

Operation & Maintenance Manual

DIESEL GENERATOR, POWER UNIT ENGINE

**D1146, P086TI, DP086TA,
DP086LA, PU086T, PU086TI**

Forward

This Operation and Maintenance Manual provides information on engine management and maintenance techniques to customers and technicians of HD Construction Equipment's D1146/D1146T/P086TI/PU086T/PU086TI/DP086TA/DP086LA diesel engine.

To provide the best engine to our customers, the D1146/D1146T/P086TI/PU086T/PU086TI/DP086TA/DP086LA diesel engine is designed to satisfy all requirements for low noise, economic fuel consumption, high speed and durability with the latest technology and quality.

Exact operation and proper maintenance are essential for operating engines for an extended time with optimum conditions and best performance. This Operation and Maintenance Manual provides detailed descriptions of specifications, specified values, defect diagnosis, component diagrams, and drawings for easier and more precise understanding of the product and for proper maintenance and troubleshooting.

With the help of the recommended operation methods and procedures, high-level maintenance techniques and safety of workers can be ensured. Please read and understand this manual before working with our engines.

To ensure best performance and quality as well as to enhance maintenance techniques, HD Construction Equipment is doing its best to continuously develop and invest. The design of our product may be changed without prior notice and HD Construction Equipment shall not be held liable for the failure of this manual to contain all the design changes made to improve the product.

We, HD Construction Equipment, do our best to provide more convenient and safe maintenance techniques and to meet the requirements of our customers. If you have any questions or find any errors in this Operation and Maintenance Manual, please do not hesitate to contact us.

Thank you for purchasing our engine and we hope this Operation and Maintenance Manual be helpful for you.

2026. 01.

950106-062014EN

HD Construction Equipment

* Items exempted from warranty coverage

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

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Table of contents

1. General introduction	1
General information	3
Danger, warning, caution, and note	4
Engine maintenance	7
2. Operation and maintenance	9
Starting and stopping of the engine	11
Break-in period of the engine	13
Operation in winter	15
Inspection and repair of the engine	16
3. Performance and specifications	17
Engine specifications and performance	19
Exterior view drawing of the engine (D1146/PU086)	24
Exterior view drawing of the engine (D1146T/PU086T)	26
Exterior view drawing of the engine (P086TI)	28
Exterior view drawing of the engine (DP086TA)	30
Exterior view drawing of the engine (DP086LA)	33
Exterior view drawing of the engine (PU086TI)	36
Engine identification number	39
4. Regular inspection	41
General information	43
Regular inspection table	44
Cooling system	47
Lubrication system	52
Fuel system	56
Intake/exhaust system	64
Cylinder block/head	67
Electric system	69
Others/driving system	70
5. About the engine	73
Marking system of units	75
Tightening torque	76
Engine Disassembly	79
Engine Assembly	88

6. Cooling system	107
General information	109
Thermostat	111
7. Lubrication system	113
General information	115
Oil pump	117
8. Fuel system	119
General information	121
Fuel injection pump	124
Fuel feed pump	140
9. Intake/exhaust system	145
General information	147
Turbocharger	148
10. Cylinder block/head	157
General information	159
Cylinder block	160
Cylinder head	161
Valve	163
Rocker arm	166
Tappet and push rod	168
Camshaft	169
11. Electric system	171
General information	173
Starter	174
Alternator	178
12. Others/driving system	183
General information	185
Crankshaft	186
Piston	189
Connecting rod	193
Others	194

1. General introduction

General information	3
General Information	3
Danger, warning, caution, and note	4
General Information	4
General Instructions	4
Precautions in Starting the Engine.....	5
Cautions for Inspection and Repair.....	5
General Repair.....	6
Other Safety Instructions and Environmental Pollution.....	6
Use of Genuine Parts.....	6
Engine maintenance	7
Prevention of damage and abrasion	7
Prevention of Pollution	7
Handling of Engine Oil	7
HVO (Hydro treated Vegetable Oil).....	8

General information

General Information

This Operation and Maintenance Manual provides the most efficient methods for engine maintenance as well as quick, efficient methods to determine the cause of engine faults to ensure that any actions taken by authorized skilled technicians are done in the most efficient and efficient way possible. If maintenance is performed by unskilled technicians, or maintenance without the specified tools and facilities, serious bodily injury or critical faults in engine performance may occur.

Regular inspection and maintenance are required to maintain long-term optimal engine conditions and best performance. In the event that a part must be replaced, only genuine parts as defined by the parts the list (PARTS BOOK) should be used. HD Construction Equipment shall not be held liable for any critical damage or faults which may be caused by the use of unauthorized or remanufactured parts.

The maintenance methods stated in this Operation and Maintenance Manual are the most efficient and safest work procedures. Some work procedures require special tools.

For questions about genuine parts and special tools, please contact us.

This Operation and Maintenance Manual includes 'Danger,' 'Warning,' and 'Caution' in order to reduce possible injuries and engine faults which may occur while performing maintenance. If workers do not follow the instructions, critical faults in engine performance and operation or serious bodily injury may occurred. 'Danger,' 'Warning,' and 'Caution' instructions must be followed. However, we inform you that it is not possible to describe all possible and unexpected dangers which may arise while performing engine maintenance.

1. General introduction

Danger, warning, caution, and note

General Information

This Operation & Maintenance manual divides maintenance operations such as performing engine checks, trouble-shooting, or diagnosing faults into three categories, "Danger," "Warning," and "Caution." In addition, Note) is used to provide additional descriptions and information required for maintenance technicians to successfully operate HD Construction Equipment engines. The recommended repair methods and 'Danger,' 'Warning,' and 'Caution' can enhance the degree of completion of engine maintenance and prevent bodily injury which may occur to workers. However, this manual cannot predict all possible risks.

DANGER

Workers MUST observe instructions, otherwise fatal or serious injuries to workers and other persons may occur.

WARNING

Workers must follow this instruction as failing to do so may result in the death or serious bodily harm of workers or others.

CAUTION

Workers must observe this instruction since failing to do so may cause critical faults which can have impact on the engine performance and operation.

Note) Indicates additional description, information, and references for workers' easy understanding.

General Instructions

1. In order to maintain the best long term performance and safety, please read and understand this manual and execute routine inspections and regular inspections.
 2. We have divided the content of this manual into causes of bodily injury and damage to assets and causes of pollution.
-

WARNING

When a safety accident, such as skin contact with corrosive acids or fuel, burns with hot oil, exposure of eyes to fuel or antifreeze, occurs while starting, inspecting, or repairing an engine, see a doctor immediately.

WARNING

During operating the engine, be careful not to touch the safety guard of cooling fan. Otherwise, it can cause serious injuries such as a cutting of fingers to you by the rotating cooling fan.

WARNING

During operating the engine, be careful not to touch the safety guard of v-belt. Otherwise, it can cause serious injuries such as a cutting of fingers to you by the rotating v-belt.

WARNING

V-belt safety guard is an optional item for customers. In order to prevent accidents, you should install a vbelt safety guard. If v-belt safety guard is not installed, you should not access to the engine in operating. The engine maker won't be responsible for an accidents or injury arising without an installation of v-belt safety guard.

WARNING

Immediately after stopping the engine or during driving, be careful not to touch a part of turbocharger. Otherwise, it can cause you to severe burns due to a hot turbocharger. If you need to contact the turbocharger for maintenance, you should wait until the temperature of the turbocharger will be lower sufficiently.

WARNING

Immediately after stopping the engine or during driving, be careful not to touch a part of exhaust manifold or heat screen. Otherwise, it can cause severe burns to you due to the hot exhaust manifold or heat screen. In particular, be careful not to touch the heat screen installed on the exhaust manifold because it has also a high temperature.

WARNING

If you need an emergency engine stop, use an electronic emergency stop device installed on a generator at first instead of mechanical emergency stop of engine. It is difficult to operate a mechanical emergency stop device mounted on a fuel pump and it can cause serious burns to you by contact with the exhaust manifold. The operator is requested to install the separate cable for operating the mechanical emergency stop. The engine maker won't be responsible for an accidents or injury arising without an installation of separate auxiliary cable.

Precautions in Starting the Engine

1. Before starting the engine, please read this manual carefully and fully understand 'Danger,' 'Warning,' and 'Caution'. If you cannot fully understand it or have any question, please contact us.
2. For safety reasons, attach "Warning" signs around engines in operation to keep people other than workers from accessing the engines. Let engine operators know that they are responsible for the safety of the engine room.
3. Only authorized people may start and operate engines. Unauthorized people should not be allowed to handle engines.
4. Do not get close moving or rotating parts while the engine is in operation.
5. Do not touch the hot engine during operation since.
6. Exhaust gas is poisonous. Fully ventilate before starting engine. If the space is enclosed, ensure that it is well ventilated.
7. Keep vicinity of engine, ladders and stairways free of oil and grease. Accidents caused by slipping can have serious consequences.

