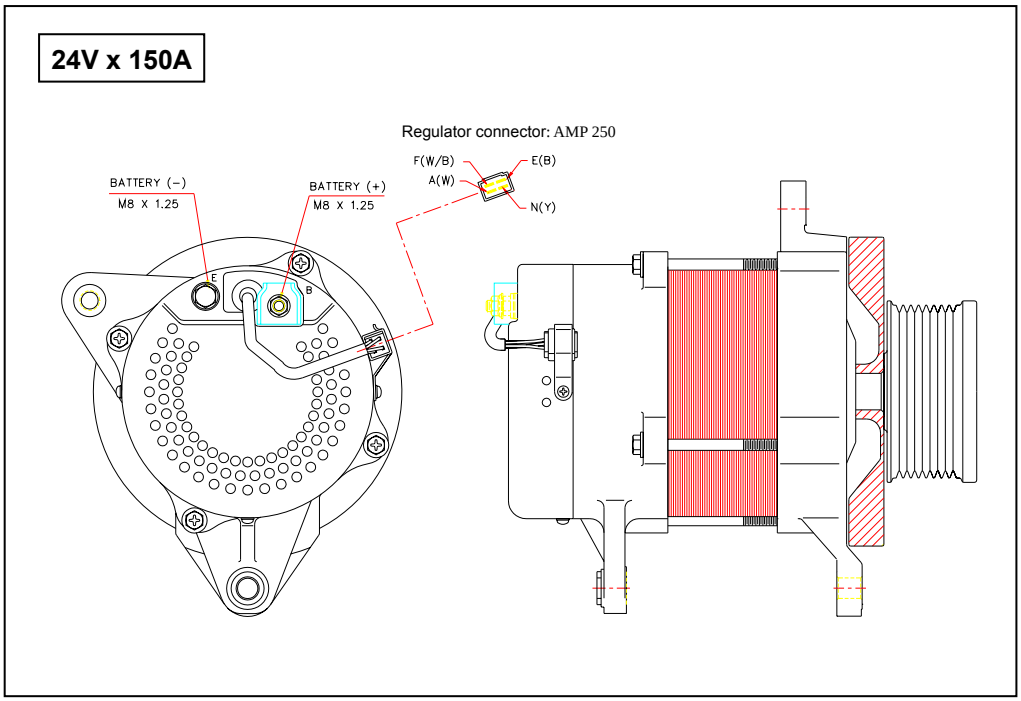
- The alternator is fitted with integral silicon rectifiers. A transistorized regulator mounted on the alternator body interior limits the alternator voltage.
- The alternator should not be operated except with the regulator and battery connected in circuit to avoid damage to the rectifier and regulator.



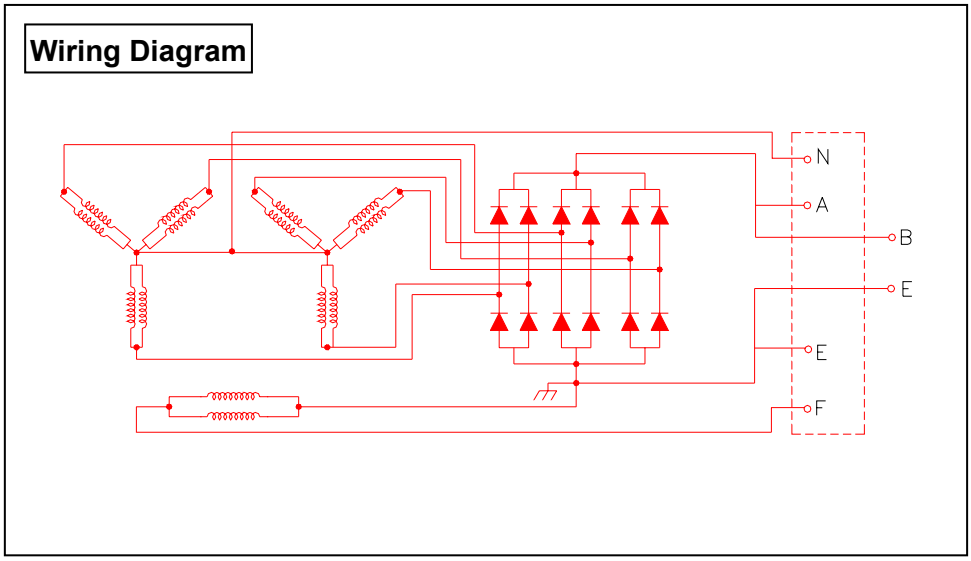
- The alternator is maintenance-free, nevertheless, it must be protected against dust and, above all, against moisture and water.



b) Alternator (24Vx150A)

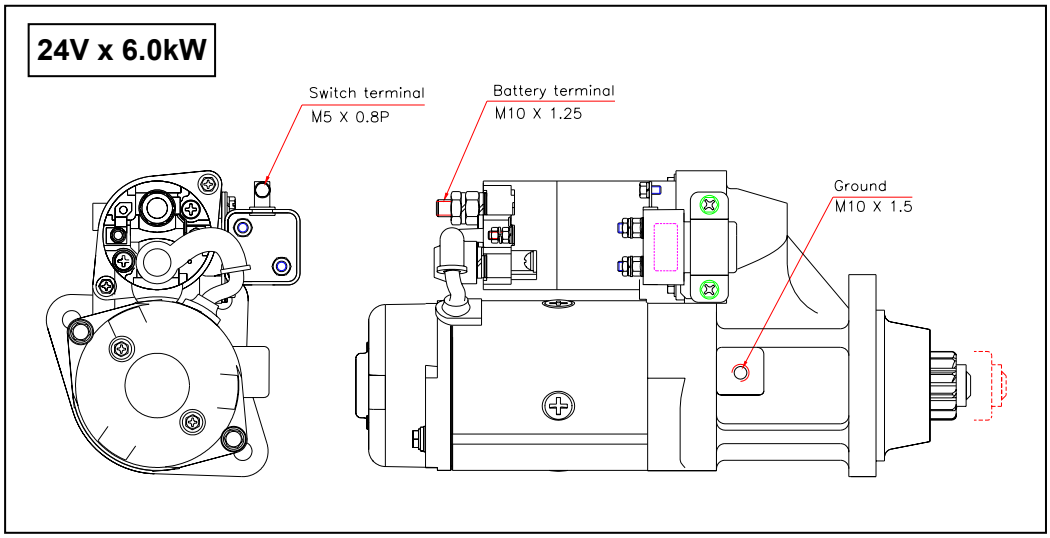


- **Regulator connector**
  - **N** terminal : cut off the charging lamp with detect the voltage by regulator.
  - **A** terminal : switching the regulator on sensing the output voltage.
  - **E** terminal : Regulator earth terminal (-)
  - **F** terminal : supply the amperage on the rotor coil.

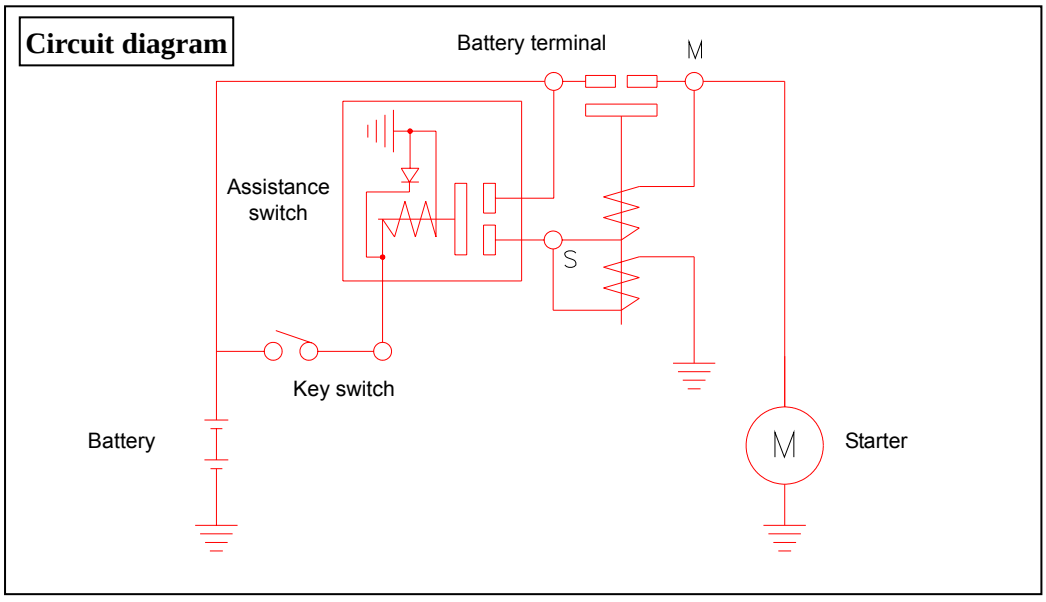


2.3.27. Starting motor

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



Always protect starter motor against moisture.

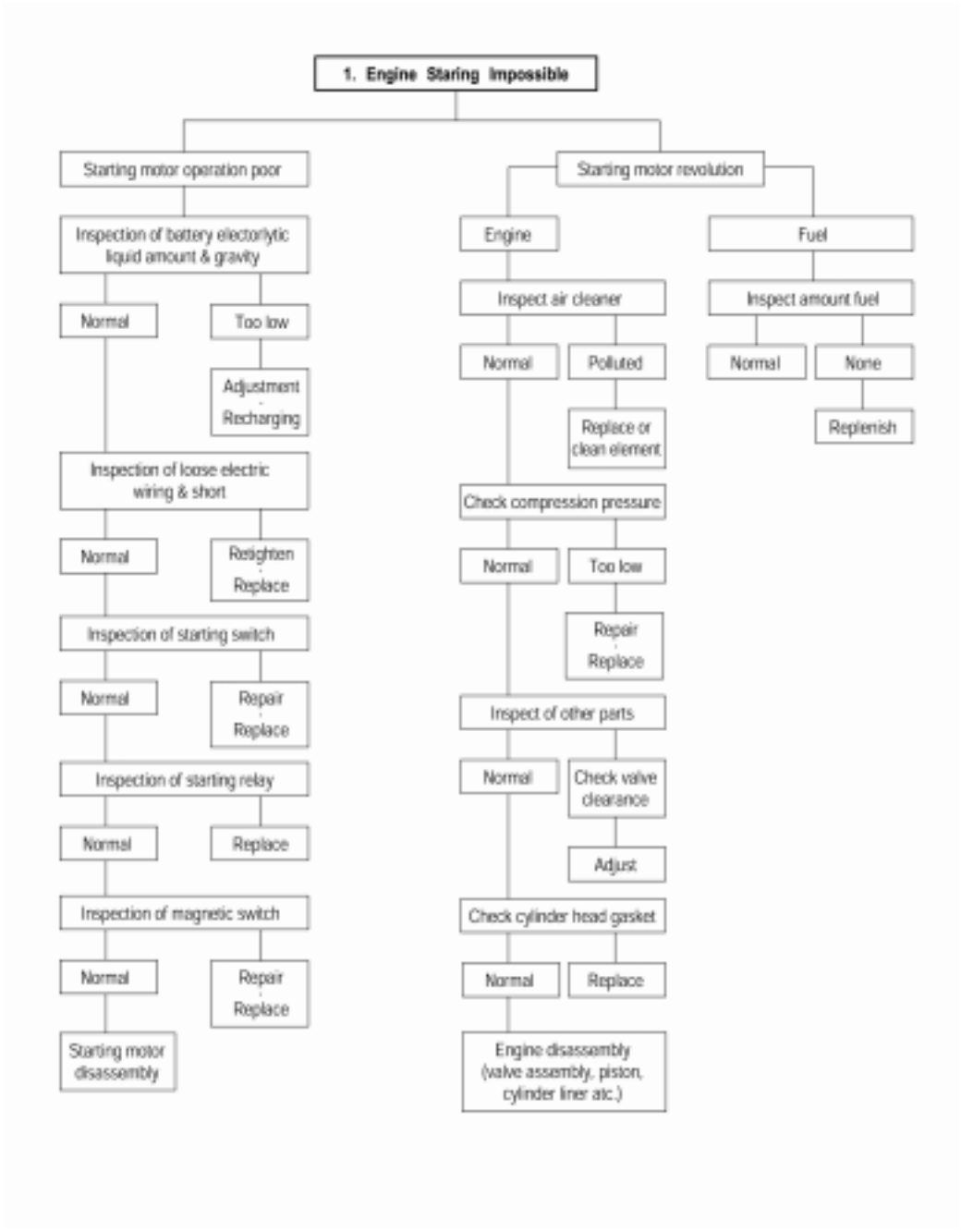


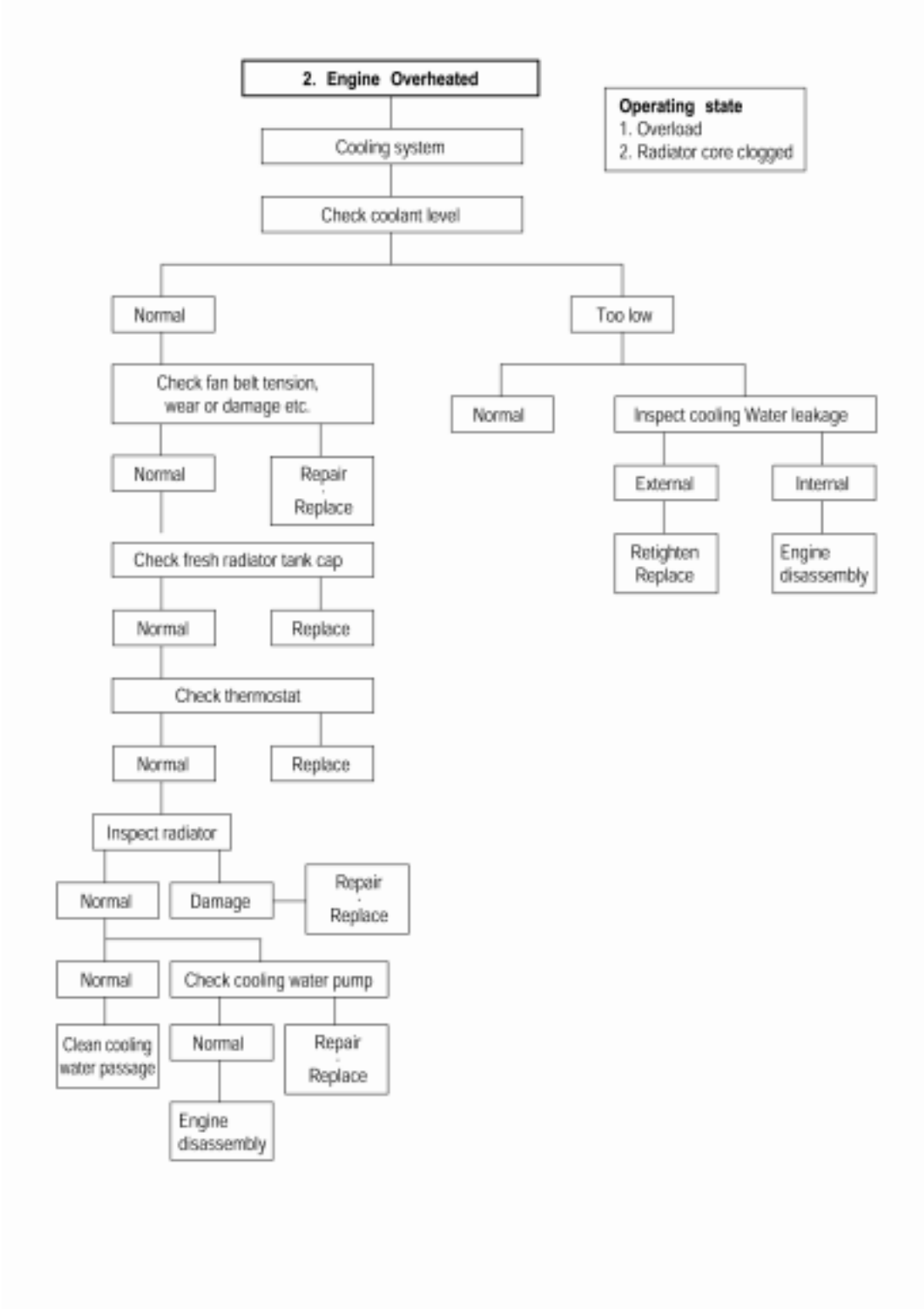
IMPORTANT:

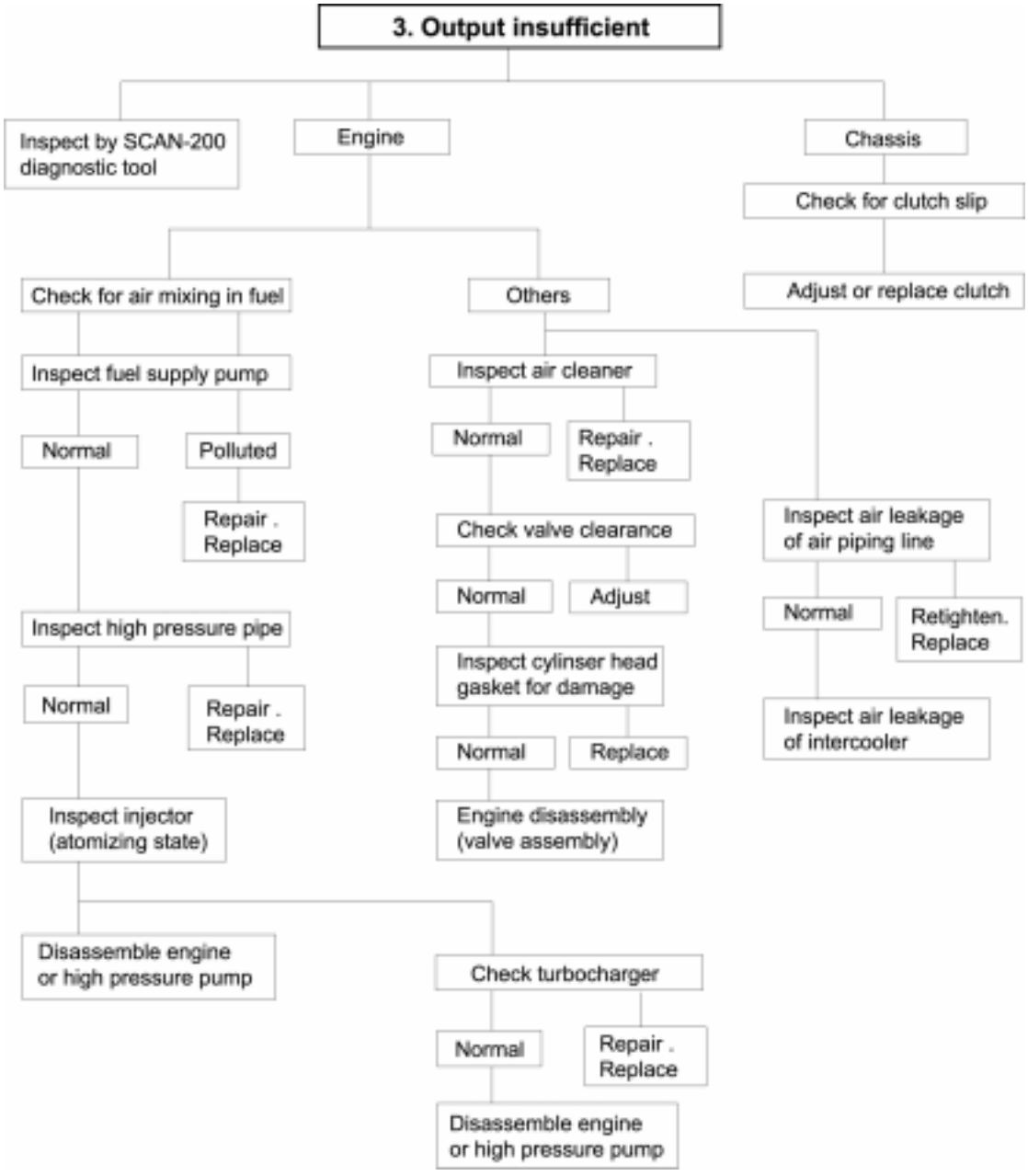
Always disconnect the battery earth cable before starting work on the electrical system. Connect up the earth cable last, as there is otherwise a risk of short-circuit.

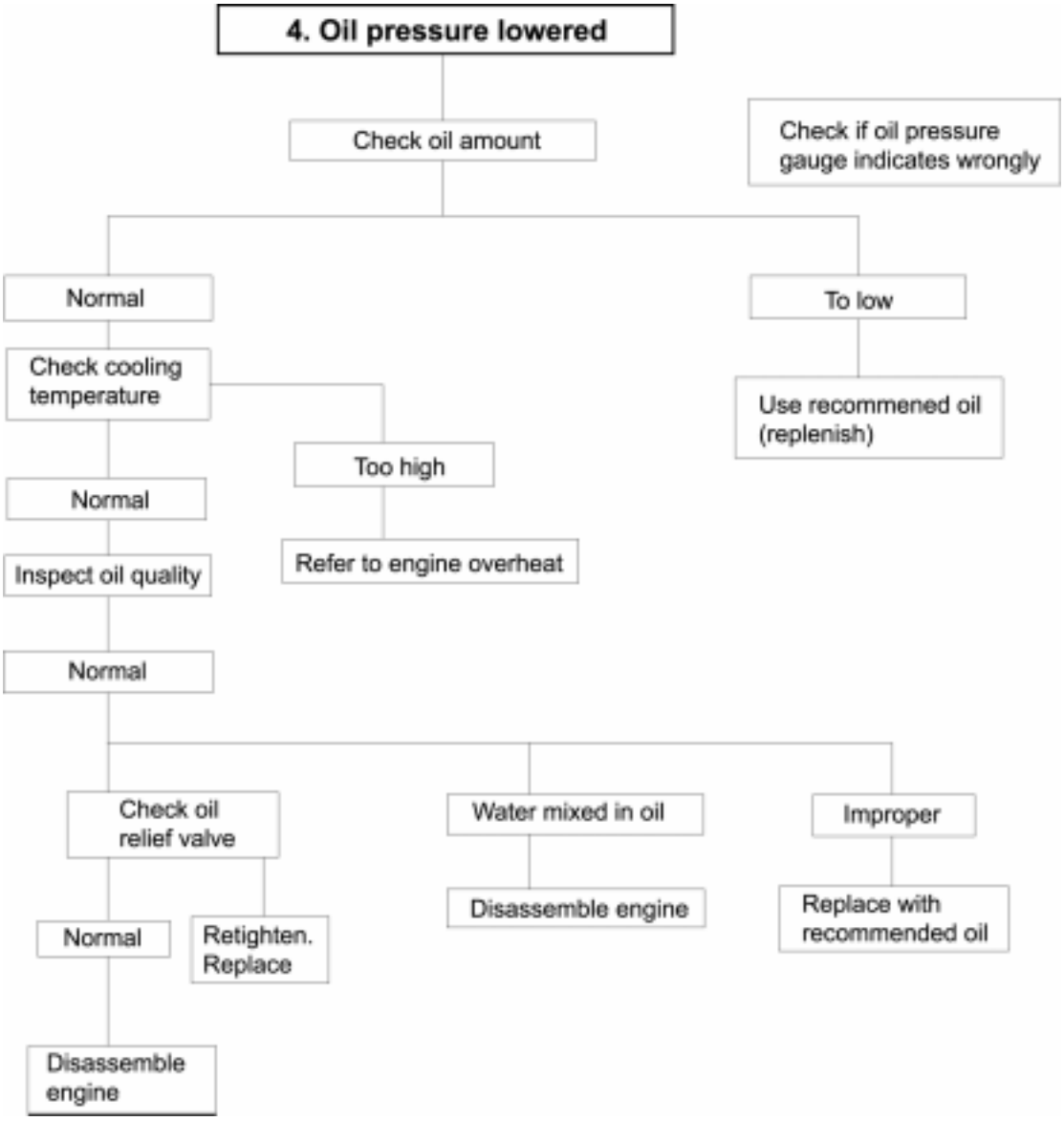
2.4. Diagnosis and Remedy

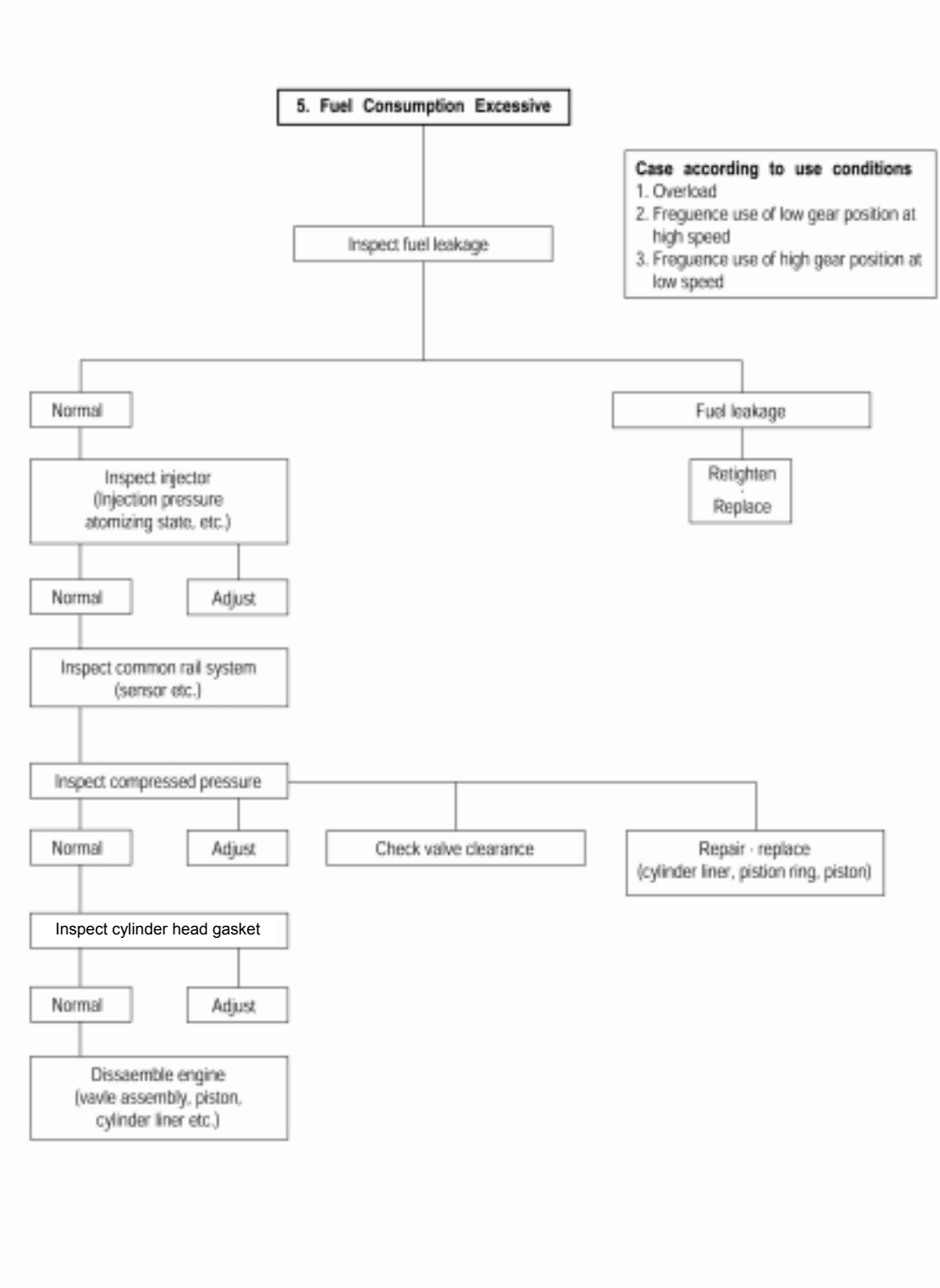
- The following description summarizes the probable cause of and remedy for general failure by item.
- Inspect the electrical parts problem with SCAN-200 and refer diagnostic manual.
- Immediate countermeasures should be taken before a failure is inflamed if any symptom is detected.

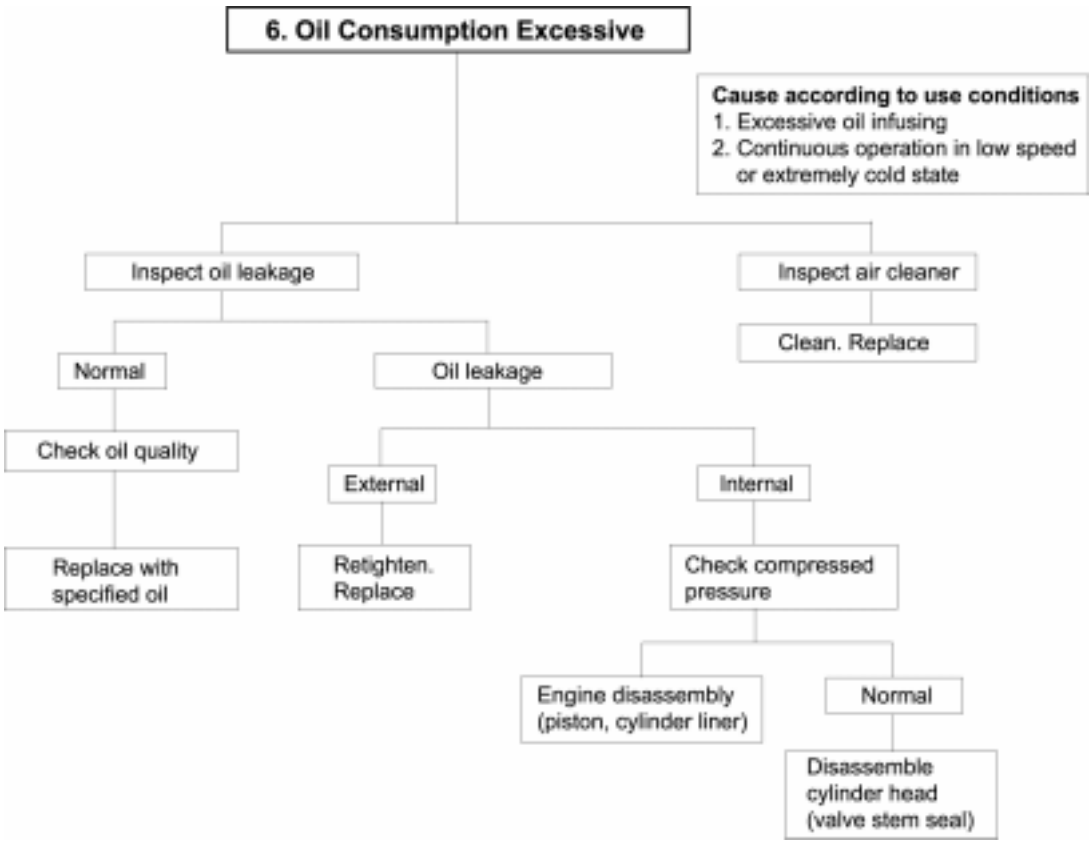


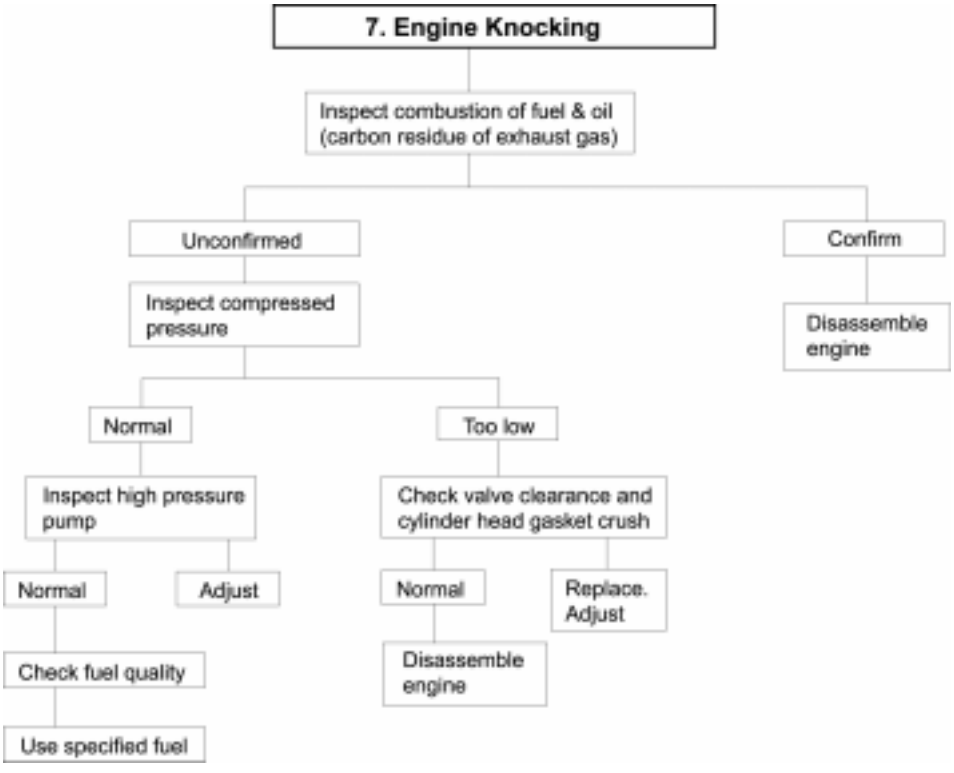

2. Engine Overheated
Operating state
1. Overload
2. Radiator core clogged
Cooling system
Check coolant level
Normal
Too low
Check fan belt tension, wear or damage etc.
Normal
Inspect cooling Water leakage
Normal
Repair Replace
External
Internal
Retighten Replace
Engine disassembly
Check fresh radiator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

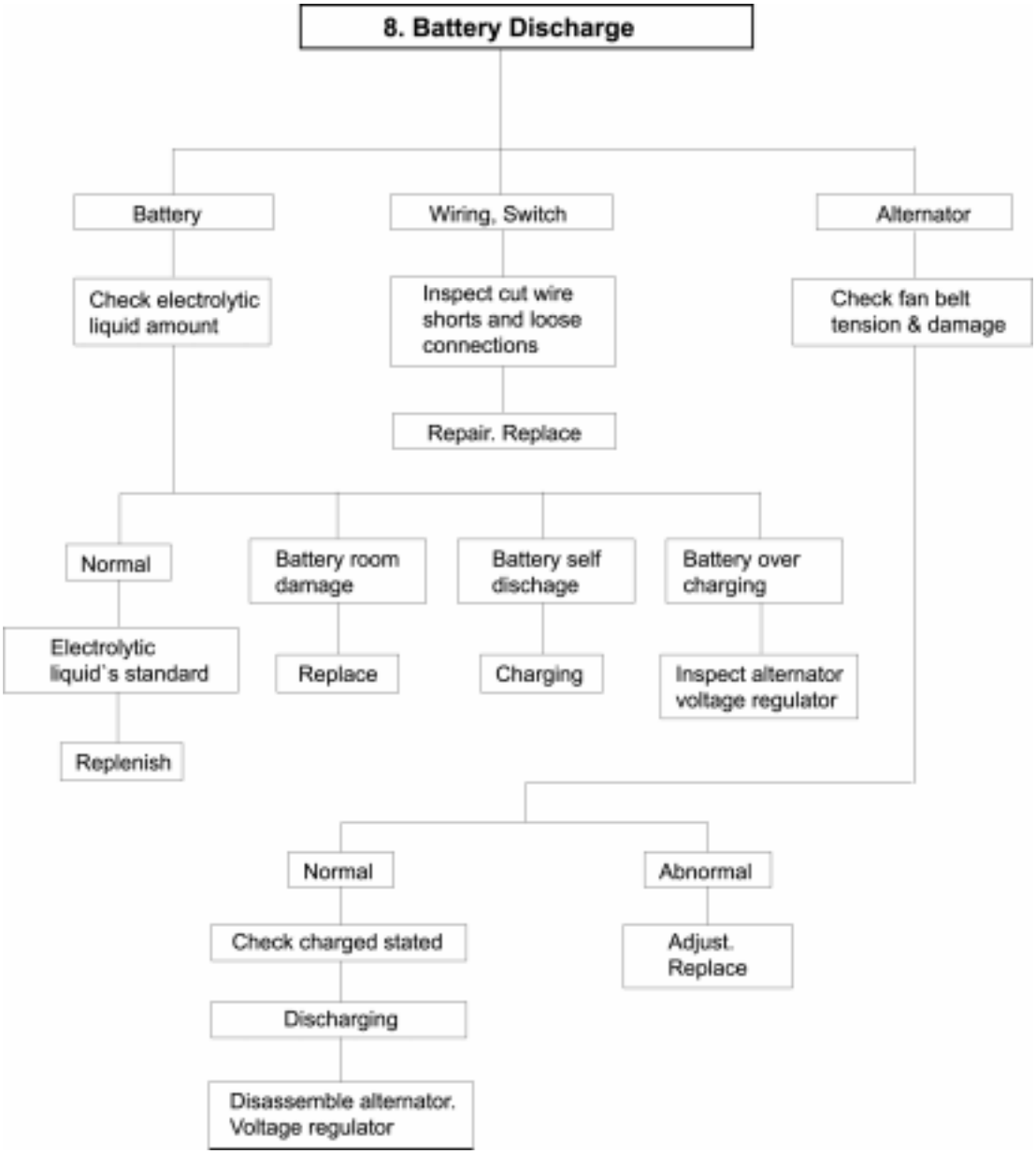

3. Output insufficient
Inspect by SCAN-200 diagnostic tool
Engine
Chassis
Check for clutch slip
Check for air mixing in fuel
Others
Adjust or replace clutch
Inspect fuel supply pump
Inspect air cleaner
Normal
Polluted
Normal
Repair . Replace
Repair . Replace
Check valve clearance
Inspect air leakage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


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

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				
	Clean the fuel strainer of fuel feed pump			O				
	Check the fuel line leakage	O						
	Check fuel injection timing							When necessary
	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. Use of original parts for repair and replacement

For engine is being mechanically harmonized with many parts, only when the original parts that the manufacture recommends to use is used, the engine trouble would be preventively maintained and capable to keep up the maximum performances.

For the analogous parts not the original parts are poor in qualities and gives ill performances, it may rather bring early engine failure.

3. Disassembly and Reassembly of Major Components

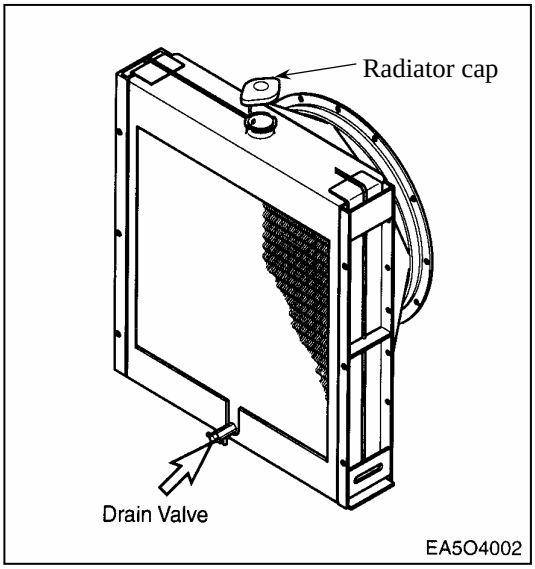
3.1. Engine Disassembly

3.1.1. General precautions

- For the various tool storage before disassembly and parts storage after disassembly, the shelf for parts is prepared.
- At the time of disassembly and reassembly, do the work with the naked and clean hand, and also the working place must be maintained clean.
- The torn parts after disassembly must be kept not to collision each other.
- In disassembling, torn parts should be laid in disassembled order.
- Before performing service operation, disconnect the grounding cable from the battery for reducing the chance of cable damage and burning due to short-circuiting.

3.1.2. Cooling water

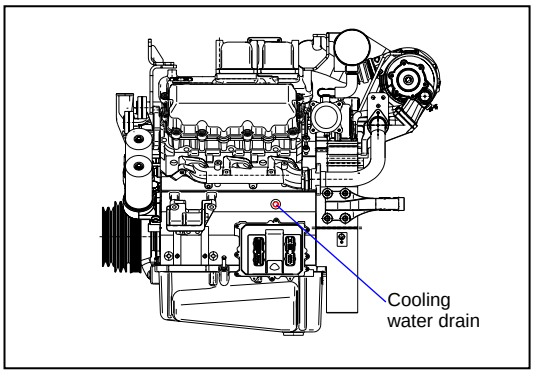
- Remove the radiator cap. Open the drain valve at the radiator lower part to drain the coolant as the right figure.



CAUTION:

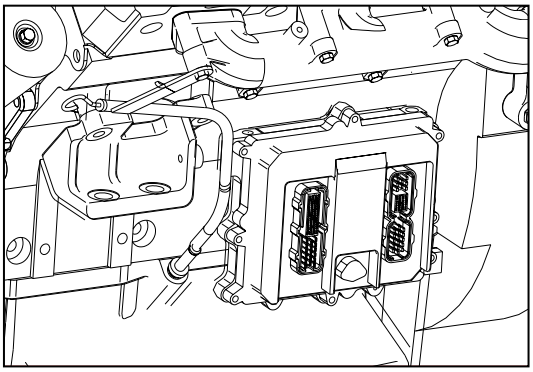
When removing radiator filler cap while the engine is still hot, cover the cap with a rag, then turn it slowly to release the internal steam pressure. This will prevent a person from scalding with hot steam spouted out from the filler port.

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



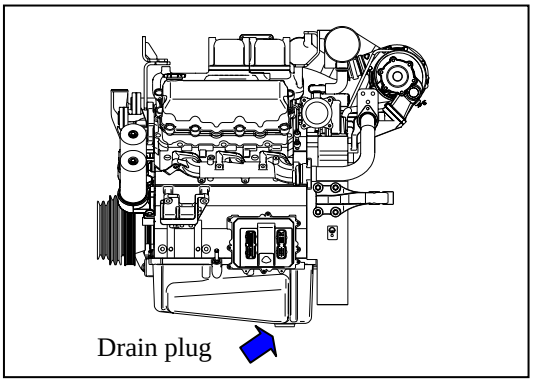
3.1.3. Oil level gauge

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



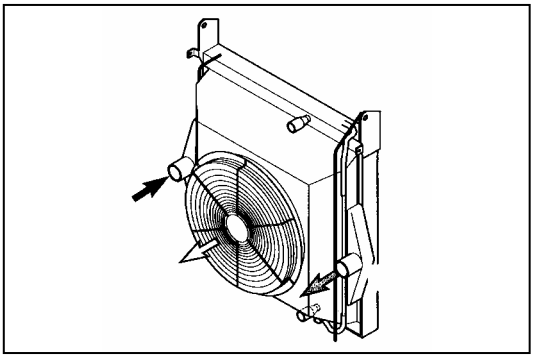
3.1.4. Engine oil

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



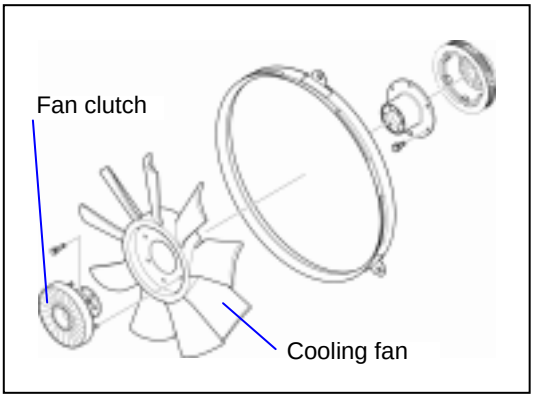
3.1.5. Inter cooler

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



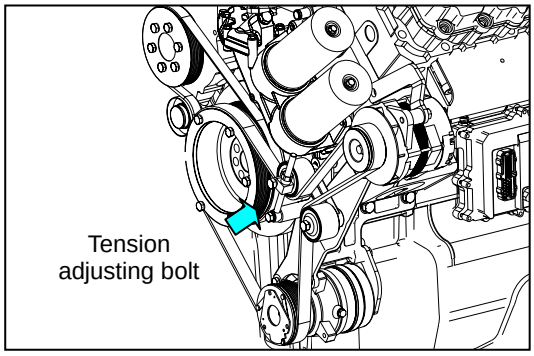
3.1.6. Cooling fan & fan clutch

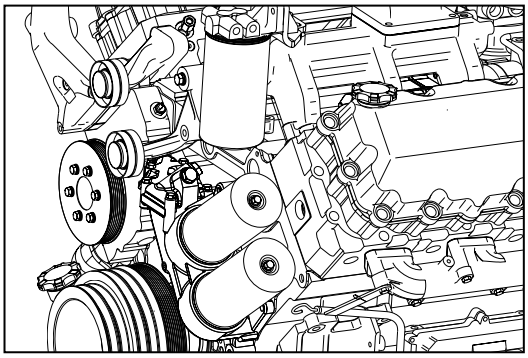
- Remove fan fixing bolts, then take off the cooling fan and clutch.



3.1.7. V-belt

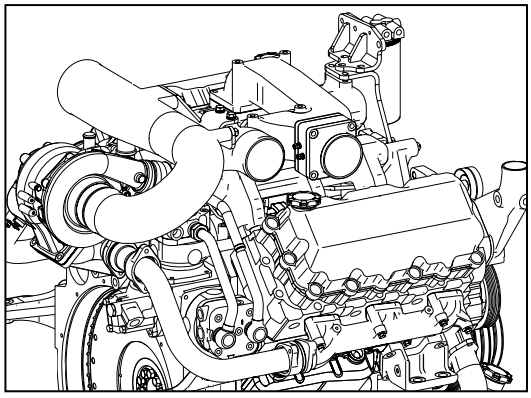
- Loosen the V-belt tension adjusting bolts, and remove the V-belt.

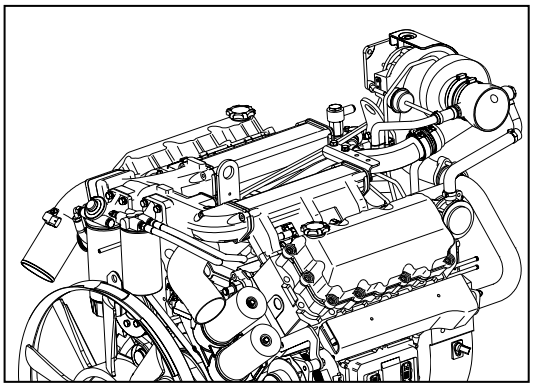




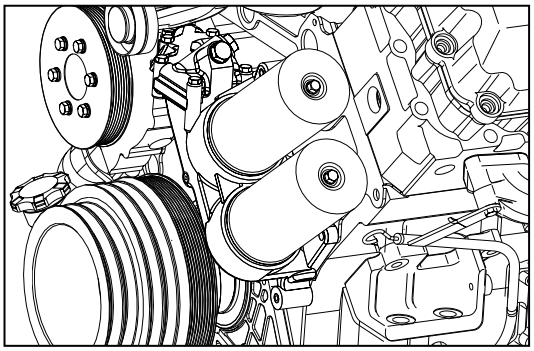
3.1.8. Air pipe & air heater

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



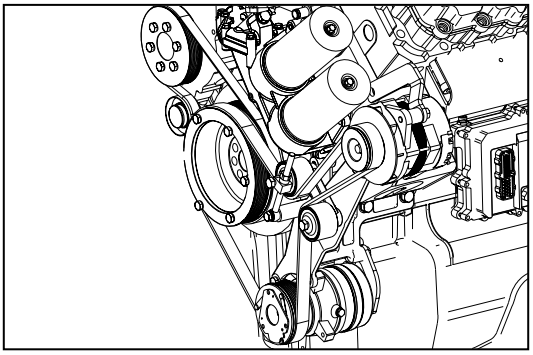


3.1.9. Oil filter



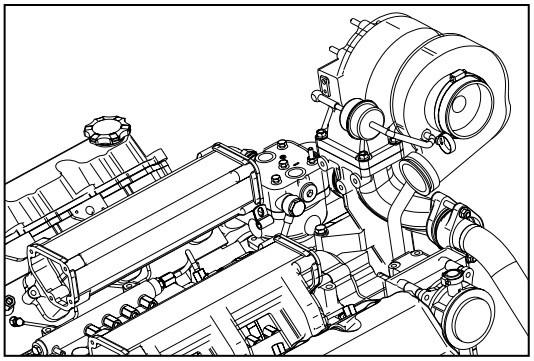
- Loosen the filter housing fixing bolts then the spring will force the filter housing to move upward a little.
- Do not use again the cartridge removed after use.
- Unscrew the oil filter head fixing bolts and take off the oil filter head.

3.1.10. Alternator



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

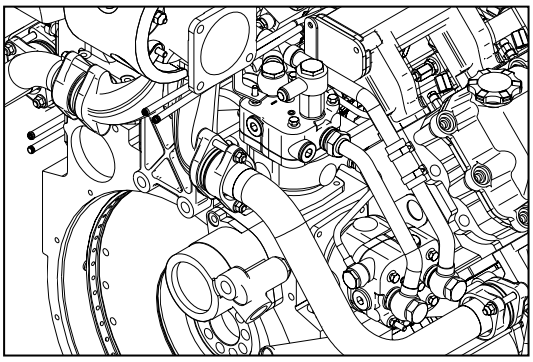
3.1.11. Turbocharger

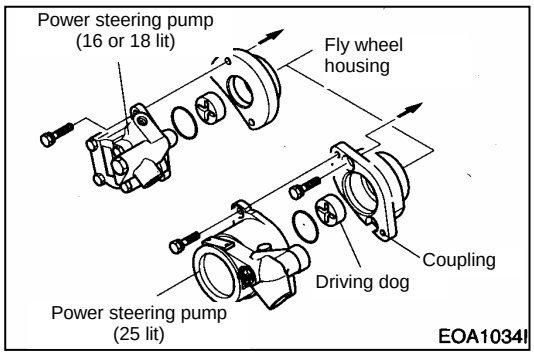


- Loosen the hose clamp for connecting the intake stake and tear down the air pipe.
- Unscrew the turbo charger lubrication supplying bolt and tear down oil pipe
- Unscrew the turbo charger fixing nuts and take off the turbo charger from the exhaust manifold.

3.1.12. Power steering pump

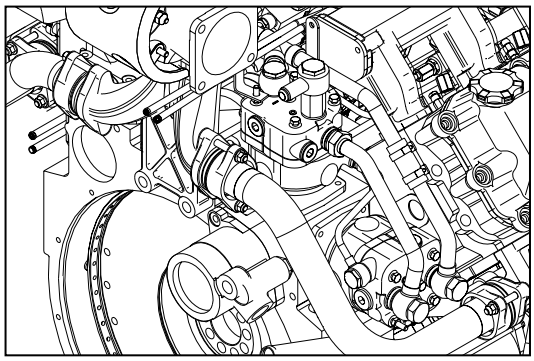
- Unscrew the power steering pump fixing bolts, remove the power steering pump and driving coupling.

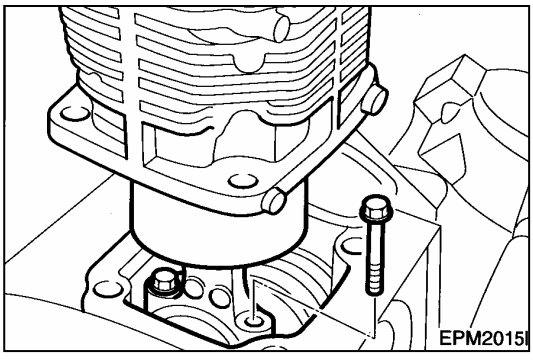




3.1.13. Air compressor

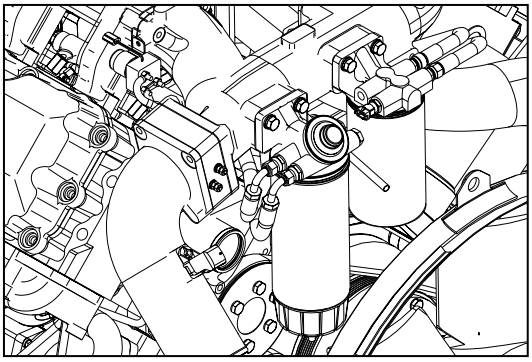
- Remove water and air pipes from air compressor.
- Unscrew the cylinder head bolts and remove the compressor head.
- Disassemble the flange on the front side of the flywheel housing and remove the air compressor liner.





3.1.14. Fuel filter

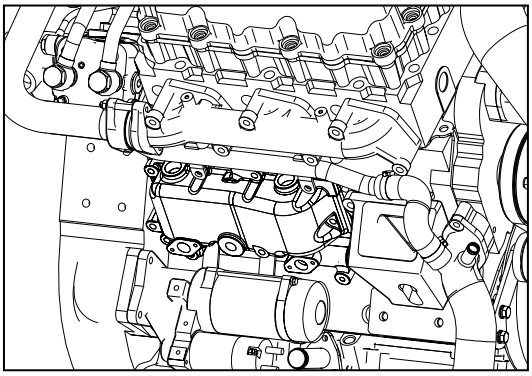
- Disassemble the fuel hose for the fuel supply and suction.
- Remove the fuel filter fixing bolts and disassemble the fuel filter.



NOTE:
Seal the fuel filter to prevent from mixing foreign material into inside of the fuel filter after disassembling.

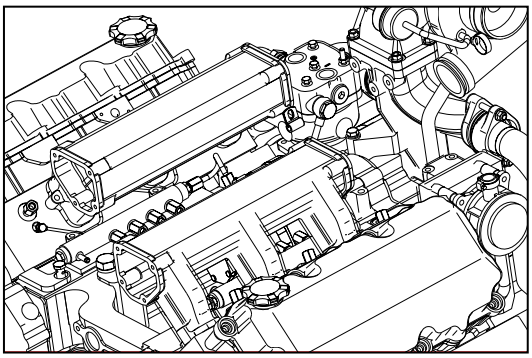
3.1.15. Exhaust manifold

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



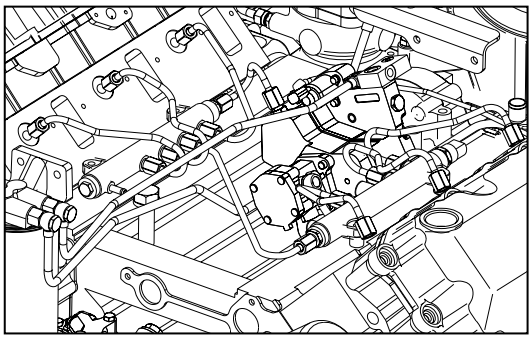
3.1.16. Intake manifold

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



3.1.17. Common rail and high pressure pipe

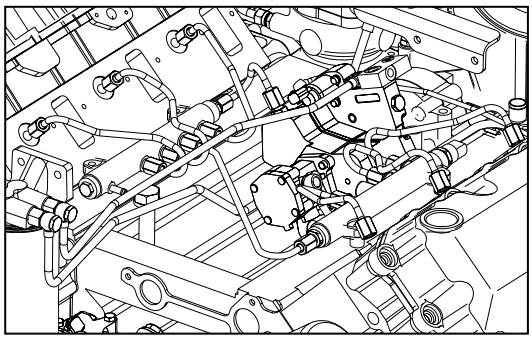
- Remove the high pressure pipe between fuel high pressure connecter and common rail.
- Remove the common rail fixing bolts and take off the common rail.



NOTE:
Seal the pipe to prevent from mixing foreign material into inside of the pipe after disassembling.

3.1.18. Fuel high pressure pump

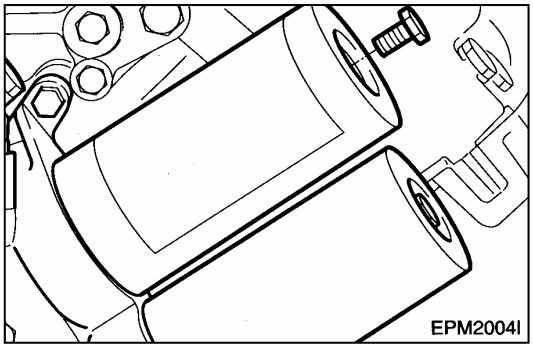
- Remove the connecting pipe of the fuel high pressure pump.
- Remove the fuel high pressure pump fixing bolts and take off the fuel high pressure pump by pushing to backward.



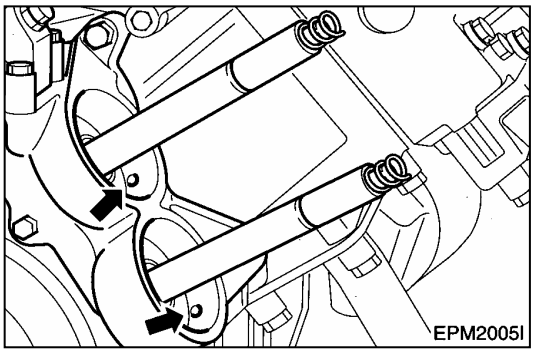
NOTE:
Seal the fuel high pressure pump to prevent from mixing foreign material into inside of the fuel high pressure pump after disassembling.

3.1.19. Oil filter

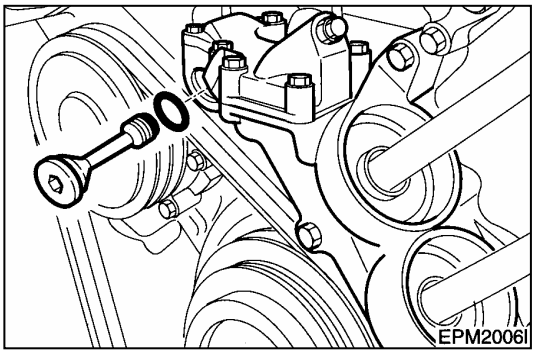
- Loosen the oil filter housing fixing bolts then the spring will force the filter housing to move upward a little.



- Allow an interval of 2 ~ 3 minutes until the engine oil by-passes to the oil pan, then take off the filter.

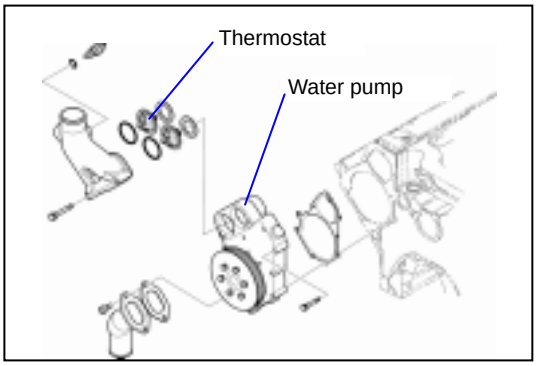


- Unscrew the oil filter head fixing bolts and take off the oil filter head



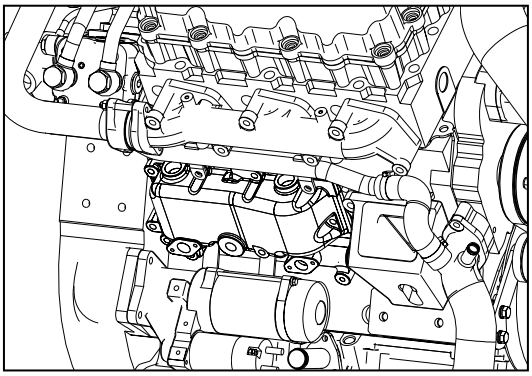
3.1.20. Water pump

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



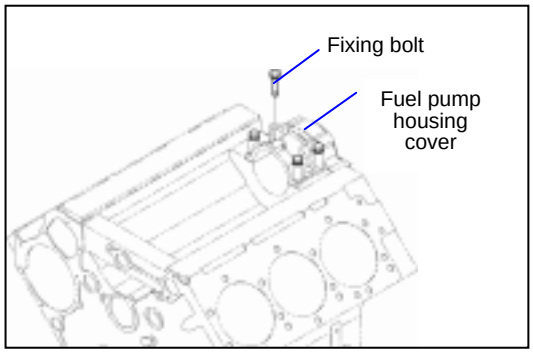
3.1.21. Starting motor

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



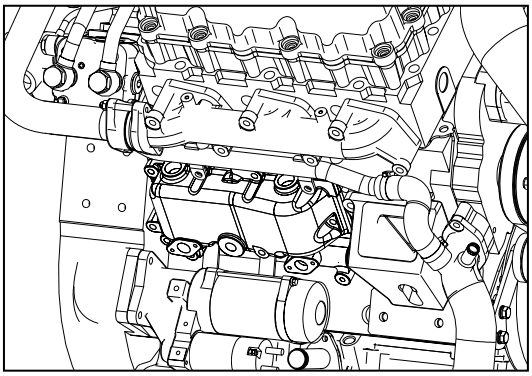
3.1.22. Fuel pump housing cover

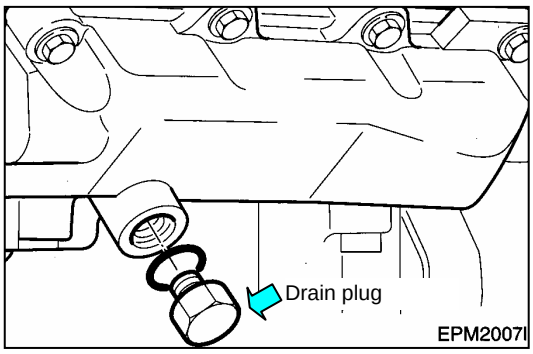
- Remove the fuel pump housing cover fixing bolts and take off the fuel pump housing cover.
- Fuel pump housing cove and cylinder block should be handled as a set because they are tooled in pairs.



3.1.23. Oil cooler

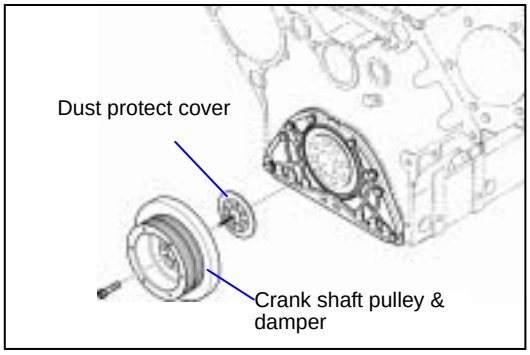
- Remove the drain plug from the oil cooler cover and drain out the cooling water.
- Remove the oil cooler cover fixing bolts and disassemble the oil cooler.
- Remove the oil cooler fixing bolts and take off the oil cooler.





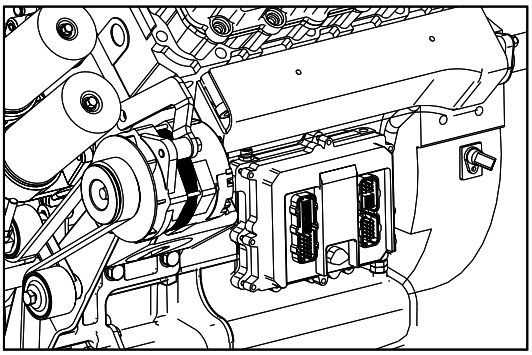
3.1.24. Vibration damper

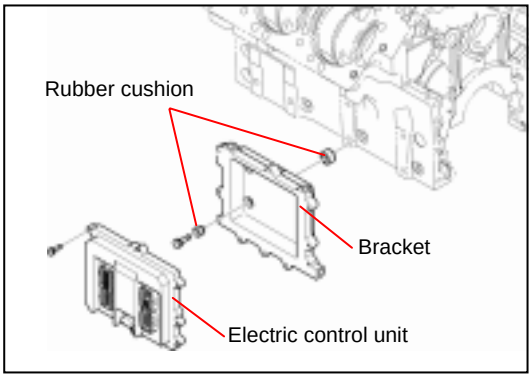
- Remove the fixing bolts for crankshaft pulley in reverse order of assembling and disassemble the crankshaft pulley and vibration damper.



3.1.25. Electric control unit

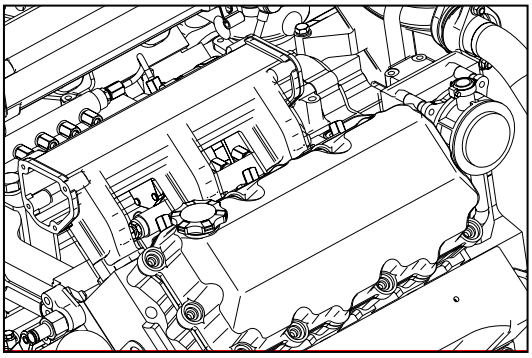
- Remove the electric control unit fixing bolts, then take off the electric control unit and bracket.





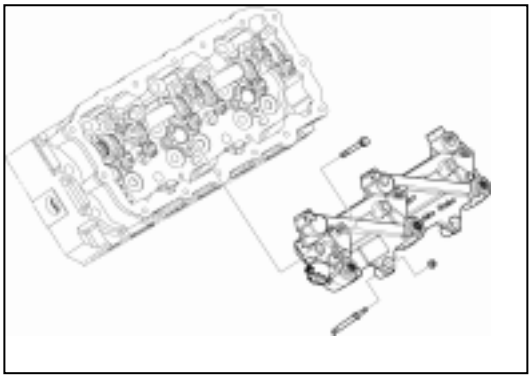
3.1.26. Cylinder head cover

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



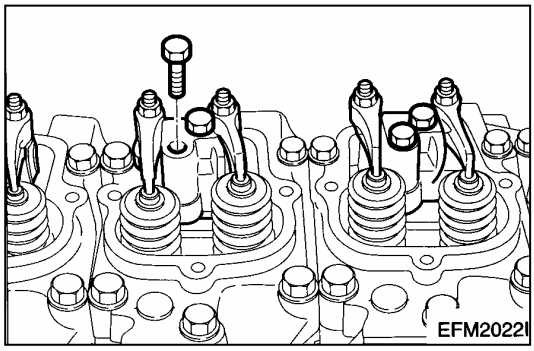
3.1.27. Engine brake

- Remove the engine brake fixing bolts and take off the engine brake from the cylinder head.



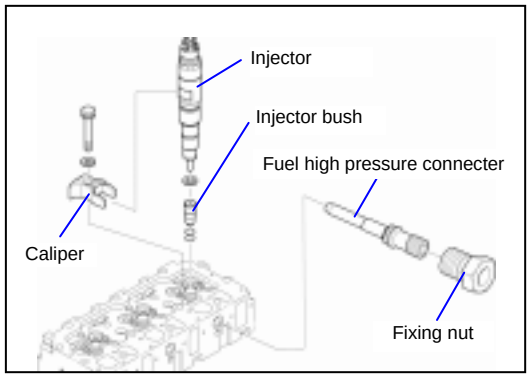
3.1.28. Rocker arm

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



3.1.29. 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.



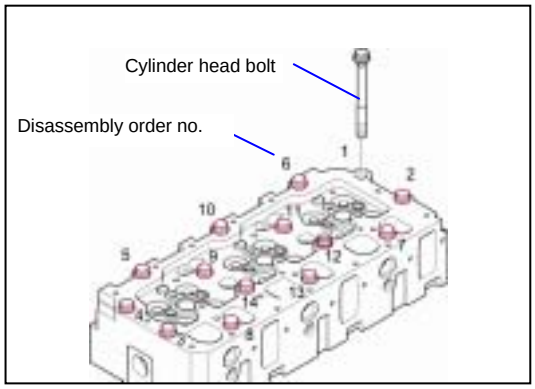
CAUTION:

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.

3.1.30. Cylinder head

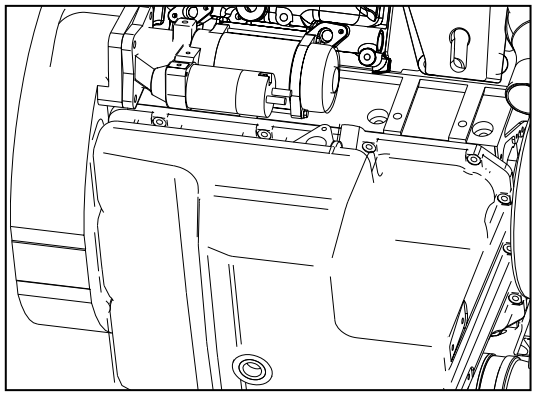
- Loosen the cylinder head fixing bolts in the reverse order of assembling, and remove them all and then take the cylinder head out.
- Remove the cylinder head gasket and scrap it.
- Eliminate the residue from the cylinder head face and cylinder block face.



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

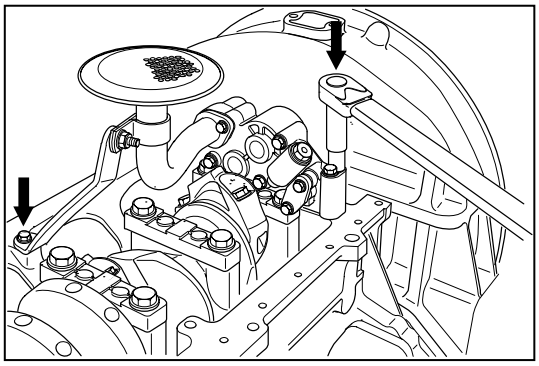
3.1.31. Oil pan

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

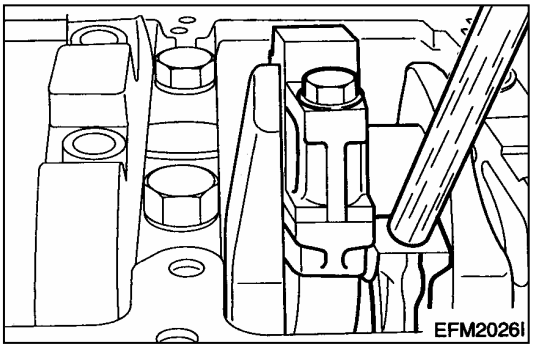


3.1.32. Oil pump

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



3.1.33. Piston



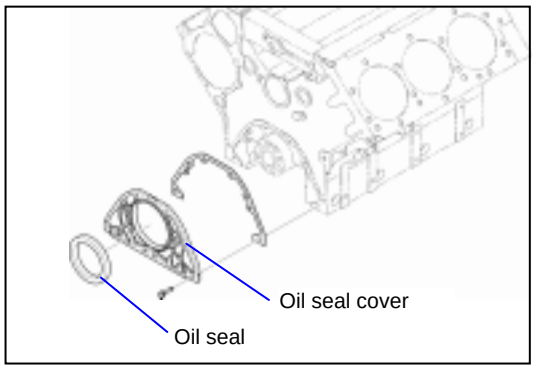
- Remove the connecting rod cap bolts in the reverse order of assembling.
- Tapping the upper and lower of connecting rod caps lightly with an urethane hammer, separate them and take the bearings out.
- By pushing the piston assembly with a wooden bar toward the cylinder head's direction remove the piston.

CAUTION:

Be careful for the removed pistons not to collide each other or with the other parts.

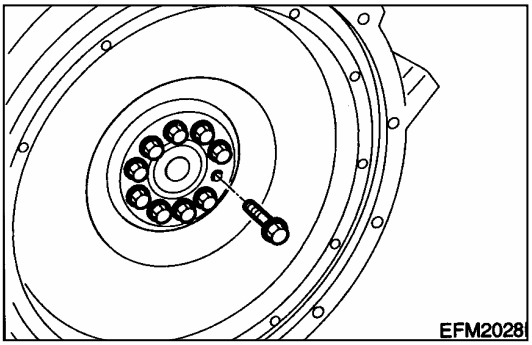
At the storage of pistons, maintain them in the order of cylinders. (In order for connecting rod caps not to mix one another, temporarily assemble them to the corresponding connecting rods.)

3.1.34. Front oil seal cover



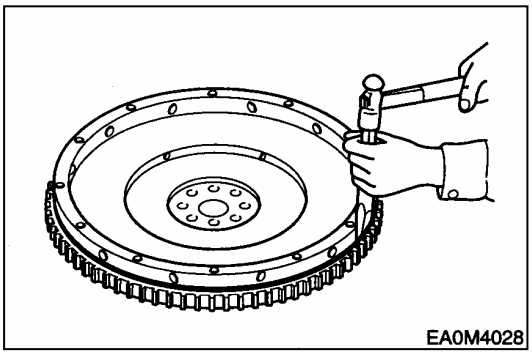
- Remove the oil seal holder fixing bolts and tear down.
- Remove the oil seal holder fixing bolts and tear down.

3.1.35. Fly wheel



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

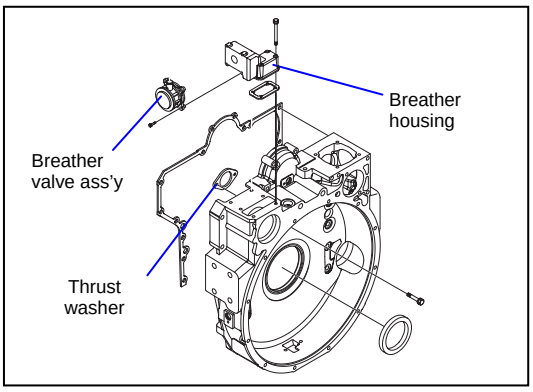
- Remove the flywheel ring gear.
- Heat the ring gear evenly with a gas burner (up to 200 °C) to invite volumetric expansion.
- Tapping around the edges of the ring gear with a hammer and brass bar to remove it.



CAUTION:
Do not damage the flywheel.

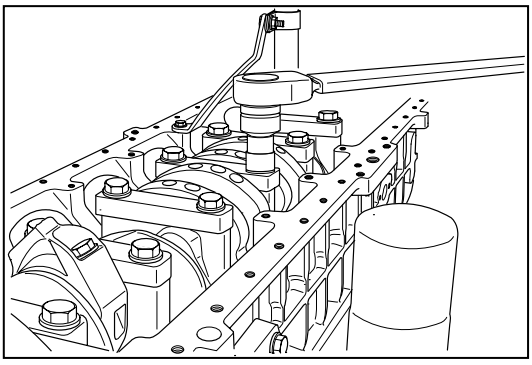
3.1.36. Flywheel housing

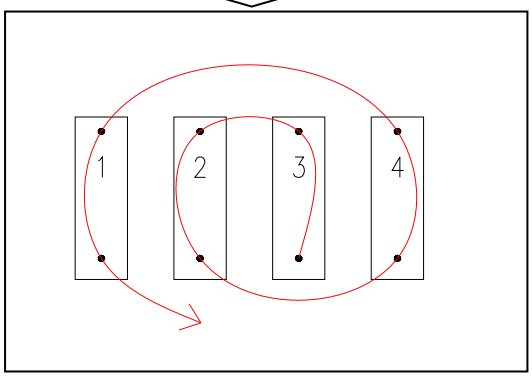
- Remove the flywheel housing fixing bolts and take them out.
- Remove the oil seal from the flywheel housing.



3.1.37. Crank shaft

- Remove the fixing bolts from bearing caps.
- Remove the main bearing cap fixing bolts in the reverse order of assembling.
- Maintain the removed bearing caps in the order of cylinders.
- Temporarily install the bolts at the both side of crankshaft, and lift the crankshaft with a rope.





NOTES:

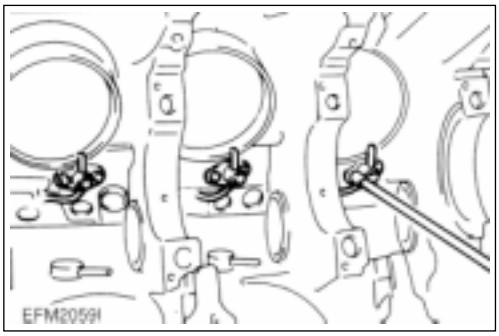
Do not mingle with the metal bearings and bearing caps randomly. To prevent mixing, temporarily assemble the metal bearings to the corresponding bearing caps in turn.

3.1.38. Cam shaft & tappet

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

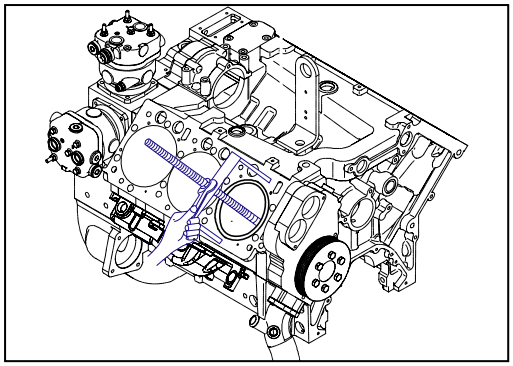
3.1.39. Oil spray nozzle

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



3.1.40. Cylinder liner

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

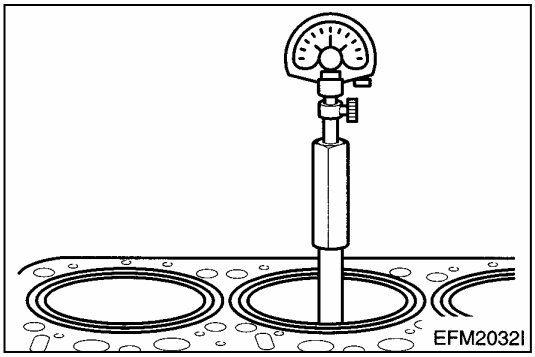


3.2. Measurement and Inspection of Major Parts

3.2.1. Cleaning and inspection of cylinder block

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

3.2.2. Cylinder liner measurement

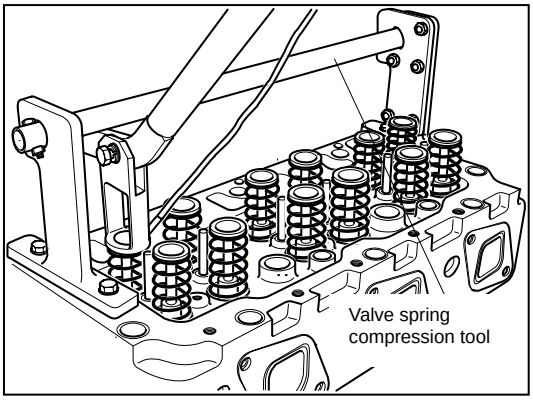


- Assemble the cylinder liner at the cylinder block and measure inner diameters at upper, middle, lower 3 levels by 45° interval and calculate the average values after eliminating the max. and min. values.
- If the measured values are very close to the limit value or beyond, replace it.

Liner inner diameter	Standard	Limit
	ϕ127.990 ~ ϕ128.010 mm	0.15 mm

3.2.3. Cylinder head

1) Cylinder head disassembly



- Be careful for the cylinder head gasket contacting surface of cylinder head not to be damaged.
- Remove the cotter pin pressing the valve spring by means of a special tool.
- Take out the valve stem seal.

- Pull out the intake and exhaust valves.

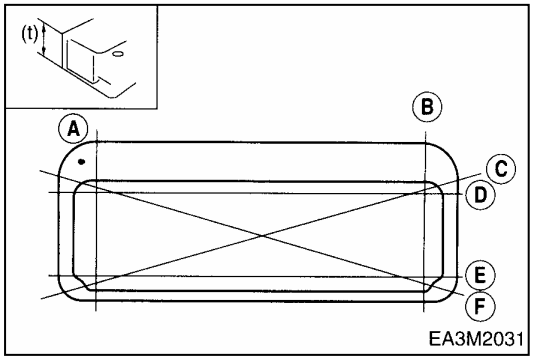
2) Inspection and measurement of cylinder head

a) Damage check

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

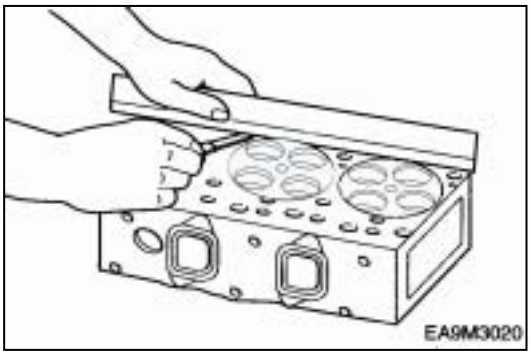
b) Distortion of lower surface

- 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 thickness>

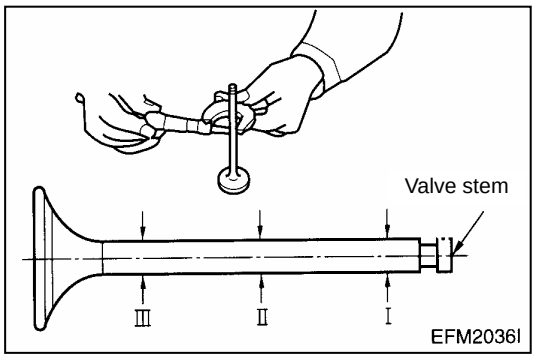
	Standard	Limit
Warpage	0.08 mm or less	0.1 mm
Thickness : t (reference)	116.9 ~ 117.1 mm	116.4 mm



3) Inspection and measurement of valve and valve guide

a) Valve

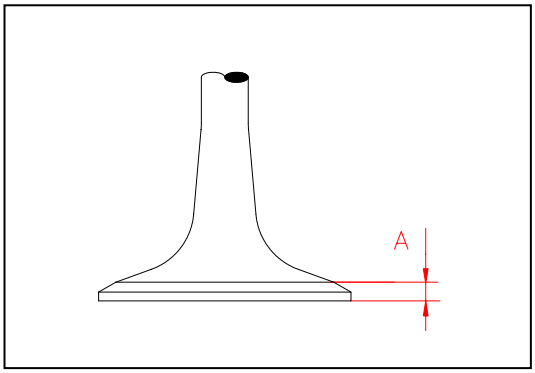
- After cleaning the valves with clean diesel oil, measure the valve stem's outside diameter at upper, middle, and lower to determine the wears and if there is minor damage, correct it and when the wears is more than max allowable limit value, replace the valves.



<Valve stem outer diameter>

	Standard	Limit
Intake	ϕ7.963 ~ ϕ7.977 mm	ϕ7.94 mm
Exhaust	ϕ7.950 ~ ϕ7.964 mm	ϕ7.93 mm

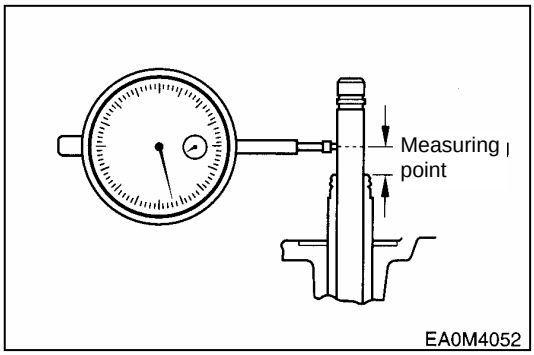
- Inspect the scratch and wear of valve stem seal contacting face, and if necessary correct with the grinding paper but if severe replace it.
- If valve head thickness (H) becomes less than 1.6mm for intake and 1.3mm for exhaust, replace the valve.



<Valve head thickness>

	Standard	Limit
Intake (A)	3.0 ~ 3.4 mm	2.5 mm
Exhaust (B)	3.3 ~ 3.7 mm	2.8 mm

b) Valve guide



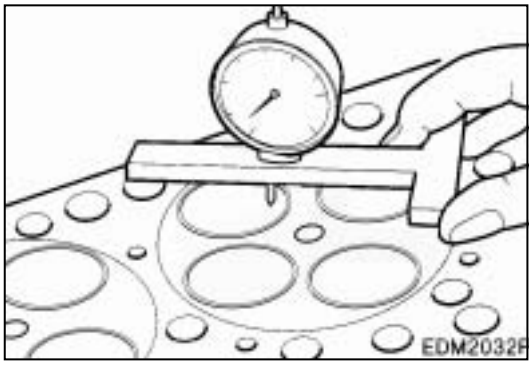
- Insert the valve into valve guide and measure the clearance between valve and valve guide by the shaking degree of valve.
- If the clearance is bigger, measure the valve and then replace the more worn valve guide.

<Valve stem end play>

	Standard	Limit
Intake	0.023 ~ 0.052 mm	0.10 mm
Exhaust	0.036 ~ 0.065 mm	0.15 mm

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

c) Valve seat



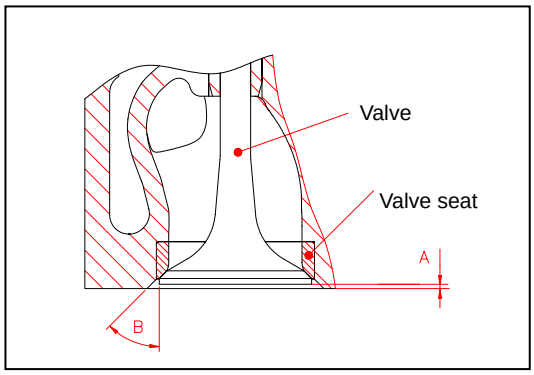
- Inspect the damage and wear of valve seat and if necessary replace it.
- Assemble the valves at the cylinder head and using the measuring instrument from the lower face, measure the projection amount of valve. If the measured value is more than the use limit, replace the valve seat.

< Valve seat thickness >

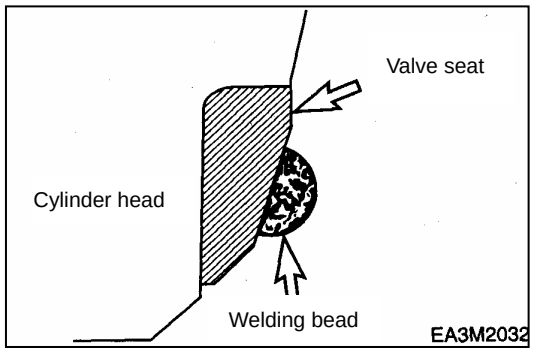
	Standard	Limit
Intake (A)	0.38 ~ 0.42 mm	0.7 mm
Exhaust (A)	0.38 ~ 0.42 mm	0.8 mm

< Valve seat angle >

Intake (B)	Exhaust (B)
60^{O}	45^{O}

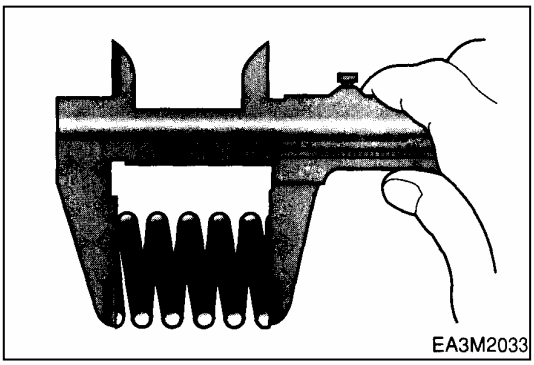


- The disassembly of valve seat can be pulled out by means of a special tool with the arc welding done at two points of valve seat rotating tool or valve seat.
- Regarding the valve seat assembling, shrink the valve seat by putting it in the dry ices for about 1 hour or so, and then press it into the cylinder head by means of a special tool.
- It is necessary to work boring of inner diameter of it when replace the valve seat.
- After coating the grinding powder paste on valve head contacting face of valve seat, and after executing a sufficient lapping operation with the rotating and grinding motion of valve, wipe off the grinding agent thoroughly.



d) Valve spring

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

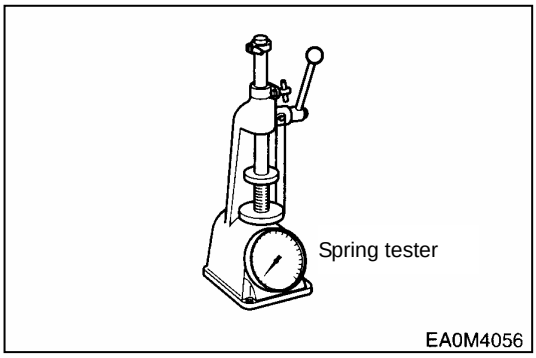


Free length		Standard
Intake	Inside	62.5 mm
Exhaust	Inside	62.0 mm
	Outside	62.5 mm

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

< Valve spring tension >

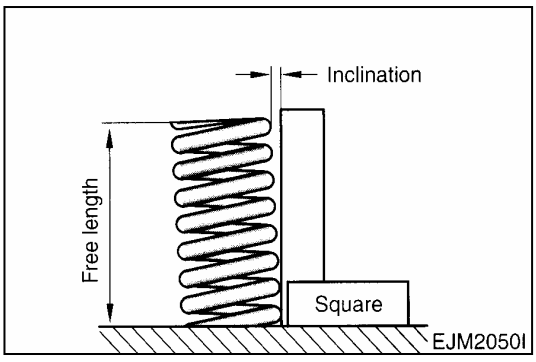
	Set length		Spring force	Limit
Intake	Inner	44 mm	39.4 kg	±2 kg
		31.6 mm	65.8 kg	±2.5 kg
Exhaust	Inner	41 mm	20.5 kg	±1.5 kg
		28.6 mm	32.6 kg	±2 kg
	Outer	44 mm	39.4 kg	±2 kg
		31.6 mm	65.8 kg	±2.5 kg



- **Valve spring inclination**

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

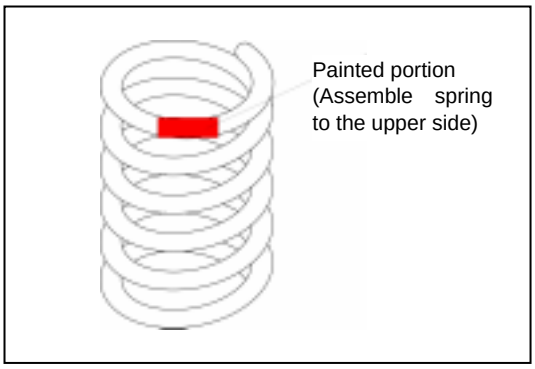
If the measured value exceeds the specified limit, the valve spring must be replaced.



	Standard	Limit
Valve spring inclination	Less than 1.6	2.0 mm

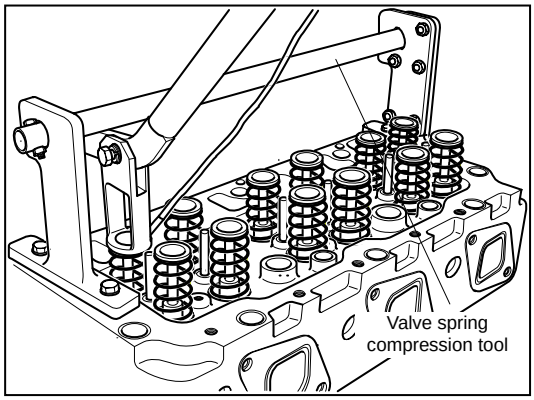
4) Cylinder head assembling

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



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

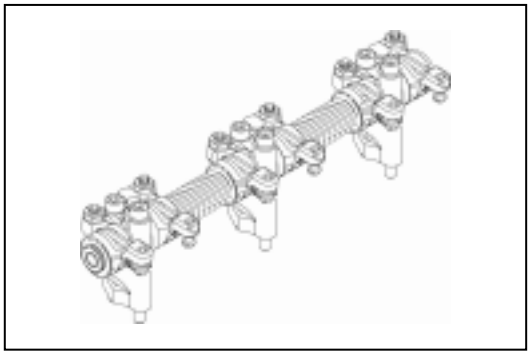
- Pressing the spring down with a special tool, assemble by inserting the valve cotter.
- After the valve is assembled, inspect the valve tapping it lightly with an urethane hammer if accurate assembling was done.