Cautions for Inspection and Repair

1. Inspection and repair of engine should be performed only when the engine is stopped.
 2. If it is inevitable to perform inspection or repair on the operating engine, do not get close to the rotating parts.
-

DANGER

When accessories such as necklaces, rings, watches, or gloves become stuck in rotating parts while the engine is running, serious bodily injury may occur.

WARNING

Do not exchange or disassemble a pipe or hose (from the engine fuel circuit, engine oil circuit, coolant circuit, or compressed air circuit) while the engine is running. The leaked liquid may cause bodily injuries.

3. Use an engine oil drain container that is large enough to prevent the overflow of engine oil while draining engine oil.
 4. Open the engine coolant cap after fully cooling the engine to exchange or replenish coolant.
-

WARNING

If the coolant cap is opened while the engine is still hot, hot water will spurt out and may cause burns. Open the engine coolant cap after fully cooling the engine.

5. Fuel is highly flammable. Smoking or use of fire around an engine may cause fire.
-

WARNING

Only refuel when the engine is stopped.

6. Mark and separately manage the containers for storing coolant from beverage bottle for avoiding confusion. See a doctor immediately in case of drinking coolant.
 7. Follow the instructions provided by the battery manufacturer when checking or handling batteries.
-

WARNING

Battery fluid is corrosive and dangerous because of its explosiveness and toxicity. Therefore, it should only be handled by a skilled technician who specializes in battery fluid.

8. Only authorized skilled technicians should repair and maintain engines.
9. Only appropriate tools should be used. If the jaws of a wrench are worn out, the wrench might slip during use, causing safety accidents.
10. Do not allow other persons to stay or pass under an engine when lifting the engine with a crane. Before lifting the engine, ensure that there is no one around the engine and to secure enough safety space.

1. General introduction

11. Before inspecting or replacing the electrical apparatus, disconnect the battery ground wire first. Connect the battery ground wire after completing all required work for checking or replacing the electrical apparatus in order to prevent a short circuit.
12. Before performing electric welding works, turn off engine, block the power supply to the engine, and remove the wire harness connector.
13. Do not give any electric or mechanical shocks or perform welding works on the electrical apparatus or the ECU.

General Repair

1. Wait until the engine is properly cooled down before starting work, since you may get burned by the heated engine.
2. Disconnect the battery ground wire from to prevent damage of wires and sensors caused by a short circuit.
3. Engine oil and coolant may damage paint and should be stored in a separate container and marked for safe management.
4. Store the disassembled parts in a specified space to avoid damage or pollution.
5. Use specified and special tools for efficient and safe repair.
6. If parts need to be replaced, use only genuine parts for replacement. Using unauthorized or remanufactured parts may cause critical damage and faults in engine performance.
7. Replace parts such as cotter pins, gaskets, Orings, seal rings, oil seals, and washers with new ones during repairs. Reuse of parts may be the cause of engine faults and engine may not operate properly.
8. Group and store disassembled parts in disassembling order. Due to the fact that bolts and nuts vary in strength, shape and torque according to their assembly position. Please divide and store them accordingly to these characteristics.
9. Clean disassembled parts to remove foreign substances before inspecting or reassembling parts. Use compressed air to clean the oil holes or holes.
10. Thinly spread oil or grease on rotating parts or parts requiring lubrication, before assembling them.
11. If required, use a specified adhesive to assemble gaskets to prevent water or oil from leaking.
12. Assemble bolts and nuts with the specified tightening torque.
13. After completing repairs, conduct a final inspection and perform a test operation to check if all works have been successfully completed.

Other Safety Instructions and Environmental Pollution

Observe the following instructions to protect workers from danger and to prevent the environmental pollution while performing engine repairs.

1. Good ventilation and low humidity should be maintained in the work space.
2. The workspace should be clean, in good order, and no flammables are allowed in the workshop.
3. Smoking is strictly forbidden in the workshop.
4. Workers should wear working clothes, protective goggles, and safety shoes.
5. Workers are not allowed to wear accessories such as necklaces, rings, watches, and earrings.
6. Start the engine in a well-ventilated space and fully ventilate the space before starting engine to prevent carbon monoxide poisoning.
7. Wait until the engine is properly cooled down before starting work, since you may get burned by the heated engine.
8. Do NOT work on rotating or running parts once the engine has been started.
9. Discard oil according to the regulations set forth by the relevant authorities.
10. If engine oil or fuel leaks on the floor or is improperly discharged, serious environmental pollution of sea, river or underground water may occur.
11. Discard the undiluted anticorrosive agent, antifreeze, filter elements, and cartridges as special wastes.
12. Discard coolant and special waste according to the regulations of the appropriate authorities.

WARNING

Failure to observe the regulations of the relevant authorities violates environmental pollution regulations and may be subject to legal penalties.

Use of Genuine Parts

An engine consists of many parts which are mechanically harmonized. To prevent engine faults in advance and use engines with best performance for a long period, maintenance and replacement of expendable parts should be conducted regularly.

Use of genuine parts is recommended. Using unauthorized or remanufactured parts may cause critical damage and faults to engine for which HD Construction Equipment shall not be held liable.

Engine maintenance

Prevention of damage and abrasion

Using an engine for any purposes other than the designed purpose may cause critical faults to the engine for which HD Construction Equipment shall not be held liable. For details concerning the usage and purpose of the engine, please direct questions to HD Construction Equipment Sales Team. Do NOT adjust, convert, or change the ECU without HD Construction Equipment authorization.

If a problem is found in an engine, figure out and solve the cause to prevent the critical faults in advance.

Use of genuine parts is recommended. Using unauthorized or remanufactured parts may cause critical damage and faults to engine for which HD Construction Equipment shall not be held liable.

Consider the following while managing engines.

1. Use clean, specified, and qualified fuel only. Use fuel recommended in this Operation and Maintenance Manual.

CAUTION

Using inappropriate or unspecified fuel may cause critical damage and faults in engine performance.

2. Do not operate an engine without lubrication oil or coolant. Use only the products (engine oil, cooling water, anticorrosive agent, and etc) recommended by HD Construction Equipment.
3. Always keep surroundings of the engine clean.
4. Use fuel recommended in this Operation & Maintenance manual.
5. Conduct inspections and exchanges regularly according to the regular inspection table.
6. If the engine is overheated, do not stop it immediately, but operate it at idle status for five minutes or more to lower the engine temperature to the proper level.

WARNING

If the radiator cap is opened while the engine is still hot, hot water will spurt out and may cause burns.

7. Check the engine oil level on a flat surface. Do not exceed the maximum of the oil level gauge.

CAUTION

Immediately replenish engine oil when the engine oil level is below the lower limit of the engine oil gauge.

8. If there are gauges for battery, oil pressure and coolant and temperature, check if they indicate a normal status.
9. Do not operate engine without coolant.

CAUTION

Always use coolant mixed with antifreeze. If coolant without antifreeze is used, the coolant may freeze causing the coolant passage in the cylinder block to freeze and damaging the engine.

CAUTION

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

Prevention of Pollution

Consider the following to manage engine without causing environmental pollution.

1. Discharge oil and coolant using collection containers.
2. Discard oil and coolant according to the regulations of the relevant authorities.
3. Be careful not to let discharged oil and cooling water flow into the ground or the sewer. Otherwise, serious pollution of the drinking water source may occur.
4. Classify the oil, filters, and filter cartridges as environmental pollution wastes and discards them according to regulations.
5. Classify the antifreeze, cooling water, and anticorrosive agent as hazardous wastes and discards them by observing the regulations.

Handling of Engine Oil

Prolonged and repeated contact of skin with engine oil may cause skin to dry out and contract, causing dermatitis.

Engine oil includes substances toxic to the human body.

Handle engine oil by observing the following safety rules:

1. Do not expose skin to used engine oil for a long time.
2. Always wear working clothes and gloves.
3. If skin comes in contact with engine oil, immediately wipe it off with water, soap or hand cleaners.
4. Do not clean skin with gasoline, fuel, thinner, or solvent.
5. Apply a skin care cream after cleaning from oil.
6. Do not put oil-stained gloves or cloth in ones pocket.

1. General introduction

WARNING

Discard oil according to the regulations set forth by the relevant authorities. Disposing of discharged oil into the ground, sewers, drains, rivers, or the sea will cause serious environmental pollution. Violation of regulations regarding discard of engine oil without observing the handling regulations, will be punished.

HVO (Hydro treated Vegetable Oil)

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

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

HD Construction Equipment approves the use of up to 100%

HVO for engines in accordance with the EU standard EN15940.

2. Operation and maintenance

Starting and stopping of the engine	11
Preparing for Start.....	11
Starting the Engine	11
Running in	11
During Operation.....	11
Stopping the Engine.....	12
Break-in period of the engine	13
General Information	13
Break-in Period of a New Engine	13
Check Points	13
Cold Start Operation	13
Inspection after Starting the Engine	13
Operation in winter	15
Cold Start	15
Preventing Coolant from Freezing	15
Preventing Overcooling of the Engine	15
Engine Oil	15
Inspection and repair of the engine	16
Checking Engine Parts after Prolonged Operation	16
Inspection and Repair of Turbocharger.....	16
Intake System	16
Exhaust System	16
Lubrication System	16

Starting and stopping of the engine

Preparing for Start

Check the following before starting the engine for the first time after purchase.

1. Before starting an engine, check the levels of fuel, coolant, and oil and replenish those fluids if required.
2. Check if engine oil level is between the upper and lower limit of the oil level gauge. The upper and lower limit of the oil level gauge indicate the maximum and minimum of the engine oil level.

CAUTION

- When replenishing engine oil, do not exceed the maximum on the oil level gauge. Too much oil may cause damage to the engine.
- The oil required to fill the oil filters and pipes depends upon the engine equipment and use and must be determined individually at the time of initial commissioning. Make a note of the determined quantity.

3. Be careful not to mix foreign substances in fuel, engine oil, or coolant while adding the fluid, and keep the fluid clean while it is not in use. Use fuel, oil, and coolant recommended by HD Construction Equipment. Otherwise, critical damage to the engine may occur

Starting the Engine

Observe the following when starting the engine.

1. Insert key in starting lock.
2. Moving control lever to idle speed.
3. Key switch rotate clockwise.
4. Do not operate for longer than 10 seconds at a time.
5. After ignition of the engine, take-off the hands in key switch.
6. and adjust control lever for desired speed.
7. If engine fails to start, release the key, wait about 1 minute, then operate starter again.

8. Avoid running the cold engine for any length of time since in any internal combustion engine this is liable to cause increased wear due to corrosion. Prolonged idling is harmful to the environment.

CAUTION

- On initial start of an overhauled engine or after long periods without use, press shutdown lever in “stop” position and operate starter motor for a few seconds (max. 10) until oil pressure is indicated.
- Ensure that the engine can not be started by unauthorized persons.

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

Running in

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

During Operation

CAUTION

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

1. Oil pressure
 - 1) 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.
2. Coolant temperature
 - 1) Operating an engine with too low coolant temperature increases fuel consumption, abrasion of the cylinder liner, and shortens the engine's life span.
3. Alternator

In order to avoid damage to the alternator, observe the following instructions while the engine is running.

2. Operation and maintenance

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

Stopping the Engine

Cut off the main circuit breaker of the generator control panel but do not stop the engine immediately.

Keep running the engine at idle speed for about 5 minutes before stopping the engine.

Break-in period of the engine

General Information

HD Construction Equipment engines are subjected to a final approval test to ensure the provision of high quality engines before being shipped. However, engines are not operated for a long period of time in this test. Therefore, new engines require a break-in period of during the initial 50 hours after delivery. By properly breaking-in an engine, the highest levels of engine performance can be maintained long-term.

Break-in Period of a New Engine

If the engine's bearings are not properly broken in, they may be easily damaged and the lifetime of the engine may be shortened by overloading or high speeds. In order to prevent this, please follow the guidelines below for the initial 50 hours after delivery of new engine.

1. Fully warm up the engine until the engine temperature reaches the normal operation condition, before starting operation of the engine.
2. Do not overload the engine or operate it at too high RPM.
3. Do not operate the engine with high speed at idle.
4. Do not rapidly start up or stop the engine.
5. Operate the engine with less than 70 % of the engine load.
6. Inspection, check, and repair of engines should be managed by officially-certified technicians at certified service centers in compliance with corresponding rules.

Check Points

check the following during the break-in period of a new engine.

1. Periodically check if the engine oil level is between the minimum and maximum limit of the oil level gauge.

CAUTION

If you cannot accurately check the oil level through the oil level gauge, rotate the oil level gauge to 180 degree, put it in the guide tube, and then pick it out again to check.

2. If the oil indicator lamp on the apparatus is turned on or blinks, the oil pressure may be insufficient. In this case, check the oil level and replenish oil if required. When replenishing engine oil, do not exceed the maximum on the oil level gauge. If the oil level is normal, check other related parts such as the oil pressure sensor, oil pump, or oil line.

CAUTION

The oil pressure may increase with high rpm and decrease with low rpm. In addition, the pressure of cold oil may be higher at a specific rpm than that of warm oil. This phenomenon may occur when the engine operates properly.

3. Check the coolant level to check if the coolant circulates properly. If the coolant in the radiator is not enough, the coolant level indicated may not be accurate.
4. Exchange engine oil and oil filter after the break-in period.

CAUTION

If engine oil and oil filter need to be replaced, use only genuine engine oil and parts recommended by HD Construction Equipment.

Cold Start Operation

Slowly warm up the engine in case of starting up in cold weather or in areas with cold climate. Do not rapidly raise the rpm or load before the engine has not been warmed up. The engine may consume oil until its piston ring is in position. Please check the engine oil level frequently for the initial 50 hours of the break-in period.

Inspection after Starting the Engine

Check the pressure of the engine lubrication system by using the engine oil pressure gauge mounted on the apparatus while the engine is in operation. If pressure decreases on oil pressure gauge, immediately stop the engine. In addition, make sure that the recharge alarm indicator lamp of the alternator is turned off while the engine is operating.

1. Tightly connect the +/- terminals to prevent gaps between them. The sheath of battery connection cables should not be damaged or broken.
2. If the recharge alarm indicator lamp suddenly turns on or blinks during engine operation and the engine stops, fix the fault of the electric apparatus.

2. Operation and maintenance

3. If color or odor of exhaust gas is unusual during operation, stop the engine, diagnose the cause and fix the fault.
4. Check the engine status through the alarm indicator lamp and gauges mounted on the apparatus during operation.

Operation in winter

Cold Start

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

CAUTION

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

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

CAUTION

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

Preventing Coolant from Freezing

When only water used as coolant without mixing with anti-freeze, corrosion in the engine, degradation of cooling efficiency, and freezing of the engine in winter may occur. If the engine is not operated for a long period during cold weather or in areas with cold climate, fully discharge the coolant from the engine. Freezing of coolant leads to critical damage to the engine. Please use a mixture of coolant with antifreeze at revised ratio when replacing or replenishing the coolant. The antifreeze prevents coolant from freezing.

Preventing Overcooling of the Engine

When the engine is cooled below the normal operating temperature, thermal efficiency is lowered and fuel consumption as well as abrasion of the cylinder liner may increase. Therefore, the engine should be operated within the normal operating temperature. If the engine has been sufficiently operated, but the temperature of coolant remains below the normal operating temperature, check the water temperature controller or other parts related to the cooler.

Engine Oil

When viscosity of engine oil increases due to its low temperature during cold weather or in areas with cold climate, the rpm may not be stable after starting the engine. To prevent this, replace oil to engine oil for cold weather or areas with cold climate. When replacing engine oil, use of HD Construction Equipment genuine engine oil is recommended.

2. Operation and maintenance

Inspection and repair of the engine

Checking Engine Parts after Prolonged Operation

Wear, corrosion, or degradation of engine elements and assemblies may occur, causing lowered performance of engine parts. To maintain high engine performance, check the engine after prolonged operation to enhance durability of the engine.

Unexpected faults may occur in some weak engine parts after normal operation of the engine, when operation time is prolonged. In this case, it is difficult to maintain high engine performance by simply repairing some parts. It is recommended to replace or repair the entire related parts in order to diagnose the causes more accurately and maintain high engine performance.

To prevent engine failure in advance and use the engine safely for a long period, perform periodic replacements and inspections.

It is recommended to perform engine adjustments and preventive inspections during spring after the engine was exposed to winter or cold weather. This allows economic, long-term use of the engine without faults.

As the following parts affect the engine output and performance, they should be regularly checked and inspected.