3.2.4. Rocker arm ass`y

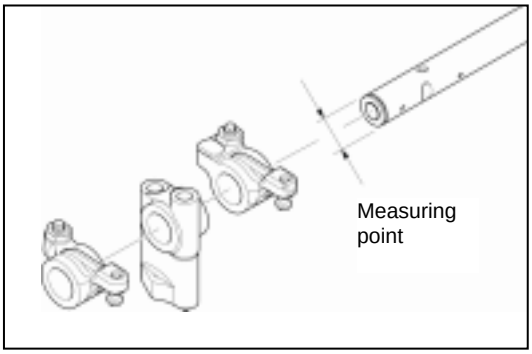
1) Rocker arm disassembling

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



2) Inspection and measurement

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

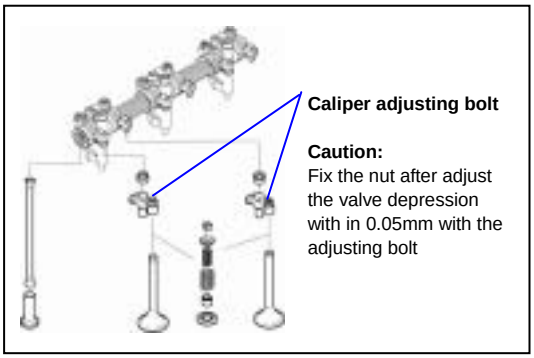


< Rocker arm Specification >

	Standard	Limit
Bush inner diameter	ϕ24.991 ~ ϕ25.012 mm	ϕ25.04 mm
Shaft outer diameter	ϕ24.739 ~ ϕ24.960 mm	ϕ24.90 mm
Clearance	0.031 ~ 0.073 mm	0.14 mm

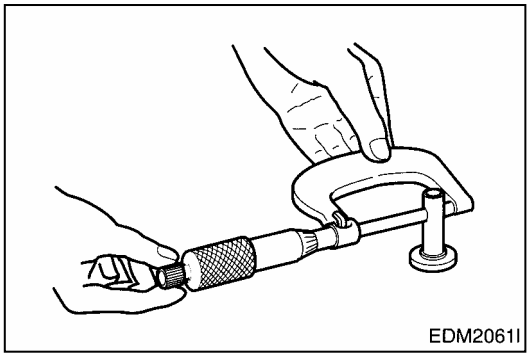
a) Rocker arm

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



b) Tappet & push rod

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

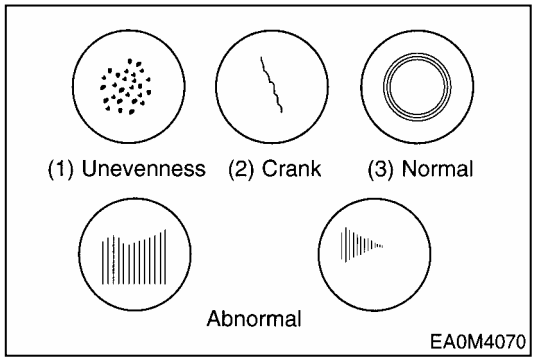


Standard	ϕ19.944 ~ ϕ19.965 mm

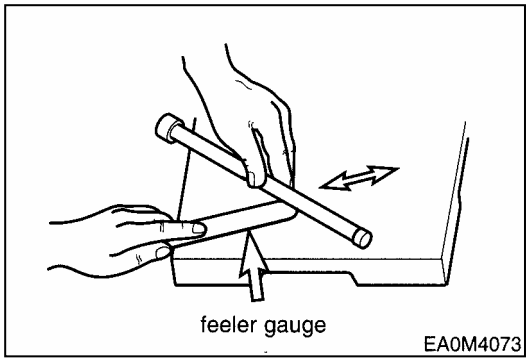
<Clearance of block and tappet>

Standard	Limit
0.035 ~ 0.077 mm	0.13 mm

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



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



< Run-out >

Limit	0.3 mm or less

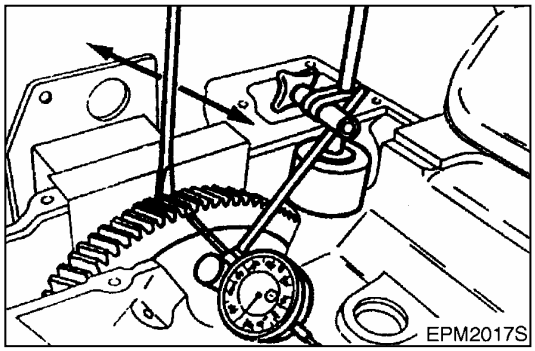
3) Rocker arm reassembling

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

3.2.5. Cam shaft

1) Axial end play

- Push the camshaft toward the crankshaft pulley side.
- Place a dial gauge onto the camshaft gear.
- Measure the camshaft's axial end play, moving the camshaft gear by means of a driver.



Standard	0.10 0.55 mm

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

2) Inspection and measurement of camshaft

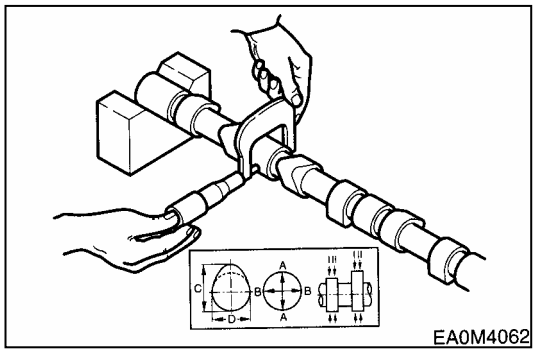
- **Visual check**

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

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

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

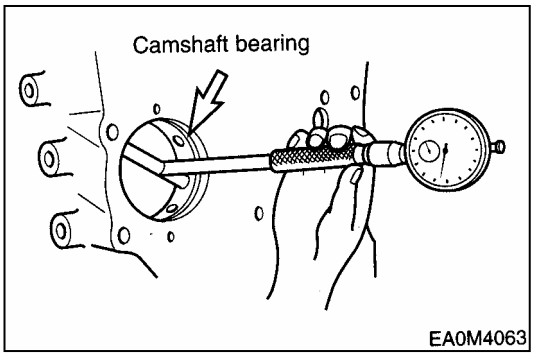
If the measured number is less than the specified limit, the camshaft must be replaced.



		Standard	Limit
Cam lobe height (C)	Intake	55.06 mm	54.76 mm
	Exhaust	56.57 mm	56.27 mm
Cam journal diameter (A,B)		ϕ69.91 ~ ϕ69.94 mm	ϕ69.64mm

- **Camshaft bearing diameter**

Measure the camshaft bush inside diameter with a cylinder gauge.



< Cam bearing inside diameter>

Standard		Limit
Thrust bush	ϕ70.07 ~ ϕ70.09 mm	-
Cam bush inside diameter	ϕ70.00 ~ ϕ70.03 mm	ϕ70.06 mm

- **Clearance between camshaft journal and bush**

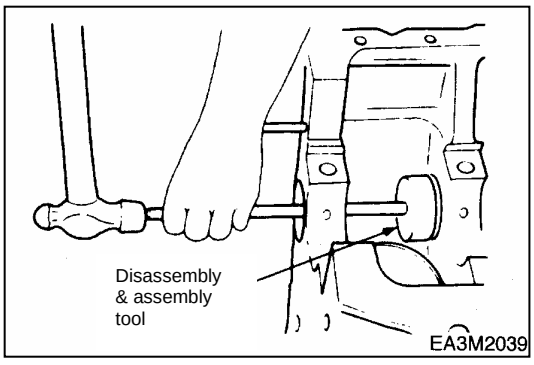
Calculate the clearance by complying measured value of the camshaft bearing inside diameter and journal bearing outside diameter. Replace the camshaft bearing if the calculated value is beyond the specified limit.

<Clearance >

Standard	limit
0.060 ~ 0.120 mm	0.18 mm

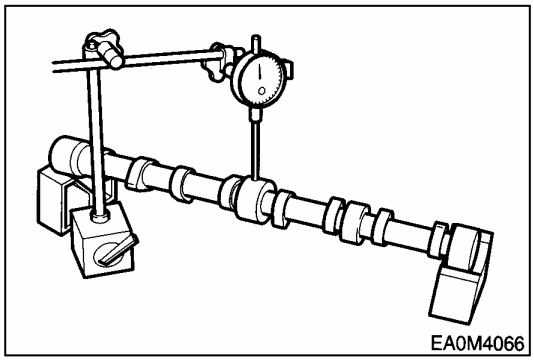
- **Camshaft bearing replacement**

Use with the special tool for replacement of bearing.



- **Camshaft run-out**

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



< Camshaft run-out >

Standard	Limit
0.05 mm	0.1 mm

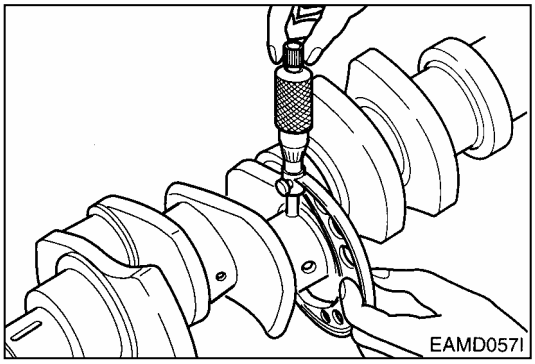
3.2.6. Crank shaft

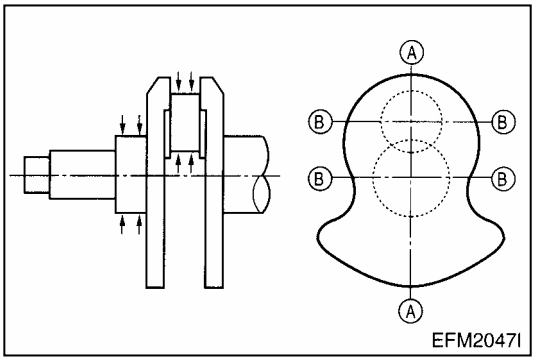
1) Inspection and measurement

- Inspect for any scratch or damage on the crankshaft journal and crank pin with naked eyes.
- Inspect for any crack by means of magnetic powder and color check, and replace the cracked ones.

a) Journal and pin diameter

- With outside micrometer, measure the outside diameter of crank journal and crank pin at the direction and position of the figure shown and take the wear.
- In case that the lopsided wear is more than the limit value, grind to the undersize, and use the undersized bearing.
- If the amount of wear is within the limit, you can correct the wear using an oil stone or oiled grinding paper of fine grain size. (be sure to use grinding paper which has been immersed in oil)





<Journal and pin outside diameter>

	Standard
Journal diameter	ϕ103.98~ ϕ104.00 mm
Pin diameter	ϕ89.98 ~ ϕ90.00 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.

< Kinds of bearings for undersize>

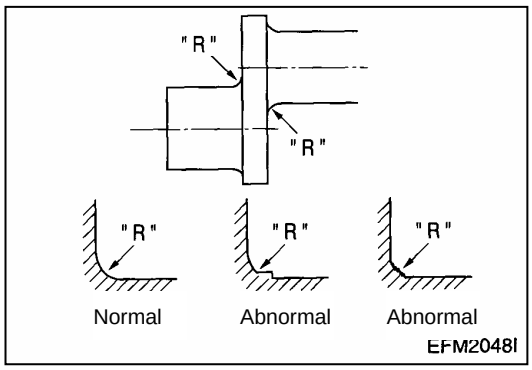
- **Standard**
- **0.25 (Inside diameter 0.25mm less than standard)**
- **0.50 (Inside diameter 0.50mm less than standard**
- **0.75 (Inside diameter 0.75mm less than standard**
- **1.00 (Inside diameter 1.00mm less than standard)**

NOTE:

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

NOTE:

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



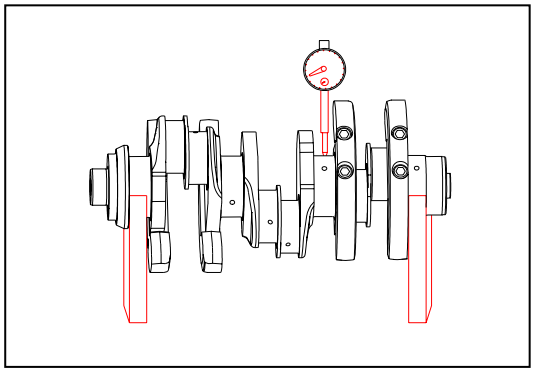
<"R" part standard value>

① **Crank pin 'R' :** $3.0^{0}_{-0.5}$

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

b) Run out of crankshaft

- Place the crankshaft on the V-block.
- Turn the crankshaft with a dial Indicator on the surface plate and measure the run out of crankshaft, replace or correct the camshaft bearing if the measured value is beyond the limit.



< Run out of crankshaft >

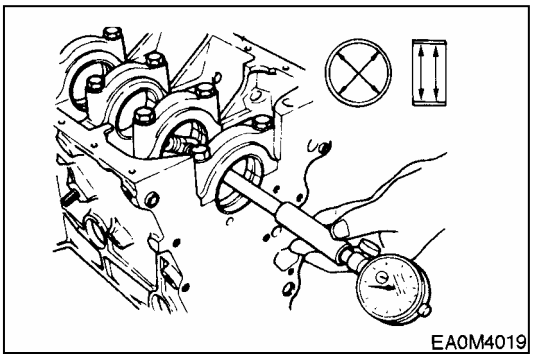
Standard	Limit
0.04 mm	0.2 mm

2) Crankshaft bearing and connecting rod bearing

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

a) Oil clearance of crankshaft and bearing

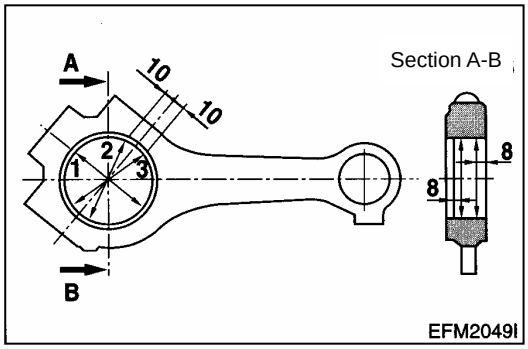
- Assemble the main bearing at the cylinder block and after tightening the bearing cap at the specified torque, measure the inside diameter of bearing



Torque	30 kg.m + 90^{O}

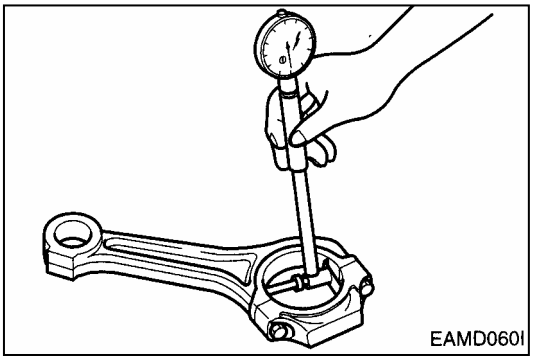
Journal bearing nominal diameter	ϕ103.98 ~ ϕ104.00 mm

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



Torque	10 kg.m + 90°

Connecting rod bearing nominal diameter	ϕ89.98 ~ ϕ90.00 mm



b) Bearing oil clearance

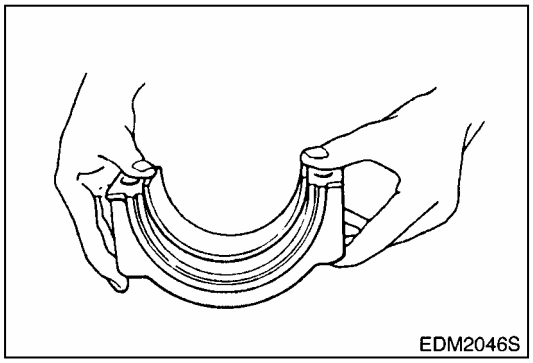
- Compare the two values obtained through measurement of bearing inside diameter (journal bearing, connecting rod bearing) with the outside diameter of journal and pin of crankshaft to determine the 0il clearance

Standard		Limit
Journal bearing	0.066 ~ 0.132 mm	0.166 mm
Connecting rod bearing	0.054 ~ 0.116 mm	0.154 mm

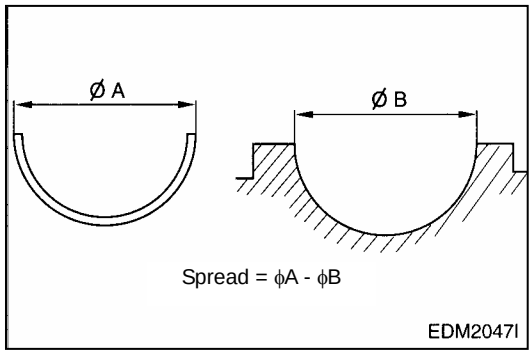
- In case that this clearance value exceeds the limit value, grind the crankshaft journal and pin and then use the undersized bearing.

c) Journal and connecting bearing inspection

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

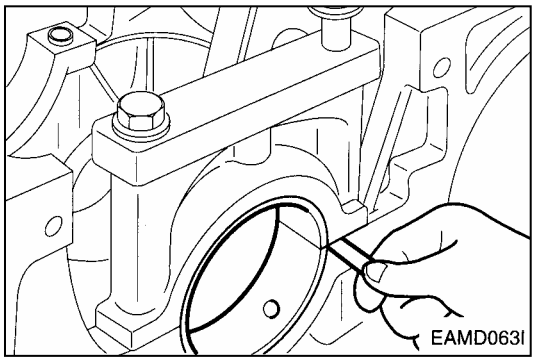


- The spread of journal bearing and connecting rod bearing should be measured with special tool as a figure, but measure it under condition of assembling as below for convenience of working in the field.



- **Journal bearing**

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

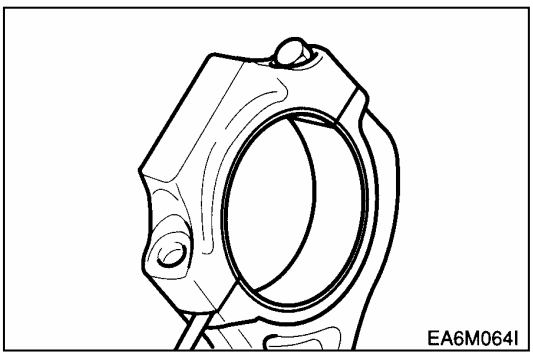


<Cylinder block and bearing clearance>

Standard	0.3 ~ 1.2 mm

- **Connecting rod bearing crush**

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

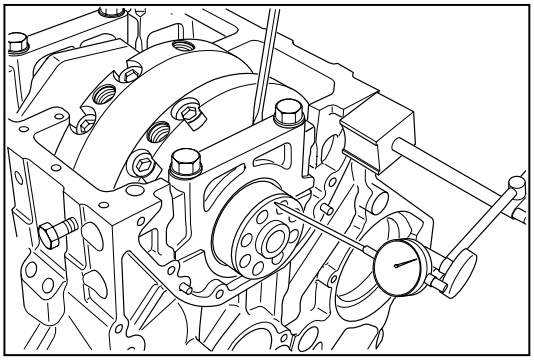


< Connecting rod bearing clearance >

Standard	0.5 ~ 1.4 mm

d) Crank shaft end play

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



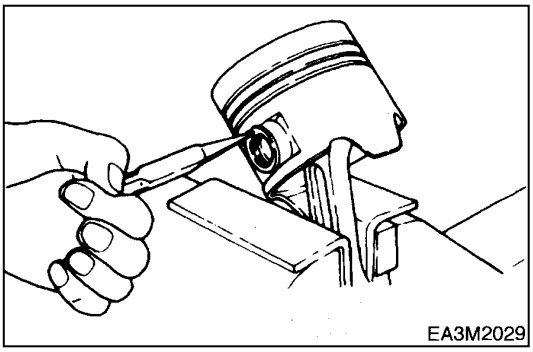
< Crank shaft end play >

Standard	Limit
0.190 ~ 0.322 mm	0.452 mm

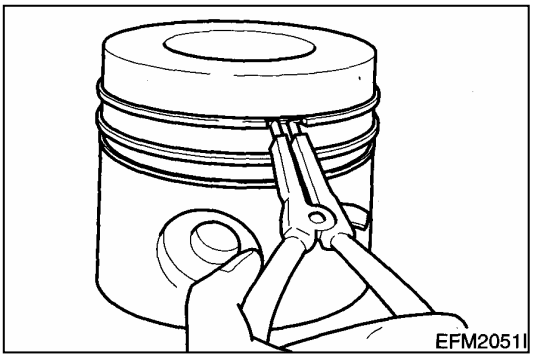
3.2.7. Piston

1) Piston disassembling

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

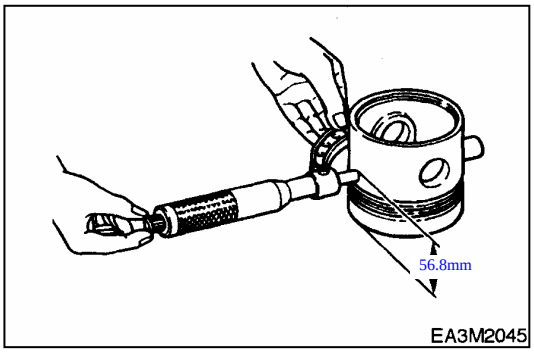


- With a pair of pliers, remove the piston rings.
- Clean the piston thoroughly.



2) Check and measurement

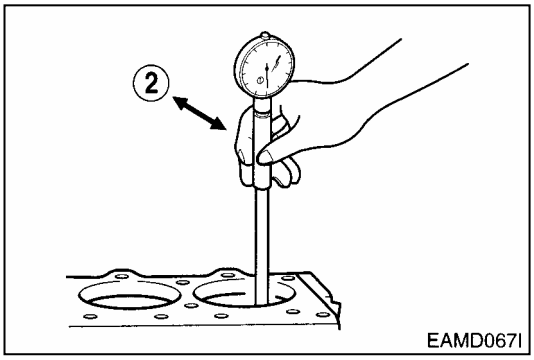
- With naked eyes, inspect the piston for any wear, crack and scratch and particularly inspect carefully at the ring grooves for any wear.
- With the outside micrometer, measure the piston's outside diameter the measuring position is 71.5mm from the piston lower end, and the direction of measurement must be perpendicular to the piston pin direction.



Standard	ϕ127.739 ~ ϕ127.757 mm

a) Cylinder bore diameter

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



Standard	ϕ127.990 ~ ϕ128.010 mm

b) Piston and cylinder clearance

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

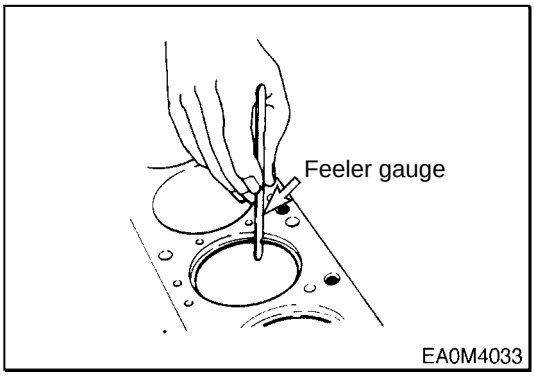
Standard	0.233 ~ 0.271 mm

c) Piston ring and ring groove

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

d) Piston ring cut part clearance

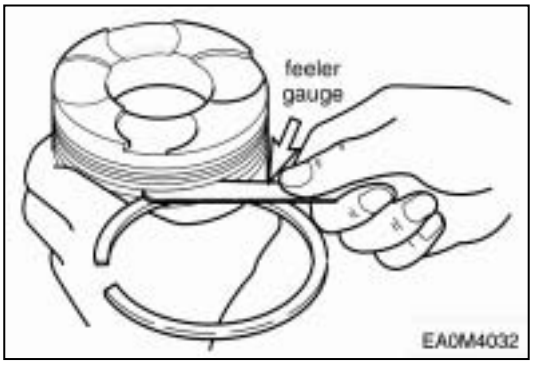
- Measure the piston ring cut part.
- Insert the piston ring at the cylinder liner's upper part perpendicularly.
- With a feeler gauge, measure the gap clearance of piston ring.
- If the measured value exceeds the limit value, replace it



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

e) Piston side clearance

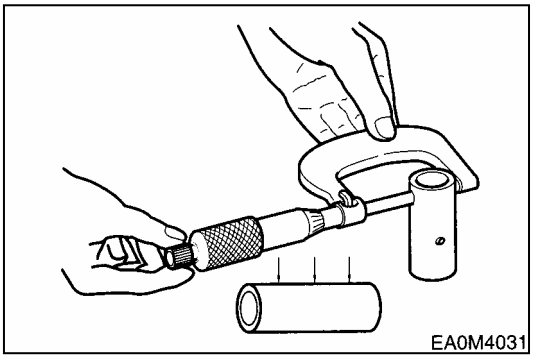
- Assemble the piston ring at the piston.
- Measure the each ring's side clearance and if the measured value exceeds the limit value, replace rings or piston.



	Standard	Limit
Top ring	0.105 ~ 0.155 mm	0.20 mm
2nd ring	0.050 ~ 0.085 mm	0.15 mm
Oil ring	0.030 ~ 0.070 mm	0.15 mm

f) Piston pin

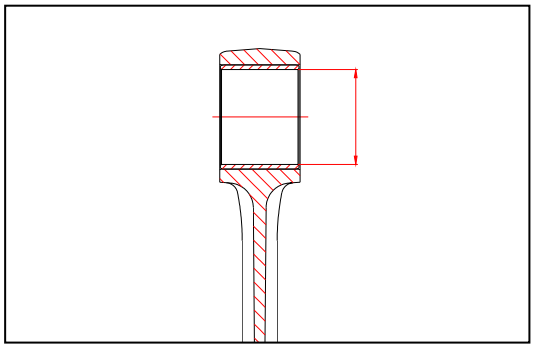
- Measure the amount of wear on the piston pin at the points as shown. The measured values are beyond the limit replace the pin.



Standard	Limit
ϕ 45.994 ~ ϕ 46.0 mm	ϕ 44.983 mm or less

g) Piston pin and connecting rod bush clearance

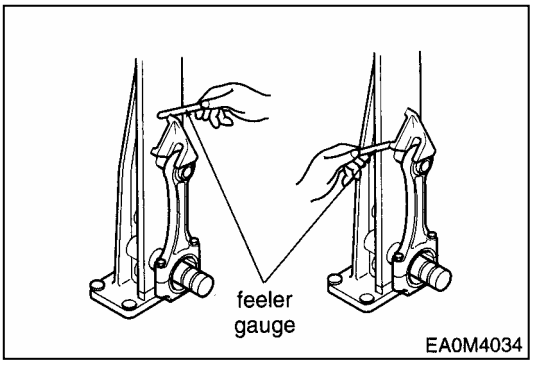
- Inspect the clearance between the piston pin and the connecting rod bush, if it is more than the use limit value, replace either one that is more severe.



Limit	0.055 ~ 0.071 mm

h) Connecting rod

- 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.



- Measure the alignment of the connecting rod piston pin bushing holes with connecting rod big end holes. At this time also, use both connecting rod tester and feeler gauge.

Standard	Limit
0.02 mm	0.1 mm

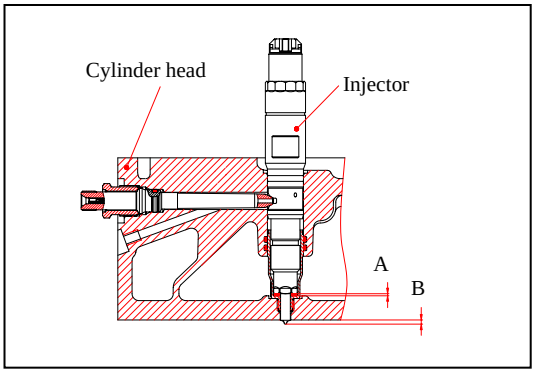
- Assemble the connecting rod to the crankshaft and measure connecting rod big end side clearance using a feeler gauge.

Standard	Limit
0.175 mm ~ 0.321mm	0.5

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

3.2.8. Injector projection

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



	Standard
A (Thickness of seal ring)	1.9 ~ 2.1 mm
B (Projection of injector)	2.6 mm

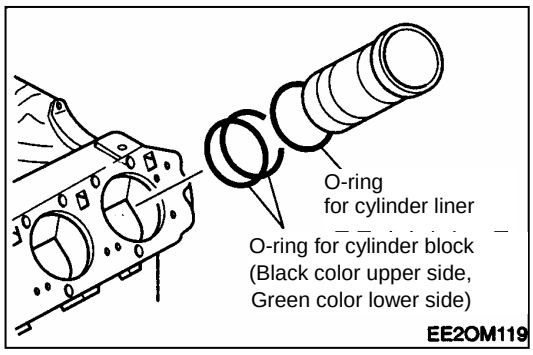
3.3. Engine Reassembly

3.3.1. Preparation and precaution before and after engine reassembly

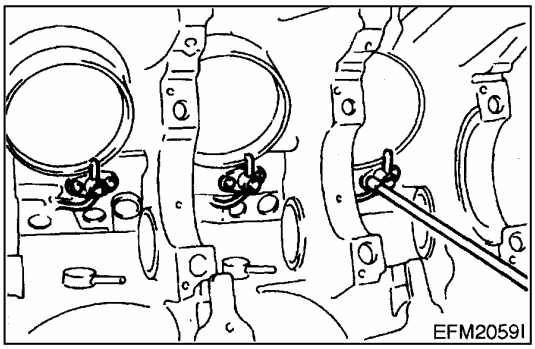
- Clean all the parts thoroughly and also clean thoroughly by blowing into each passage of oil and cooling water.
- Disposition the various special and general tools for assembling in order.
- In order to coat the lapping parts with engine oil, prepare the clean engine oil.
- Prepare the sub-material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

3.3.2. Cylinder liner

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



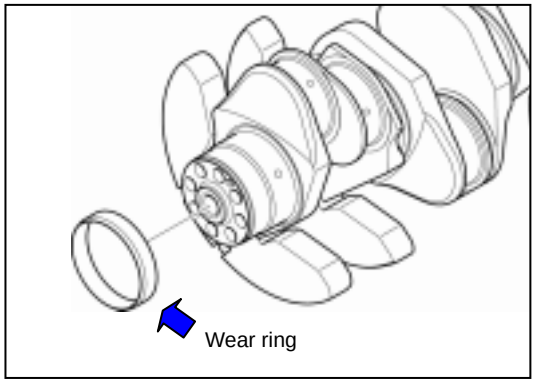
3.3.3. Oil spray nozzle



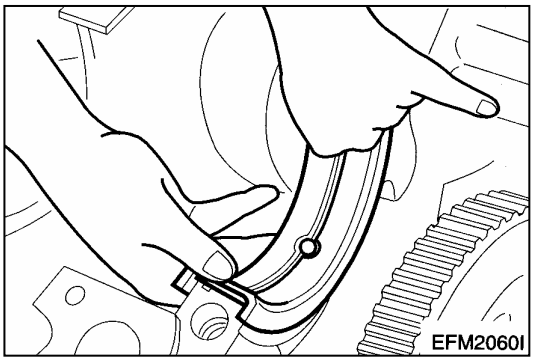
- Tighten the oil injection nozzle flange with hollow screws.
- Assemble the oil injection nozzle with the fixing bolts.

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

3.3.4. Crank shaft

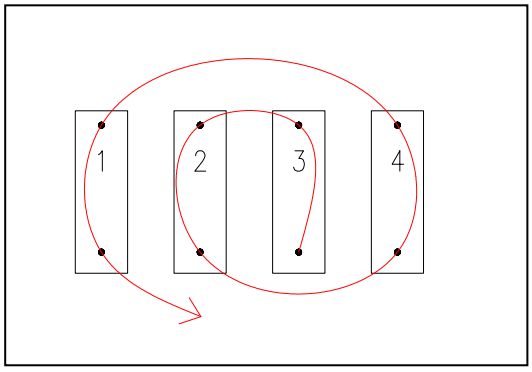


- Put the wear ring into the heater to heat it up to 150 ~ 200 °C level, push it over the crankshaft by means of a jig.

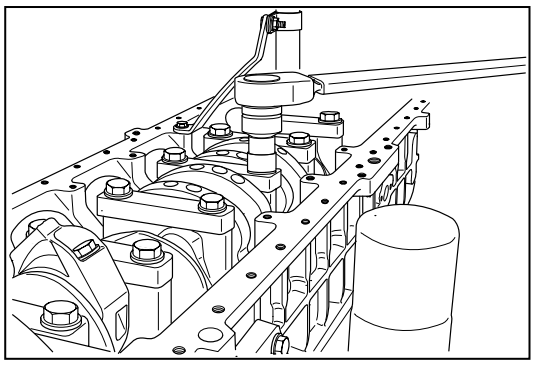


- Assemble the main bearing to the cylinder block and coat it with engine oil. Then assemble the bearing that has a hole to the cylinder block side and one that has no hole to the bearing cap and be careful not to change.
- Assemble temporarily one bolt each at both bolt holes of crankshaft and by connecting the wire to the bolts, lift it with crane or chain block and put down on the cylinder block carefully.

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



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



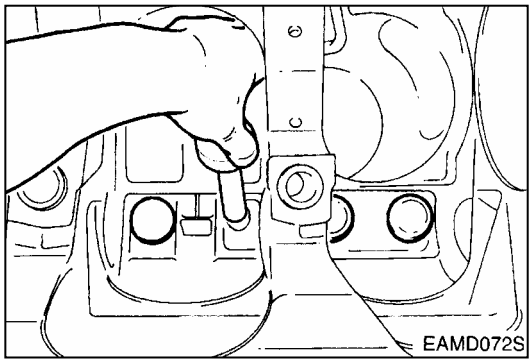
< Bearing cap bolt's tightening order >

(1) First step : Coat the bolts with engine oil.
(2) Second step: Screw down 1 2 threads.
(3) Third step : Tighten with about 15 kg.m by wrench.
(4) Fourth step : Tighten with about 25kg.m by torque wrench.
(5) Fifth step : Tighten with 30kg.m by torque wrench.
(6) Sixth step : Tighten with final rotating angle method 90° +10°.
However, according to above tightening order, tighten step by step

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

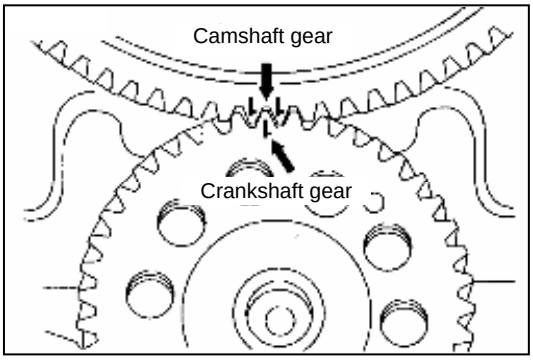
3.3.5. Tappet

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



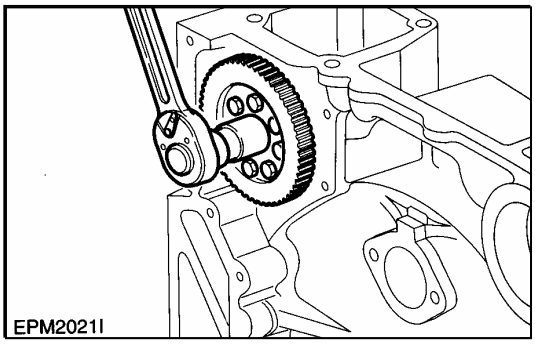
3.3.6..Cam shaft

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



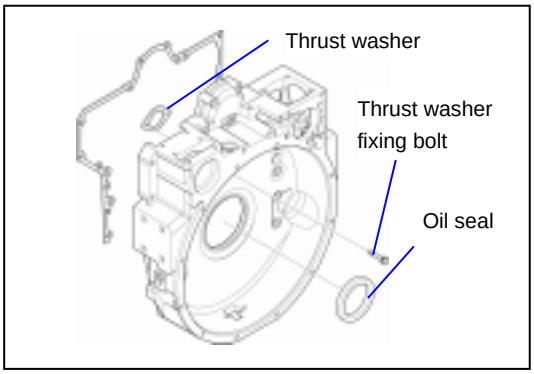
3.3.7. Flywheel housing

- Assemble the following parts in the flywheel housing before installing the flywheel housing onto the cylinder block.
- Assemble the air compressor crankshaft with the drive gear.
- Apply loctite to the fixing bolt and assemble the thrust washer.

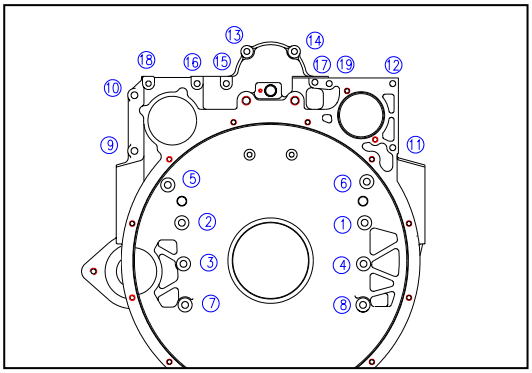


Torque	Air compressor gear	36 kg.m
	Thrust washer fixing bolt	4 kg.m

- Coat the oil seal (P.T.F.E.) with lubricating oil and assemble the oil seal carefully for it not to deviate or be damaged by means of special tool. (Mandrel for assembling.)



- Attach the gasket on the surface of cylinder block where the flywheel housing is to be installed. (In order to prevent the gasket slip down, coat a grease on the cylinder block surface.
- Temporarily assemble 2ea of guide bolts for installing the flywheel housing to the cylinder block.

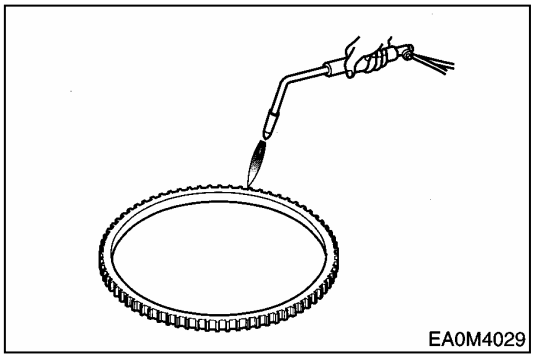


- After fitting the flywheel housing holes to the guide pins and engage temporarily 2 ~ 3 threads of fixing bolts, and according to the tightening order (zigzag method) tighten them in the specified torque.

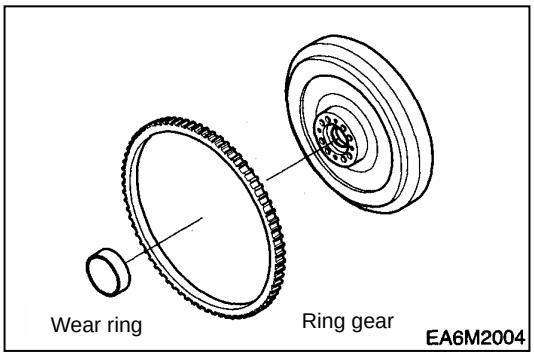
Torque	M10	7.5 kg.m
	M12	11.2 kg.m

3.3.8.. Fly wheel

- Installation of flywheel ring gear with a gas burner, heat the ring gear evenly until heat expansion takes place, then install it using a hammer.
- Do not allow the temperature of the ring gear to exceed 200°C (392°F).

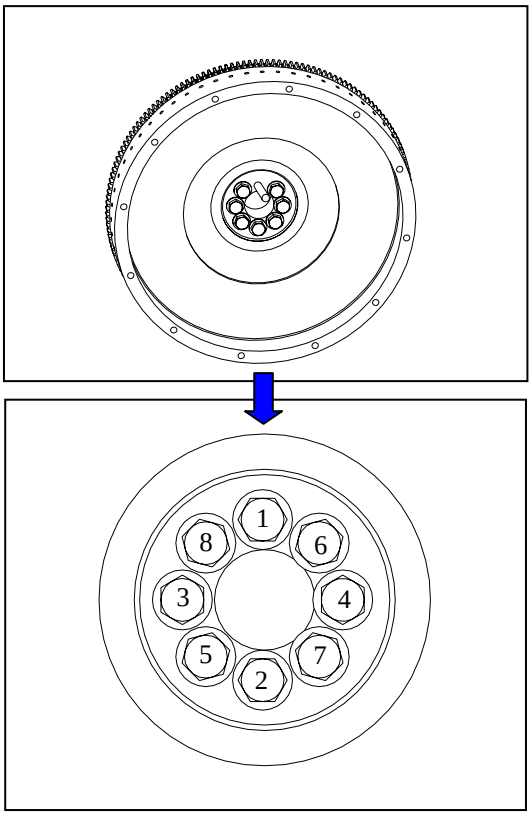


- By means of mandrel, assemble pilot bearing to the flywheel.
- By means of mandrel, press in the wear ring at the backward face. (Apply mounting face with #262 loctite.)



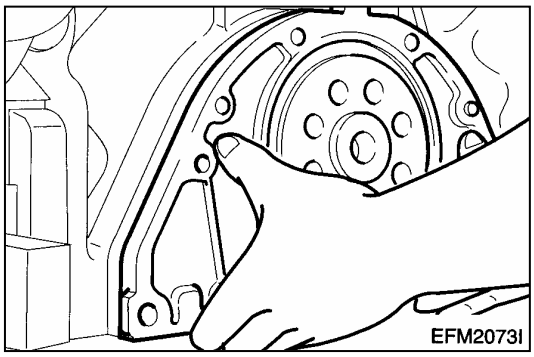
- Install two guide bolts for installing the flywheel to the crankshaft.
- After letting the guide pin insert through the flywheel holes and engaging the fixing bolts by 2 3 threads temporarily, tighten them to the specified torque according to tightening order. (Zigzag order)

Torque	26 kg.m



3.3.9. Front oil seal holder

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



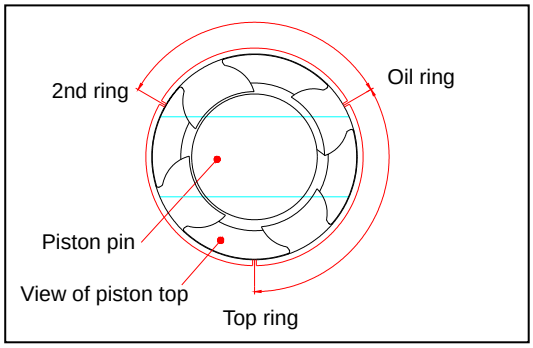
NOTE:
Without coating the oil seal with oil or lubricant, assemble it in the dry state.

- Apply lubricating oil to the inside of oil seal and tighten the fixing bolts in the zigzag method.

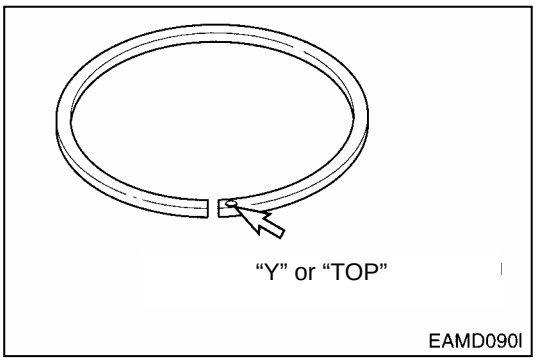
Torque	2.2 kg.m

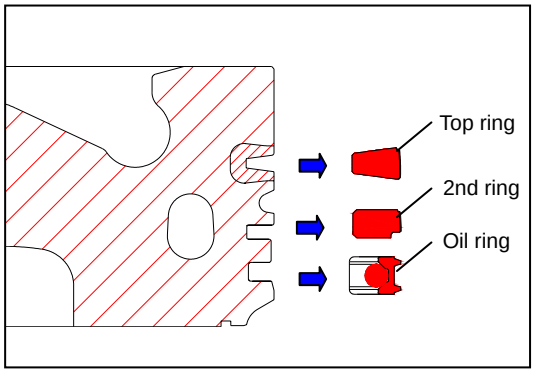
3.3.10. Piston

- Line up the piston assembly in the order of cylinders and fit the bearings to the connecting rods and bearing caps. However, take care not to swap between the connecting rods and bearing caps.

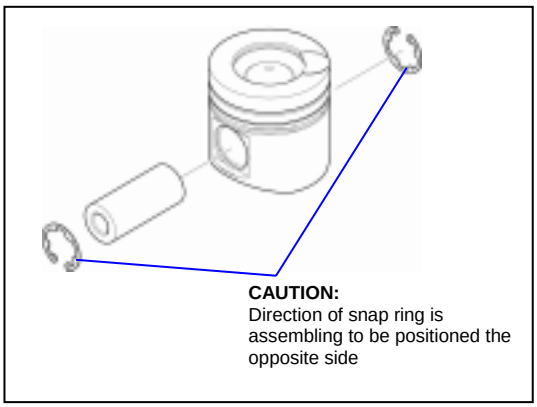


- Coat the pistons and connecting rod bearings sufficiently with clean engine oil.
- By means of a special tool, insert the piston rings and adjust the angles between the ring gaps at 120°.
- Identify the mark "**Y**" or "**TOP**" on the ring end to prevent the top and bottom of the piston ring from being interchanged and make the marked portion face upward.
  (The surface marked as "**Y**" or "TOP" is upper surface.)
- Push in the piston with hands or wooden bar into cylinder. (Be careful for piston and rings not be damaged.
- Pushing the piston down, rotate the crankshaft about 180° and fit the bearing cap to the connecting rod.





- Coat the tap parts of connecting rod bolts and their seats with engine oil, and after engaging 2 3 threads of bolts primarily rind then tighten them to the specified torque. (10 kg.m + $90^{\circ}{}^{+10^{\circ}}$)



<Connecting rod bolt tightening order>

(1) First step : Coat the bolts with engine oil.

(2) Second step: Engage 2 3 threads by hands.

(3) Third step : Tighten to about 7kg.m with wrench.

(4) Fourth step : By means of torque wrench tighten to 10 kg.m.

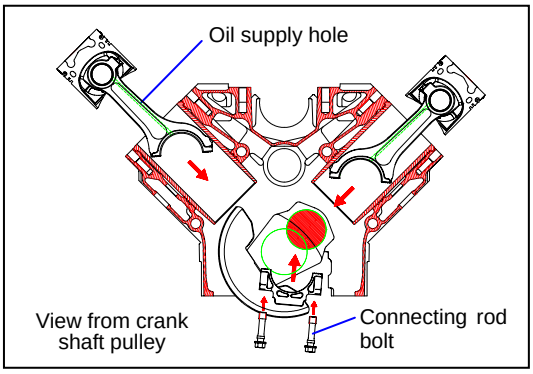
(5) Fifth step : Finally assemble by means of rotation angle method 90°+10°.