1. Parts affecting intake and exhaust
 - Air filter
 - Inter cooler
 - turbocharger, silencer
 - Other parts
2. Parts affecting lubrication and cooling
 - Air filter
 - Oil filter
 - Antifreeze
 - Other parts

Inspection and Repair of Turbocharger

As performance of turbocharger significantly affects the engine performance, regular inspection and repair should be made and inspection and maintenance regulations should be observed.

Intake System

Be careful to handle air filter carefully. In regards to the dry air filter, intake resistance should be small to ensure a smooth intake of air.

Exhaust System

If exhaust gas is leaked from the connections in the exhaust pipe, the turbocharger efficiency is lowered, causing degraded engine output and seizure of related parts in the worst case. As parts related to exhaust and turbocharger are used at high temperature, be careful not to mix the bolts and nuts with other parts when performing repair.

Lubrication System

Inspection and exchange of oil and oil filter should be performed while considering their exchange cycle. Overheated engine oil significantly affects the engine performance as well as the engine itself.

3. Performance and specifications

Engine specifications and performance	19
Engine specification	19
Engine output	23
Exterior view drawing of the engine (D1146/PU086)	24
Front/Rear (D1146/PU086)	24
Left/Right (D1146/PU086)	25
Exterior view drawing of the engine (D1146T/PU086T)	26
Front/Rear (D1146T/PU086T)	26
Left/Right (D1146/PU086)	27
Exterior view drawing of the engine (P086TI)	28
Front/Rear (P086TI)	28
Left/Right (P086TI)	29
Exterior view drawing of the engine (DP086TA)	30
Front/Rear (DP086TA)	30
Left/Right (DP086TA)	31
Top (DP086TA)	32
Exterior view drawing of the engine (DP086LA)	33
Front/Rear (DP086LA)	33
Left/Right (DP086LA)	34
Top (DP086LA)	35
Exterior view drawing of the engine (PU086TI)	36
Front/Rear (PU086TI)	36
Left/Right (PU086TI)	37
Top (PU086TI)	38
Engine identification number	39
Engine code and manufacturing number	39
Engine number engraving	39

3. Performance and specifications

Engine specifications and performance

Engine specification

Items		D1146/ PU086	D1146T/ PU086T	P086TI	DP086TA	DP086LA	Remarks
Engine type		4 cycle, in-line, water-cooled type, natu- rally aspirated	4 cycle, in-line, water-cooled type, turbo charged	4 cycle, in-line, water-cooled type, turbo charged inter cooled			
Combustion chamber type		Direct injection type					
Cylinder liner type		Replaceable dry liner					
Timing gear system		Gear driven type					
No. of piston ring		Compression ring 2, oil ring 1					
No. of cylinder - bore x stroke (mm)		6 - 111 × 139					
Total piston displacement (cc)		8,071					
Compression ratio		17.9 : 1	17.0 : 1	17.1 : 1			
Engine dimension (length x width x height) (mm)		1,224 x 830 x 974	1,224 x 830 x 1,082	1,248 x 918 x 1,102	1,242 x 746 x 1,113	1,242 x 1,122 x 1,113	
Engine weight (kg)		720 / 780	780 / 780	790			
Rotation		Counter clockwise					Viewed from flywheel
Fuel injection order		1 - 5 - 3 - 6 - 2 - 4					
Fuel injection timing		18°	18° / 12°	12°	19°	14°	BTDC static
Injection pump type		In - line “AD” type		In-line “P” type	In-line “P” type		
Governor type		Mechanical governor type (RSV)		Electrical governor type	Electrical gavernor type		
Injection nozzle type		Multi-hole type					
Fuel injection pressure (kg/cm ²)		214					at 200rpm
Compression pressure (kg/cm ²)		28					
Valve clear- ance (mm)	Intake	0.3 ±0.05					at cold
	Exhaust	0.3 ±0.05					at cold
Intake valve	Open at	16°					BTDC
	Close at	36°					ABDC
Exhaust valve	Open at	46°					BBDC
	Close at	14°					ATDC

3. Performance and specifications

Items		D1146/ PU086	D1146T/ PU086T	P086TI	DP086TA	DP086LA	Remarks
Lubrication method		Full forced pressure feed type					
Oil pump type		Gear type driven by camshaft					
Oil filter type		Full-flow, cartridge type					
Lubricating oil capacity (lit)	Max.	15.5					
	Min.	12					
Oil specification	Oil class (API)	API CI-4					
	SAE	10W40					
Oil cooler type		Water cooled					
Water pump		Centrifugal type driven by belt					
Cooling Method		Fresh water forced circulation					
Cooling water capacity (lit)		14 / 11					engine only
Thermostat type		Wax pallet type					
Alternator voltage - capacity (V - A)		24 - 45					
Starting motor voltage - output (V - kW)		24 - 4.5		24 - 6.0			

3. Performance and specifications

Items		PU086TI		Remarks
		EBPPA	EBPPB	
Engine type		4 cycle water cooled turbo charged inter cooled		
Combustion chamber type		Direct injection type		
Cylinder liner type		Replaceable dry liner		
Timing gear system		Gear driven type		
No. of piston ring		Compression ring 2, oil ring 1		
No. of cylinder - bore x stroke (mm)		6 - 111 × 139		
Total piston displacement (cc)		8,071		
Compression ratio		17.1 : 1	15.9 : 1	
Engine dimension (length x width x height) (mm)		1,242 x 918 x 1,100	1,116 x 728 x 1,106	
Engine weight (kg)		792	800	
Rotation		Counter clockwise		Viewed from flywheel
Fuel injection order		1 - 5 - 3 - 6 - 2 - 4		
Fuel injection timing		15° ±1°	18° ±1°	BTDC static
Injection pump type		Mechanical Inline Type		
Governor type		Mechanical governor type (RSV)		
Injection nozzle type		Multi-hole type		
Fuel injection pressure (bar)		210		
Compression pressure (bar)		25.0		at 200 rpm
Valve clearance (mm)	Intake	0.3 ±0.05		at cold
	Exhaust	0.3 ±0.05		at cold
Intake valve	Open at	16°		BTDC
	Close at	36°		ABDC
Exhaust valve	Open at	46°		BBDC
	Close at	14°		ATDC
Lubrication method		Full forced pressure feed type		
Oil pump type		External spur gear type		
Oil filter type		Full-flow, cartridge type		
Lubricating oil capacity (lit)	Max.	15.5		
	Min.	12		

3. Performance and specifications

Items		PU086TI		Remarks
		EBPPA	EBPPB	
Oil specification	Oil class (API)	API CI-4		
	SAE	10W40		
Oil cooler type		Water cooled		
Water pump		Centrifugal (Pulley type)		
Cooling Method		Radiator		
Cooling water capacity (lit)		13.2		engine only
Thermostat type		Wax pellet type		
Alternator voltage - capacity (V - A)		24 - 45		
Starting motor voltage - output (V - kW)		24 - 6.0		

3. Performance and specifications

Engine output

(Production tolerance: ±5%)

Generating-Set Engines			Condition			Remarks
			Continuous	Prime	Stand by	
D1146	Standard	50HZ (1,500 rpm)	-	105PS (77kW)	116PS (85kW)	
		60HZ (1,800 rpm)	-	130PS (96kW)	143PS (105kW)	
D1146T	Standard	50HZ (1,500 rpm)	-	145PS (107kW)	160PS (118kW)	
		60HZ (1,800 rpm)	-	170PS (125kW)	187PS (138kW)	
P086T	DP086TA	50HZ (1,500 rpm)	-	186PS (137kW)	207PS (152kW)	
		60HZ (1,800 rpm)	-	228PS (168kW)	254PS (187kW)	
P086TI	Standard	50HZ (1,500 rpm)	205PS (151kW)	240PS (177kW)	270PS (199kW)	
		60HZ (1,800 rpm)	253PS (186kW)	279PS (205kW)	303PS (223kW)	
	P086TI-1	50HZ (1,500 rpm)	-	203PS (149kW)	223PS (164kW)	
		60HZ (1,800 rpm)	-	237PS (174kW)	260PS (164kW)	
	DP086LA	50HZ (1,500 rpm)	-	273PS (201kW)	305PS (224kW)	
		60HZ (1,800 rpm)	-	310PS (228kW)	344PS (253kW)	

(Production tolerance: ±5%)

Power-Unit Engines			Max. Output			Remarks
			rpm	PS	kW	
PU086	6 Cyl.	Naturally Aspirated	2,200	160	118	Max. power rating
PU086T	6 Cyl.	Turbo Charged	2,200	205	151	Max. power rating
DP086LAF	6 Cyl.	Turbo Charged	1,500	304	224	Max. power rating
DP086TAF	6 Cyl.	Turbo Charged	1,500	206.7	152	Max. power rating
PU086TI (EBPPA)	6 Cyl.	Turbo Charger & Intercooler	2,200	290	213.3	Max. power rating (Power unit)
PU086TI (EBPPB)	6 Cyl.	Turbo Charger & Intercooler	2,450	310	228	Max. power rating (Fire pump)

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

Note) Ratings Definitions

The power ratings of Emergency Standby and Prime are in accordance with ISO 8528.