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

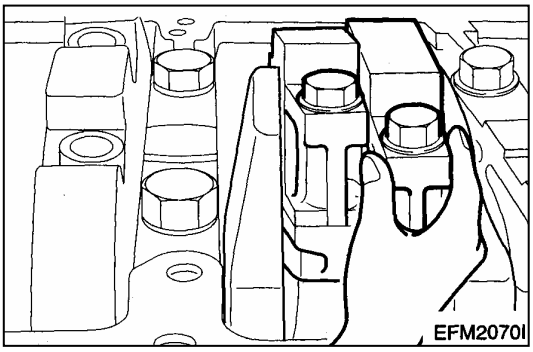
< Standard length of bolt and use limit>

From head seat to bolt tip

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

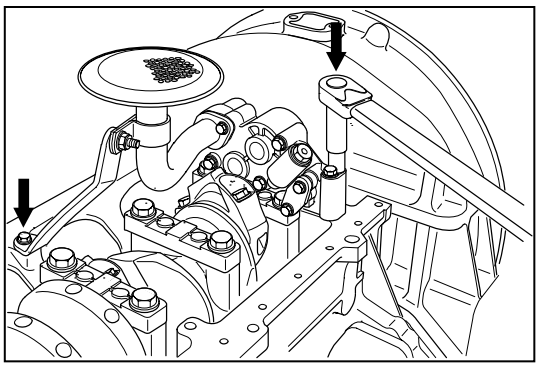


- By moving the connecting rod bearing cap by hands, make sure if there is any play in left and right.
- With the same method as above, assemble in each cylinder rotating the crankshaft.



3.3.11. Oil pump

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



- Assemble the oil pump and pressure regulating valve by tightening the fixing bolts.

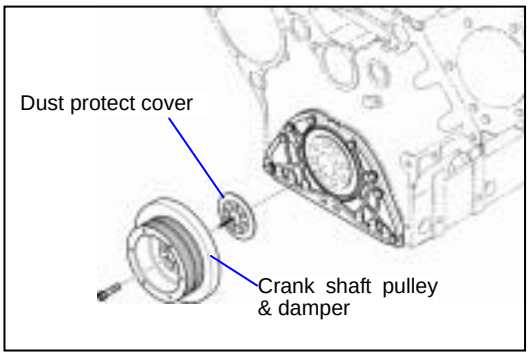
Oil pump back lash	0.1 ~ 0.45 mm

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

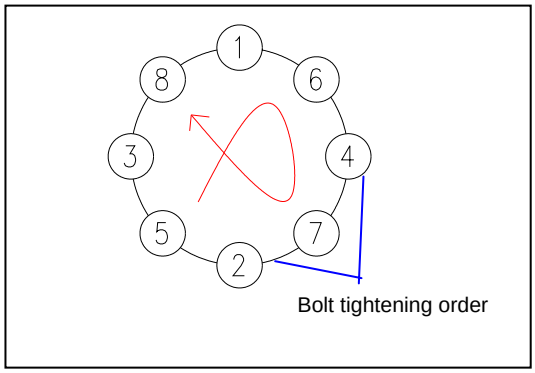
Torque	2.2 kg.m

3.3.12 Vibration damper

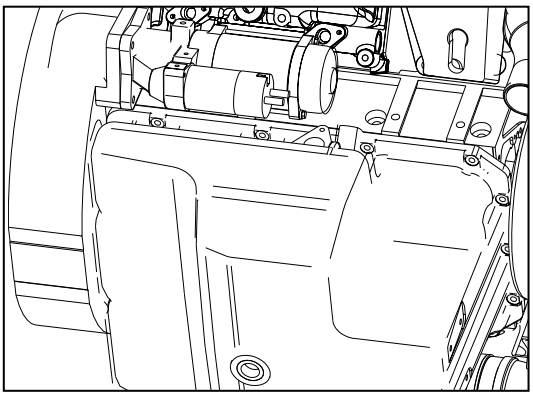
- Install the vibration damper on the crankshaft pulley.
- Install the crankshaft pulley assembly on the crankshaft, then tighten the bolts with apply engine oil.



Torque	Vibration damper and pulley	6 kg.m
	Crankshaft pulley	21 kg.m



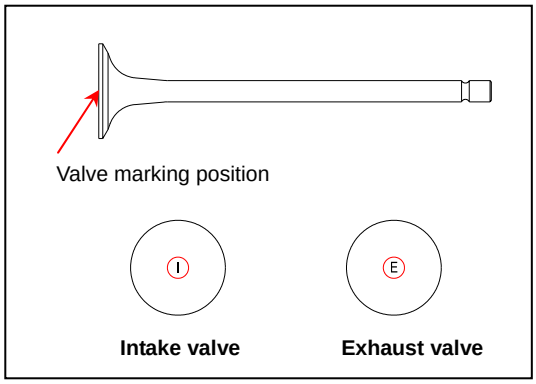
3.3.13. Oil pan



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

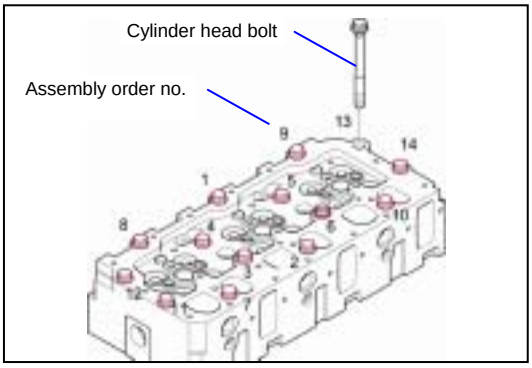
Torque	2.2 kg.m

3.3.14. Intake & exhaust valve



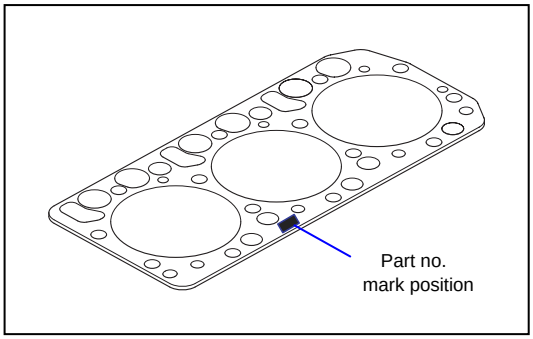
- Identify the marks of "**I**" and "**E**" impressed on the valve head before assembling the valve with the valve head.
- With a valve stem seal fitting jig, assemble the valve stem seal on the valve guide.

3.3.15. Cylinder head



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

- Assemble a gasket fitting with the fixing pin of cylinder block.
- Position the cylinder head assembly on the cylinder block aligning with its dowel pin. (Take care not to damage the head gasket.)
- Coat the cylinder head bolts with engine oil and tighten them to the specified torque according to step by step.



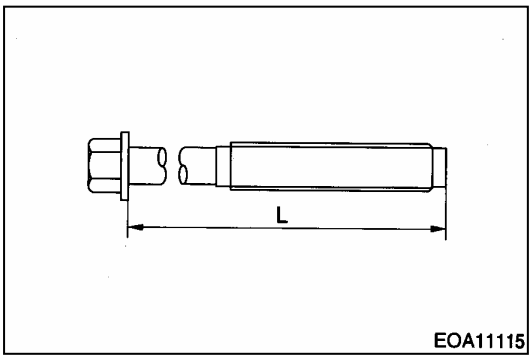
< Cylinder head bolts tightening order>

1) First step : Coat bolts with engine oil.
2) Second step : Tighten temporarily 1 2 threads by hands.
3) Third step : Tighten to about 8 kg.m with a wrench.
4) Forth step : Tighten to 15kg.m with a torque wrench.
5) Fifth step : Rotate 90° by rotation angle method.
6) Sixth step : Rotate 90° by rotation angle method.
7) Seventh step : Finally tighten additionally rotating 60°.

< Standard length of bolt and use limit >

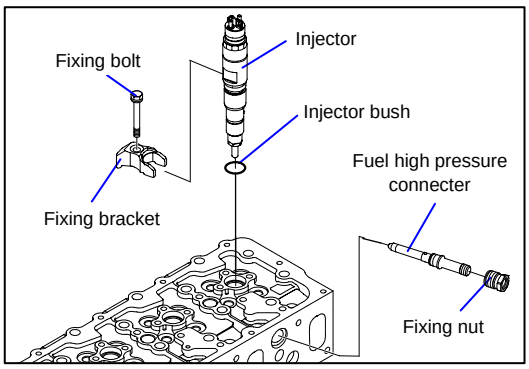
(From head seat to bolt tip)

Standard length	Limit
176 mm	178.5 mm



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

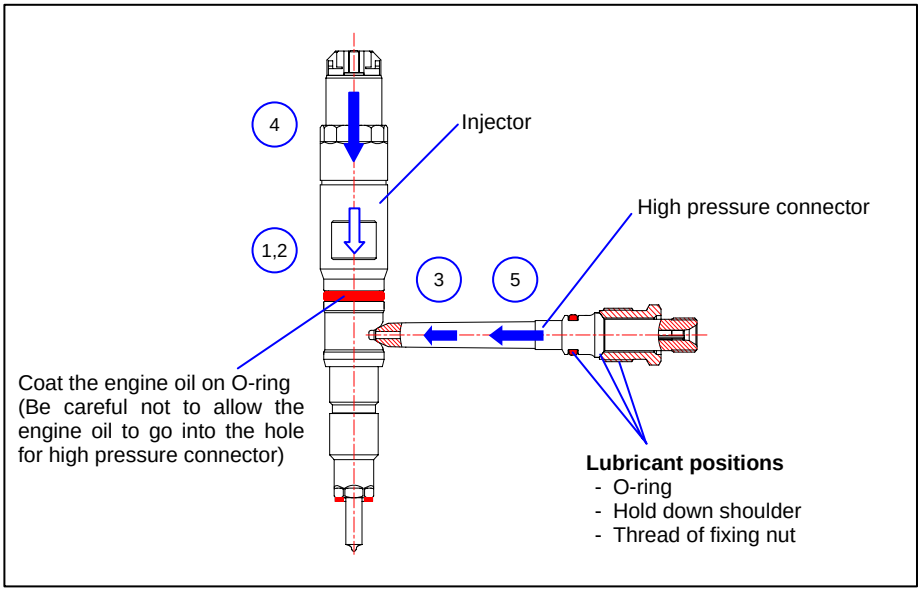
3.3.16. Injector



- Clean all the parts thoroughly and be careful not to fall into the foreign material.
- Especially take deeper care on fuel line from common rail up to injector because this area has no filtering function.
- Clean the holes which an injector and a high pressure connector will be put into before they are assembled.
- Whenever disassembling the injector, fuel high pressure connector must be replaced with a new one.
- If fuel goes in the combustion chamber during disassembling the injectors from the fuel return line and/or gap around the injector and high pressure connector, please remove the fuel by sucking with hand pump or short cranking with fuel stop.

< Injector and high pressure connector assembly procedure >

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



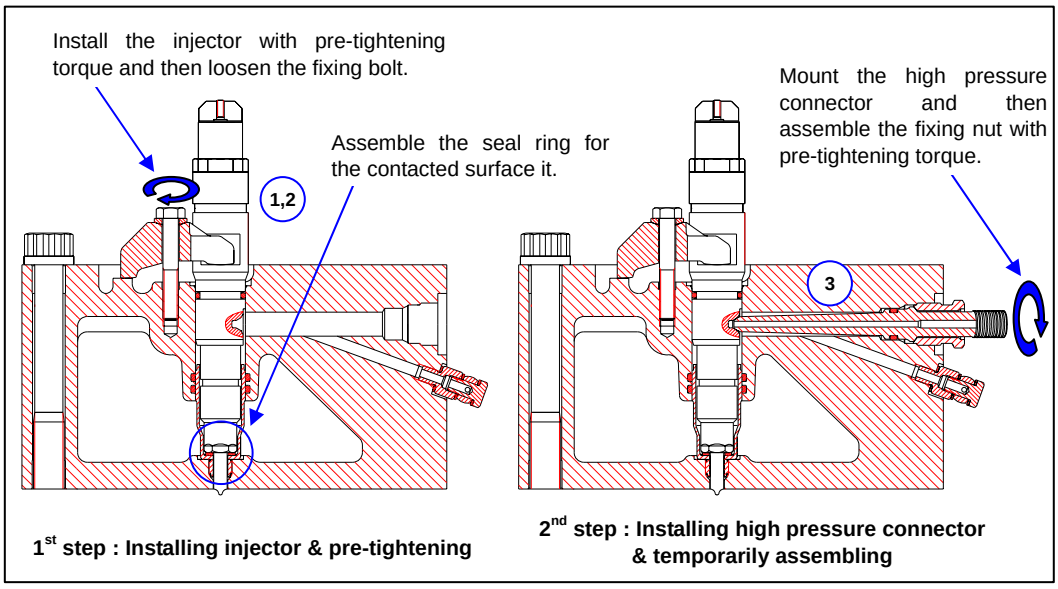
2) Clean the holes which an injector and a high pressure connector will be put into before they are assembled. Engine oil and fuel that might went into during disassembly should be wiped out especially for the holes where a fuel high pressure connector & an injector will be put into.

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

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

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

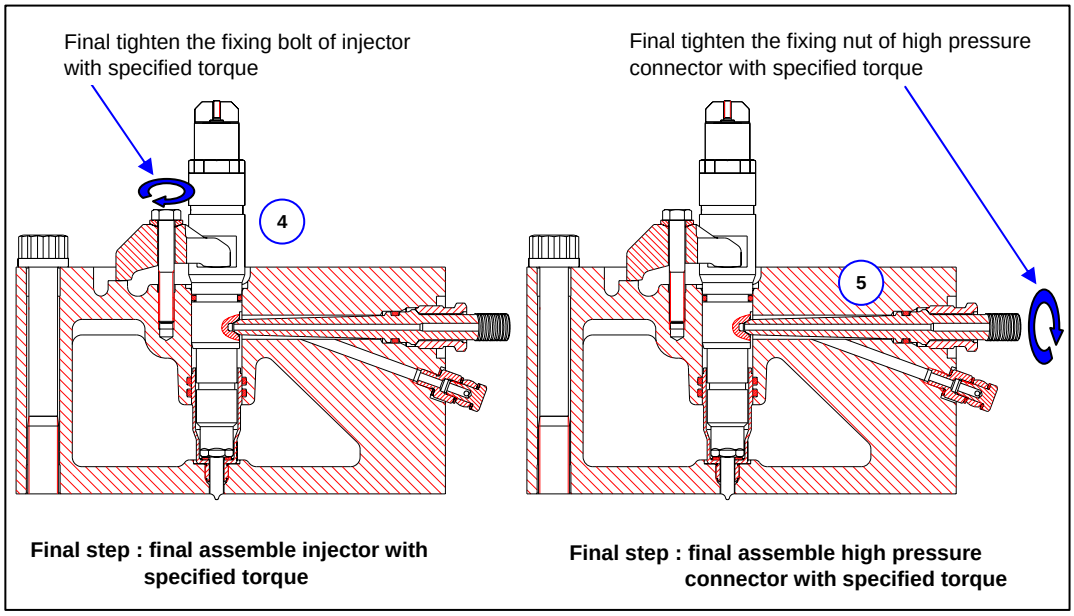
6) (3) Coat the fresh and clean engine oil on O-ring, Hold down shoulder and Thread of fixing nut. Grasp high pressure connector with balls vertical and insert it into the hole on while aligning the balls of connector and slot of the head. Push the connector into the hole until feeling it contacted.



Temporarily torque	Injector fixing bracket bolt	Fuel high pressure connector fixing nut
	0.3 kg.m	1.5+0.5 kg.m

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

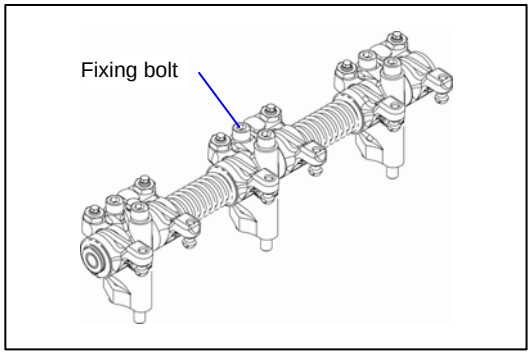
8) (5) Finally assemble the high pressure connector. Tighten the fixing nut of high pressure connector according to the specified torque by the torque wrench.
Please keep and obey this procedure and work order.



Final torque	Injector fixing bracket bolt	Fuel high pressure connector fixing nut
	3.5 kg.m	5 ~ 5.5 kg.m

3.3.17. Rocker arm

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

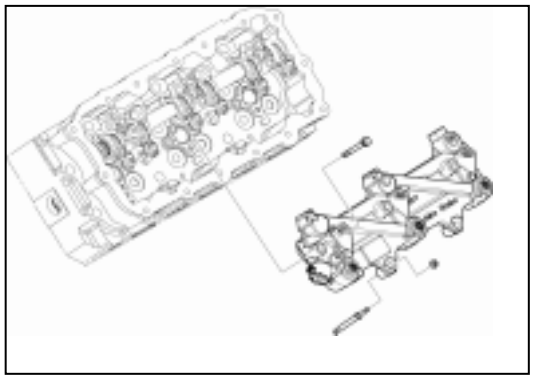


Torque	6.2 kg.m

Torque	6.2 kg.m

- Adjust the valve clearance as reference of major maintenance part.

3.3.18. Engine brake

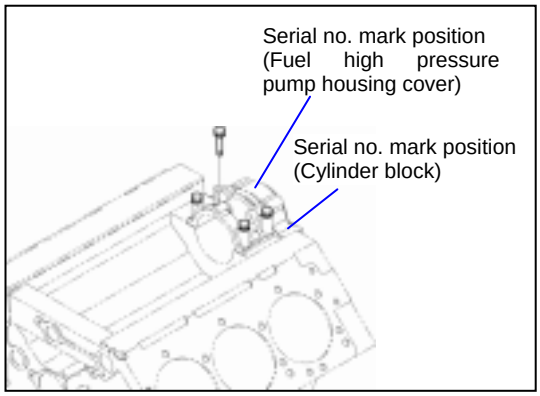


- Put the engine brake on the rocker arm of the cylinder head, then assemble the engine brake.
- Adjust the clearance of the slave.

Fixing bolt	6.2 kg.m
Fixing nut	2.5 kg.m

Slave clearance	1.5mm

3.3.19. Fuel high pressure pump housing cover



- Coat with the liquid gasket on the surface of the cylinder block for mounting of the fuel high pressure pump housing cover.
- Assemble the fuel high pressure pump housing cover after check the serial number of the cylinder block and the pump housing cover.
- Tighten the fixing bolts of the fuel high pressure pump housing cover by the specified tightening torque.

Torque	7.5 kg.m

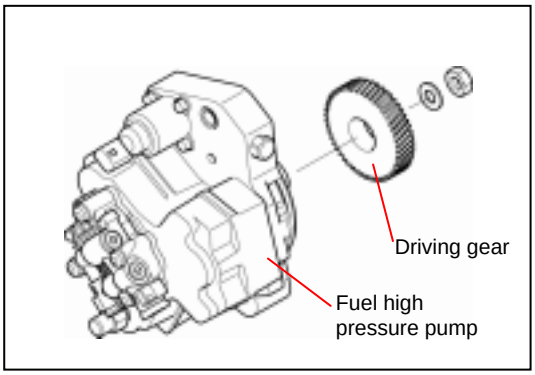
NOTES:

Do not mingle with the pump housing cover and cylinder block randomly.

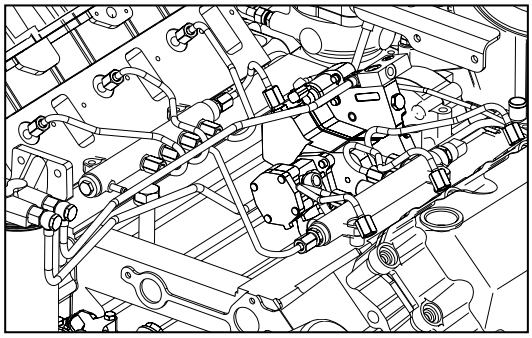
3.3.20. Fuel high pressure pump

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

Gear nut torque	11±0.5 kg.m



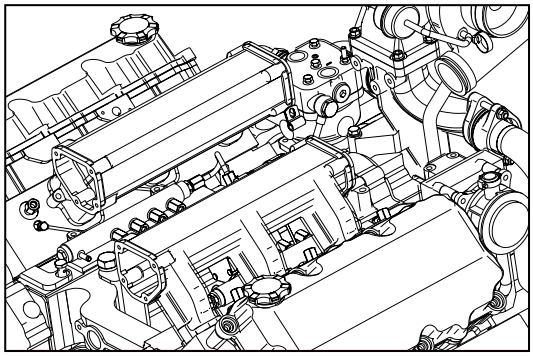
- Install the fuel high pressure pump on the backside of the fly wheel housing.
- Assemble the stud bolt after apply the loctite.
- Assemble the fuel high pressure pump fixing bolts with specified torque.



Torque	4.4 kg.m

3.3.21. Intake manifold

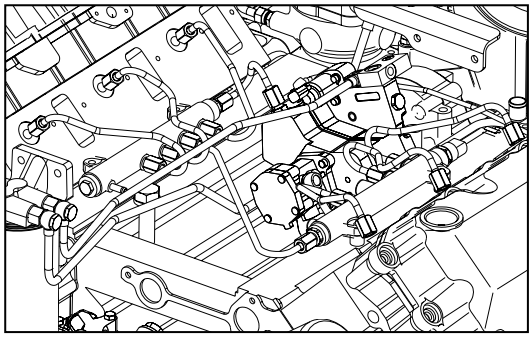
- Attach a new gasket to the cylinder head side.
- Assemble the intake manifold by tightening the fixing bolts.
- Assemble both sides by the above method.
- Attach a gasket to the equalizing pipe that connects the intake manifolds of both sides and assemble both manifolds by tightening the fixing bolts.



Torque	2.2 kg.m

3.3.22. Common rail & high pressure pipe

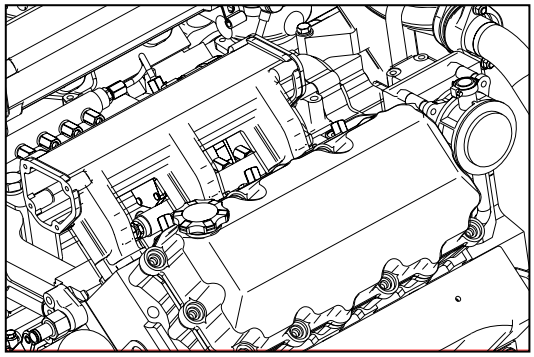
- Assemble the common rail on the cylinder block.
- Install the fuel high pressure pipe between the common rail and the fuel high pressure connector, then tighten the cylinder by cylinder with specified torque.



Torque	Fuel high pressure pipe	Side of common rail	3.0 kg.m
		Side of fuel high pressure connector	3.0 kg.m
		Common rail from fuel high pressure pump	3.0 kg.m
	Common rail fixing bolt		2.2 kg.m

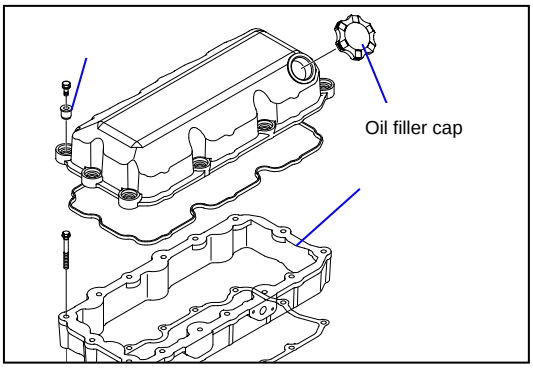
3.3.23. Cylinder head cover

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



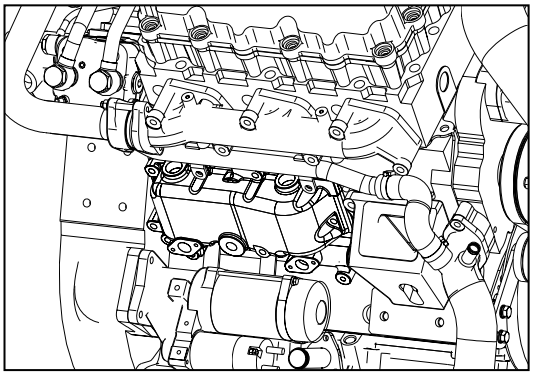
Torque	Middle cover	3.6 kg.m
	Cylinder head cover	2.2 kg.m

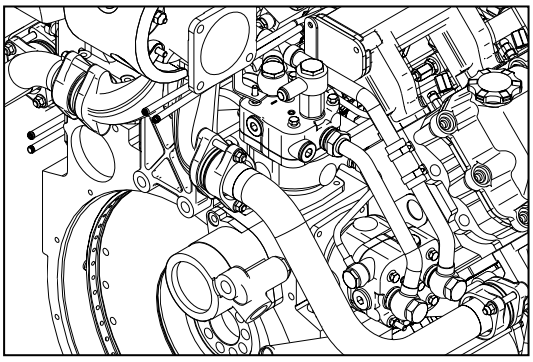
- Insert the oil filler cap.



3.2.24. Exhaust manifold

- Attach a new gasket to the exhaust manifold.
- Fix the pipe that is connected exhaust manifold by tightening the fixing bolts.
- Assemble both sides in the same method as above.

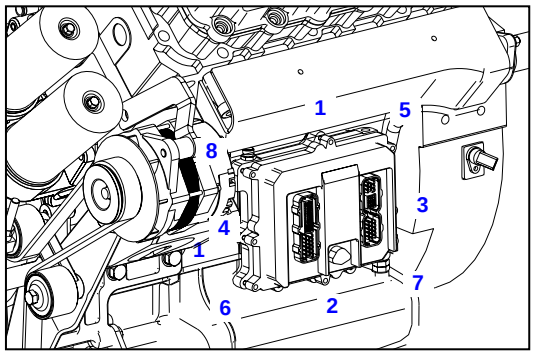




Torque	8.0 kg.m

3.3.25. Electric control unit

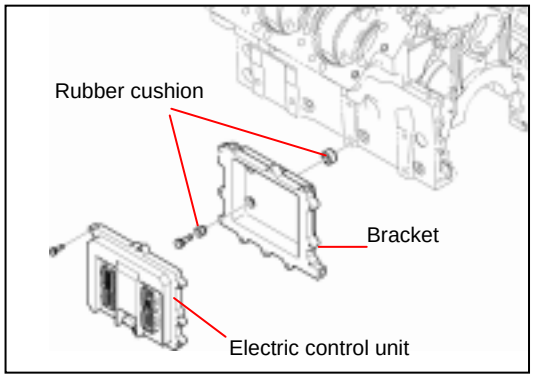
- Install the electric control unit fixing bracket on the cylinder block, then assemble the electric control unit.



Torque	Bracket fixing bolt	4.5 kg.m
	Electric control unit fixing bolt	10±2 N.m

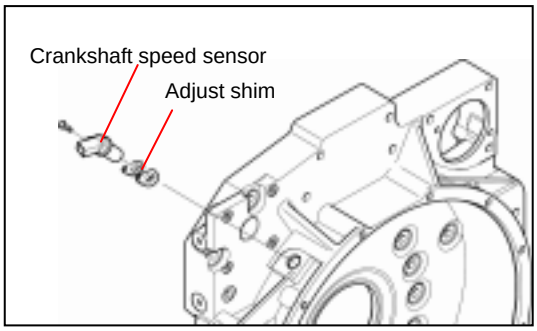
- Assemble the electric control unit (ECU) according to the right figure order.

- Refer to the chapter of 3.4 about relation of the common rail system and the electric control unit.



3.3.26. Crankshaft speed sensor

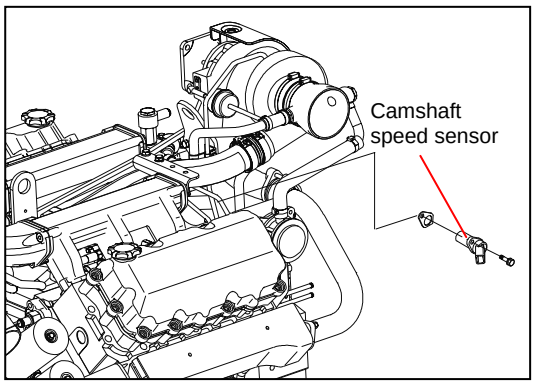
- Measure the clearance of the assembling part of the sensor and fly wheel, then assemble it with the adjust shim.



Clearance	1. 0 ±0.1mm
Torque	1.0 kg.m

3.3.27. Camshaft speed sensor

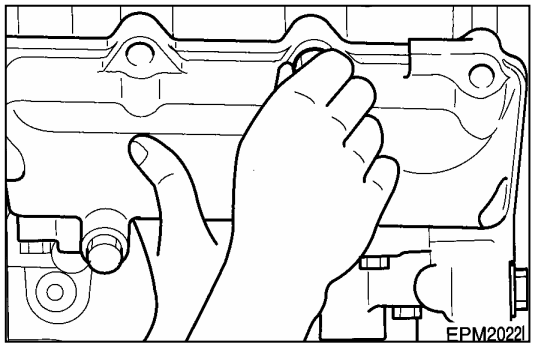
- Measure the clearance of the assembling part of the sensor and timing gear, then assemble it with the adjust shim.



Clearance	1. 0 ±0.1mm
Torque	1.0 kg.m

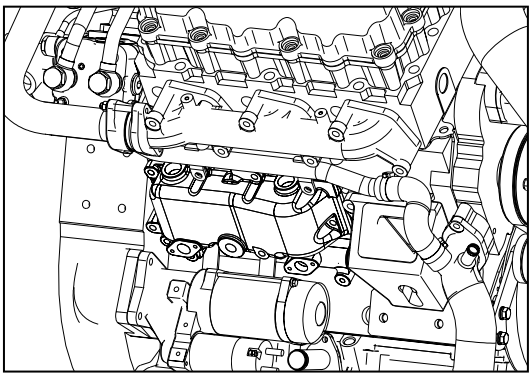
3.3.28. Oil cooler

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



Torque	4.4 kg.m

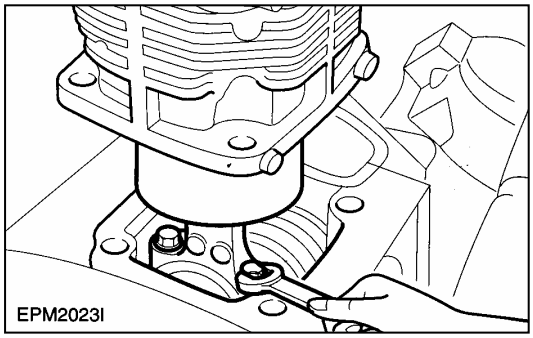
3.3.29. Starter



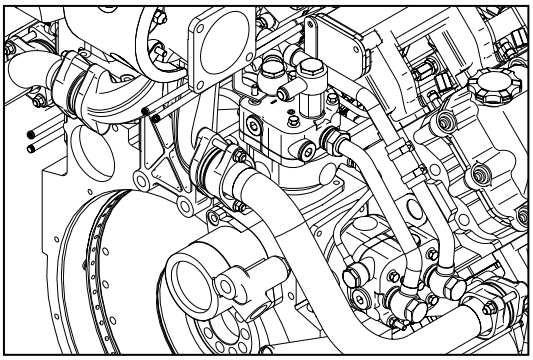
- Install stud bolts at the bolt holes on the flywheel housing for installing the starter.
- Insert the starter into the flywheel housing and tighten the fixing nuts.

Torque	8.0 kg.m

3.3.30. Air compressor



- Assemble the piston assembly into air compressor cylinder liner before installing it to the flywheel housing. (Same method as that of piston reassembly)
- Fit a gasket to the air compressor fitting surface of the flywheel housing.

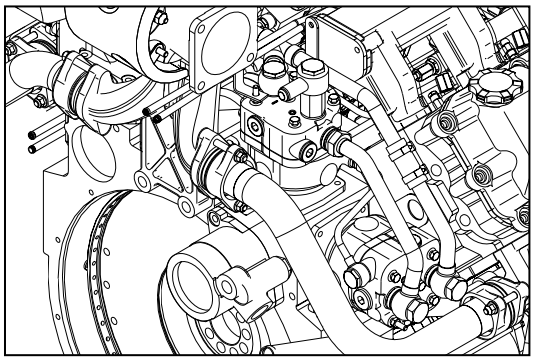


- Assemble the connecting rod of the air compressor liner assembly with the air compressor crankshaft and tighten it to the specified torque.
- Tighten the air compressor liner with the fixing bolts.
- Tighten the air compressor liner of side positioned with the fixing bolt by special tool. (“T” type socket spanner)
- Mount gasket on the air compressor liner.
- Tighten the air compressor head fixing bolts to the specified torque.

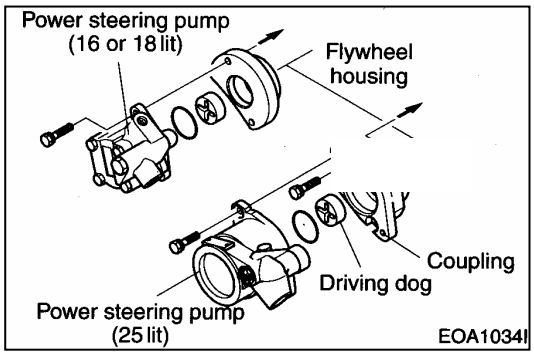
Torque	Connecting rod bolt	3.5 kg.m
	Liner fixing bolt	4 kg.m
	Head bolt	3 kg.m

3.3.31. Power steering pump

- Assemble the power steering pump to the fly wheel housing.
- Set the power steering pump to the driving coupling carefully to prevent from damage of the O-ring.
- Assemble the steering pump fixing bolt by specified torque.

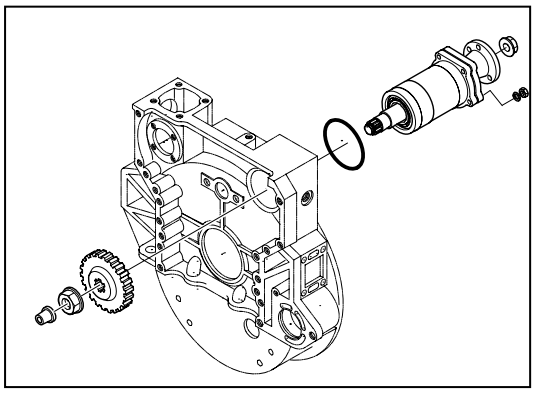


Torque	4.4 kg.m



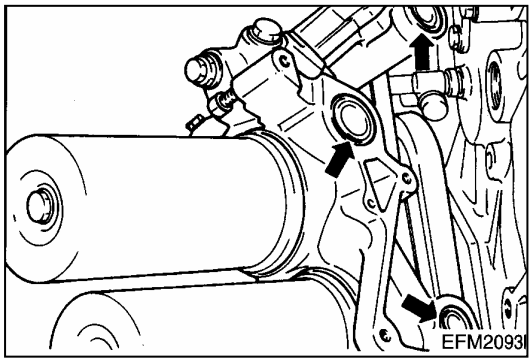
3.3.32. Power take off (P.T.O)

- Assemble the P.T.O assembly to the fly wheel housing carefully to prevent from damage of the O-ring.
- Assemble the P.T.O gear fixing nut and coupling nut by specified torque.

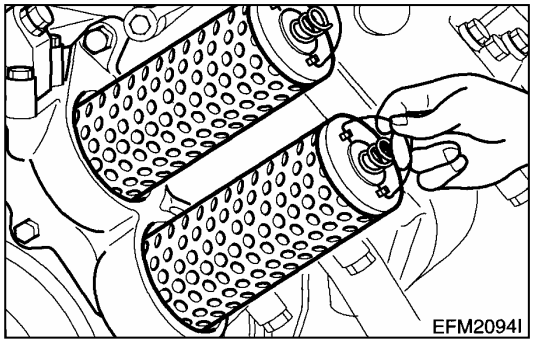


3.3.33. Oil filter

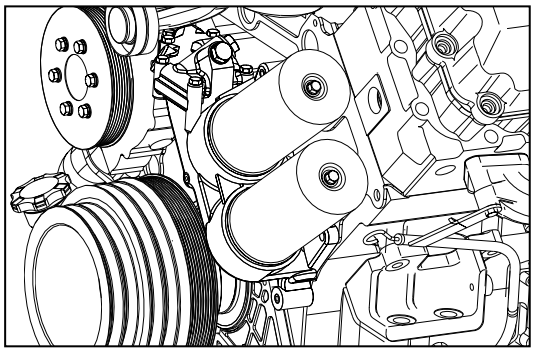
- Insert greased O-rings into the oil port of the oil filter head. (Prevent the O-ring from slipping out.)
- Install the filter head on the cylinder block and tighten bolts in a diagonal sequence.



- Install the oil filter element in the oil filter assembly.
- Install new O-rings (Packings) in the oil filter housing. (Filter element, Cu-washer, and packing are supplied together as A/S parts.)



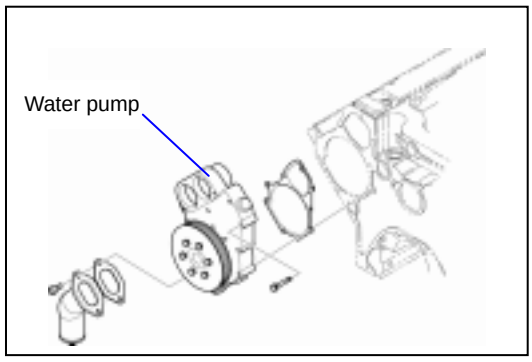
- Assemble the oil filter housing with the filter head (Be careful not to damage the O-ring.)
- Place Cu-washer over filter housing fixing bolt and tighten the bolt.



3.3.34. Water pump

- Attach a gasket at the cooling water pump. (at cylinder block side.)
- Assemble the cooling water pump by tightening the fixing bolts. (Zigzag method.)

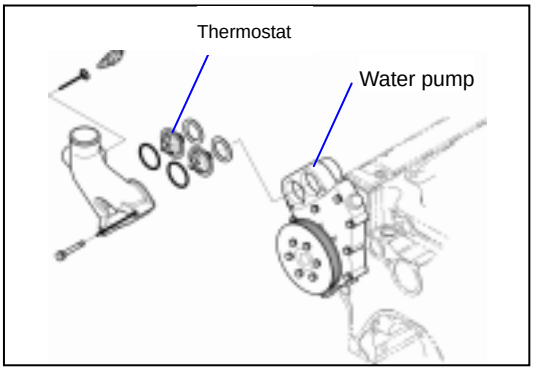
Torque	4.4 kg.m



3.3.35. Thermostat

- Put the thermostat into the water pump with gasket.
- Put the O-ring into the thermostat, then assemble cooling water pipe by tightening the fixing bolt.

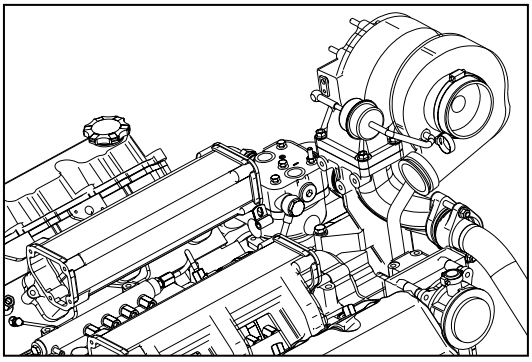
Torque	2.2 kg.m



2.3.36. Turbo charger

- Attach a gasket to the exhaust elbow and assemble the turbocharger with fixing bolts.
- Attach a gasket on the oil supply pipe and assemble the pipe with the fixing bolts.
- Attach a gasket on the oil discharge pipe and assemble the pipe by tightening the bolts.

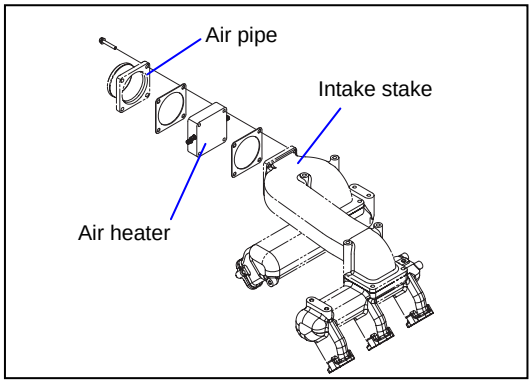
Turbocharger fixing nut torque	4.4 kg.m



3.3.37. Intake stake & air heater

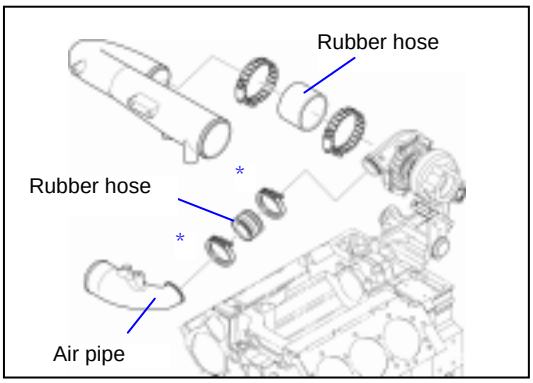
- Connect the intake stake to the intake manifold.
- Assemble the air heater according the direction of an arrow impressed on the air heater and assemble the pipe by tightening the bolts.

Torque	2.2 kg.m

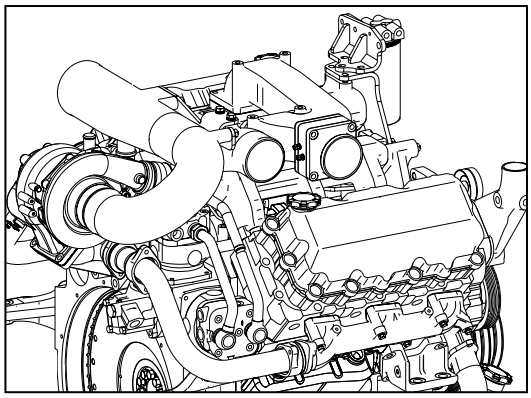


- Install the air pipe, then connect the rubber hose into the turbocharger and assemble with clamping.

Torque (*mark)	2.2 kg.m



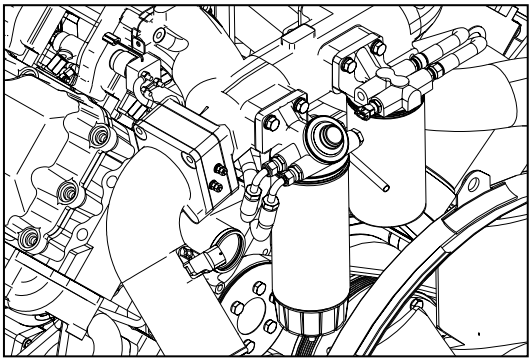
- Take care for the direction of assembly when install the air heater.



3.3.38. Fuel filter

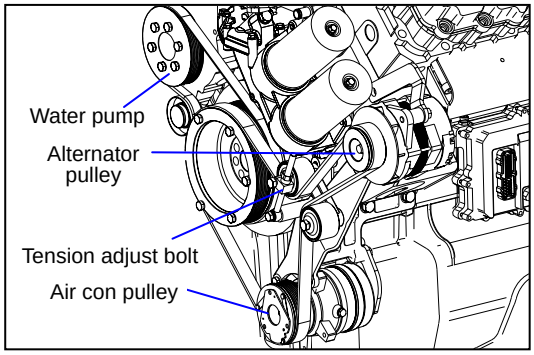
- Assemble the fuel filter with the intake manifold.
- Assemble the fuel filter after fill the fuel into inside of the cartridge when replace the new fuel filter.

Torque	2.2 kg.m

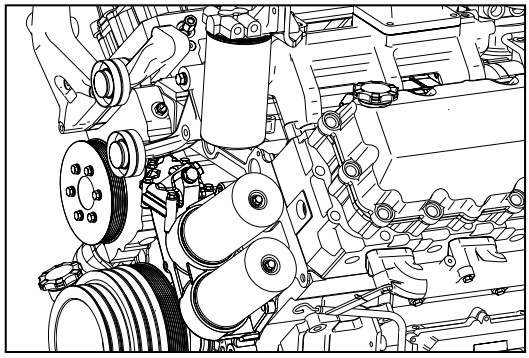


3.3.39. Alternator & belt

- Install the alternator bracket and auto tensioner bracket to the cylinder block, then tighten the fixing bolts.
- Install the alternator, idle pulley and auto tensioner.

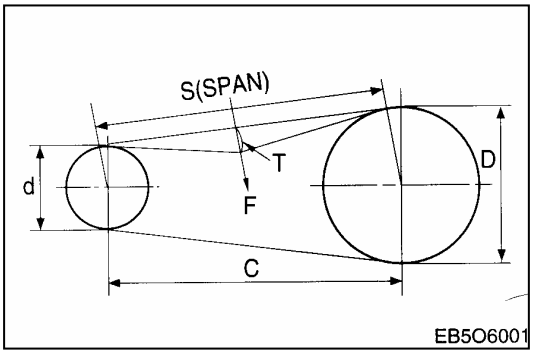


- Put the belt into the crankshaft pulley, alternator pulley, water pump and air con pulley for connecting.
- Do not adjust the tension of the auto tensioner.



- Poly belt will be properly tensioned if the deflection force “F” is applied midway between the belt’s tangent points with the pulley.

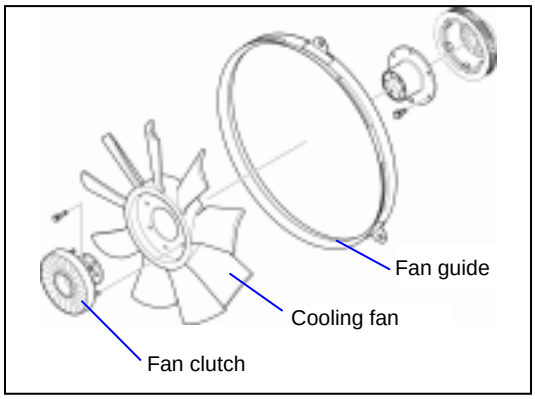
  (T) = 0.015 x S
  (about 1.5mm per 100mm)
  (T : Deflection, S : span)



3.3.40. Cooling fan

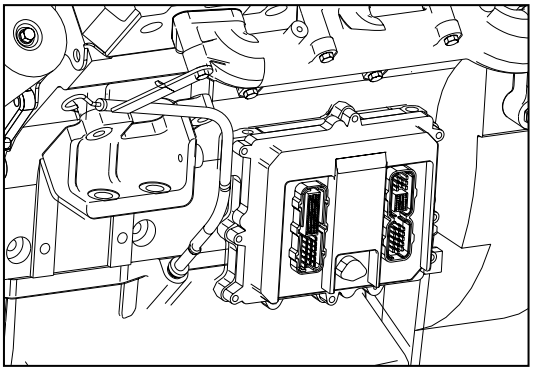
- Install the flange to the crankshaft pulley, then assemble the cooling fan and the fan clutch to the pulley by tightening the fixing bolts.

Torque	2.2 kg.m



3.3.41. Oil level gauge

- Apply sealant (Loctite #262) to the bottom side of the guide tube.
- Then assemble the guide tube and oil level gauge on the oil pan.



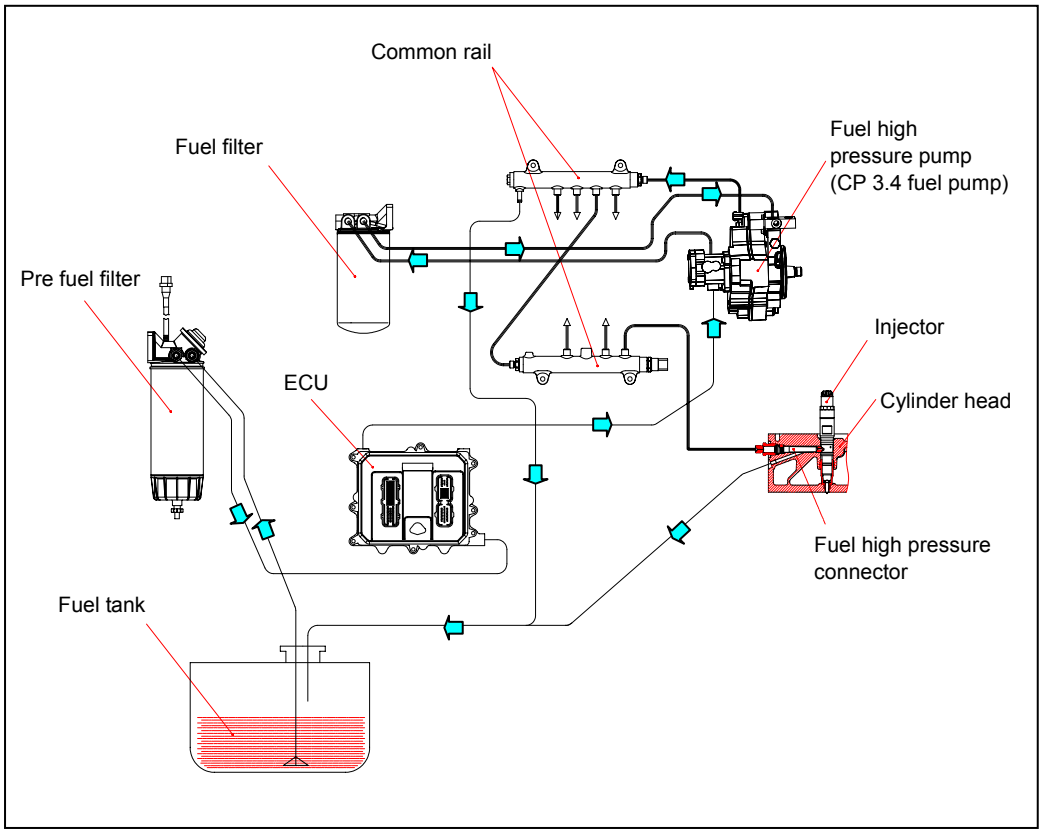
3.3.42. Others

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



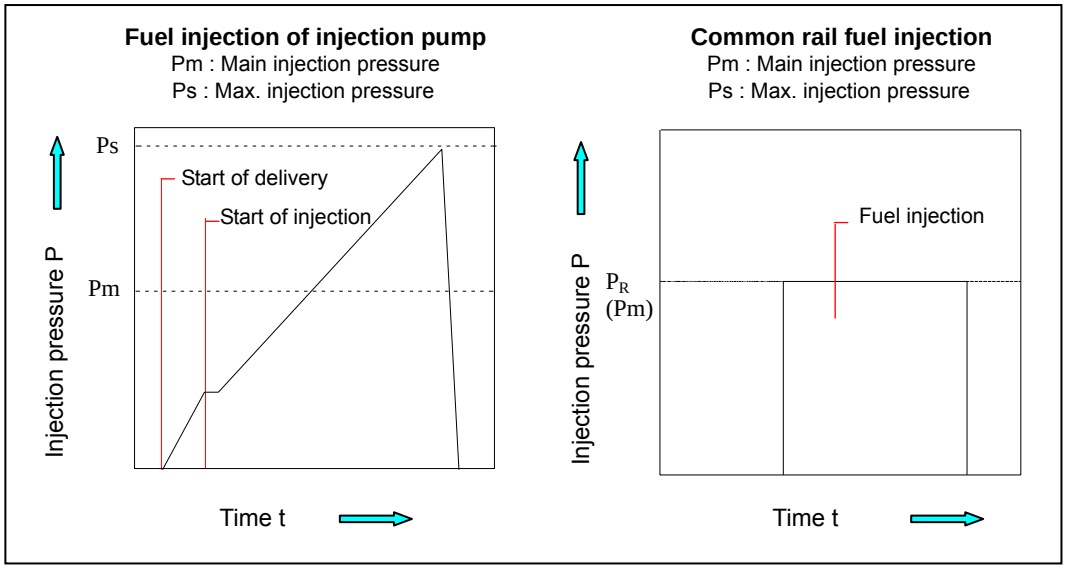
3.4.2. Major components of the common rail system

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

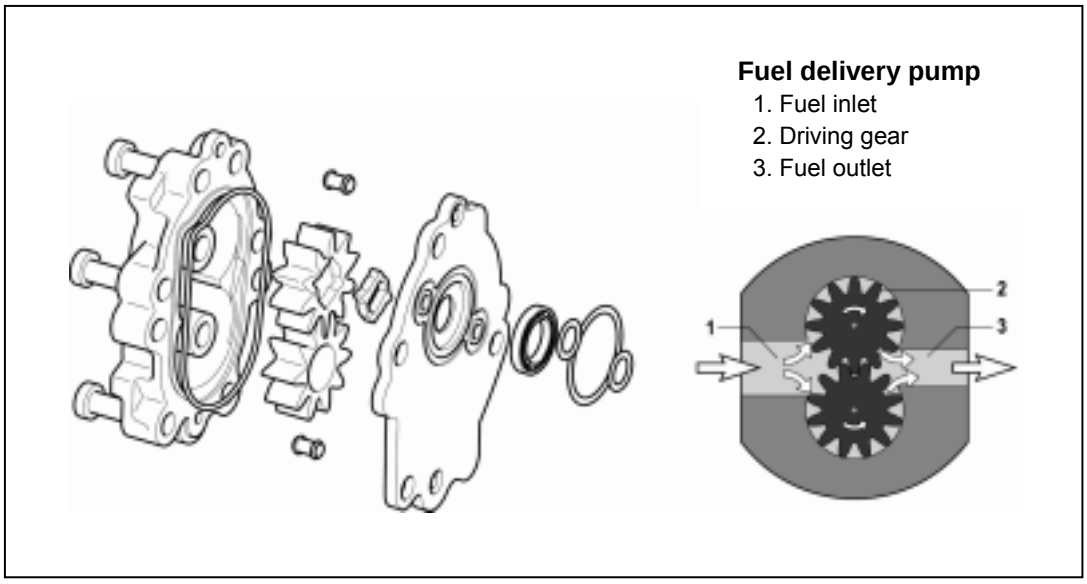
- The common rail fuel injection system comprises a low pressure stage for the low pressure delivery of fuel, a high pressure stage for the high pressure delivery, and the ECU.

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.

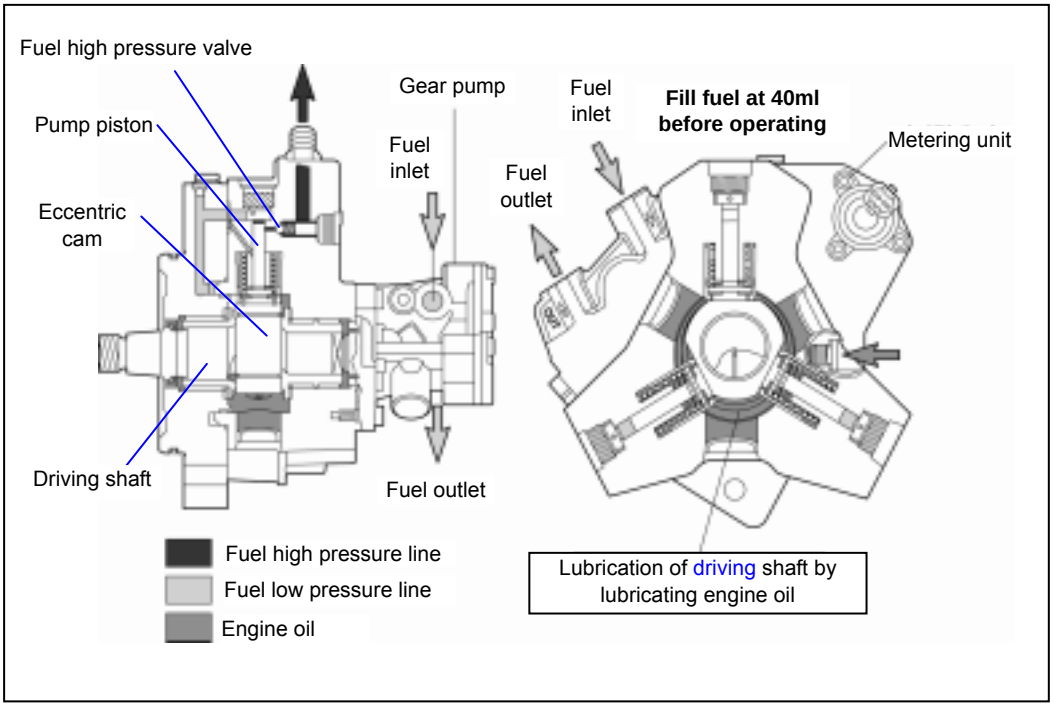
- **Fuel high pressure pipe**

  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

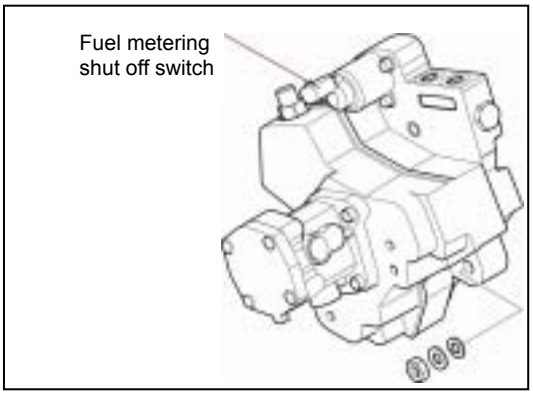
The fuel supply pump fuel from the tank to the high pressure pump through the fuel inlet and the safety valve. It forces the fuel through the safety valve into the high pressure pump. The driveshaft with its eccentric cams moves the piston of the pump up and down in accordance with the shape of the cam.

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.

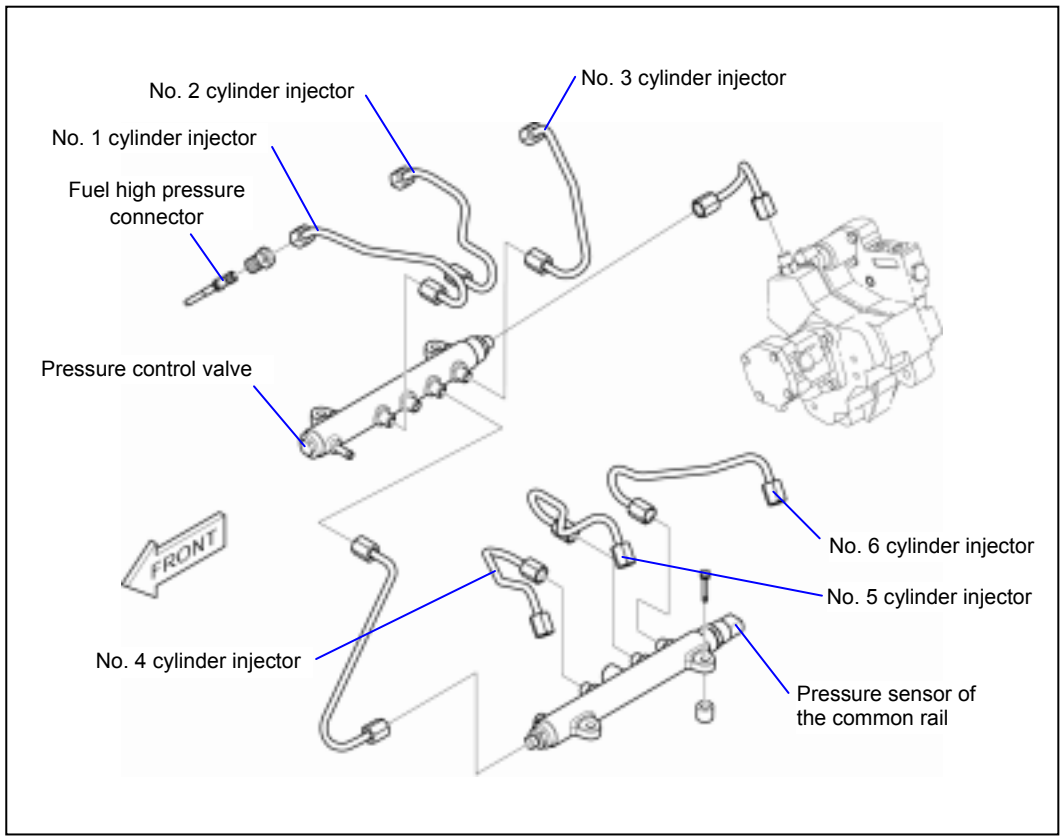
5) Fuel metering shut off valve



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.

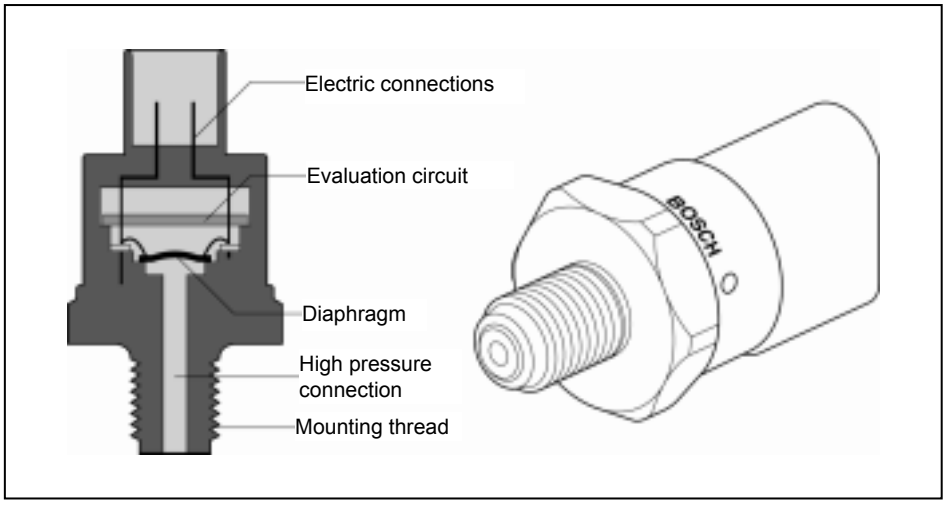
6) Common rail

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.



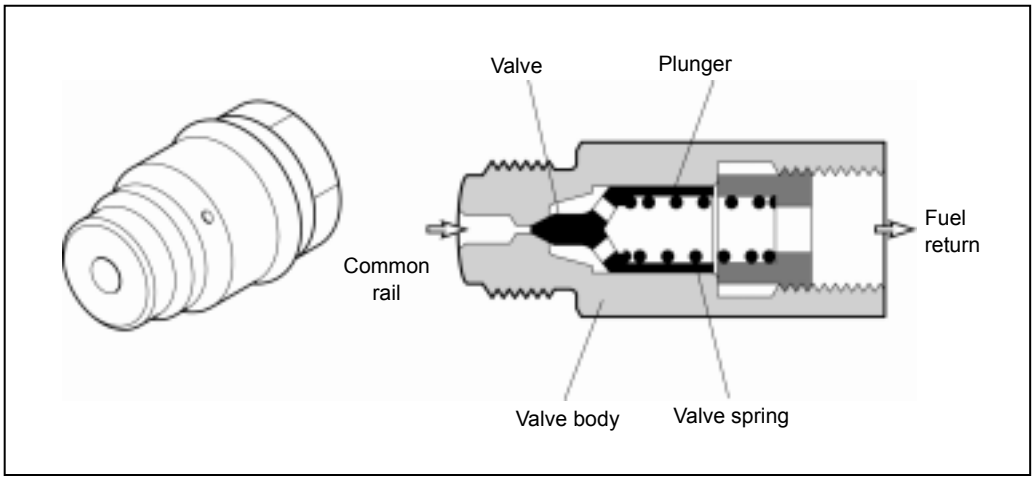
7) Common rail pressure sensor

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.



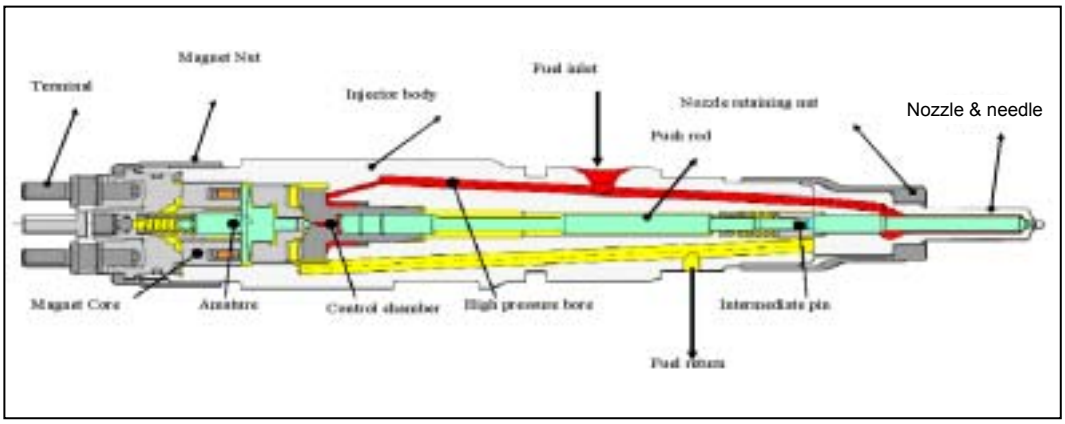
3.4.12. Pressure limiter valve

- 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)

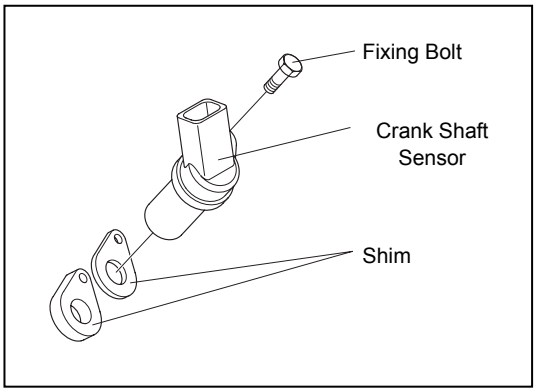
As soon as the solenoid valve is no longer triggered, the valve spring forces the armature downwards and the ball closes the bleed orifice. The armature is a 2-piece design. Here, although the armature plate is guided by a driver shoulder in its downward movement, it can "over spring" with the return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

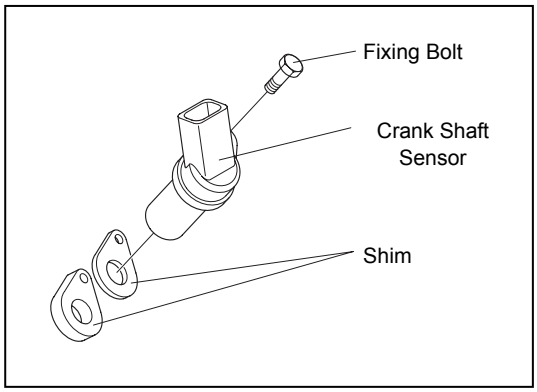
The nozzle needle's closing speed is determined by the flow through the feed orifice. Injection ceases as soon as the nozzle needle comes up against its bottom stop again.

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



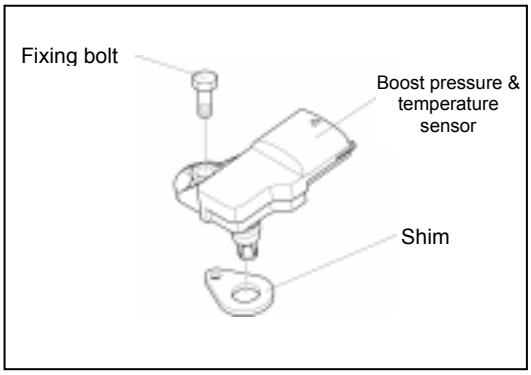
- The camshaft controls the engine's intake and exhaust valves. It turns at half the speed of the crankshaft. When a piston travels in the direction of TDC, the camshaft position determines whether it is in the compression phase with subsequent ignition, or in the exhaust phase. This information cannot 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.

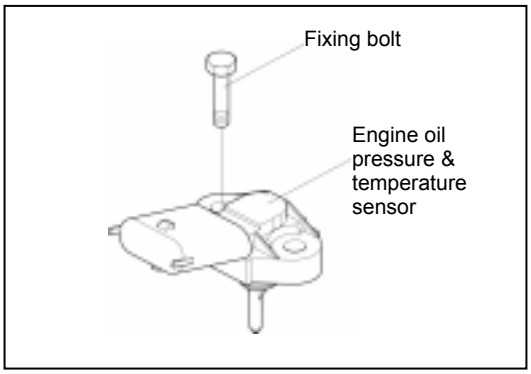
3.4.17. Boost pressure & temperature sensor

- 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.



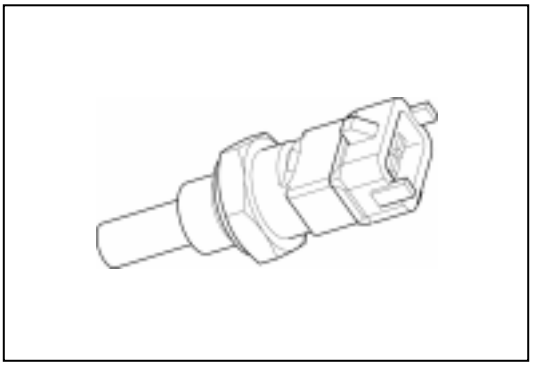
3.4.18. Engine oil pressure & temperature sensor

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



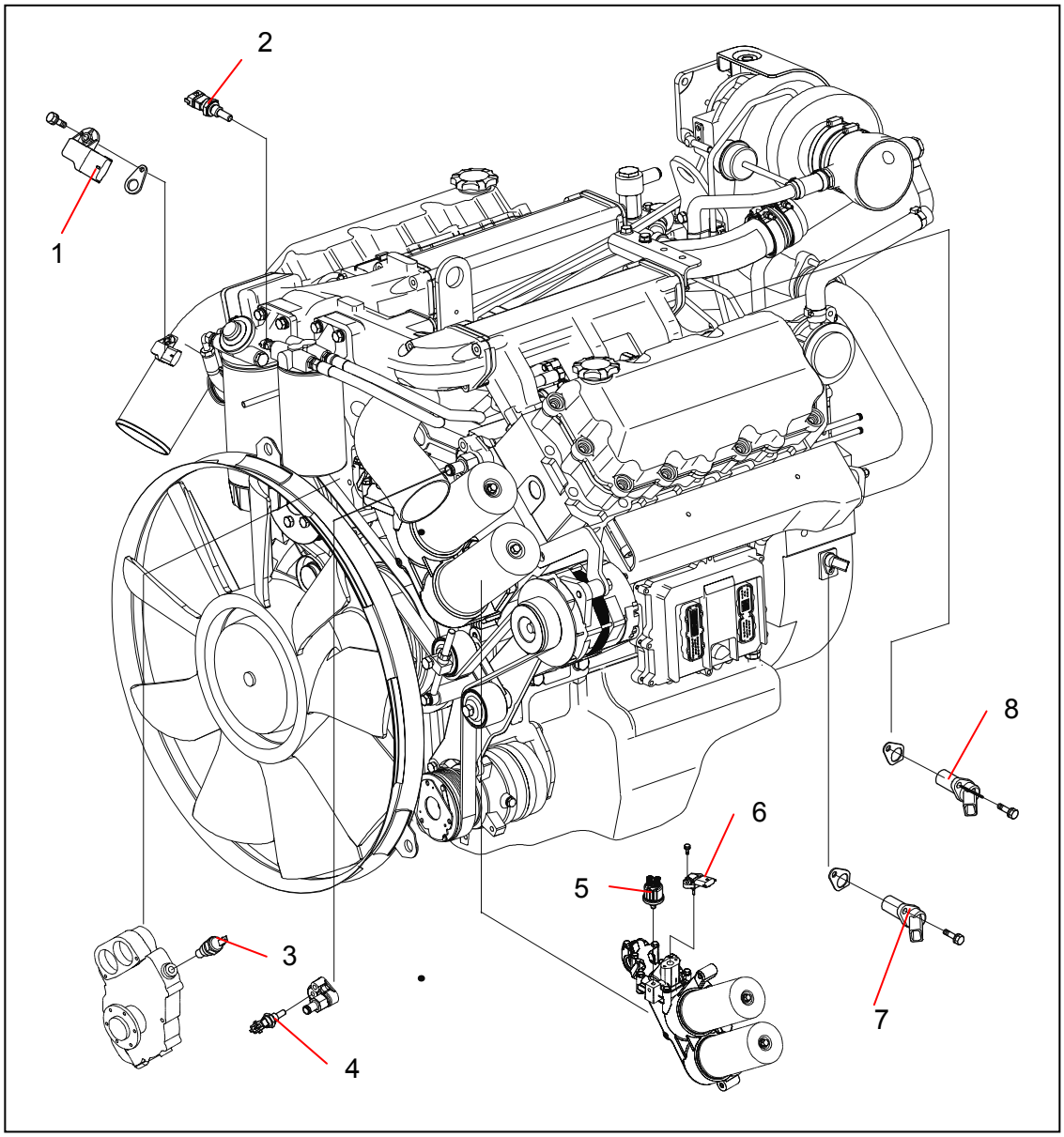
3.4.19. Engine coolant temperature sensor

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



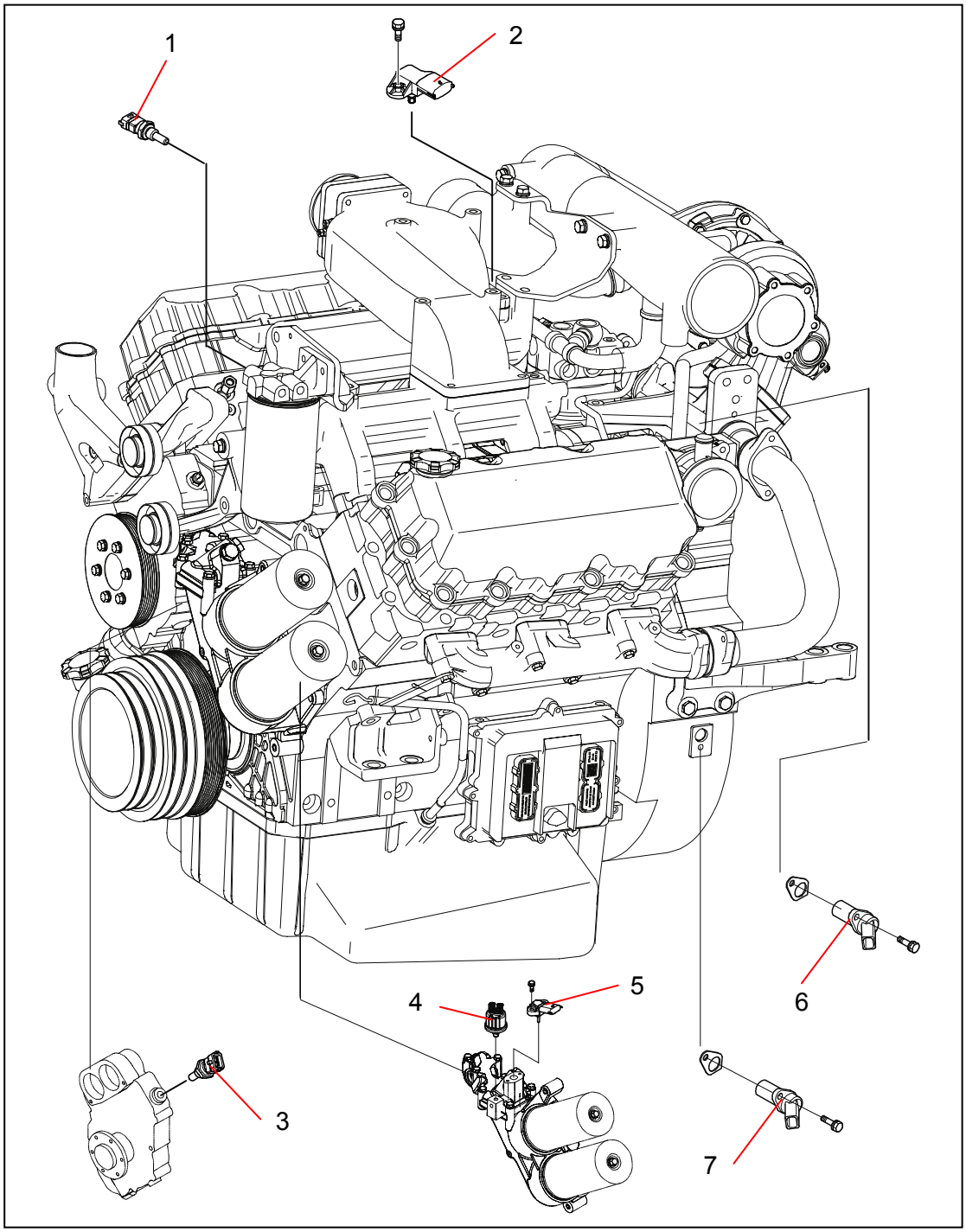
3.5. Electrical System

3.5.1. Electrical parts – Truck



1	Boost pressure & temperature sensor
2	Fuel temperature sensor
3	Coolant temperature sensor (for gauge unit)
4	Coolant temperature sensor
5	Oil pressure sensor (for gauge unit)
6	Engine oil pressure & temperature sensor
7	Crankshaft speed sensor
8	Camshaft speed sensor

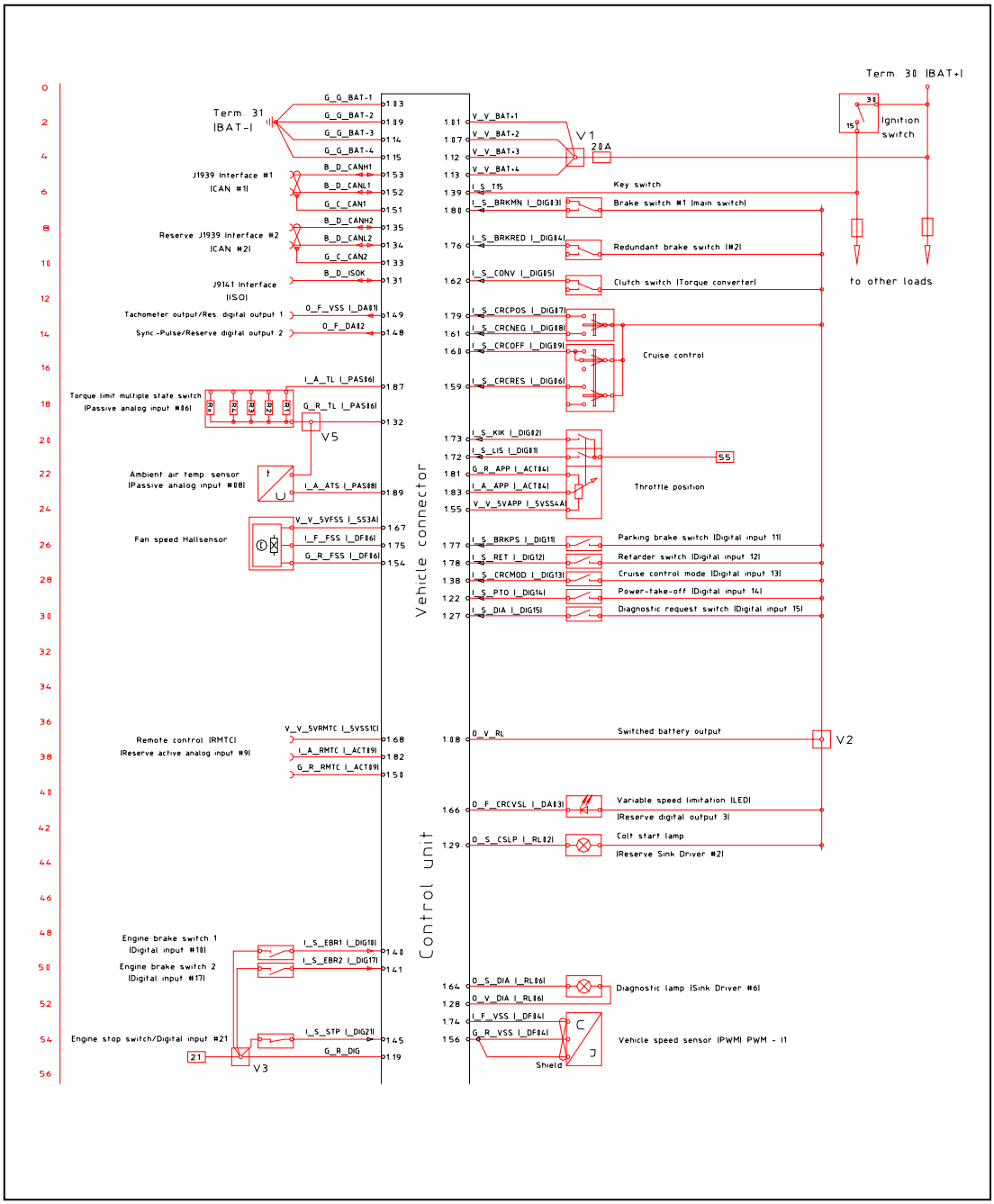
3.5.2. Electrical parts - Bus



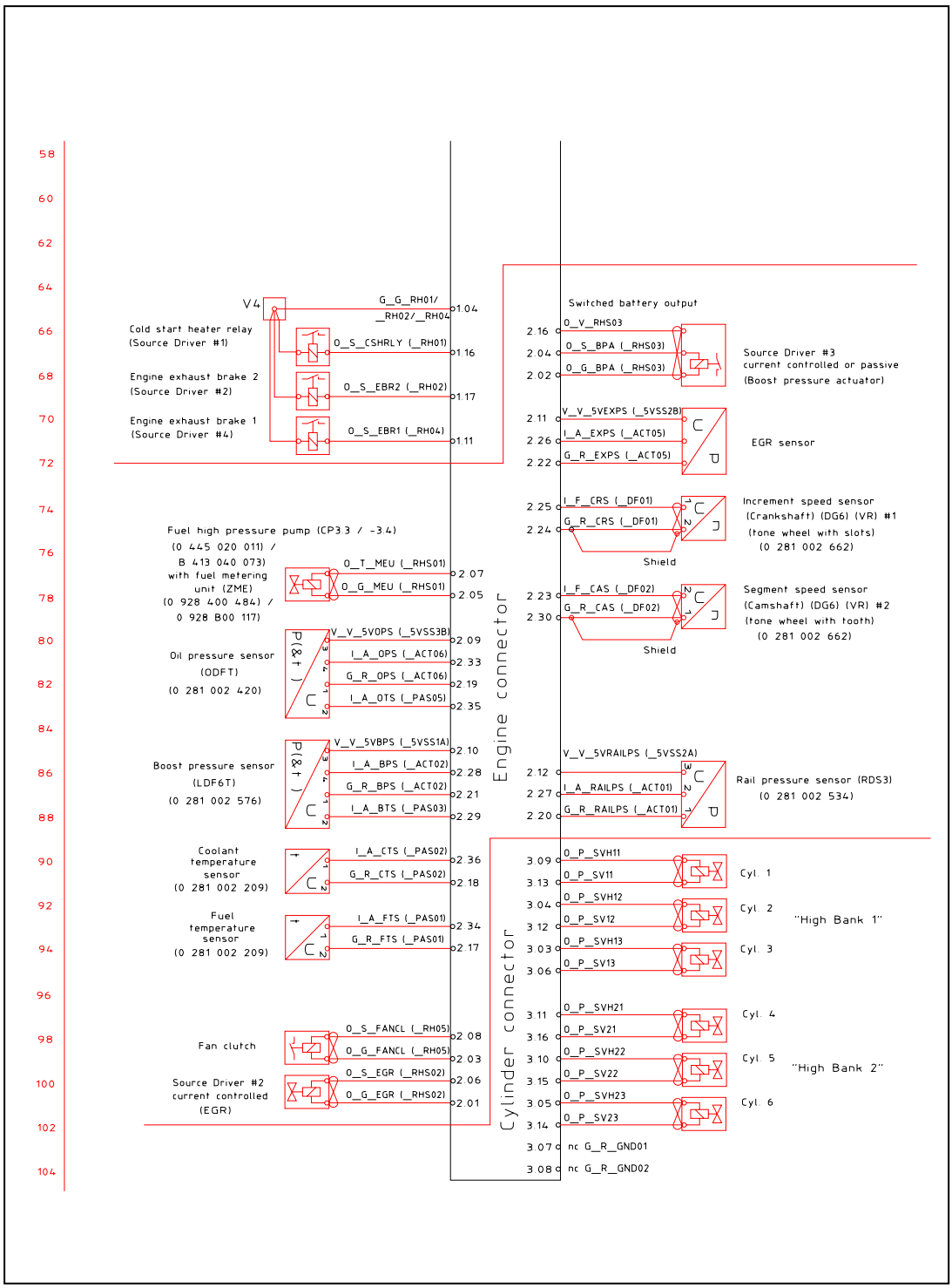
1	Fuel temperature sensor	5	Engine oil pressure & temperature sensor
2	Boost pressure & temperature sensor	6	Camshaft speed sensor
3	Coolant temperature sensor	7	Crankshaft speed sensor
4	Oil pressure sensor (for gauge unit)		

3.5.3. Harness of electrical control unit

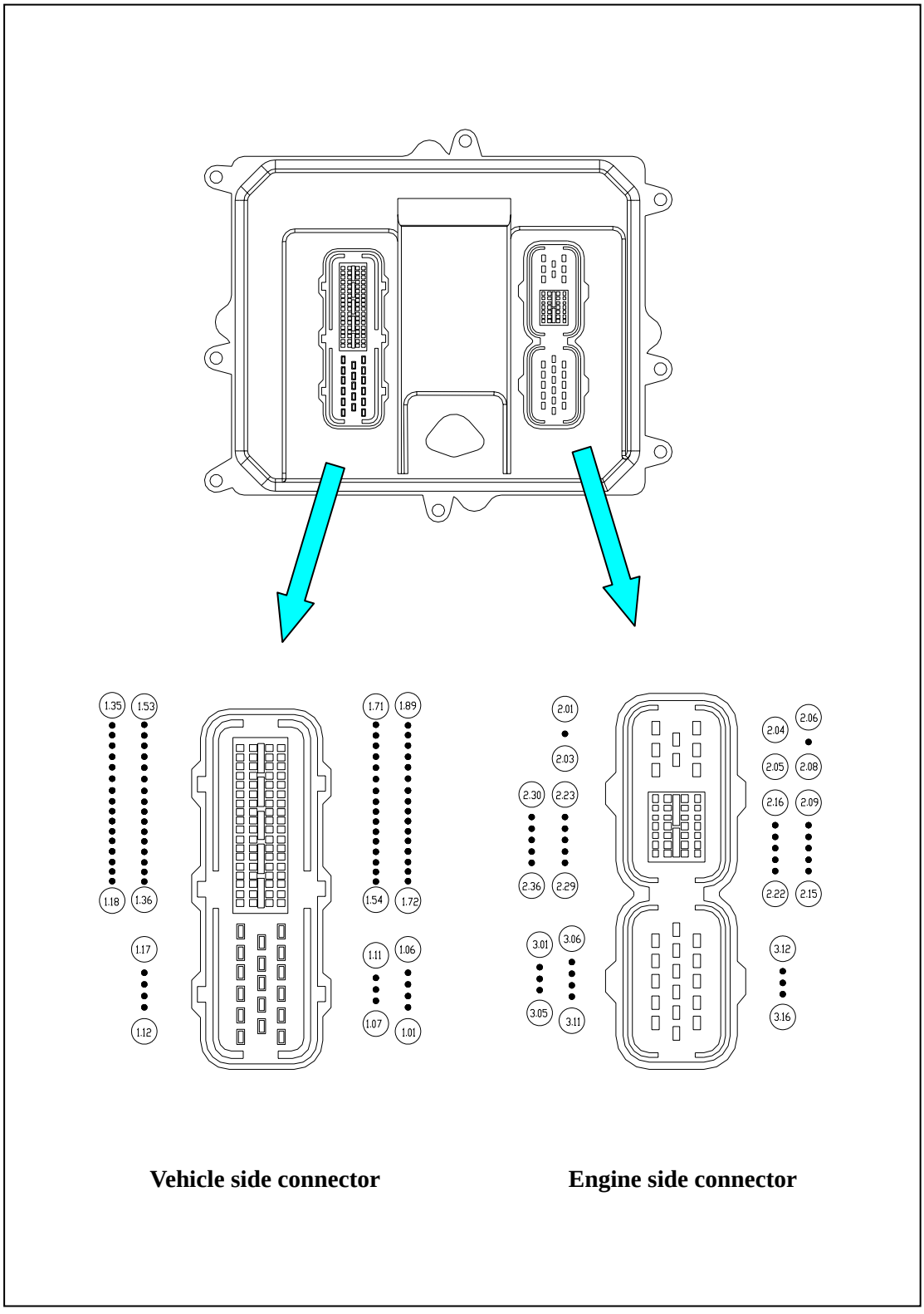
a) Harness of electrical control unit - A



b) Harness of electrical control unit - B



3.5.4. Connector of electrical control unit (ECU)



Vehicle side connector **Engine side connector**

3.5.5. Electrical Control Unit

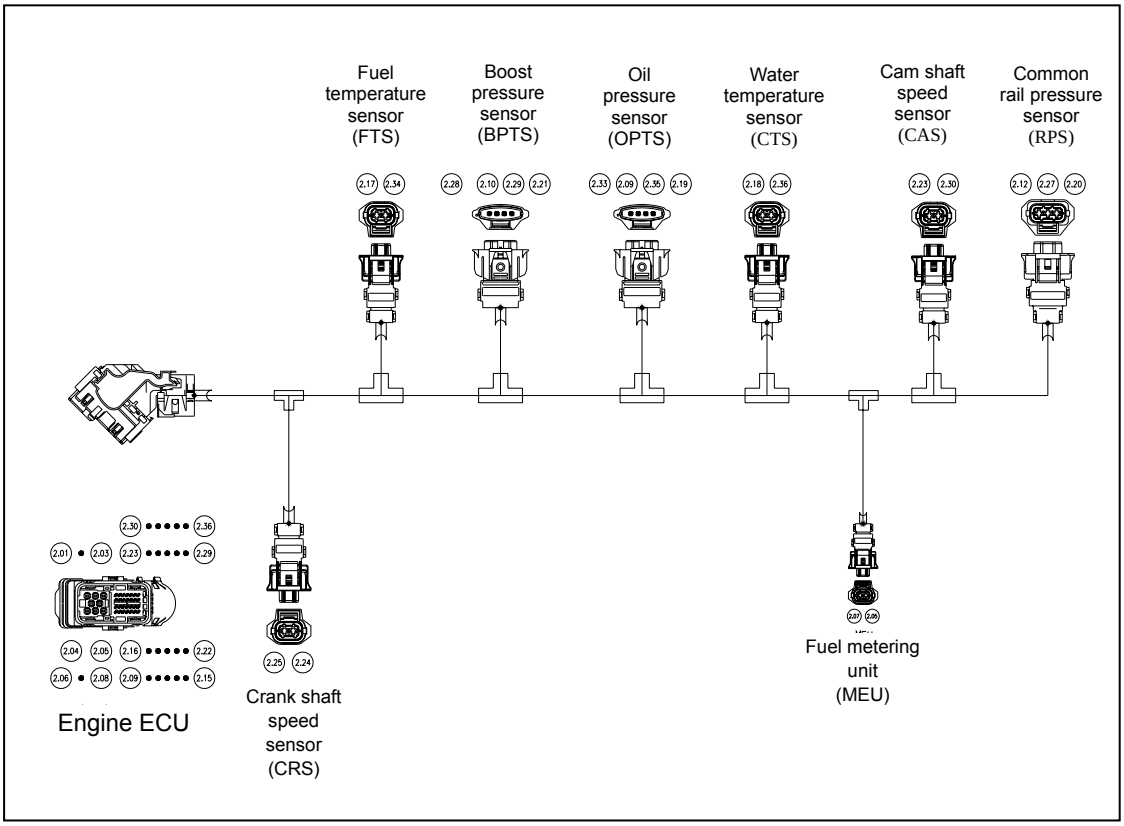
Pin no.	Signal		Part name
	BOSCH	DOOSAN	
1.01	V_V_BAT+1	V_V_BAT+1	Battery plus (+24V)
1.03	G_G_BAT-1	G_G_BAT-1	Battery minus (-24V)
1.04	G_G_RH01	G_G_RH01	Ground (-24V)
1.07	V_V_BAT+2	V_V_BAT+2	Battery minus (+24V)
1.08	O_V_RL	O_V_RL	ECU Battery voltage (+24V)
1.09	G_G_BAT-2	G_G_BAT-2	Battery minus (-24V)
1.11	O_S_EBR1	O_S_RH04	Engine brake 1 power output
1.12	V_V_BAT+3	V_V_BAT+3	Battery plus (+24V)
1.13	V_V_BAT+4	V_V_BAT+4	Battery plus (+24V)
1.14	G_G_BAT-3	G_G_BAT-3	Battery minus (-24V)
1.15	G_G_BAT-4	G_G_BAT-4	Battery minus (-24V)
1.16	O_S_CSHRLY	O_S_RH01	Air heater relay
1.17	O_S_EBR2	O_S_RH02	Engine brake 2 power output
1.19	G_R_DIG	G_R_DIG	Digital ground
1.22	I_S_PTO	I_S_DIG14	Power take off (PTO) signal
1.27	I_S_DIA	I_S_DIG15	Diagnostic operation switch
1.28	O_V_DIA	O_V_RL06	ECU Battery voltage (+24V) for diagnostic lamp operation
1.29	O_S_CSLP	O_S_RL02	Cold starting lamp
1.31	B_D_ISOK	B_D_ISOK	ISO K-line
1.32	G_R_TL	G_R_PAS06	Torque limitation ground
1.33	G_C_CAN2	G_C_CAN2	ECU network 2 , shield
1.34	B_D_CANL2	B_D_CANL2	ECU network 2 , low
1.35	B_D_CANH2	B_D_CANH2	ECU network 2 , high
1.38	I_S_CRCMOD	I_S_DIG13	Cruise control mode switch
1.39	I_S_T15	I_S_T15	Key switch (Terminal 15)
1.40	I_S_EBR1	I_S_DIG10	Engine brake switch 1 signal
1.41	I_S_EBR2	I_S_DIG17	Engine brake switch 2 signal
1.45	I_S_STP	I_S_DIG21	Engine stop switch signal
1.48	O_F_DA02	O_F_DA02	#1 Injector operation – frequency
1.49	O_F_VSS	O_F_DA01	Vehicle speed sensor output signal
1.50	G_R_RMTC	G_R_ACT09	Remote control, sensor ground
1.51	G_C_CAN1	G_C_CAN1	ECU network 1, shield
1.52	B_D_CANL1	B_D_CANL1	ECU network 1, low
1.53	B_D_CANH1	B_D_CANH1	ECU network 1, high
1.54	G_R_FSS	G_R_DF06	Fan speed sensor ground
1.55	V_V_5VAPP	V_V_5VSS4A	Accelerator pedal sensor supply (5V)
1.56	G_R_VSS	G_R_DF04	Vehicle speed sensor ground
1.59	I_S_CRCRES	I_S_DIG06	Cruise control – resume
1.60	I_S_CRCOFF	I_S_DIG09	Cruise control – off
1.61	I_S_CRCNEG	I_S_DIG08	Cruise control – set/decelerate
1.62	I_S_CONV	I_S_DIG05	Clutch switch (torque converter)
1.64	O_S_DIA	O_S_RL06	Diagnostic lamp
1.66	O_F_CRCVSL	O_F_DA03	Variable speed limitation output signal
1.67	V_V_5VFSS	V_V_5VSS3A	Fan speed sensor supply (5V)
1.68	V_V_5VRMTC	V_V_5VSS1C	Remote control supply (5V)