Fuel Stop power in accordance with ISO 3046.

Electric power (kWe) must be considered cooling fan loss, alternator efficiency, altitude derating and ambient temperature.

STANDBY POWER RATING is applicable for supplying emergency power for the duration of the utility power outage.

No overload capability is available for this rating. A standby rated engine should be sized for a maximum of an 80% average load factor and 200 hours of operation per year. This includes less than 25 hours per year at the Standby Power rating.

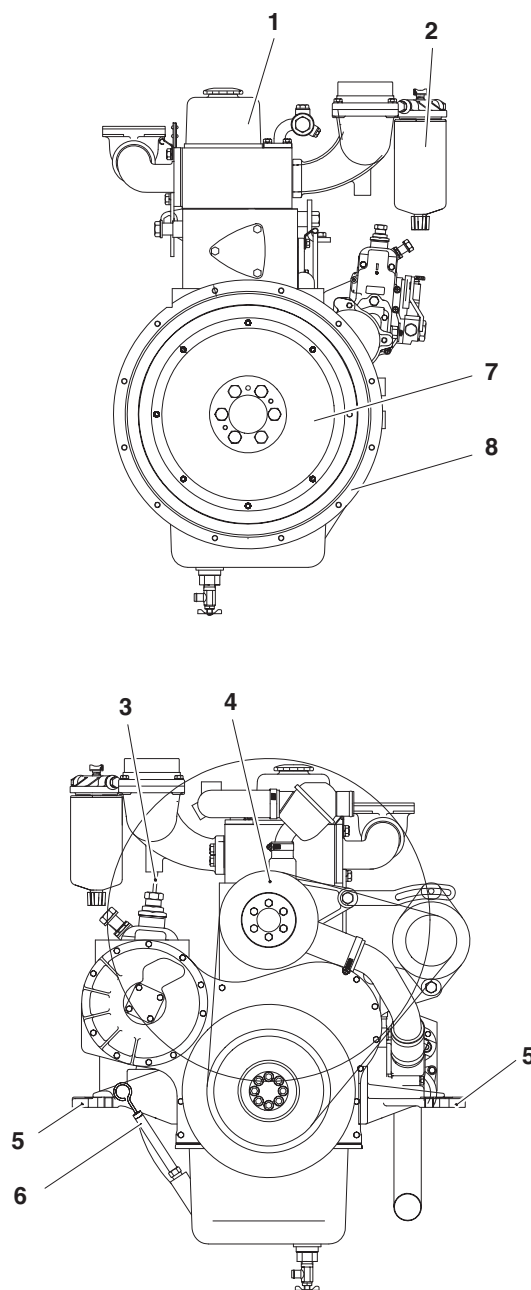
PRIME POWER RATING is available for an unlimited number of hours per year in variable load application. Variable load should not exceed a 70% average of the Prime Power rating during any operating period of 24 hours. The Total operating time at 100% Prime Power shall not exceed 500 hours per year. A 10% overload capability is available for a period of 1 hour withing a 12 hour period of operation. Total operating time at the 10% overload power shall not exceed 25 hours per year.

3. Performance and specifications

Exterior view drawing of the engine (D1146/PU086)

Note) The images shown represent the standard model; they do not include all models.

Front/Rear (D1146/PU086)



EA9O1003_1

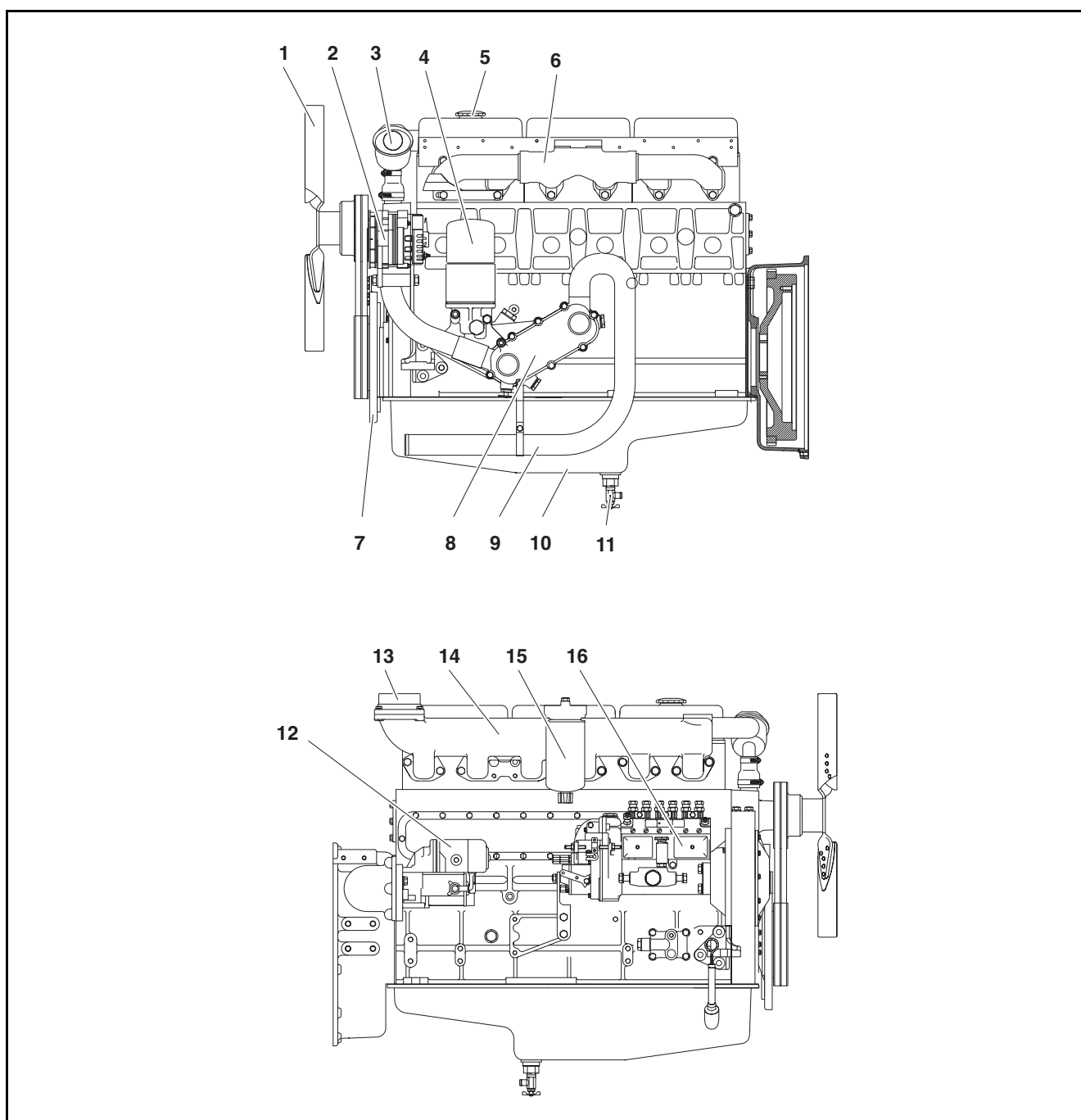
- 1. Cylinder head cover
- 2. Cooling water pipe
- 3. Fuel injection pipe

- 4. Water pump
- 5. Mounting bracket
- 6. Oil level gauge

- 7. Flywheel
- 8. Flywheel housing

3. Performance and specifications

Left/Right (D1146/PU086)