Pin no.	Signal		Part name
	BOSCH	DOOSAN	
1.72	I_S_LIS	I_S_DIG01	Low idle position switch signal
1.73	I_S_KIK	I_S_DIG02	Kick-down input signal
1.74	I_F_VSS	I_F_DF04	Vehicle speed sensor input signal
1.75	I_F_FSS	I_F_DF06	Fan speed sensor signal
1.76	I_S_BRKRED	I_S_DIG04	Redundant brake switch signal
1.77	I_S_BRKPS	I_S_DIG11	Parking brake signal
1.78	I_S_RET	I_S_DIG12	Retarder switch
1.79	I_S_CRCPOS	I_S_DIG07	Cruise control activator–set/accelerator
1.80	I_S_BRKMN	I_S_DIG03	Main brake switch signal
1.81	G_R_APP	G_R_ACT04	Accelerator pedal sensor ground
1.82	I_A_RMTC	I_A_ACT09	Remote control input signal
1.83	I_A_APP	I_A_ACT04	Accelerator pedal sensor signal
1.87	I_A_TL	I_A_PAS06	Torque limitation signal
1.89	I_A_ATS	I_A_PAS08	Ambient temperature sensor signal
2.01	O_G_EGR	O_G_RHS02	Power ground output for EGR actuator
2.02	O_G_BPA	O_G_RHS03	Power ground output for boost pressure actuator
2.03	O_G_FANCL	O_G_RH05	Power ground output for fan clutch
2.04	O_T_BPA	O_T_RHS03	Boost pressure actuator
2.05	O_G_MEU	O_G_RHS01	Fuel metering unit (low side)
2.06	O_T_EGR	O_T_RHS02	EGR actuator
2.07	O_T_MEU	O_T_RHS01	Fuel metering unit (high side)
2.08	O_S_FANCL	O_S_RH05	Fan clutch
2.09	V_V_5VOPS	V_V_5VSS3B	Oil pressure sensor supply (5V)
2.10	V_V_5VBPS	V_V_5VSS1A	Boost pressure sensor supply (5V)
2.11	V_V_5VEXPS	V_V_5VSS2B	Exhaust gas back pressure sensor supply (5V)
2.12	V_V_5VRAILPS	V_V_5VSS2A	Common rail pressure sensor supply (5V)
2.16	O_V_RHS03	O_V_RHS03	ECU battery plus output (+24V)
2.17	G_R_FTS	G_R_PAS01	Fuel temperature sensor ground
2.18	G_R_CTS	G_R_PAS02	Coolant temperature sensor ground
2.19	G_R_OPS	G_R_ACT06	Oil pressure sensor ground
2.20	G_R_RAILPS	G_R_ACT01	Common rail pressure sensor ground
2.21	G_R_BPS	G_R_ACT02	Boost pressure sensor ground
2.22	G_R_EXPS	G_R_ACT05	Exhaust gas back pressure sensor ground
2.23	I_F_CAS	I_F_DF02	Camshaft speed sensor signal
2.24	G_R_CRS	G_R_DF01	Crankshaft speed sensor ground
2.25	I_F_CRS	I_F_DF01	Crankshaft speed sensor signal
2.26	I_A_EXPS	I_A_ACT05	Exhaust gas back pressure sensor signal
2.27	I_A_RAILPS	I_A_ACT01	Common rail pressure sensor signal
2.28	I_A_BPS	I_A_ACT02	Boost pressure sensor signal
2.29	I_A_BTS	I_A_PAS03	Boost air temperature sensor signal
2.30	G_R_CAS	G_R_DF02	Camshaft speed sensor ground
2.33	I_A_OPS	I_A_ACT06	Oil pressure sensor signal
2.34	I_A_FTS	I_A_PAS01	Fuel temperature sensor signal
2.35	I_A_OTS	I_A_PAS05	Oil temperature sensor signal

Pin no.	Signal		Part name
	BOSCH	DOOSAN	
2.36	I_A_CTS	I_A_PAS02	Coolant temperature sensor signal
3.03	O_P_SVH13	O_P_SVH13	#3 cylinder injector power supply
3.04	O_P_SVH12	O_P_SVH12	#2 cylinder injector power supply
3.05	O_P_SVH23	O_P_SVH23	#6 cylinder injector power supply
3.06	O_P_SV13	O_P_SV13	#3 cylinder injector power return
3.07	nc	G_R_GND01	
3.08	nc	G_R_GND02	
3.09	O_P_SVH11	O_P_SVH11	#1 cylinder injector power supply
3.10	O_P_SVH22	O_P_SVH22	#5 cylinder injector power supply
3.11	O_P_SVH21	O_P_SVH21	#4 cylinder injector power supply
3.12	O_P_SV12	O_P_SV12	#2 cylinder injector power return
3.13	O_P_SV11	O_P_SV11	#1 cylinder injector power return
3.14	O_P_SV23	O_P_SV23	#6 cylinder injector power return
3.15	O_P_SV22	O_P_SV22	#5 cylinder injector power return
3.16	O_P_SV21	O_P_SV21	#4 cylinder injector power return

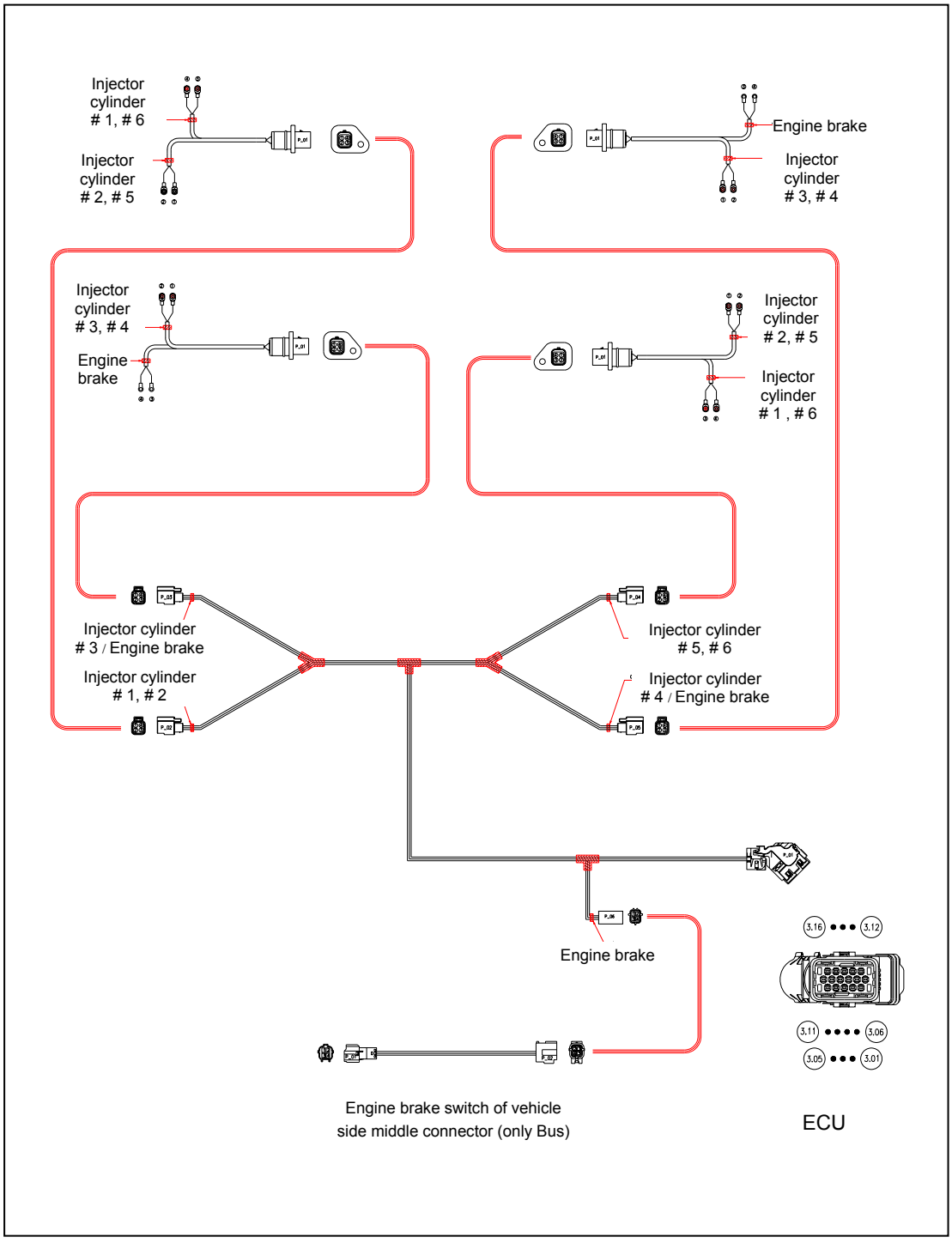
nc = not connected

3.5.6. Engine harness - 1

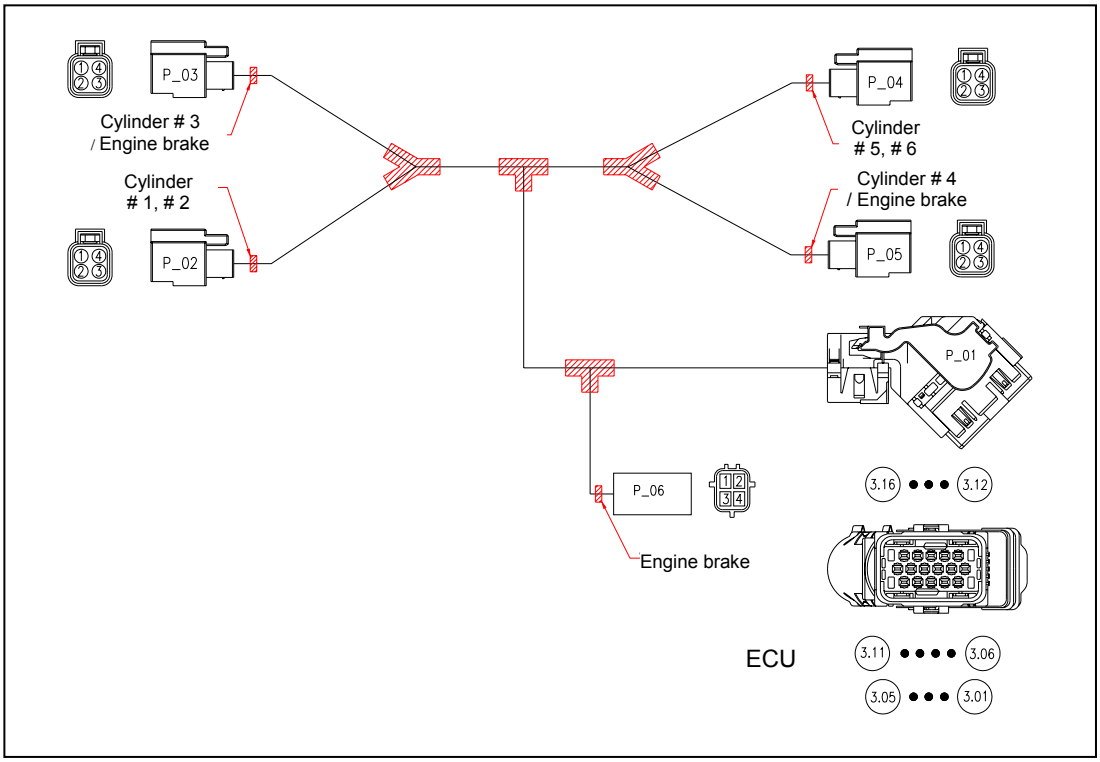


Part name	Signal	Pin position		Wire color	Circuit name
		ECU no.	Connecting pin no.		
2.25	CRS	ECU no. 25	Crankshaft sensor 1	White	Speed sensor signal
2.24		ECU no. 24	Crankshaft sensor 2	Blue	Speed sensor earth(-)
2.30	CAS	ECU no. 30	Camshaft sensor 1	White	Speed sensor signal
2.23		ECU no. 23	Camshaft sensor 2	Blue	Speed sensor earth (-)
2.07	MEU	ECU no. 07	Fuel metering unit 1	White	Fuel metering unit (high)
2.05		ECU no. 05	Fuel metering unit 2	Blue	Fuel metering unit (low)
2.19	OPTS	ECU no. 19	Oil pressure sensor1	Blue	Oil pressure sensor earth (-)
2.35		ECU no. 35	Oil pressure sensor 2	White	Oil temperature sensor signal
2.09		ECU no. 09	Oil pressure sensor 3	White	Oil pressure sensor power supply (5V)
2.33		ECU no. 33	Oil pressure sensor 4	White	Oil pressure sensor signal
2.21	BPTS	ECU no. 21	Boost pressure sensor 1	Blue	Boost pressure sensor earth(-)
2.29		ECU no. 29	Boost pressure sensor 2	White	Boost temperature sensor signal
2.10		ECU no. 10	Boost pressure sensor 3	White	Boost pressure sensor power supply (5V)
2.28		ECU no. 28	Boost pressure sensor 4	White	Boost pressure sensor signal
2.20	RPS	ECU no. 20	Rail pressure sensor 1	Blue	Rail pressure sensor earth (-)
2.27		ECU no. 27	Rail pressure sensor 2	White	Rail pressure sensor signal
2.12		ECU no. 12	Rail pressure sensor 3	White	Rail pressure sensor power supply (5V)
2.36	CTS	ECU no. 36	Coolant temperature sensor 1	White	Coolant temperature sensor signal
2.18		ECU no. 18	Coolant temperature sensor 2	Blue	Coolant temperature sensor earth (-)
2.34	FTS	ECU no. 34	Fuel temperature sensor 1	White	Fuel temperature sensor signal
2.17		ECU no. 17	Fuel temperature sensor 2	Blue	Fuel temperature sensor earth(-)

3.5.7. Harness of injector & engine brake (Engine harness - 2)

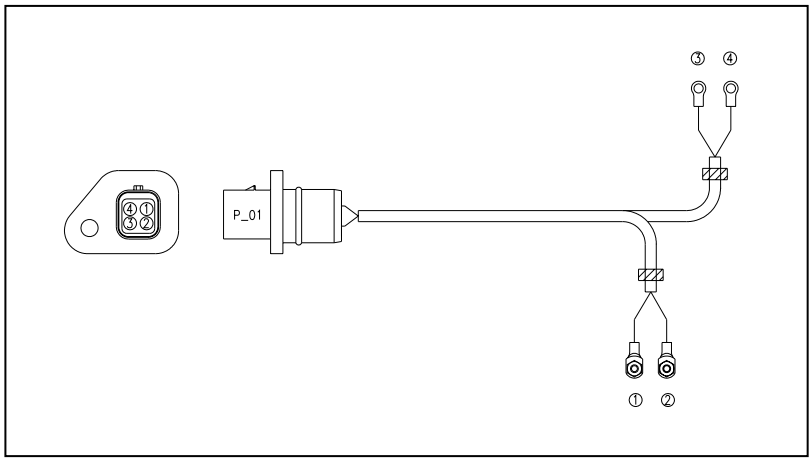


1) Harness of injector & engine brake (outside)



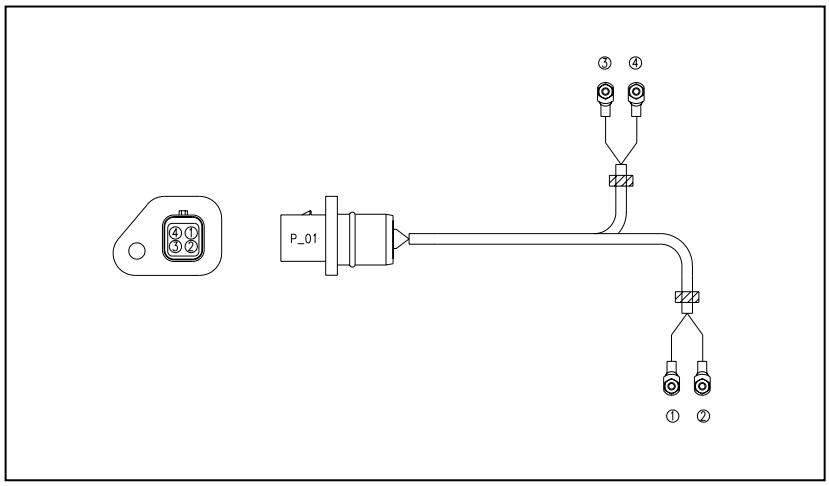
Side of ECU		Side of injector		Wire color	Circuit name
Connector no.	Pin no.	Connector no.	Pin no.		
P_01 Y462 U03 027 (1 928 404 202) (BOSCH)	3.09	P_02 936254-1 (AMP)	3	White	High side of injector 1
	3.13		4	White	Low side of injector 1
	3.04		1	White	High side of injector 2
	3.12		2	White	Low side of injector 2
	3.03	P_03 936254-1 (AMP)	1	White	High side of injector 3
	3.06		2	White	Low side of injector 3
	3.11	P_05 936254-1 (AMP)	1	White	High side of injector 4
	3.16		2	White	Low side of injector 4
	3.10	P_04 936254-1 (AMP)	1	White	High side of injector 5
	3.15		2	White	Low side of injector 5
	3.05		3	White	High side of injector 6
	3.14		4	White	Low side of injector 6
P_06 174259-2 (AMP)	1	P_03 936254-1 (AMP)	1	White	Engine brake 1st
	2		2	White	
	3	P_05 936254-1 (AMP)	3	White	Engine brake 2nd
	4		4	White	

2) Harness of injector & engine brake - A (inside)



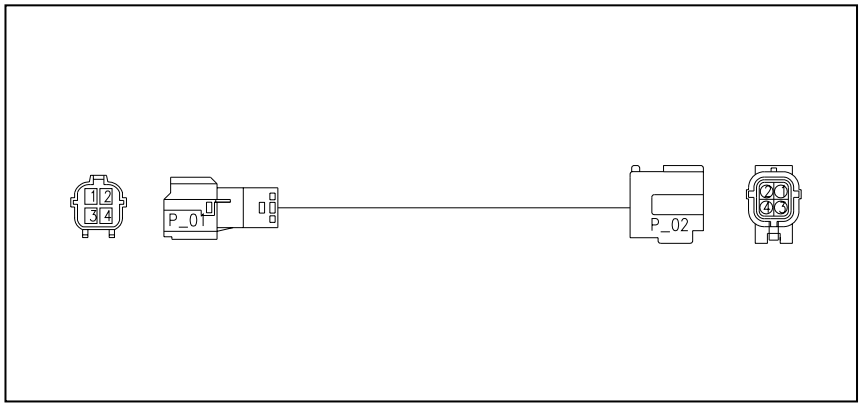
Side of ECU harness		Side of engine brake		Wire color	Circuit name
Connector no.	Pin no.	Connector no.	Pin no.		
P_01 99013-00300 (AMP) 65.26810-5003 (DHIM)	1	Y462 U00 226(Bosch)	1	White	High side of injector
	2	45360.212.179(GHW)	2	White	Low side of injector
	3	GP110012(KET)	3	White	Engine brake 1st
	4		4	White	Engine brake 2nd

3) Harness of injector & engine brake – B (inside)



Side of ECU harness		Side of engine brake		Wire color	Circuit name
Connector No	Pin No	Connector No	Pin No		
P_01 99013-00300 (AMP) 65.26810-5003 (DHIM)	1	Y462 U00 226(Bosch)	1	White	High side of injector
	2	45360.212.179(GHW)	2	White	Low side of injector
	3	GP110012(KET)	3	White	Engine brake 1st
	4		4	White	Engine brake 2nd

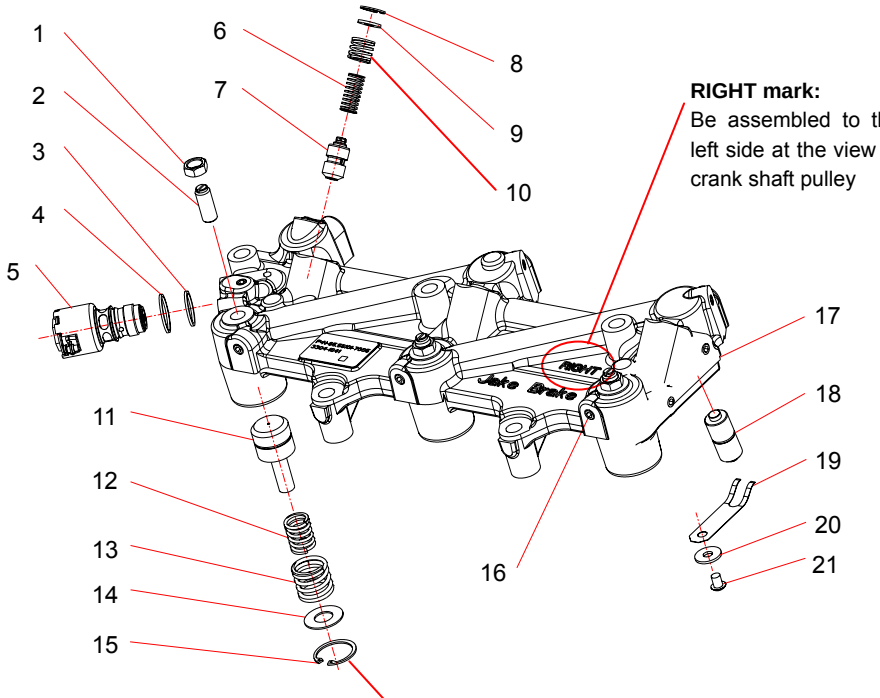
4) Harness of injector & engine brake



Side of engine		Side of vehicle		Wire color	Circuit name
Connector no.	Pin no.	Connector no.	Pin no.		
P_01 MG 640333 (KET)	1	P_02 174257-2 (AMP)	1	White	Engine brake 1st
	2		2	White	
	3		3	White	Engine brake 2nd
	4		4	White	

3.6. Engine brake

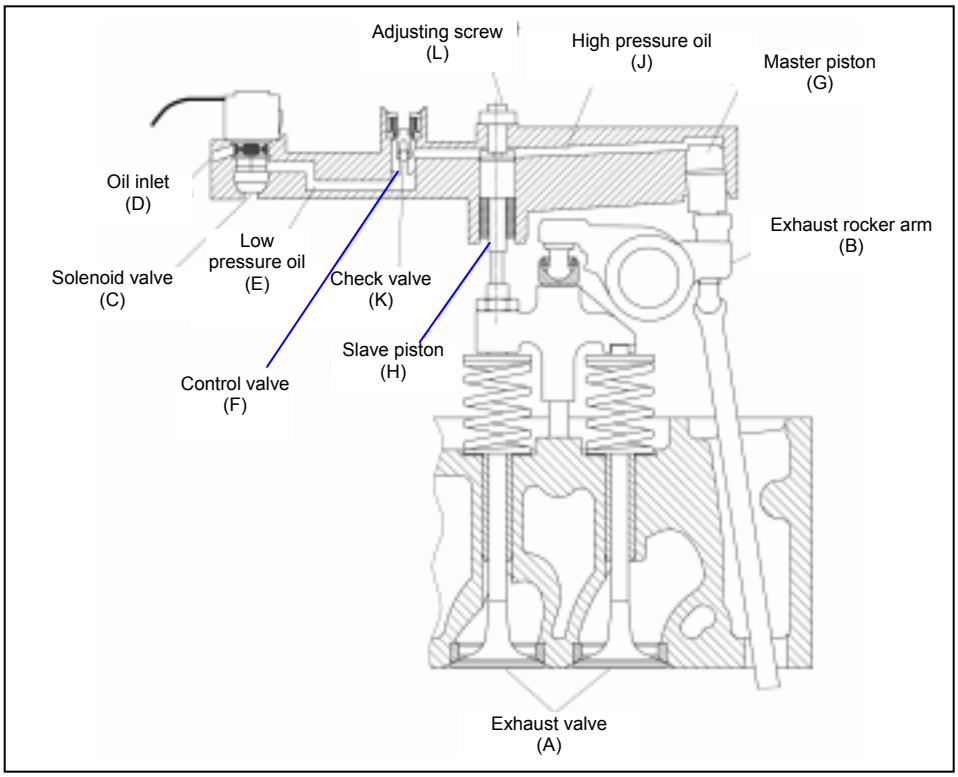
3.6.1. Engine brake construction



1	Adjusting nut	12	Spring (inner)
2	Adjusting screw	13	Spring (outer)
3	Sealing (center)	14	Spring retainer
4	Sealing (upper)	15	Stopping ring
5	Solenoid valve ass'y (24V)	16	Plug screw
6	Spring (inner)	17	Housing (for right)
7	Control valve ass'y	18	Master piston
8	Snap ring	19	Plate spring
9	Control valve cover	20	Washer
10	Spring (outer)	21	Screw
11	Slave piston		

3.6.2. Theory of operation

- Energizing the engine brake effectively converts a power producing diesel engine into a power absorbing air compressor. This is accomplished by opening the cylinder's exhaust valve (A) near the top of the normal compression stroke, releasing the compressed cylinder charge back into the atmosphere.

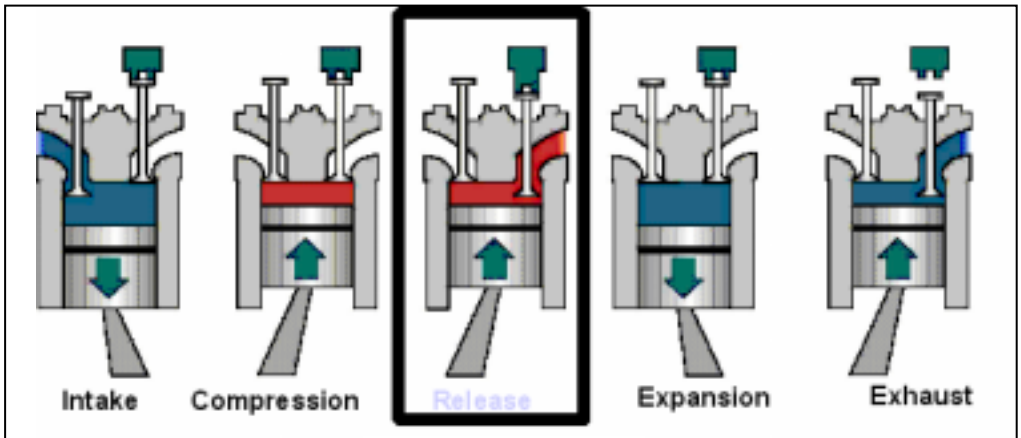


- The blow-down of the compressed cylinder charge to atmosphere prevents return of the stored energy to the piston on the expansion stroke. The effect is a net energy loss, since the work done in compressing the cylinder charge is not returned to the crankshaft during the expansion stroke. The energy being lost is slow the vehicle on level roads and help control vehicle speeds on downhill grades.
- The power required to operate the brake is obtained from the engine's camshaft and rocker arms (B). The motion of the exhaust rocker arm is utilized to open the exhaust valve and blow-down the cylinder.
- Energizing the solenoid valve (C) permits engine lube oil to flow under pressure (D, E) through the control valve to both the master piston (G) and slave piston (H).
- Oil pressure causes the master piston (G) to move down, coming to rest on the corresponding exhaust rocker arm (B).

- The exhaust rocker arm moves up (as in normal injector cycle), forcing the master piston upward and creating a high pressure oil flow (J) to the slave piston of the braking cylinder. The check ball valve (K) in the control valve traps high pressure oil in the master/slave piston system.
- Under the influence of the high pressure oil flow, the slave piston moves down, momentarily opening the exhaust valves at a pre-determined amount of slave stroke. The adjusting screw (L) uncovers a passageway in the slave piston, thus allowing oil to flow back to the underside of the control valve, where it is stored for the next cycle. Prior to top dead center position, the exhaust valve is forced open, releasing the compressed cylinder air to the exhaust manifold.
- Compressed air escapes into the atmosphere, completing a compression braking cycle.

NOTE:
Never remove any engine brake component with engine running. Personal injury may result**.**

- Engine Brake is a relatively trouble free device. However, inspections and routine maintenance are necessary to assure proper operation.



Engine brake operation

3.6.3. Engine brake disassemble and valve adjustment

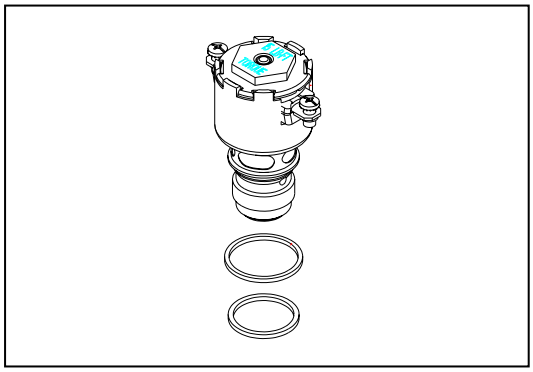
- Clean engine thoroughly. Remove all accessory components required to remove cylinder head covers. Set entire overhead as with no brake, refer to engine manual procedures. (intake valve and exhaust valve)

3.6.4. Engine brake operation check

- The engine brake installation is now completed. The following procedures should be made.
  1) Start the engine and allow to running for a few minutes.
  2) Manually activate and release the engine brake solenoid several times to allow the housing to be filled with oil. This is done by depressing the solenoid disc or inserting a small rod into the hole on the top of the solenoid..
  3) Watch the master piston to be sure it is moving down onto the injector rocker arm pad.
  4) Watch the slave piston assembly. It should move down to contact the pin in the exhaust valve screw.
  5) Repeat steps 2-4 for each housing to insure proper function.
  6) Shut down engine. Clean the gasket surface for the cover.

3.6.5. Solenoid valve

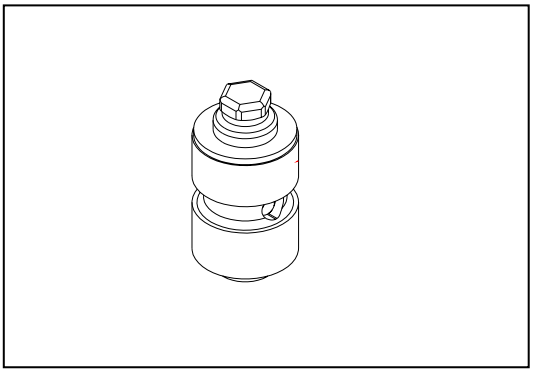
CAUTION:
Do not disassemble or tamper with the solenoid valve. Engine damage could result. The solenoid valve is not field serviceable.



1. Disconnect solenoid harness. Using socket and extension, unscrew solenoid valve.
2. Remove and discard the two rubber seal rings.
3. Wash out the solenoid valve with approved cleaning solvent. Use a brush to clean the oil screen. When clean, dry the valve with compressed air.
4. Clean out the solenoid valve bore in the housing. Use clean paper towels. Never use rags as they may leave lint and residue, which can plug the oil passageways.
5. Coat the new solenoid rings with clean engine oil. Install the upper and lower seal rings on the solenoid body.
6. Be sure the seals are seated properly and carefully screw the solenoid into the housing without unseating the seals. Be careful not to twist the seals while installing.

Solenoid valve torque	20 Nm

3.6.6. Control valve

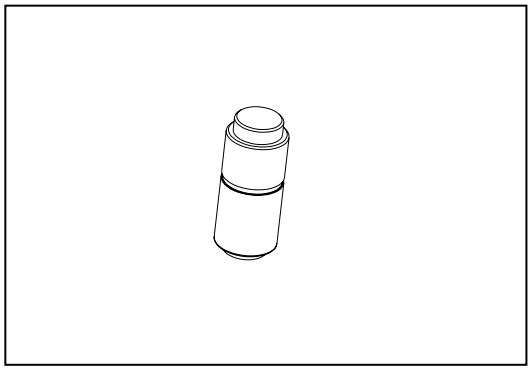


CAUTION:
Remove control valve covers carefully to avoid personal injury. Control valve covers are under load from the control valve springs.

1. Apply pressure on the control valve cover and remove the hex head capscrew.
2. Slowly remove cover until spring pressure ceases then remove the two control valve springs.
3. Using needle-nose pliers, reach into the bore and grasp the stem of the control valve. Remove the control valve.
4. Wash the control valves with approved cleaning solvent. Push a wire into the hole in the base of the valve to the distance required to ensure that the ball check is free. The ball should lift with light pressure on the wire. If the ball is stuck, replace the control valve. Dry the valve with compressed air with wipe clean with a paper towel.
5. Thoroughly clean the control valve bore in the housing using clean paper towels. Never use rags as they may leave lint and residue, which can plug the oil passageways.
6. Coat the parts with clean engine oil. Reassemble parts, reversing the removal procedure.

3.6.7. Master piston

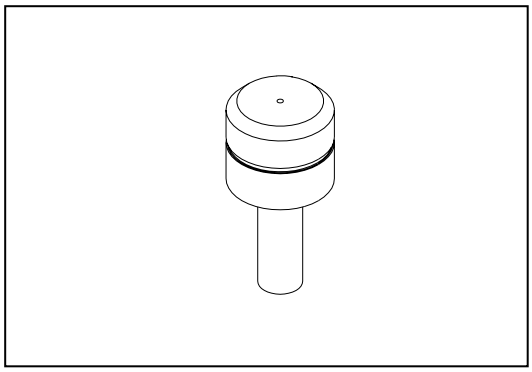
CAUTION:
Wear safety glasses. The master piston spring is under strong compression. Use caution when removing the retaining ring and cover. If the spring is accidentally discharged, personal injury may result.



1. Remove the capscrew, washer, spring and master piston from the brake housing.
2. If the hard facing is damaged, inspect the corresponding rocker arm adjusting screws for excessive wear or pitting.
3. If binding occurs, check for damage to the master piston or bore. Replace as needed.
4. Reassemble in reverse order. When tightening the capscrew, make certain the two spring tabs do not interface with sides of the master piston center raised portion.

Master piston tighten torque	12.5 Nm

3.6.8. Slave piston



CAUTION:

Wear safety glasses. The slave piston is retained by springs that are under heavy compression. If the following instructions are not followed and proper tools not used, the springs will be discharged with enough force to cause personal injury.

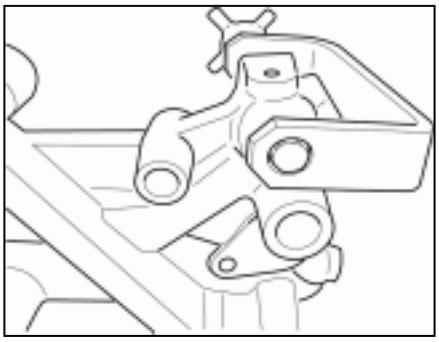
1. Remove the locknut on the slave piston adjusting screw. Back out the adjusting screw until the slave piston is fully retracted.
2. Place the hole in the slave piston clamp fixture over the slave piston adjusting screw. Replace locknut. Finger tighten to hold fixture securely.
3. While holding the fixture in position, screw the holder down over the slave piston until the spring retainer is contacted.
4. Turn the handle slowly until the retainer is depressed to about 1 mm, relieving pressure against the retaining ring.

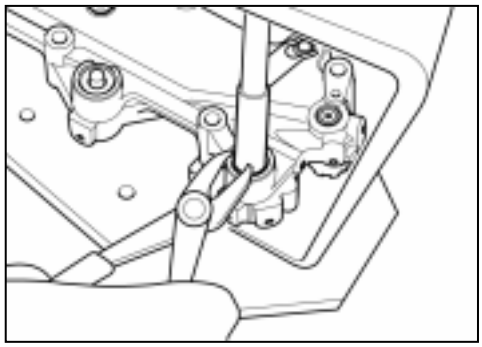
5. Remove the retaining ring using retaining ring pliers. Back out the holder until the springs are loose. Remove the fixture.
6. Remove all components, ensuring there is no binding or burrs. Clean in an approved cleaning solvent. Inspect parts and replace as necessary.

CAUTION:

Be sure components are reassembled in proper order. The retainer must be installed with the key through the slot in the slave piston. Install the slave piston with the open area toward the center of the housing. The open area of the slave piston is for rocker arm clearance.

7. Use the clamp fixture to reinstall the piston and springs. Be sure the retaining rings are placed on the retainer before screwing the clamp-holder down.
8. Compress the slave piston springs down until the retainer is about 1 mm below the retaining ring groove. Reinstall the retaining ring. Be sure the retaining ring is fully seated in the groove.
9. Rotate the retaining ring ears 90 degree counterclockwise from the large rocker arm clearance gap in the housing.
10. Remove the clamp fixture slowly to ensure proper seating of retaining ring.





3.6.9. Troubleshooting

1) Inspection procedures

If the engine brake is not operating properly, the first step is to identify whether the problem is electrical or mechanical. First check for correct electrical operation of the brake, and then examine mechanical components as necessary.

2) Electrical power supply

Vehicle supply voltage must be at least 18 VDC at the solenoid valves when the engine brake is turned on. If voltage is insufficient, or an electrical short circuit exists, these problems must be corrected before the engine brake will operate properly.

3) Solenoid valve

If there is electrical power at the solenoid valve but the engine brake housing does not operate, the solenoid valve may be defective. The solenoid valve cannot be overhauled or repaired. If the solenoid valve is defective, it must be replaced.

CAUTION:
Do not touch the electrical connection when a solenoid is energized. Electrical shock could result.

4) Resistance check

Disconnect the wires from the solenoid valve. Connect an ohm meter to the terminals of the solenoid valve and measure the electrical resistance of the valve. Resistance should be 32.6 to 39.8 Ohms. If resistance is not within this range, replace the solenoid valve.

Solenoid resistance value	32.6 ~ 39.8 Ω less

5) Visual check

If the proper meters are not available, check for proper solenoid valve operation as follows: connect a wire supplying 24-volts to either solenoid electrical terminal. Connect the other electrical terminal to a good chassis ground. When electrical power is applied, make sure the pin on the top of the solenoid valve depresses. If the pin does not depress, replace the solenoid.

6) Mechanical or hydraulic

If the solenoid valves are working properly, the problem is likely inadequate oil supply or mechanical problem.

7) Engine brake housing oil pressure check

Oil pressure must be sufficient to compress the control valve return spring and the master piston return spring. Oil supply pressure that only partially compresses these springs will result in little or no brake performance.

3.6.10. General problem

1) Engine fails to start

Possible cause : Solenoid valve stuck in open position.

Correction : Ensure that electrical current is off to engine brakes. If solenoid valve remains open (pin down) with current off, replace solenoid valve.

2) Engine brake will not operate

Possible cause : No electrical current to solenoids.

Correction **:** Ensure electrical current is supplied from ECU. Look for short circuit in wiring. Replace any broken wires. Check solenoid for signs of shorting, replace if necessary. Replace fuse or circuit breaker if necessary.

CAUTION:
Do not touch electrical connection when system is energized.

Possible cause : Incorrect electrical power source.

Correction **:** Power supply must be a minimum of 18 VDC at the sole noid.

Possible cause : Low engine oil pressure.

Correction: Determine oil pressure at engine brakes using procedures given in this manual. If oil pressure is below specifications, engine should be repaired.

3) Engine brake activates with switches off or stays

Possible cause : High oil pressure (above 7 bar) will force solenoid valve o pen.

Correction **:** Repair engine so that oil supply is within specifications.

Possible cause : Control valve Inner spring broken.

Correction **:** Replace inner spring.

Possible cause **:** One or more control valves stuck in “on” or up position.

Correction **:** Check control valves for binding. Remove and clean or re place if necessary. Inspect lube oil for contaminants.

Possible cause : Solenoid valve sticking in “on” position.
Correction : If solenoid valve pin remains down with no electric current being supplied, replace solenoid valve.

Possible cause : Center solenoid seal ring damaged. Allows oil to enter b rake with solenoid valve closed.
Correction : Remove solenoid and replace all seal rings.

Possible cause : Solenoid valve exhaust plugged.
Correction : Remove any restrictions at exhaust (bottom) of solenoid valve.

4) Engine brake slow to operate or weak in effect

Possible cause : Improper slave piston adjustment or slave piston binding i n bore.
Correction: Readjust in accordance with procedures in this manual. Ensure that slave piston responds smoothly to the adjusting screw by loosening jam nut and turning the screw through its full travel for full slave piston motion. Make sure piston travels full range without binding or sticking

CAUTION:
Remove slave piston carefully when disassembly is necessary. Use the slave piston removal tool. Slave piston springs are under heavy compression.

Possible cause : Lower solenoid seal damaged, allowing oil to exit housing.
Correction : Remove solenoid valve and replace all seal rings.

Possible cause : Solenoid screen clogged, stopping supply of oil to brake.
Correction : Remove solenoid valve and clean or replace screen.

Possible cause : Master piston not moving in bore.
Correction : Inspect master piston and bore for scoring or burrs. If any present, clean surface with fine abrasive cloth. If u nable to remove burrs, replace piston or housing. Inspe ct lube oil for signs of contaminants, If any are present, replace oil and filters and correct cause of contaminatio n.

Possible cause : Control valves binding in housing bore.
Correction : Remove control valve. If body is scored, replace control valve. Check for contaminants in lube oil. Clean housing and control valve. If binding continues, replace housing.

5) Oil pressure dropping below minimum required for engine brake operation.

Possible cause : Upper solenoid seal ring damaged.

Correction : Remove solenoid. Inspect seal ring and replace all se al rings.

Possible cause : Aeration of lubricating oil.

Correction : Check for aeration of the oil. Activate, then deactivate engine brake.