EA9O1003_2

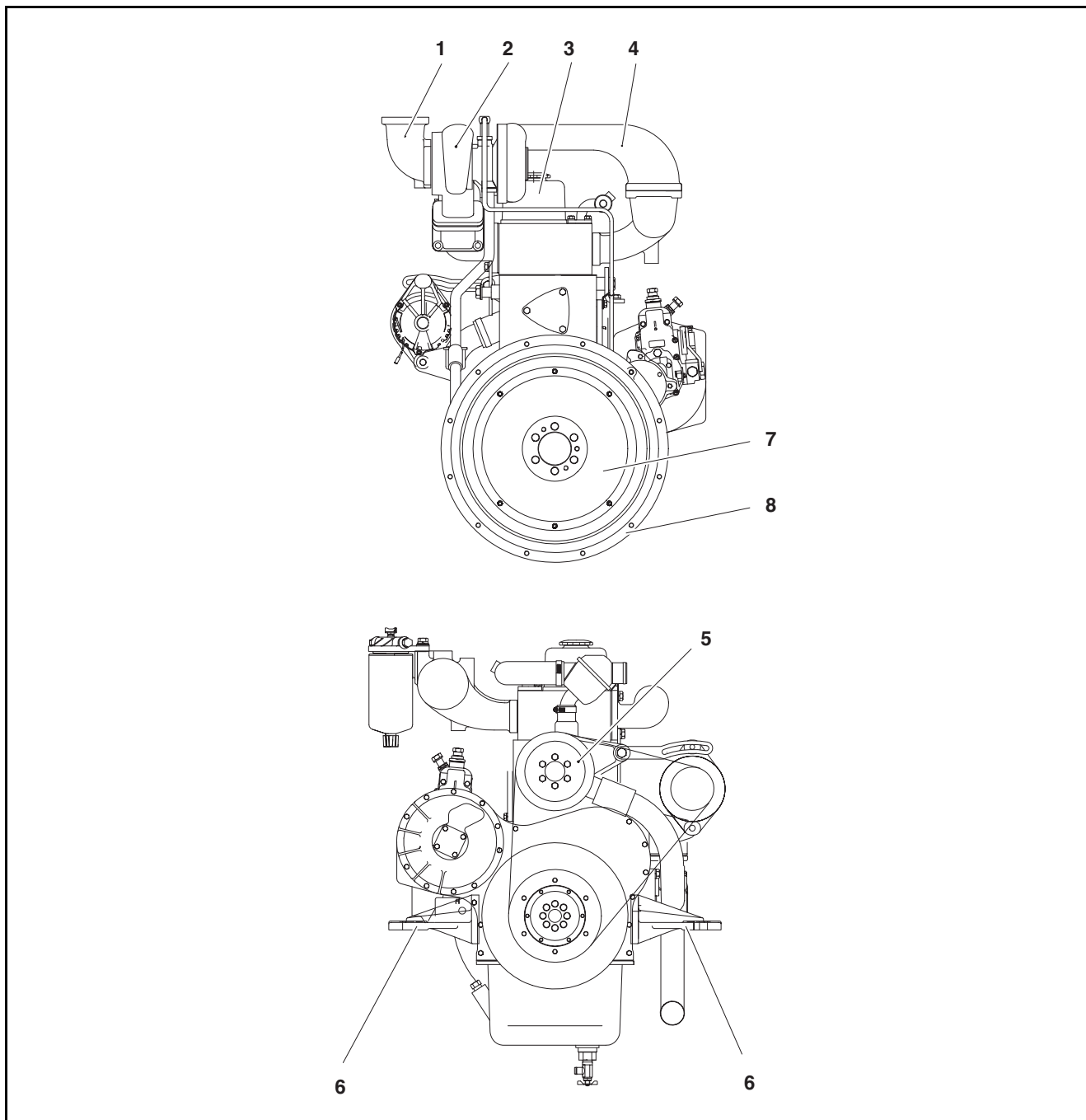
- | | | |
|---------------------|-----------------------|-------------------------|
| 1. Cooling fan | 7. Vibration damper | 13. Intake stake |
| 2. Alternator | 8. Oil cooler | 14. Intake manifold |
| 3. Thermostat | 9. Cooling water pipe | 15. Fuel filter |
| 4. Oil filter | 10. Oil pan | 16. Fuel injection pump |
| 5. Oil filter cap | 11. Oil drain valve | |
| 6. Exhaust manifold | 12. Starter | |

3. Performance and specifications

Exterior view drawing of the engine (D1146T/PU086T)

Note) The images shown represent the standard model; they do not include all models.

Front/Rear (D1146T/PU086T)



EA9O1004_1

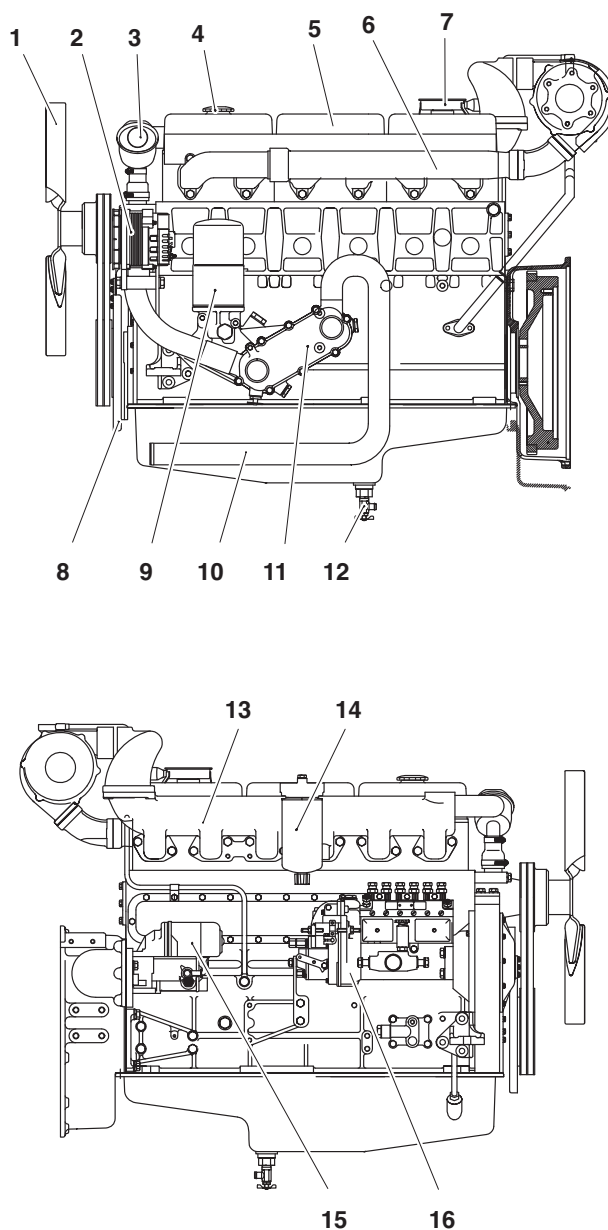
- 1. Exhaust elbow
- 2. Turbocharger
- 3. Cylinder head cover

- 4. Air pipe
- 5. Water pump
- 6. Mounting bracket

- 7. Flywheel
- 8. Flywheel housing

3. Performance and specifications

Left/Right (D1146/PU086)



EA9O1004_2

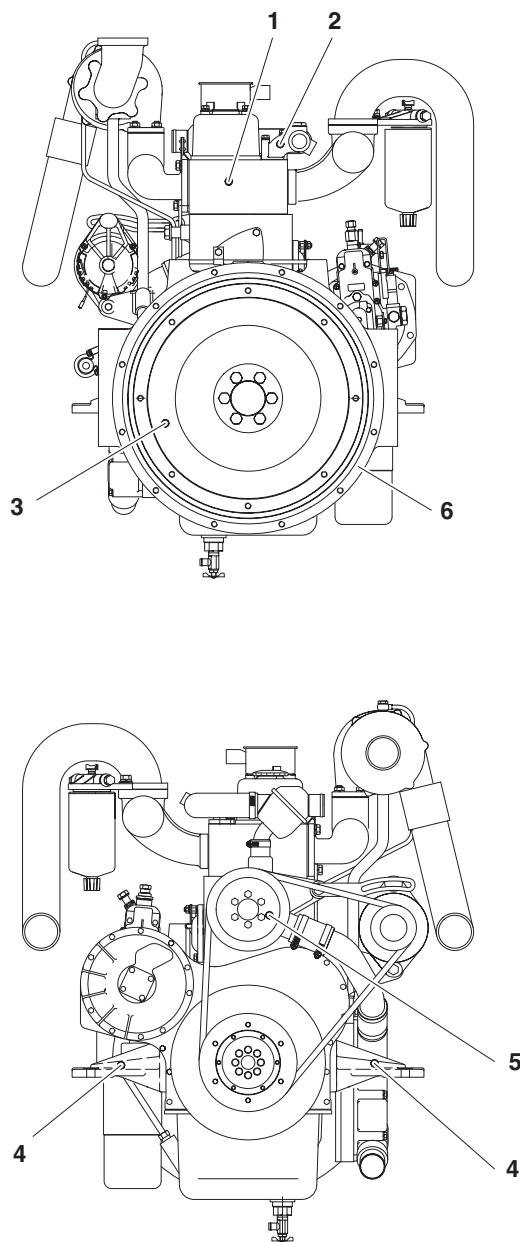
- | | | |
|------------------------|------------------------|-------------------------|
| 1. Cooling fan | 7. Breather | 13. Intake manifold |
| 2. Alternator | 8. Vibration damper | 14. Fuel filter |
| 3. Thermostat | 9. Oil filter | 15. Starter |
| 4. Oil filter cap | 10. Cooling water pipe | 16. Fuel injection pump |
| 5. Cylinder head cover | 11. Oil cooler | |
| 6. Exhaust manifold | 12. Oil drain valve | |

3. Performance and specifications

Exterior view drawing of the engine (P086TI)

Note) The images shown represent the standard model; they do not include all models.

Front/Rear (P086TI)



EA9O1005_1

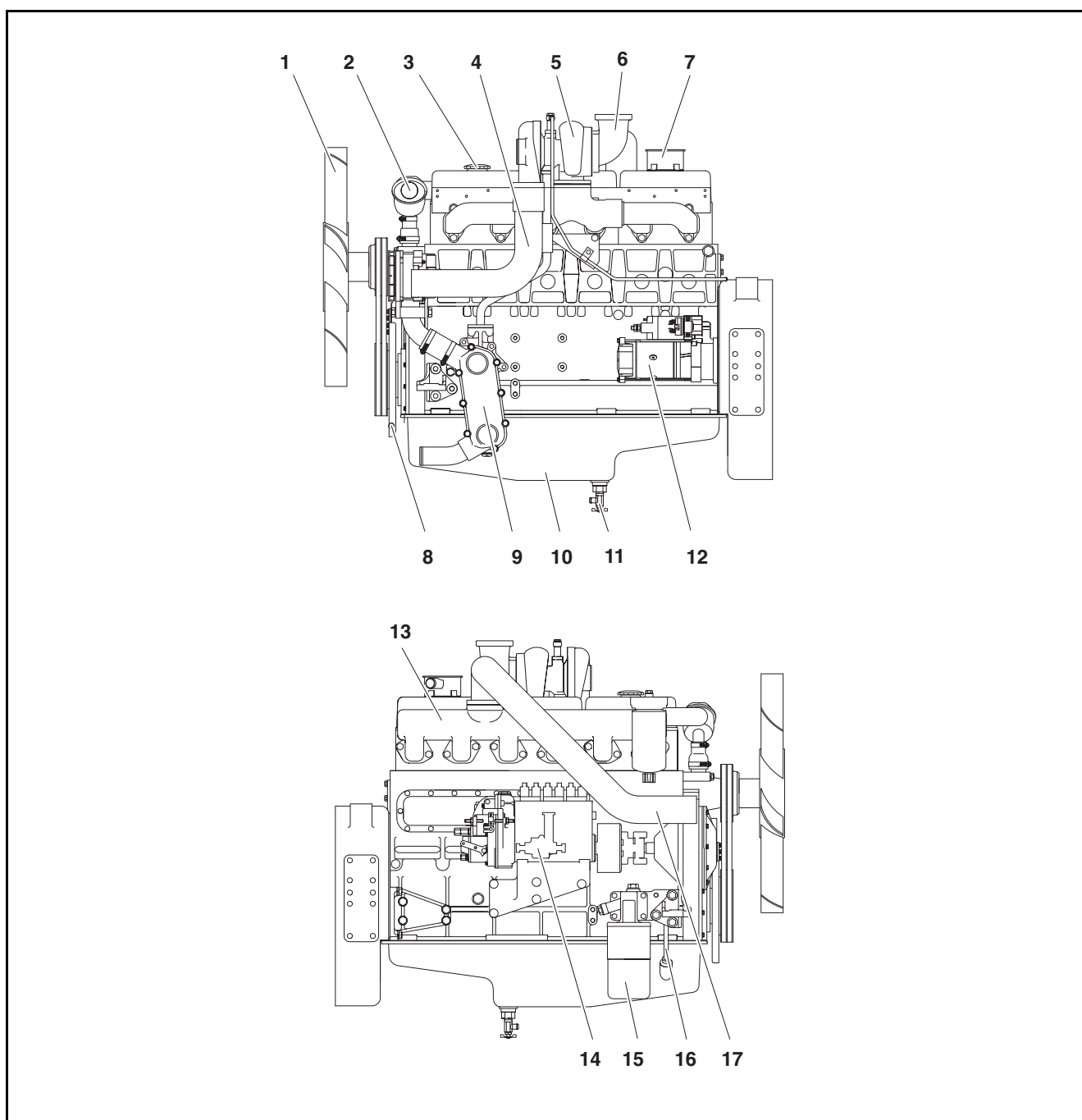
- 1. Cylinder head
- 2. Cooling water pipe

- 3. Flywheel
- 4. Mounting bracket

- 5. Water pump
- 6. Flywheel housing

3. Performance and specifications

Left/Right (P086TI)



EA9O1005_2

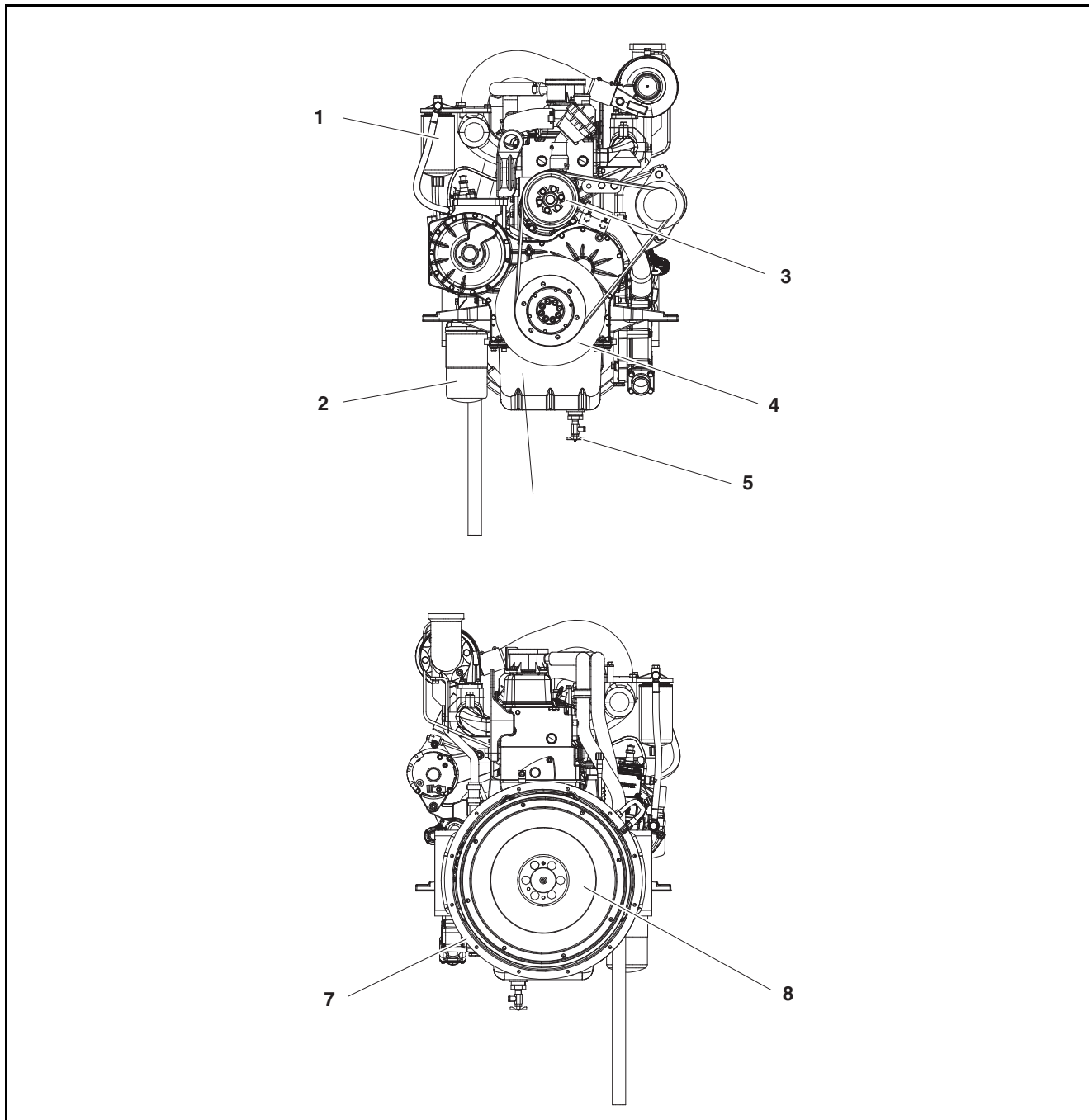
- | | | |
|-------------------|---------------------|-------------------------|
| 1. Cooling fan | 7. Breather | 13. Intake manifold |
| 2. Thermostat | 8. Vibration damper | 14. Fuel injection pump |
| 3. Oil filter cap | 9. Oil cooler | 15. Oil filter |
| 4. Air pipe | 10. Oil pan | 16. Oil level gauge |
| 5. Turbocharger | 11. Oil drain valve | 17. Air pipe |
| 6. Exhaust elbow | 12. Starter | |

3. Performance and specifications

Exterior view drawing of the engine (DP086TA)

Note) The images shown represent the standard model; they do not include all models.