3.7. Engine Diagnostic

3.7.1. Method of confirmation for the fault code

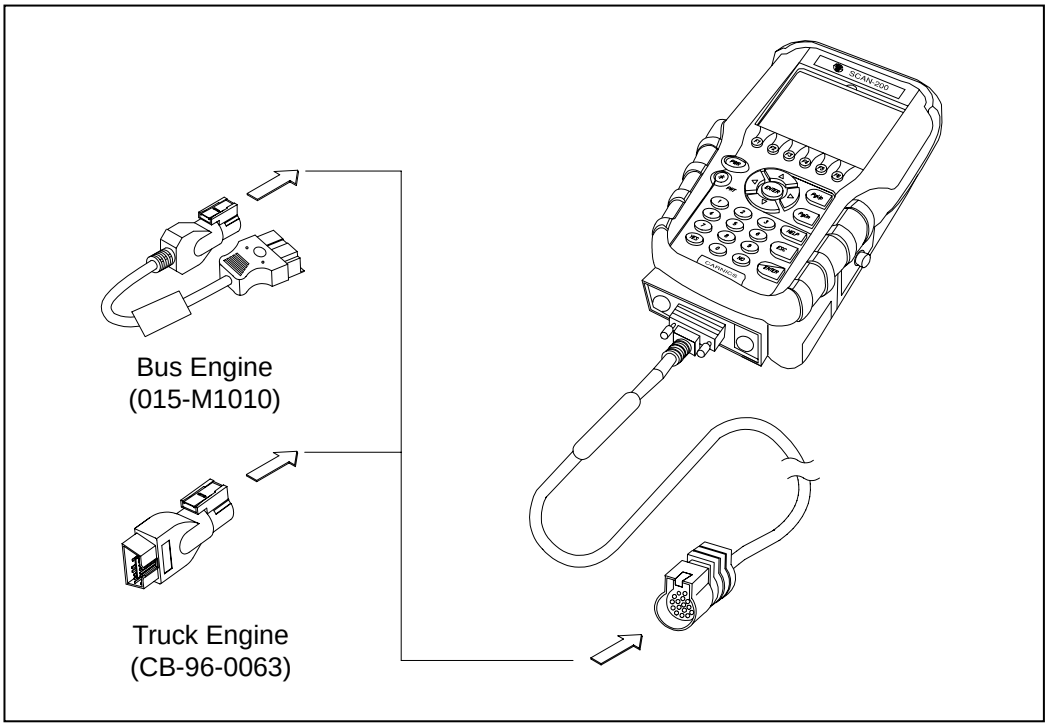
The method of performing the DV11 engine diagnostic are method by using the SCAN-200 and method of confirming the indicator code using the blinking times of the vehicle's engine indicator lamp.

DAEWOO recommend the using the SCAN-200, because it can be worked speedy and correctly.

3.7.2. Method 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.

Please know well the user's manual to shorten the time and to apply the diagnostic tool before use the SCAN-200. At the time of using the SCAN-200, if use together SCAN-200 manual and maintenance manual for the maintenance, the effect should be increased more and more.



3.7.3. Engine fault code and occurring condition

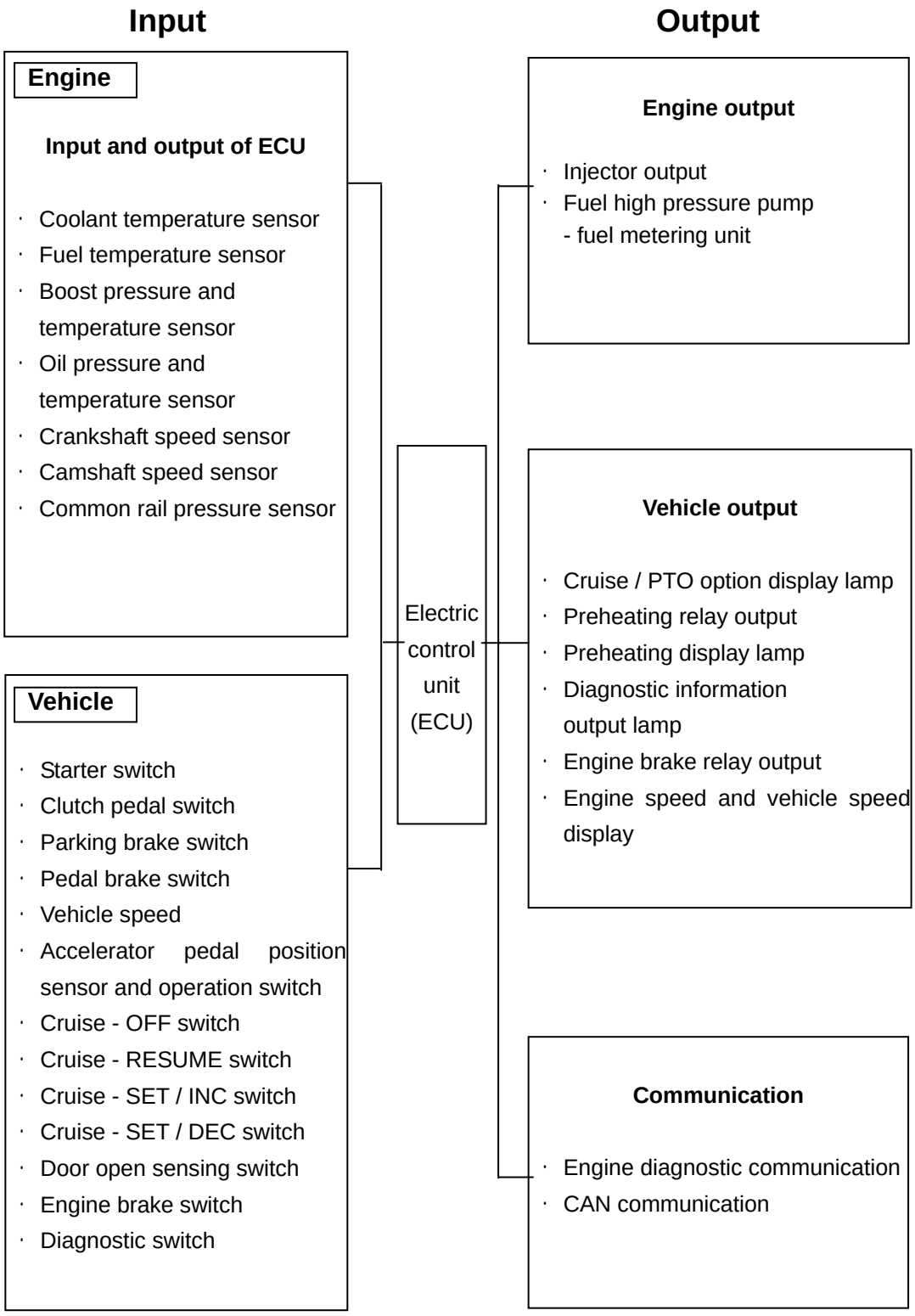
Fault code	Contents of trouble	Lamp	Condition of occurring
1.1	Relation to coolant temperature sensor is abnormal	C	* Sensor / harness is abnormal * Coolant temperature is too high
1.2	Relation to fuel temperature sensor is abnormal	C	* Sensor / harness is abnormal * Fuel temperature is too high
1.3	Relation to boost temperature sensor is abnormal	C	* Sensor / harness is abnormal * Intake temperature is excessive after intercooler * Engine / turbocharger / intercooler is abnormal
1.4	Relation to boost pressure sensor is abnormal	C	* Sensor / harness is abnormal * Intake pressure is excessive after intercooler * Engine / turbocharger / intercooler is abnormal
1.6	Atmosphere pressure sensor is abnormal	C	Atmosphere pressure sensor attached to ECU is abnormal ECU
1.7	Relation to oil temperature sensor is abnormal	N	* Sensor / harness is abnormal * Oil temperature is too high
1.8	Relation to oil pressure sensor is abnormal	C	* Sensor/harness is abnormal * Oil pressure is abnormal (Leakage etc.)
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	B	* Foot brake and accelerator pedal is operated simultaneously on driving * Foot brake switch / harness is abnormal
2.5	Vehicle speed sensor or vehicle meter is abnormal	C	Sensor / vehicle tachometer / harness is abnormal
2.7	Relation to clutch pedal is abnormal	C	Clutch pedal switch / harness is abnormal
2.8	Relation to pedal brake switch is abnormal	C	Pedal brake switch / harness is abnormal
2.9	Relation to cruise control switch is abnormal	C	Switch or harness is abnormal
3.2	Common rail pressure is excessive fluctuation	B	Common rail pressure is abnormal
3.6	Input signal is abnormal at operating ASR	N	ASR connector / harness is abnormal
3.7	CAN signal of ASR and Auto T/M is abnormal	N	Connector of ASR and Auto T/M / harness is abnormal
3.8	Warning which engine speed is excessive	C	Engine over-speed
3.9	ECU inner relay is abnormal	B	* ECU inner main relay is abnormal * Power supplying is abnormal
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 * Sensor gap is abnormal
4.3	Relation to cam shaft speed sensor is abnormal	C	* Sensor / harness is abnormal * 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

Fault code	Contents of trouble	Lamp	Condition of occurring
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	N	Battery voltage is abnormal : ECU, battery and alternator is abnormal
4.9	Supplying voltage of injector (#1,5,3) is abnormal	B	* Injector cable / connector is abnormal or ECU is trouble
5.1	Supplying voltage of injector (#6,2,4) is abnormal	B	
5.8	Relation to connecting of injector #1 harness is abnormal	B	* Injector cable / connector is abnormal
5.9	Relation to connecting of injector #5 harness is abnormal	B	
6.1	Relation to connecting of injector #3 harness is abnormal	B	
6.2	Relation to connecting of injector #6 harness is abnormal	B	
6.3	Relation to connecting of injector #2 harness is abnormal	B	
6.4	Relation to connecting of injector #4 harness is abnormal	B	
6.6	Relation to air heater lamp is abnormal	N	Lamp / harness is abnormal
7.1	Relation to diagnostic lamp is abnormal	N	Lamp / harness is abnormal
7.2	Air heater operation relay is abnormal	C	Air heater relay / harness is abnormal
7.3	Engine brake #2 relay is abnormal	N	#2 engine brake solenoid / connector / harness is abnormal
7.5	Engine brake #1 relay is abnormal	C	#1 engine brake solenoid / connector / harness is abnormal
8.3	Relation to high pressure pump control is abnormal	C	Fuel metering unit of high pressure pump / harness is abnormal
8.6	Engine speed meter of vehicle is abnormal	N	Engine tachometer of vehicle/ harness is abnormal
9.1	Abnormal starting	B	Starting procedure is abnormal, ECU is abnormal, power supplying is abnormal
9.2	Ignition of #1 cylinder is not good	C	*Injector is abnormal, compression pressure is a drop, camshaft / crankshaft speed sensor signal is abnormal
9.3	Ignition of #5 cylinder is not good	C	
9.4	Ignition of #3 cylinder is not good	C	
9.5	Ignition of #6 cylinder is not good	C	
9.6	Ignition of #2 cylinder is not good	C	
9.7	Ignition of #4 cylinder is not good	C	
9.8	Ignition of several cylinder is not good	C	
9.9	Injector is opened too long	C	Opening time of injector is excessive from standard values
10.1	Engine speed is abnormal (Additional function)	C	Error is occurred when calculate engine speed using crankshaft / camshaft speed sensor
10.2	Relation to accelerator pedal is abnormal	B	Foot brake and accelerator pedal is operated simultaneously when vehicle is started
10.3	Cooling fan is abnormal	C	Sensor or connector harness is abnormal
10.4	Fuel pressure is abnormal	B	Fluctuation of fuel pressure in common rail is excessive
11.1	Smooth running control is abnormal	N	Cylinder's deflection of injector solenoid is excessive
11.2	Smooth running control is abnormal	N	Cylinder's deflection of injector solenoid is excessive
11.3	Smooth running control is abnormal	N	Cylinder's deflection of injector solenoid is excessive

Fault code	Contents of trouble	Lamp	Condition of occurring
11.4	Smooth running control is abnormal	N	Cylinder's deflection of injector solenoid is excessive
11.5	Smooth running control is abnormal	N	Cylinder's deflection of injector solenoid is excessive
11.6	Smooth running control is abnormal	N	Cylinder's deflection of injector solenoid is excessive

* 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.

3.7.4. Input and output of the ECU



3.8. Operating condition of the ECU

3.8.1. 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.

3.8.2. Vehicle running

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

3.8.3. 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.

3.8.4. Engine brake control

- Engine brake is worked by the operation of the engine brake switch in the dashboard.
  - Engine brake : There is section of one shift and two shift.
    - One step : the function of the braking is operated at the three cylinders only.
    - Two step : the function of the braking is operated at the six cylinders all.

- **Operating method**
  Engine brake switch : [first step] , [second step] , [OFF]

- **Operating condition**
  - Engine brake switch : normal
  - Vehicle speed : more than specified speed.
  - Engine speed : more than specified speed.
  - Oil temperature : more than specified temperature.

- **Free condition**
  - Engine speed : less than specified speed.
  - Vehicle speed : less than specified speed.
  - Accelerator pedal : depressed or pedal trouble.
  - Clutch pedal : depressed or pedal trouble.
  - Oil temperature : less than specified value.

3.8.5. Cruise control

- Provide the driver with ability to control in order to travel and maintain a setting speed.
- **Operation switch : [SET/INC], [SET/DEC] , [RESUME] , [CRUISE OFF]**

- **Operating method**
  - Range of vehicle speed of possible cruise control : 40 - 100 km/h
  - Cruise control is standard by when the vehicle speed is more than 40km/h, cruise control is disabled when the vehicle speed is less than 40km/h.
  - Setting of the cruise control by using the accelerator pedal.
    - After the vehicle speed is raised by pressing the accelerator pedal, pressed switch [SET] at the time of desired vehicle speed.
    - Switch [SET/INC] or [SET/DEC] have the functions of [SET] all.
  - Setting of raise / drop by using the switch during cruise running.
    - Adjusting for raising of cruise vehicle speed : switch [SET/INC] is pressed.
    - Adjusting for dropping of cruise vehicle speed : switch [SET/DEC] is depressed.
    - Switch [SET/INC], [SET/DEC] is depressed once, is increased as one step, and is increased continuously when is kept on depressing.

- Cruise control disablement : switch [CRUISE OFF] is depressed.
  - At this time, the vehicle speed is controlled at indicated speed of the accelerator pedal.

- The state of the cruise running is disabled temporarily when the accelerator pedal is depressed. When the vehicle speed become at the set speed before of the cruise running because of reducing speed after the vehicle speed is increased, the function of cruise is maintained once more at that speed.

- [RESUME] switch
  - This switch is depressed at the vehicle speed more than 40km/h after the cruise control is disabled, return to the last cruise set speed of the vehicle, then the cruise control is operated.
  - After [CRUISE OFF], the switch [RESUME] is not operated by depressing when the cruise vehicle speed is not reset.
- When the driver is descending and accelerating steep a grade in cruise driving, the engine brake is automatically operated to maintain the set speed of the vehicle.

- **Disablement condition**
  - Cruise control related switch : trouble
  - Pedal brake : depressed or trouble
  - Clutch pedal : depressed
  - Engine brake : operated
  - Bus door : opened
  - Vehicle speed : less than 40 km/h
  - Vehicle speed sensor : trouble
  - Engine speed : more than high idle speed
  - Gear shift : too low
  - Reduction level : rapid reduced
  - Case of out from specified control range
    - Hill Up : when the gear shift is needed by the gradeability
    - Hill Down : when the control is not operated sufficiently with the engine brake.

3.8.6 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.

3.8.7. 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.

3.8.8. 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.

3.8.9. 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.

3.8.10. 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.

3.8.11. 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.

3.8.12. Power take off (PTO)

- Power take off (PTO) of the operation mode is controlled.

- **Operation condition**
  - Cruise control switch : no trouble
  - Brake pedal : no trouble, not depressed
  - Engine brake switch : off
  - Parking brake : operated
  - Clutch pedal : not depressed
  - Vehicle speed : stop

- **Operation method**
  - Operation of PTO is possible by using the cruise control switch.

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 DAEWOO vehicle 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 DAEWOO recommended the fuel and lubrication oil and coolant do not used, DAEWOO do not guarantee the field claim.

4.2. Breaking-In

- DAEWOO 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, 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

- 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 (API CI-4)

- **Engine oil capacity**

Engine oil capacity				
Model		In oil pan		Total (lit)
		Max (lit)	Min (lit)	
DV11	Bus	34	26	37
	Truck	32	26	35

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

4.3.2. Temperature of cooling water

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

4.3.3. 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 10°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.

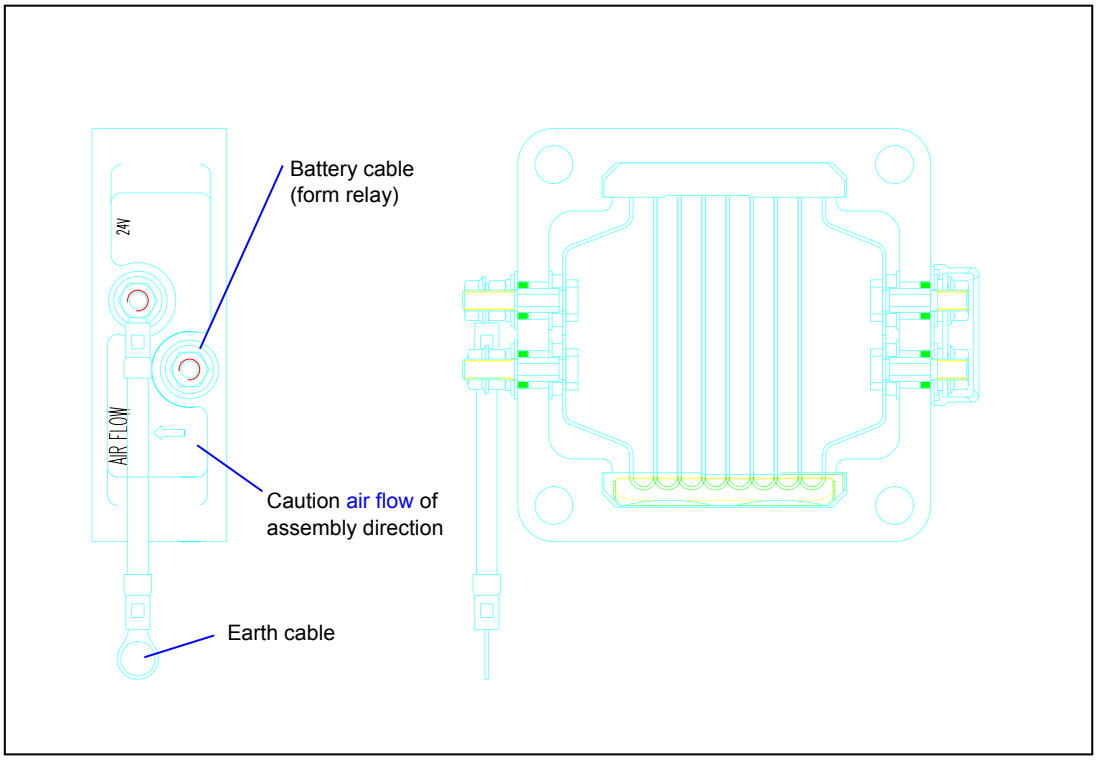
- If the coolant temperature is above 10°C, air eater needs not be heated.

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	DC22V (120A ±10%)
Rated current	2.64 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.

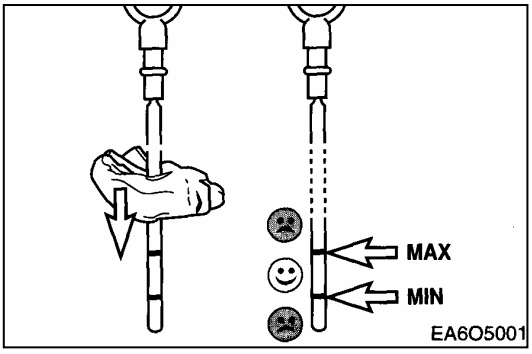
- Daily inspections in bellow figure should be checked every day.
- The maintenance should be executed thoroughly at regular intervals.
  (refer to appendix “General engine inspection cycle”.)

4.6.2. Exchanging of lubrication oil

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

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

4.6.3. Oil level gauge



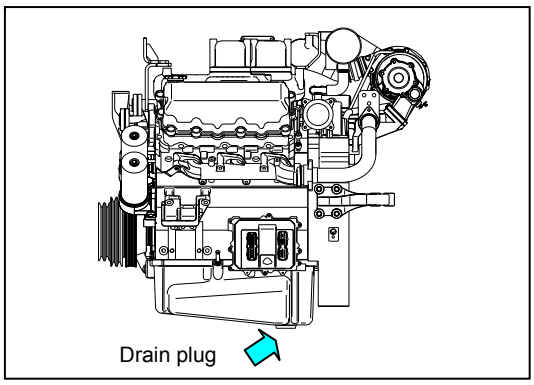
- Check the oil level in the engine sump daily with an oil level gauge.
- The notches in oil level gauge must indicate the oil level between the max.
- The oil level should be checked with the engine horizontal and only after it has been shut down for about 5 minutes.
- Examining the viscosity and the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

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

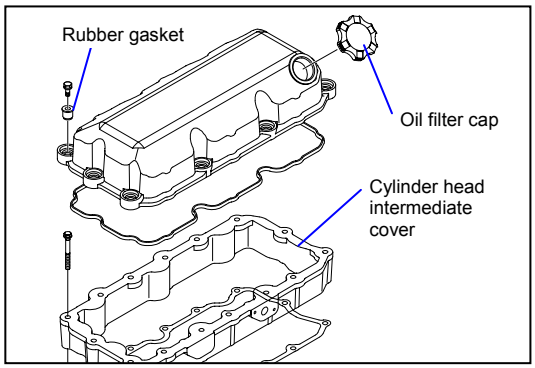
4.6.4. Oil exchange procedure

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

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



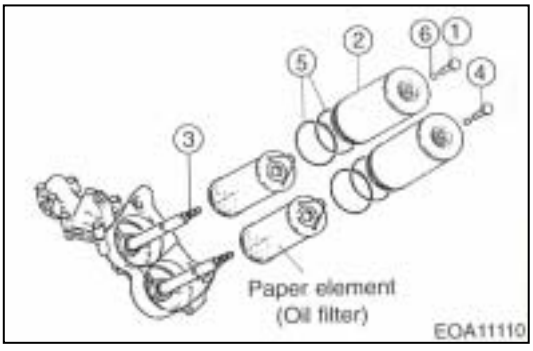
- Refill with new engine oil at the oil filler neck on the head cover and the lubricating oil in accordance with the oil capacity of the engine through oil filler.
- Be careful about the mixing of dust or contaminator during the supplement of oil. Then confirm that oil level gauge indicates the vicinity of its maximum level.

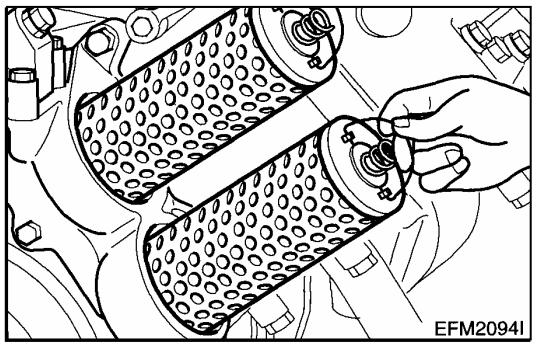


- For a few minutes, operate the engine at idling in order to circulate oil through lubrication system.
- Thereafter shut down the engine. After waiting for about 10 minutes measure the quantity of oil and refill the additional oil if necessary.

4.6.5. Replacement of oil filter cartridge

- Loosen in order the fixing bolts ①④ when the engine oil is warm. (housing ② is released as 10-15mm by the spring tension.)





- Allow on interval of 3-4 minutes until the oil in the housing ② is drained automatically. (is drained automatically thorough the engine by-passes to the oil pan)
- After remove the housing ②, wash it cleanly, and remove the used filter element by catching the handle loop.
- Assemble the filter element after replace the new one. (The genuine filter element should be used.)
- Insert the O-ring ⑤ to the housing. (The filter element and O-ring and sealing are supplied simultaneously when the service components.)
- Assemble the oil filter housing ② to the oil filter head.
- Assemble the oil filter element a'ssy after insert the sealing ⑥ to the fixing bolts ①④.

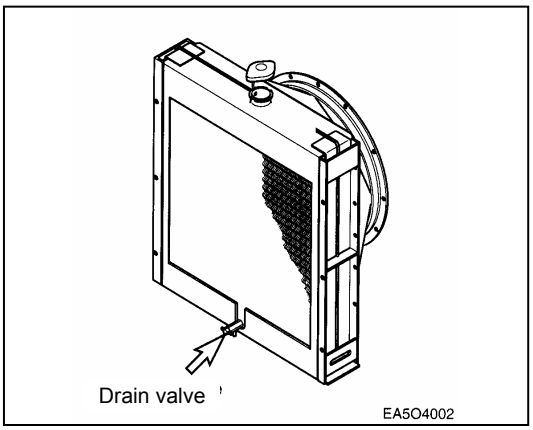
Caution:
Do not forget to assemble the drain plug after the engine oil is drained.

Caution:

DAEWOO genuine part should be used when the oil filter element is replaced

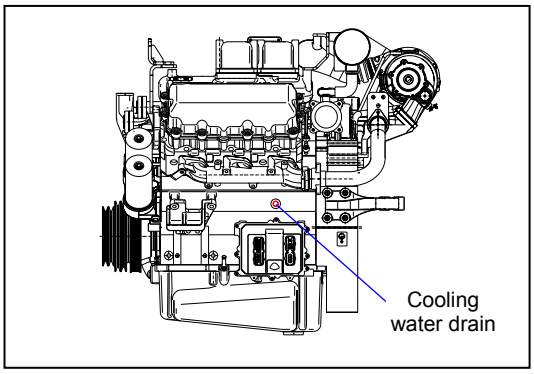
4.7. Cooling System

- The coolant must be changed at intervals of 40,000km (1,200 hour) operation or six months whichever comes first. If the coolant is being fouled greatly, it will lead an engine overheat or coolant blow off from the expansion tank.



4.7.1. Coolant draining

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



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.

4.8. Adjustment of valve clearance

4.8.1. General information

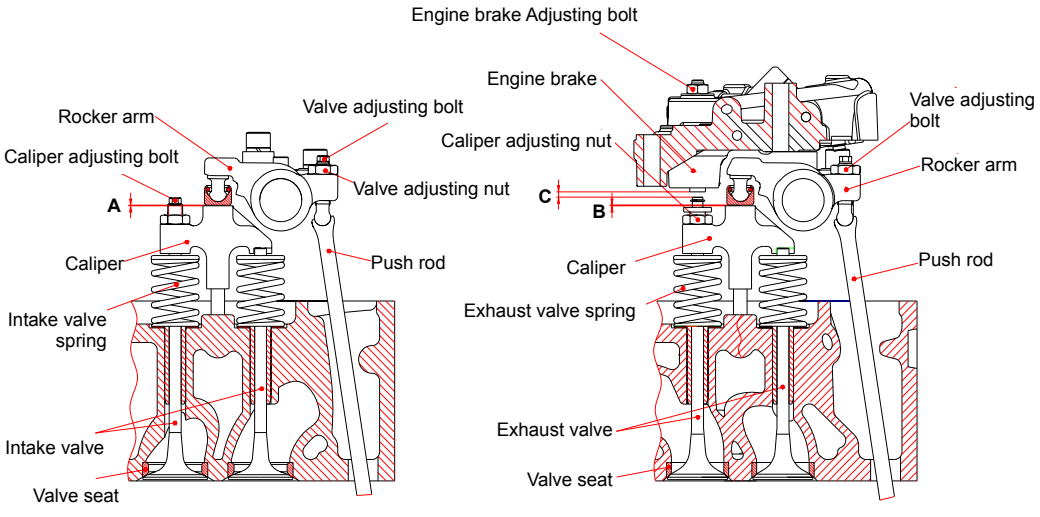
The valve clearances are to be adjusted at the times of the following situations.

- When the engine is overhauled and the cylinder heads are disassembled.
- When severe noise comes from valve train.
- When the engine is not normally operated, even though there is no trouble in the fuel system.

4.8.2. 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 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 (A)	Exhaust valve (B)	Engine brake (C)
DV11	0.4 mm	0.5 mm	1.5 mm

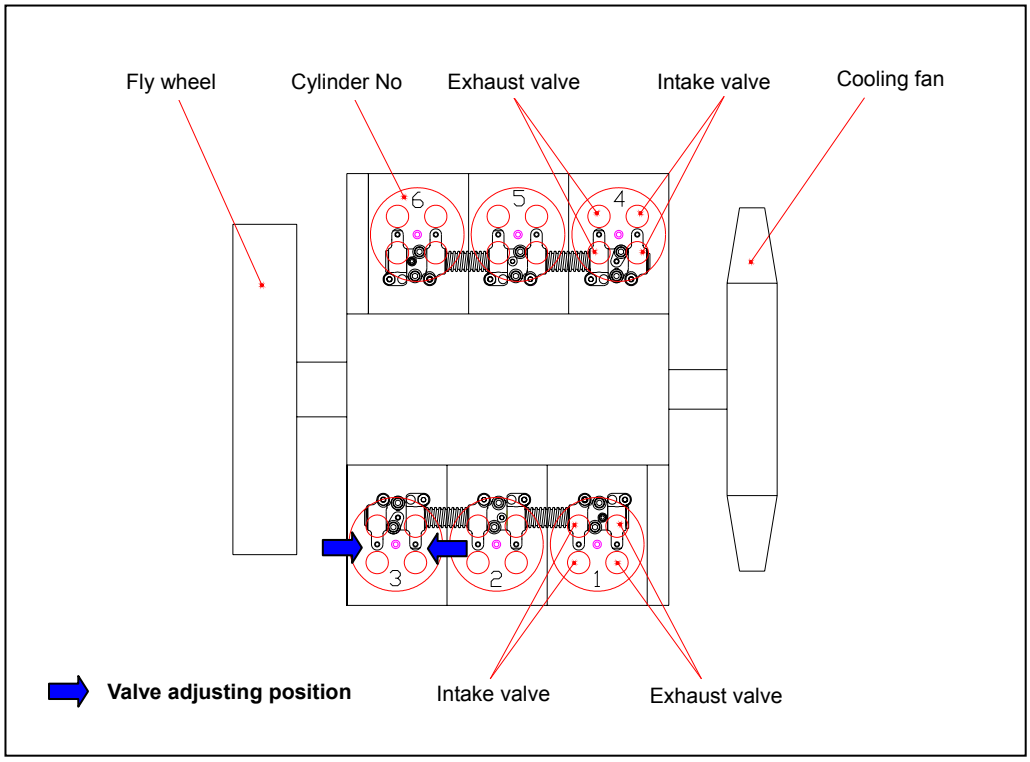


Intake valve adjusting **Exhaust valve, engine brake adjusting**

< Adjust the valve clearance as following order. >

1) Rotating the engine, let #6 cylinder overlap.
2) In time that #1 cylinder become the state of top dead center, adjust the valve clearance corresponding to " ◎ " of following lists.
3) Rotating the crankshaft by 90° rotation, adjust the valve clearance corresponding to " ⊙ ".
4) Rotating the crankshaft by 1 rotation (360° rotation), let #1 cylinder overlap.
5) In time that #5 cylinder become the state of top dead center, adjust the valve clearance corresponding to " ● " of following lists.
6) Rotating the crankshaft by 450° rotation, adjust the valve clearance corresponding to " ○ ".
7) After rechecking the valve clearance, readjust if necessary.

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



- **Adjusting of valves (Type 1)**

Cylinder No / Valve adjusting	1		2		3		4		5		6	
	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
#1 cylinder top dead center (#5 cylinder valve overlap)	◎	◎	◎					◎			◎	
Crankshaft 90° revolution							⊙					
360° revolution #5 cylinder top dead center (#1 cylinder valve overlap)				●	●				●	●		●
Crank shaft 450° revolution						○						

- **Adjusting of valves (Type 2)**

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

When each cylinder is valve overlap (Explosion cylinder No. order)	**1**	**4**	**2**	**5**	**3**	**6**
Valve adjusting cylinder No.	**5**	**3**	**6**	**1**	**4**	**2**

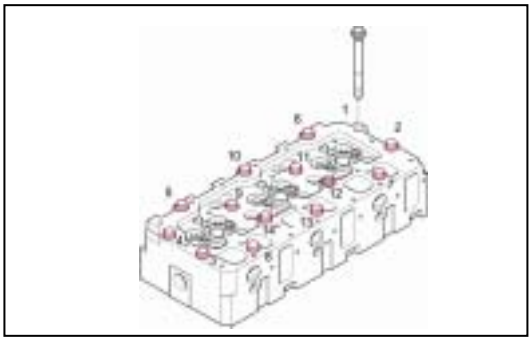
- Adjusting of engine brake (Adjusting of slave piston)

Cylinder No / Slave piston adjusting	Engine brake slave piston adjusting no.		
#1 cylinder top dead center (#5 cylinder valve overlap)	**1**	**2**	**4**
360° revolution (#1 cylinder valve overlap)	**3**	**5**	**6**

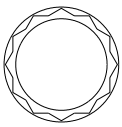
* When adjust slave piston of the engine brake, adjust only exhaust valve correspond to the cylinder number.

4.9. Tightening the Cylinder Head Bolts

- Coat the engine oil on the cylinder head bolt, assemble with specified torque according to the order of the assembling.



< Cylinder head bolts >

Spec	 M16×2.0×176
Torque	1st : 8kg.m 2nd : 180° 2rd : 150° (Angle torque)

< Cylinder head bolt's Tightening Order >

(1) **First step : Coat the bolts with engine oil.**

(2) Second step: Screw down 1 2 threads

(3) Third step : Tighten with about 8 kg.m by wrench

(4) Fourth step : Tighten with about 15kg.m by torque wrench

(5) Fifth step : Tighten with rotating angle method 90°

(6) Sixth step : Tighten with rotating angle method 90°

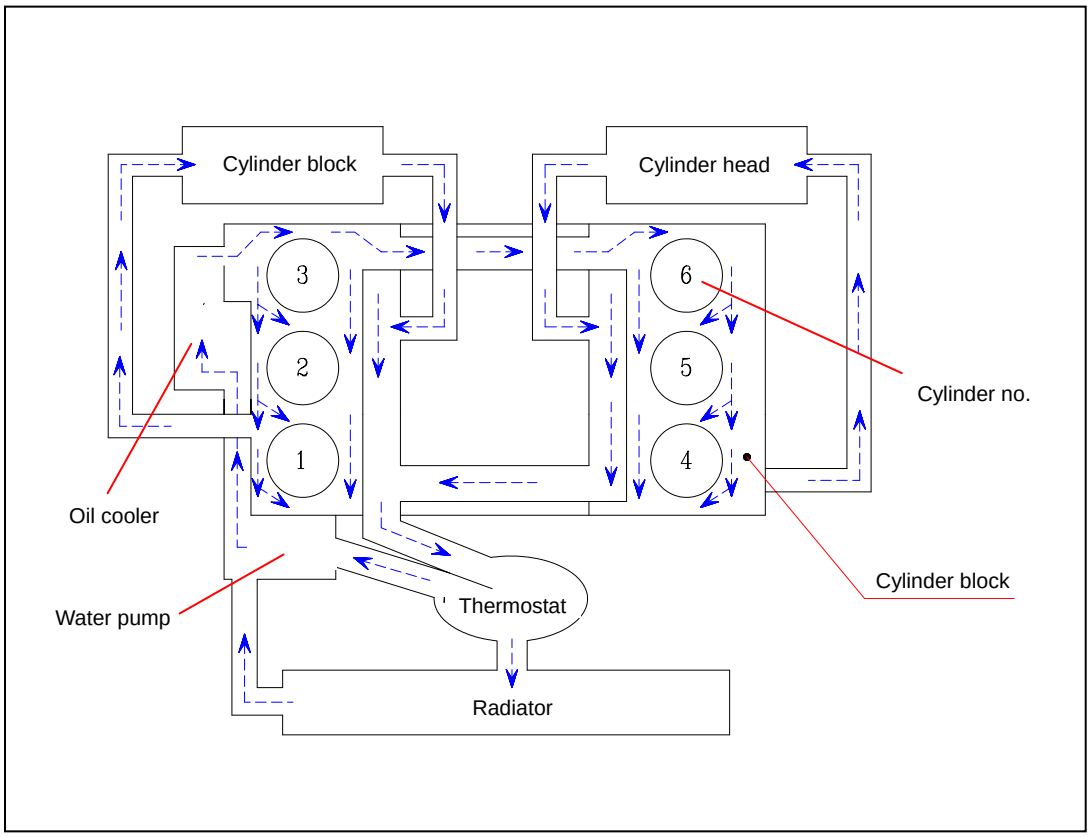
(7) Seven step : Tighten with final additional rotating angle method 60°

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

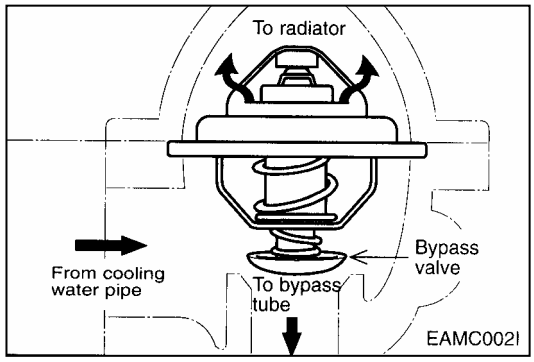
Item		Specification	
1. Water pump	Type	Centrifugal type	
	Pumping speed	3,500 rpm	
	Delivery	about 452 liter/min or more	
	Pumping back pressure	Bellow 1.8 bar	
2. Thermostat	Operating temperature	79°C type	83°C type
	Valve lift	8mm or more (at 94°C)	8mm or more (at 95°C)
	Operating temperature	79 ~ 94°C	83 ~ 95°C
3. Cooling fan and belt			
Fan diameter – Number of blades		Truck : ϕ711.2mm – 9	
Fan belt tension		Auto tensioner	

5.1.3. Thermostat

- **General descriptions and main data**

The thermostat maintains a constant temperature of coolant (90 ~ 95 °C) and improves thermal efficiency of the engine by preventing heat loss.

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

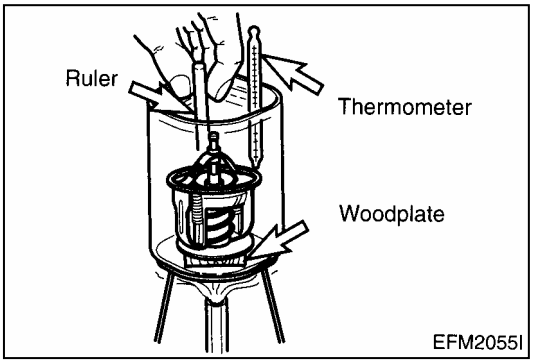


Item	In moderate climates	In tropical climates
Type	Wax-pallet type	
Open at	83 °C	71 °C
Open wide at	95 °C	85 °C
Valve lift	8 mm or more	8 mm or more

- **Inspecting**

  (1) Check the wax pallet and spring for damage.

  (2) Put the thermostat in a container of water, then heat the water slowly and check temperature with a thermometer. If the valve lift is 0.1 mm (starting to open) at temperature of 83 °C and 8 mm or more (opening wide) at temperature of 95°C, the thermostat is normal.



- **Replacing thermostat and precautions for handling**

  (1) Precautions for handling

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

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

  (3) Replacing thermostat

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

5.1.4 Diagnostics and troubleshooting

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

5.2. 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 injection pump in order to ensure normal engine performance.

- **Specifications**

Item	Specifications	Item	Specifications
Lubricating system	Forced pressure circulation	Oil filter type	Full flow
Oil pump type	Gear type	Bypass for cartridge	
Relief valve opening pressure	10 -1.5 kg/cm^2	Valve opening pressure	1.8~2.4 kg/cm^2
Oil cooler bypass		Bypass for entire oil filter	
Opening pressure	5 +1 kg/cm^2	Valve opening pressure	4.3 4.7 kg/cm^2
Adjusting valve for spray nozzle			
Opening pressure	1.5~1.8 kg/cm^2		

5.2.2. Oil pump

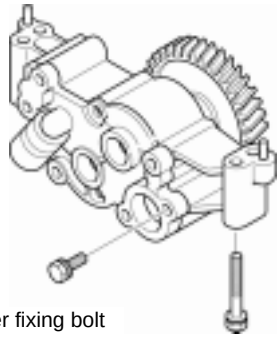
- **Disassembly**

(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

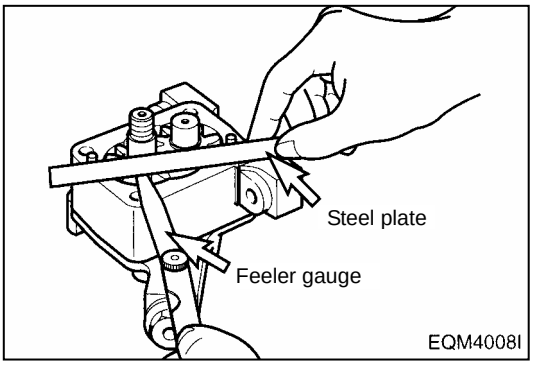

Cover fixing bolt

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.

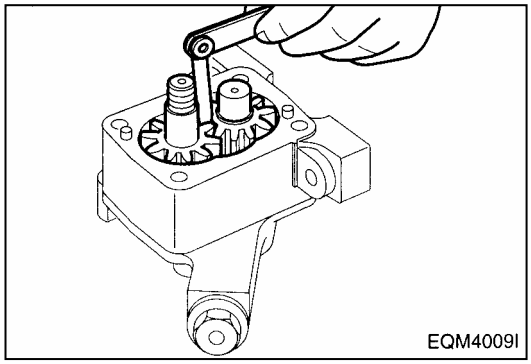
- **Inspection and correction**

(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	0.055 ~ 0.105 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.



Backlash limit	0.50 ~ 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	ϕ16.95~ϕ16.968 mm
Limit	ϕ16.95mm

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.

Clearance	0.075	0.127 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 ● Oil seal or packing leaky ● Pistons or piston rings worn ● Cylinder liner worn ● Piston rings sticking ● Valve guide oil seals or valve guides, or valve stem worn	● Use suggested oil ● Replace ● Replace pistons and/or piston rings ● Replace cylinder liner ● Replace pistons and/or piston rings ● Replace
Oil pressure too low	● Poor oil ● Relief valve sticking ● Restrictions in oil pump strainer ● Oil pump gear worn ● Oil pump feed pipe cracked ● Oil pump defective ● Oil pressure gauge defective ● Various bearings worn	● Use suggested oil ● Replace ● Clean strainer ● Replace ● Replace ● Correct or replace ● Correct or replace ● Replace
2. Oil deteriorates quickly	● Restriction in oil filter ● Gases leaking	● Replace filter element ● Replace piston rings and cylinder liner

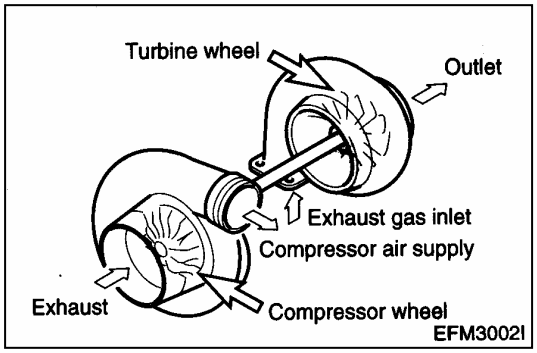
5.3. Turbo Charger

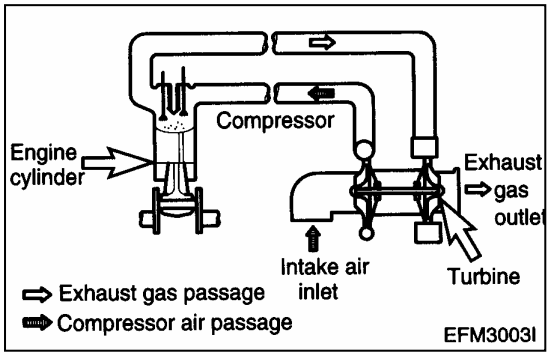
5.3.1. Specification and construction

1) Main data and specification

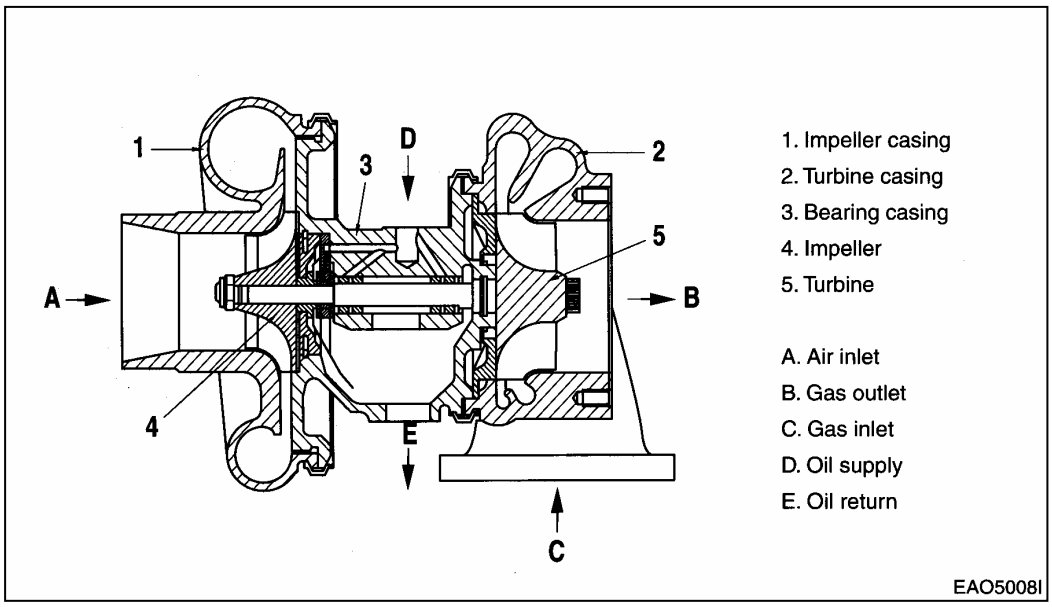
Specification		DV11
Model		Honeywell 753834-1/2
At maximum output	Air pressure at compressor outlet	Approx. 2.1 kgr/cm^2
	Air suction of turbine revolution	Approx. 24 m^3/min
	Speed of turbine revolution	Approx. 100,000 rpm
Maximum allowable speed		118,900 rpm
Maximum allowable temperature of exhaust gas at turbine inlet		750°C
Lubricating system		External oil supply
Weight		18 kg

2) Operating principle



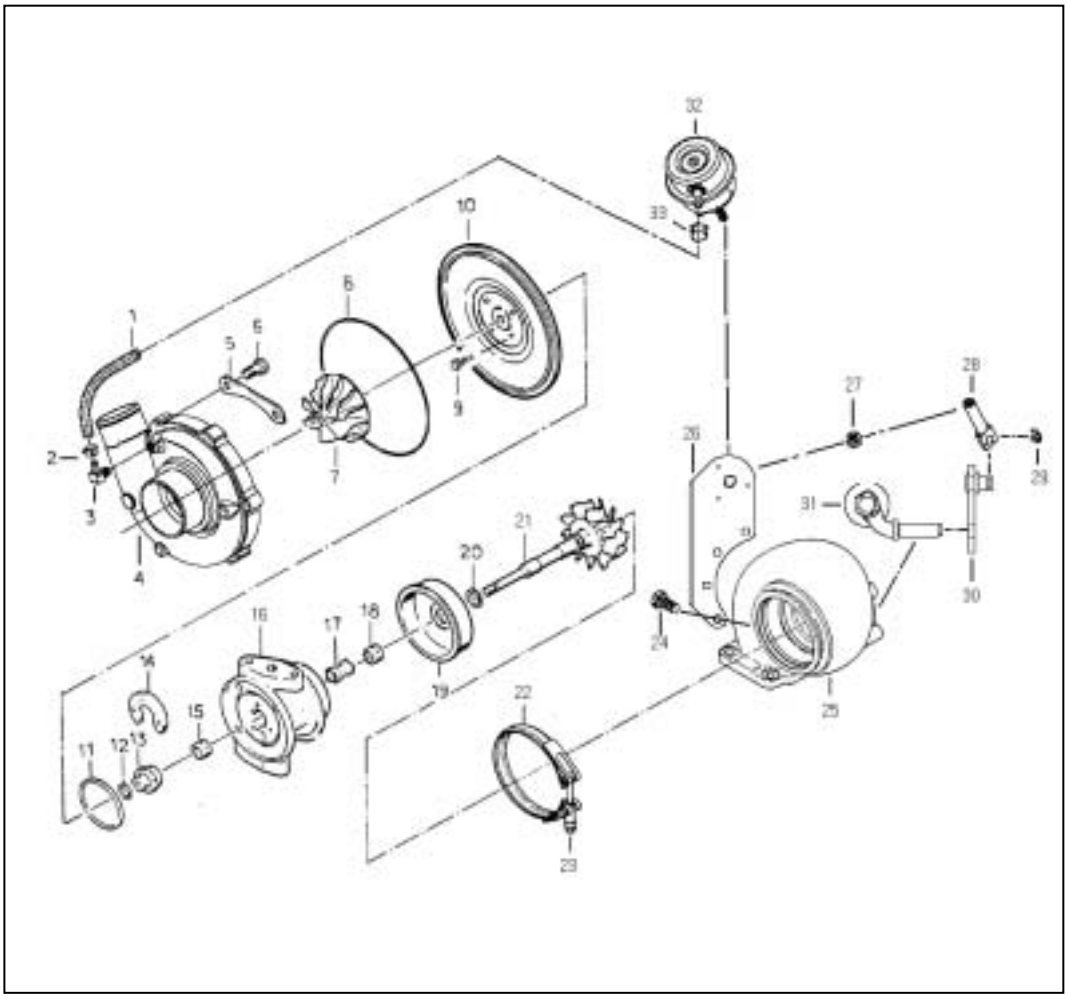


3) Construction



4) Components of turbocharger

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



1	Hose	12	Piston ring	23	Hex nut
2	Hose clamp	13	Thrust collar	24	Hex bolt
3	Connector	14	Thrust bearing	25	Turbine housing
4	Compressor housing	15	Journal bearing	26	Actuator bracket
5	Clamp, compressor	16	Center housing	27	Hex bolt
6	Hex bolt	17	Bearing spacer	28	Rod
7	Compressor wheel	18	Journal bearing	29	Retaining ring
8	O - ring	19	Shroud wheel	30	Crank ass'y
9	Hex bolt	20	Piston ring	31	Arm valve ass'y
10	Back plate	21	Turbine wheel ass'y	32	Actuator
11	Seal ring	22	V - clamp	33	Hose clamp

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 2) After confirming that oil pressure rises by starting engine with starter (until the pointer of oil pressure gauge moves or pressure indicating lamp operates), the starting must be done. 3) In case that oil, oil filter and lubricating system's part are replaced or engine was stalled for long time (more than a week), and in case of operation under cold weather, loosen the oil pipe connecting parts of turbocharger inlet, and operate the starting motor until oil comes out the connecting parts. Care must be paid that after the confirming above, retighten the pipe connecting parts without fail, and proceed with the normal starting.	2) If engine is started quickly, of course beginning with every parts of engine, for it revolves without oil that is to reach to the turbocharger, the bearing's abnormal wear or stuck may be caused. 3) In case that engine stalled for long time and of cold weather, the fluidity of oil may be get worse.
Immediately After starting	1) Perform idling operation for about 5 min. immediately after engine starting. 2) Various inspections must insure that there are no leakage of oil, gas and air.	1) Sudden load at time soon after engine starting and at the state when turbocharger did not yet reach to smooth revolution, if abrupt load is applied to engine, some parts where oil did still not reach may cause a burn to be stuck. 2) If there are the leakage of oil, gas, air, particularly oil, for the oil pressure lowers, it causes a burn of bearing to be stuck.

Operation	Caution	Reason
During operation	Following items must be confirmed. 1) Oil pressure At idling : 1.0 ~ 3.0 kg/cm^2 At full load : 3.0 ~ 5.5 kg/cm^2 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. 2) If the engine operation were continued with abnormal noises and vibration, it causes the engine trouble that can not be repaired or some other troubles.
At stop	1) At stopping the engine, perform the idling operation for 5min. and then stop it.	1) After heavy load operation, if the engine were stopped suddenly, the heat would be conducted to bearing parts from red hot turbine wings that would result in burning the oil to cause the stuck bearing metal and revolving shaft.

5.3.5. 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.
DV11	SAE 10W40	ACEA-E5 (API CI-4)

5.3.6. Periodical servicing

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

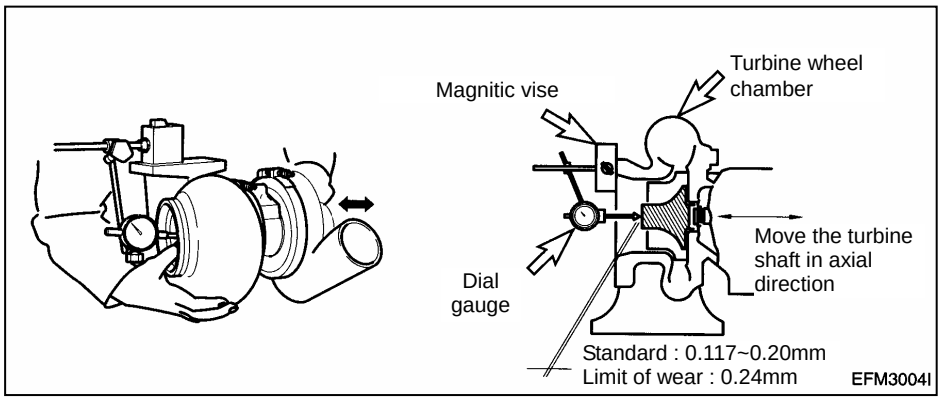
1) Guide for checking the rotor for rotating condition

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.

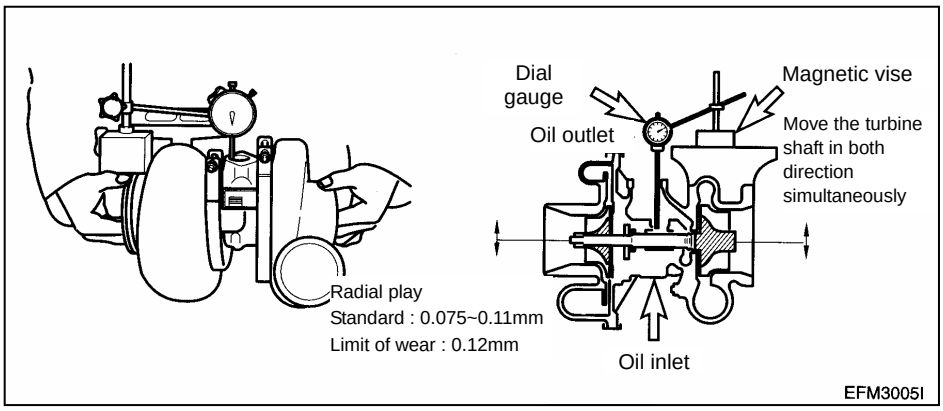
2) Guide for checking rotor end play

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)

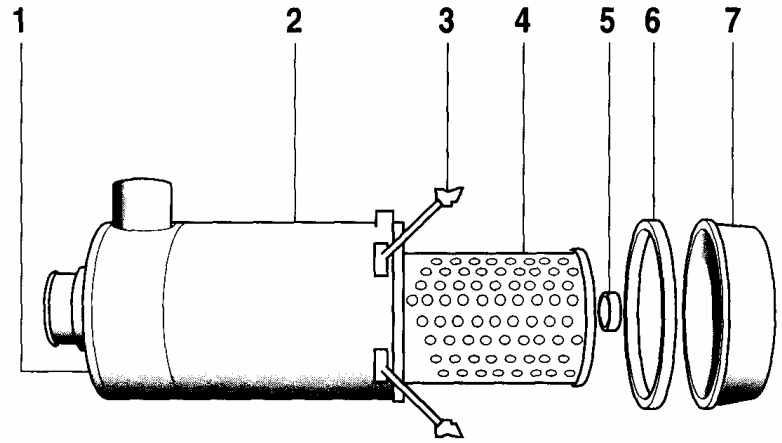
Empty the dust bowl (7) regularly. The bowl should never be filled more than halfway with dust.

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



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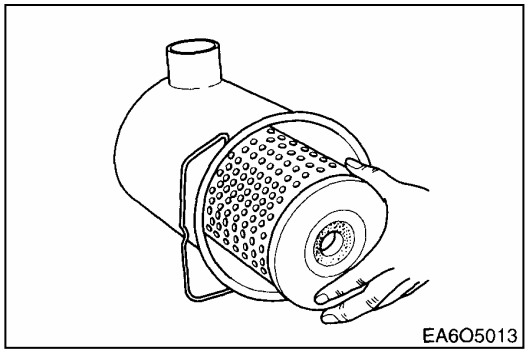
5.4.2. Changing air cleaner element

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.



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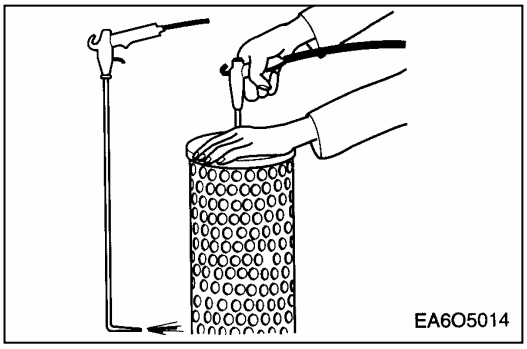
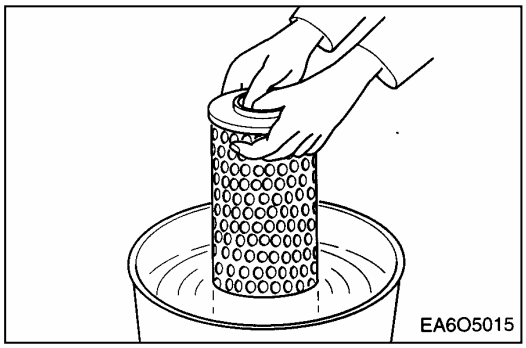
5.4.3. . Cleaning air cleaner elements

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



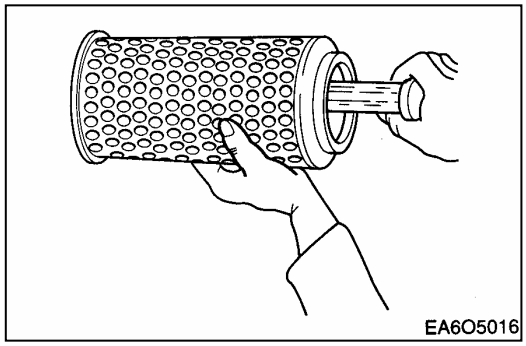
  - For the purpose, the air gun should be fitted with a nozzle extension which is bent 90° at the discharge end and which is long enough to reach down inside to the bottom of the element.
  - Moving the air gun up and down, blow out the element from the inside (maximum 5 bar) until no more dust comes 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.

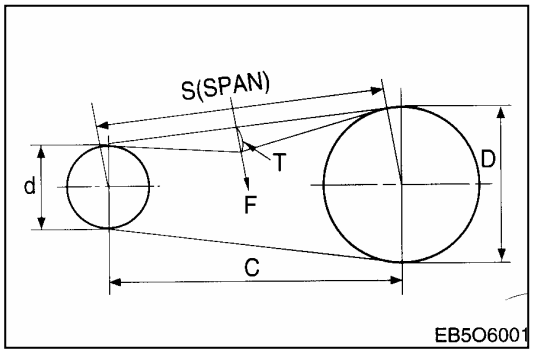
(2) Checking condition

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)

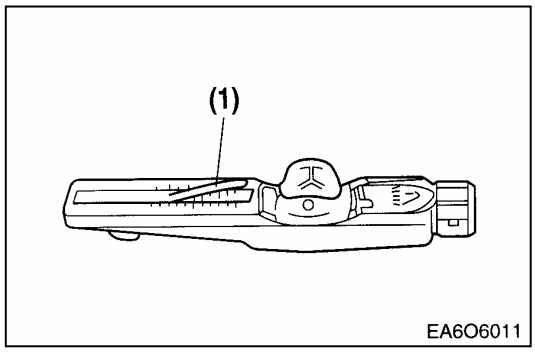
$$^{*}S = \sqrt{C^2 - \frac{(D-d)^2}{2}} \text{ (mm)}$$

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

(4) Measuring tension

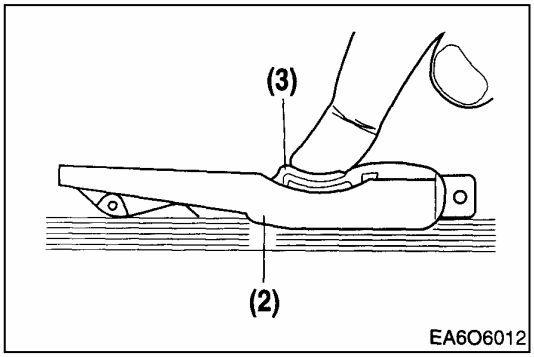
① Lower indicator arm (1) into the scale

- 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.



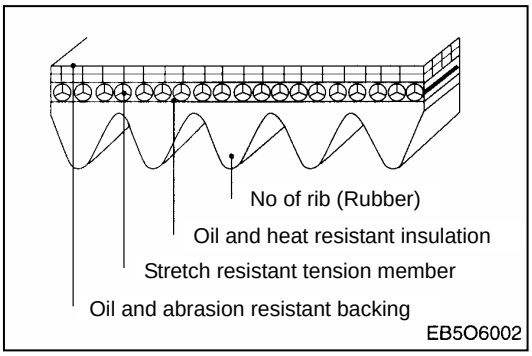
② Reading of tension

- 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.

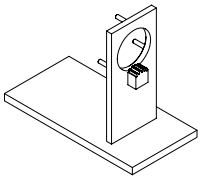
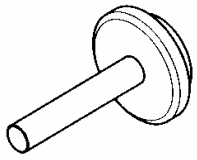
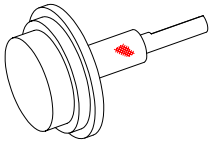
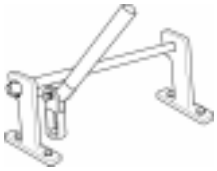
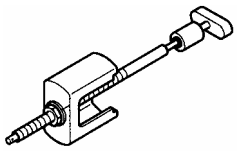
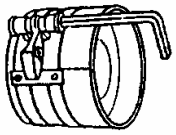
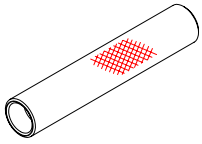


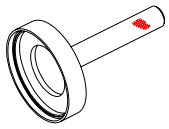
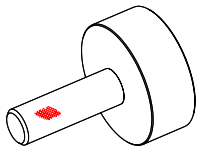
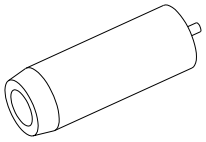
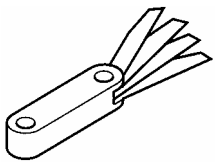
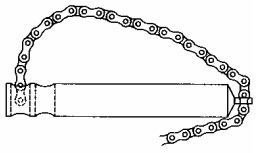
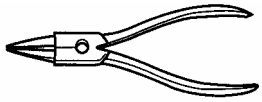
- **Poly belt tension**

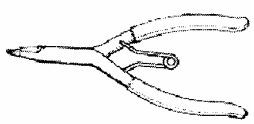
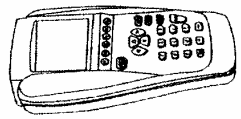
No of rib (PK type)	Force (kgf)
3	20 - 27
4	27 - 36
5	34 – 45
6	41 – 57
7	48 – 66
8	59 - 73



6. Special Tool List

No	Part no.	Figure	Tool name	Remark
1	EF.120-232		Fuel high pressure pump gear assembly	
2	EF.120-030		Oil seal insert assembly (Front)	
3	EF.120-029		Oil seal insert assembly (Rear)	
4	EF.120-238		Valve spring compression	
5	EF.123-365		Cylinder liner puller	
6	EF.120-208		Piston insert	All engine
7	EF.120-246		Valve stem seal punch	

No	Part no.	Figure	Tool name	Remark
8	E1.05508-0185		Wearing assembly (Crankshaft pulley)	
9	E1.05508-0025		Wearing assembly (Fly wheel)	
10	E1.76-035-00D		Cam shaft assembly	
11	EF.120-239		Slave piston disassembly / assembly (Engine brake)	
12	60.99901-0027		Feeler gauge	
13	65.98801-0001		Filter wrench	
14	T7610001E		Snap ring plier	

No	Part name	Figure	Tool name	Remark
15	T7621010E		Piston ring plier	
16	EF.123-322		SCAN-200 Diagnostic unit	Memory card

Appendix

● Tightening torque for major parts

Major parts	Screw (Diameter x pitch)	Strength (Grade)	Tightening torque
Cylinder block bearing cap			
- Main bolt	M18 x 2.0	12.9T	Initial 30 kg-m + angle torque 90°
- Side bolt	M12 x 1.5	10.9T	8 kg-m
Oil spray nozzle			
- Valve	M14 x 1.5	-	7 kg-m
- Fixing bolt	M6	8.8T	1.2 kg-m
Flywheel housing	M12 x 1.5	10.9T	11.2 kg-m
	M10 x 1.5	12.9T	7.5 kg-m
Balance weight	M16 x 1.5	10.9T	Initial 10 kg-m + angle torque 90°
Crank pulley	M16 x 1.5	10.9T	21 kg-m
Vibration damper	M10	10.9T	6 kg-m
Flywheel	M16 x 1.5	12.9T	26 kg-m
Connecting rod cap	M16 x 1.5	10.9T	Initial 10 kg-m + angle torque 90°
Cylinder head	M16 x 2.0	10.9T	6kg.m + 15kg.m + 90°+ 90° + 60°
Cylinder head cover	M8	8.8T	2.2 kg-m
Rocker arm bracket	M10 x 1.5	10.9T	6.2 kg-m
Lock nut (adjusting screw)	M10 x 1.0	8.8T	4.4 kg-m
Oil pump cover	M8	8.8T	2.2 kg-m
Oil pump mounting	M8	8.8T	2.2 kg-m
Oil cooler	M12	10.9T	5 kg-m
Oil pan	M8	8.8T	2.2 kg-m
Oil pan drain plug	M26 x 1.5	-	8.2 kg-m
Exhaust manifold	M10 x 1.5	10.9T	8.0 kg-m
Intake manifold	M8	8.8T	2.2 kg-m
Starting motor	M12 x 1.5	8.8T	8 kg-m
Alternator bracket	M14 x 1.5	8.8T	12 kg-m
Coolant temperature sensor	M12 x 1.5	-	2.2 kg-m (max. 2.5 kg-m)
Power take off gear shaft	M33 x 1.5	8.8T	30 kg-m
Power steering pump	M10 x 1.5	8.8T	4.4 kg-m
Air compressor			
- drive gear	M18 x 1.5	10.9T	12 kg-m
- Connecting rod cap	M8	10.9T	3.5 kg-m
- Head & Cylinder liner	M8	10.9T	3.5 kg-m

● Tightening torque for fuel injection system

Major parts	Screw (Diameter x pitch)	Strength (Grade)	Tightening torque
Fuel high pressure pump drive gear	M18 x 1.5	-	11 kg.m ±0.5 kg.m
Fuel high pressure pump cap	M10 x 1.5	10.9T	7.5 kg.m
Fuel injector	M8	10.9T	3.5 kg.m
Fuel high pressure pump (cylinder block)	M10 x 1.5	10.9T	4.4 kg.m
Fuel high pressure connector	M22 x 1.5	-	5 ~ 5.5 kg.m
Common rail	M8	-	2.2 kg.m
Fuel high pressure pipe - Connector	M14 x 1.5	-	3.0 kg.m
Fuel high pressure pipe - Common rail	M14 x 1.5	-	3.0 kg.m
Fuel high pressure pipe - Pump	M14 x 1.5	-	2.0 kg.m
Fuel return hollow screw	M8 x 1.0	-	0.8 kg.m
Fuel filter	M10 x 1.5	8.8T	4.4 kg.m
Injector cable	M4	-	0.15 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 DAEWOO engine

● Maintenance specification table

(unit : mm)

Group	Part	Inspection item		Stand value for assembly	Limit for use	Correction	Remark
Cylinder block	Cylinder block & liner	Inside diameter of cylinder liner		ϕ127.990~ϕ128.010	ϕ128.122	Replace liner	Measure unworn portion beneath the rim of the upper side
		Liner's roundness & columness (upper)		0.005	-		From top up to 168mm
		Liner's roundness & columness (lower)		0.008	-		From bottom up to 85mm
		Amount of liner projection		0.04 ~ 0.08	-		Measure at upper side of cylinder block
		The flatness of upper surface of cylinder block		0.03	-	Correct with a surface grinder	Referenced length : 150mm
		Hydraulic test for 1 minute (kg/cm^2)		4	-	Replace if leaky	Temperature 70°C
	Cylinder head & valve	Valve seat depression	Intake	-0.39 ~ -0.41	0.55	Replace valve seat	Depression of valve from lower face of cylinder head
			Exhaust	-0.39 ~ -0.41	0.55		
		Cylinder head height		116.9 ~ 117.1	116.4	Replace cylinder head	
		The flatness of lower surface of cylinder head		0.08	0.1		
		Thick of cylinder head gasket(at assembly status)		1.215 ~ 1.285	-		
		Hydraulic test for 1 minute (kg/cm^2)		4	-	Replace if leaky	Temperature 70°C
Major moving parts	Piston	Outer diameter of piston		ϕ127.739~ϕ127.757	-	Replace liner	Measure at 56.8 mm away from piston head(long diameter)
		Clearance between piston and liner		0.233 ~ 0.271	0.35	Replace one worn more	
		Inner diameter of piston pin		ϕ46.010~ϕ46.016	-		Standard diameter
		Width of piston ring grooves	Top ring	3.5	-	Replace piston if groove width is beyond specified value	Measure at 125mm of top ring groove
			2nd ring	3.040~3.060	-		
			Oil ring	4.020~4.040	-		
		Piston projection from cylinder block upper surface		0.0085~0.3765	-	Must exist	Measure unworn portion beneath the rim of the upper side
		Permissible weight difference of each piston		50g	50g↓	Replace piston	
	Piston ring	Width of piston ring	Top ring	3.34~3.36	-	Replace ring	
			2nd ring	2.975~2.990	-		
			Oil ring	3.97~3.99	-		
		Piston ring	Top ring	0.35~0.55	1.5	Replace ring	Standard gauge

Group	Part	Inspection item		Stand value for assembly	Limit for use	Correction	Remark
		gap	2nd ring	0.80 ~ 0.95	1.5		inside diameter : ϕ128
			Oil ring	0.40 ~ 0.70	1.5		
		Piston ring side clearance	Top ring	0.105~0.155	0.20	Replace ring or piston	Limit for use is if for standard clearance
			2nd ring	0.050~0.082	0.15		
			Oil ring	0.030~0.070	0.15		
		Direction of ring gap		-	-	Cross Install by 120°	
	Piston pin	Outer diameter of piston pin		ϕ45.994~ϕ46.000	ϕ45.94	Replace piston pin	
		Clearance between piston pin and its bush		0.010~0.021	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	Measure in horizontal and vertical directions
		Outside diameter of journal		ϕ103.98~ϕ104.00	ϕ102.98	Use under sized bearings respectively (0.25, 0.5, 0.75, 1.0)	
		Outside diameter of pin		ϕ89.980~ϕ90.000	ϕ88.980		
		Width of thrust journal		38.000~38.062	37.000		
		Ellipticity of journal and pin		0.01	0.025		
		Taper of journal and pin		0.02	0.03		
		Run-out of crankshaft		0.04↓	0.2↓	Adjust by a press	Measure at journal # 1, 4 supported
		Clearance between crankshaft and bearing		0.066~0.132	0.166	Replace bearings	Measure at crown part not parting line
		End play of crankshaft		0.190~0.322	0.5	Replace thrust bearing	
		Balance of crankshaft (g.cm)		60 ↓	60 or less	Check dynamic balance	Measure at 400 rpm
		Torque value journal bearing cap bolt		30kg.m + 90°	-	Coat the bolt with engine oil	Clean out foreign objects on joining surface.
		Crush height of Journal bearing cap	Main	0.3~1.2	-		Measure after tightening metal cap and releasing one bolt
			Thrust	0.3~1.2	-		
		Out diameter of wear ring after assembled		ϕ104.86~ϕ105.00	-		5 minutes or more at 220°C
		Oil seal for wear (crank shaft rear)		-	-	Replace oil seal if oil leaking	
	Connecting rod	Width of connecting rod	Small end	38.070~39.000	-		
			Big end	32.291~32.33	-		
			Cap	30.5 ~ 30.8	-		
		Inner diameter of small end		ϕ46.055~ϕ46.065	-		
		Outer diameter of big end		ϕ95.000~ϕ95.022	-		
		End play of connecting rod	Big end	0.175 ~ 0.321	0.50	Replace Connecting rod	
			Small end	1.5	-		
		Clearance between connecting rod bearing and crank pin		0.054 ~ 0.116	0.154	Replace bearing	
		Clearance between small end bush & piston pin		0.055~0.071	0.12		
		Crush height of connecting rod bearing cap		0.3 ~ 0.5	-		Measure after installing the bearing and releasing one bolt
		Perpendicularity of big end inner diameter		0.05	0.08	Replace connecting rod	
		Roundness of big end inner diameter		0.005	0.01		
		Parallelness of small end side and big end		0.02	0.1		
		Allowable weight difference per con-rods		50g ↓	-		

Group	Part	Inspection item		Stand value for assembly	Limit for use	Correction	Remark
		Torque value of connecting rod bearing cap bolt (kg.m)		10kg.m + 90°	-	Coat the bolt with engine oil	Clean out foreign objects on joining surface
	Cam shaft	Diameter(bea ring) of cam shaft side of cylinder block	Inner diameter of thrust bush	ϕ70.07~ϕ70.09	-		
			Inner diameter of cam bush	ϕ70.00~ϕ70.03	ϕ70.06		
		Diameter of cam shaft journal		ϕ69.910~ϕ69.940	ϕ69.64		
		Clearance between cam shaft and cam bush		0.060~0.120	0.18	Replace cam bush	
		End play of camshaft		0.10~0.55	0.6	Replace thrust washer	
		Run-out of camshaft		0.05	0.1	Correct or replace the cam shaft	
	Timing gear	Clearance between idle gear shaft bush and idle gear shaft		0.025~0.066	0.15		
		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		ϕ432.490~ϕ432.645	-		Heating temperature at ring gear assembly (200~230°C)
		Ring gear inner diameter		ϕ432.000~ϕ432.155	-		
		Overlap		0.335~0645	-		
		Allowable shaking amount after assembly		0.5	-		
		Outer diameter after assembly wear ring		ϕ119.860~ϕ120.000	-		
Valve system	Valve and valve guide	Outer diameter of intake valve stem		ϕ7.963~ϕ7.977	ϕ7.94	Replace valve	When replacing valve guide & seat, work simultaneously by special tools
		Outer diameter of exhaust valve stem		ϕ7.950~ϕ7.964	ϕ7.93		
		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	30°	-		
			Exhaust	45°	-		
		Diameter of valve head	Intake	ϕ42.9~ϕ43.1	-		
			Exhaust	ϕ39.9~ϕ40.1	-		
		Thickness of valve head	Intake	3.0~3.4	2.5 or less		
			Exhaust	3.3~3.7			
		Projection amount of valve guide and valve spring seat	Intake	14.8~15.2	-	Use with assembly jig	To upper side of valve guide from spring seat side of cylinder head
			Exhaust	14.8~15.2	-		

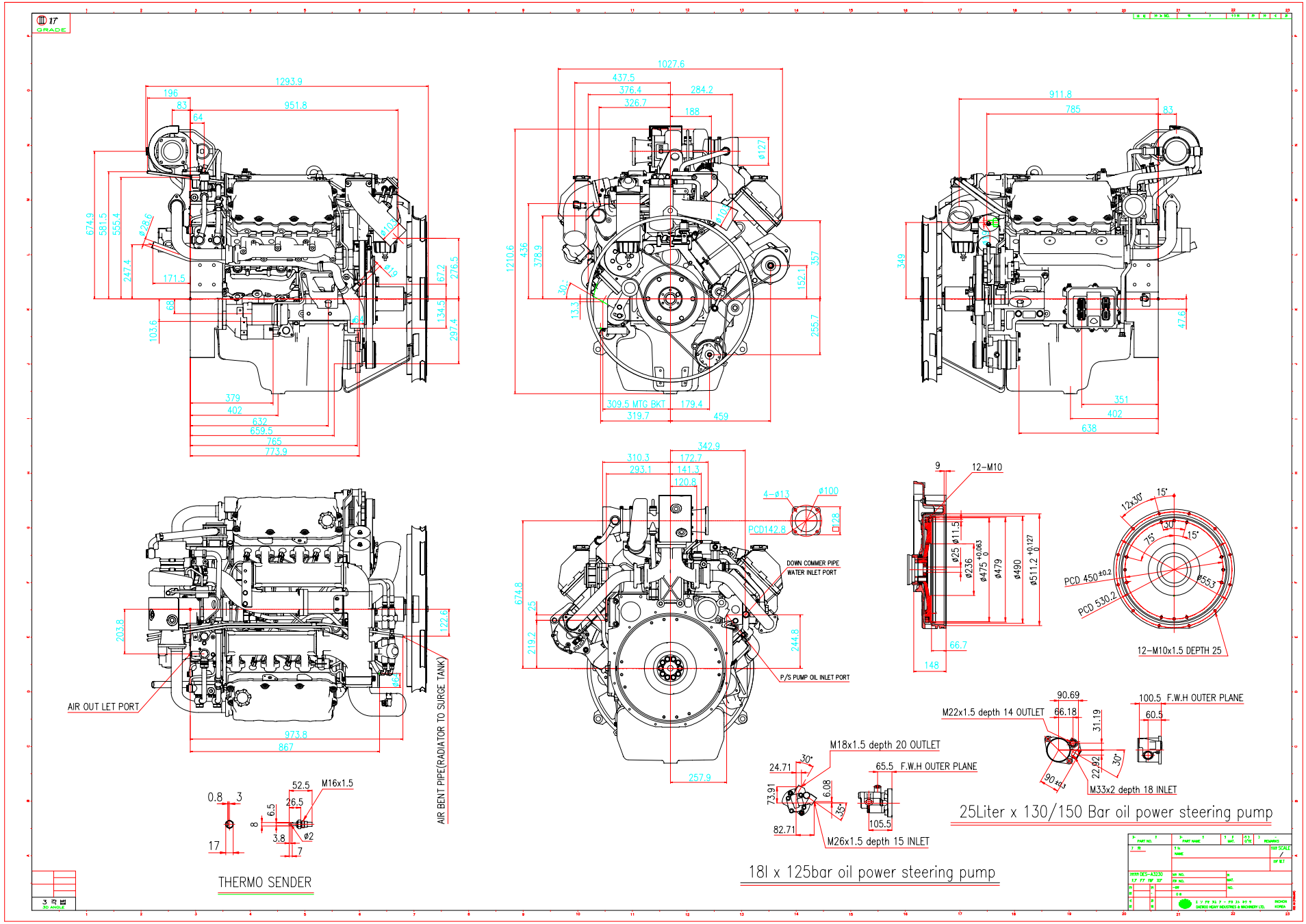
Group	Part	Inspection item			Stand value for assembly	Limit for use	Correction	Remark
		Valve seat assembly part's inner diameter of cylinder head	Intake		ϕ43.50~ϕ43.75	-		
			Exhaust		ϕ41.50~ϕ41.75			
		Diameter of valve seat	Intake		ϕ43.554~ϕ43.570	-		
			Exhaust		ϕ41.554~ϕ41.570			
		Valve seat assembly part's depth of cylinder head			11.9~12.1	-		
		Inner diameter of valve guide			ϕ8.000~ϕ8.015	-		When replacing valve guide & seat, work simultaneously by special tools
		Valve guide assembly part's inner diameter of cylinder head			ϕ14.000~ϕ14.018	-		
		Diameter of valve guide			ϕ14.028~ϕ14.039	-		
		Clearance between valve guide and cylinder head installing hole			0.01~0.039	-		Apply oil over valve guide and press it into the hole
		Concentricity between valve seat and valve guide			0.05	-	Replace valve spring	Without spring seat
		Intake valve spring	Free length		62.5	-	Replace valve spring	
			Tension force (kg)	44mm	37.4~41.4	37		
				31.6mm	63.3~68.3	63		
			Squareness (along free length direction)		1.6mm	2.0 or less		
		Exhaust valve spring	Free length		62.0	-	Replace valve spring	Inside spring
			Tension force (kg)	41mm	19~22	18.5		
				28.6mm	30.6~34.6	30		
			Squareness (along free length direction)		1.6mm	2.0 or less		
			Free length		62.5	-	Replace valve spring	Outside spring
			Tension force (kg)	44mm	37.4~41.4	37		
				31.6mm	63.3~68.3	63		
			Squareness (along free length direction)		1.6mm	2.0 or less		
	Rocker arm & push rod	Valve clearance (at cold)	Intake		0.4	-	Adjust	
			Exhaust		0.5	-		
		Joining surface of valve stem and rocker arm bush			-	-	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		

Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark
		Clearance between rocker arm shaft & rocker arm bush	0.031~0.073	0.14	Replace bush or shaft	
		Run-out of push rod	0.3	0.5	Replace or correct	
	Tappet	Tappet assembly part's inner diameter of cylinder head	ϕ20.000~ϕ20.021	-		
		Diameter of tappet	ϕ19.944~ϕ19.965	-	Replace tappet	
		Clearance between tappet & tappet hole of cylinder block	0.035~0.077	0.13	Replace tappet	
		Tappet face in contact with cam	-	-	Replace if severely worn or deformed	
Lubricating system	Engine oil	Oil pressure (kg/cm^2) (at rated speed)	3.0~5.5	-	Check oil leakage and clearance between each part	
		Oil pressure (kg/cm^2) (at idle speed)	1.0~3.0	0.8 or more	Use recommended oil	
		Oil temperature (°C)	110 or less	-		Must not exceed this value
		Permissible oil temperature in short time (°C)	Max. 120	-		
		By-pass valve for filter element (kg/cm^2)	1.8 ~ 2.4	-		
		Oil spray nozzle – Operating pressure	1.6 ~1.9		Replace valve	
		Oil spray nozzle – Closing pressure	1.3 ~1.6			
		Oil spray nozzle – Nozzle diameter	ϕ2			
	Oil pump	Delivery volume lit/min - Pump speed : 2,440rpm - Oil temperature : 50°C	175 or more	-	Replace gear or cover	
		Gear assembly part's depth of oil pump housing	43.000~43.039	-		
		Width of oil pump gear	42.910~42.950	-		
		Clearance of oil pump at axial direction	0.050~0.128	-		
		Oil pump pressure control valve (kg/cm^2)	8.5 ~ 10	-	Replace valve	
		Oil pressure control valve (kg/cm^2)	1.9 ~ 2.1	-	Replace valve	
		Clearance between drive gear shaft and cover hole	0.032~0.077	-	Replace bush or cover	
		Clearance between drive gear shaft and cover hole	0.040~0.094	-		
		Diameter of gear shaft	ϕ16.950~ϕ16.968	-	Replace gear shaft	
		Diameter of driving gear bush	ϕ28.000~ϕ28.033	-	Replace bush or cover	

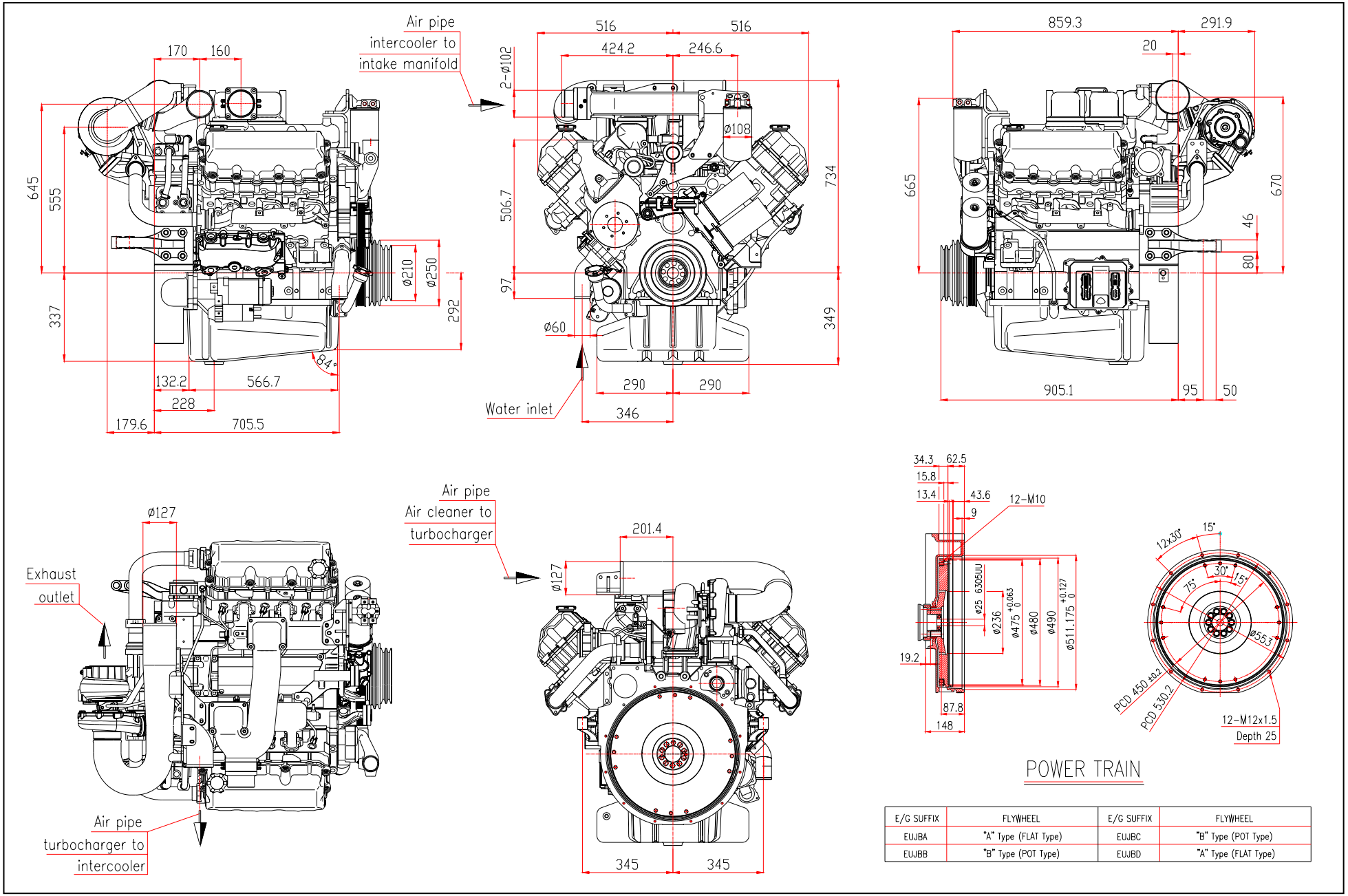
Group	Part	Inspection item	Stand value for assembly	Limit for use	Correction	Remark
	Oil filter	Damage of oil filter element	-	-	Clean or replace	
		By-pass valve pressure (kg/cm^2)	1.8 ~ 2.4			
		Oil filter control valve pressure (kg/cm^2)	4.3 ~ 4.7			
Cooling system	Radiator	Radiator & water pump for corrosion, damage & improper connecting	-	-	Correct or replace	
		Test for leakage by air pressure (kg/cm^2)	1.0	-	Submerge in water and replace if air bubbles found	
		Pressure valve for opening pressure (kg/cm^2)	0.5	-		
		Negative pressure valve for opening pressure (mmHg)	20	-		
	Water pump	Delivery volume lit/min - Pump speed : 3,500rpm - Water temp. : 25°C - Pressure : 1.8 kg/cm^2	452 or more	-	Check the water passage	
		Diameter of water pump shaft — Pulley side	ϕ25.048~ϕ25.061	-		
		Diameter of water pump shaft — Impeller side	ϕ16.045~ϕ16.056	-		
		Clearance of bearing	0.050~0.091			
		Clearance between impeller & housing	0.5 ~ 0.9	-	Replace if impeller & housing are damaged	
		Fan belt depression	Refer to adjust table	-	Adjust	
	Cooling water temperature	Operating temperature (°C)	79 ~ 95	-	Must not exceed this value	
		Permissible temperature in a short time (°C)	-	105		
	Thermostat	Opening temperature (°C)	83	-	Replace	
		Full opening temperature (°C)	95	-	Replace if defective Stroke : min. 8mm	
Fuel system	Fuel high pressure pump maker (CP pump)		Bosch	-		
	Common rail maker					
	Fuel injector maker					
	Fuel piping & others	Fuel pipe, injection pipe & injector for damage, cracks, improper O-ring	-	-	Replace	
		Damage of fuel filter cartridge	-	-	Replace cartridge	
	Injection pressure of injector (kg/cm^2)		1,600	-		
	Operating pressure of overflow valve (kg/cm^2)		10.5 ~13	-	Replace valve	
	Diameter of injector nozzle		8 - ϕ0.197			

Group	Part	Inspection item		Stand value for assembly	Limit for use	Correction	Remark
	Projection height of nozzle from the cylinder head surface(mm)			2.4 ~ 2.9	-	Replace sealing	
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 groove	#1, # 2 ring	2.51 ~ 2.53	-		
			#3, #4 ring	4.02 ~ 4.04	-		
		Inner diameter of piston pin		ϕ20.003~ϕ20.008	-		
		Diameter of piston pin		ϕ19.994~ϕ20.000	-		
		Inner diameter of connecting rod small end		ϕ20.020~ϕ20.033	-		Include connecting rod bush and bearing
		Inner diameter of connecting rod big end		ϕ31.959~ϕ31.975	-		
		Diameter of main bearing journal		ϕ29.959~ϕ29.980	-		
		Inner diameter of main bearing		ϕ30.020~30.041	-		
		Projection amount of piston		-0.75 ~ -0.2	-		
		Clearance between piston and liner		0.080 ~ 0.100	-		
		Oil clearance of connecting rod bearing		0.027 ~ 0.073	0.5		
Drive system	Gear back lash	Between crank gear & oil pump drive gear		0.10 ~ 0.45	0.3	Adjust back lash	
		Between crank gear & cam shaft gear		0.118 ~ 0.242	0.3		
		Between drive gear & fuel pump gear (CP pump)		0.050 ~ 0.178	0.45		
		Between air compressor drive gear and cam shaft gear		0.097 ~ 0.353	0.5		

1. Engine assembly view DV11 – TRUCK



2. Engine assembly view DV11 – BUS



POWER TRAIN

E/G SUFFIX	FLYWHEEL	E/G SUFFIX	FLYWHEEL
EUJBA	"A" Type (FLAT Type)	EUJBC	"B" Type (POT Type)
EUJBB	"B" Type (POT Type)	EUJBD	"A" Type (FLAT Type)