Front/Rear (DP086TA)



EK00345A

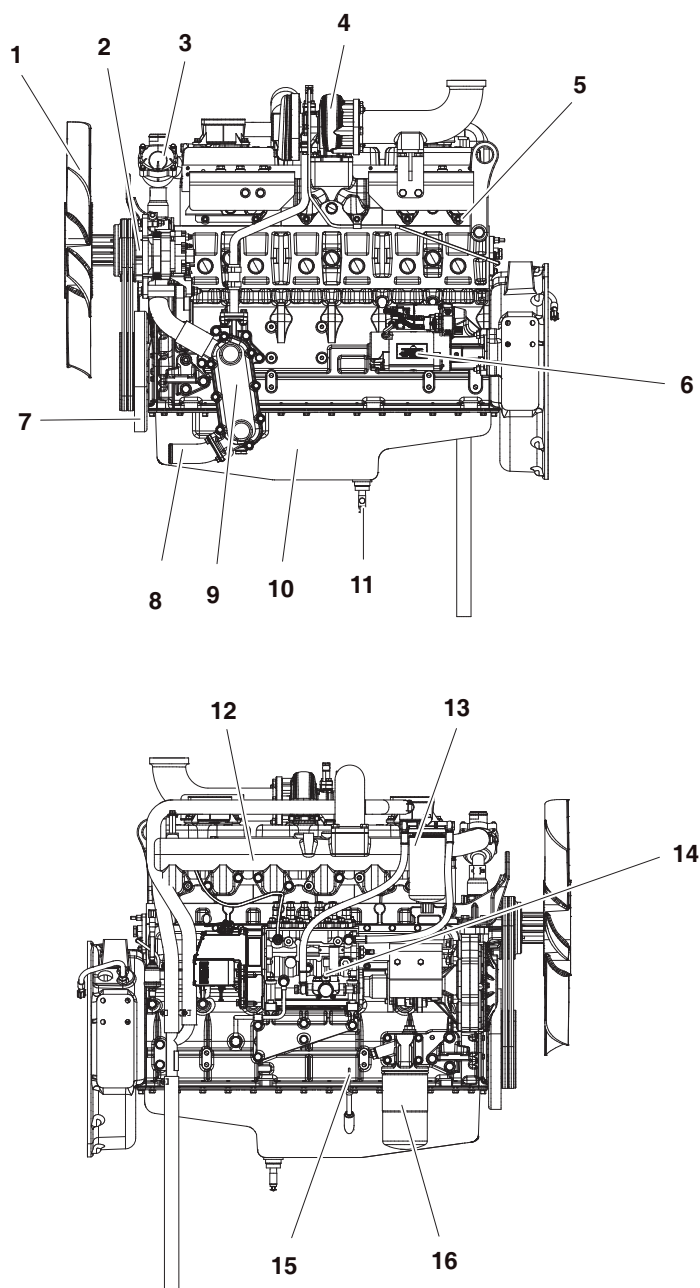
- 1. Fuel filter
- 2. Oil filter
- 3. Cooling fan pulley

- 4. Crankshaft pulley
- 5. Oil drain plug
- 6. Oil pan

- 7. Flywheel housing
- 8. Flywheel

3. Performance and specifications

Left/Right (DP086TA)

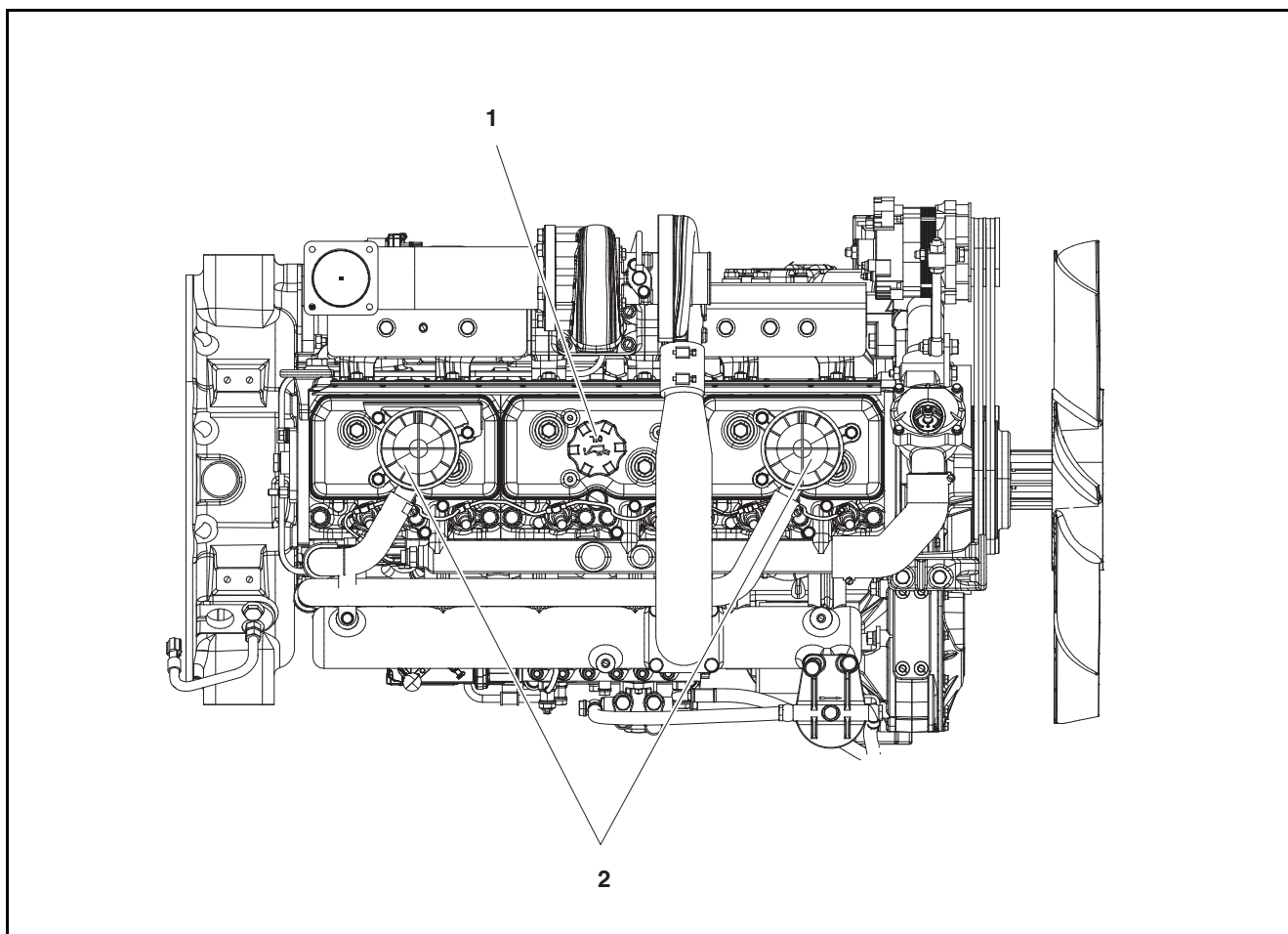


EDE08230003

- | | | | |
|-----------------|-----------------------|---------------------|-------------------------|
| 1. Cooling pan | 5. Exhaust manifold | 9. Oil cooler | 13. Fuel filter |
| 2. Alternator | 6. Starter | 10. Oil pan | 14. Fuel injection pump |
| 3. Thermostat | 7. Vibration damper | 11. Oil drain valve | 15. Oil level gauge |
| 4. Turbocharger | 8. Cooling water pipe | 12. Intake manifold | 16. Oil filter |

3. Performance and specifications

Top (DP086TA)



EK00347A

1. Oil cap

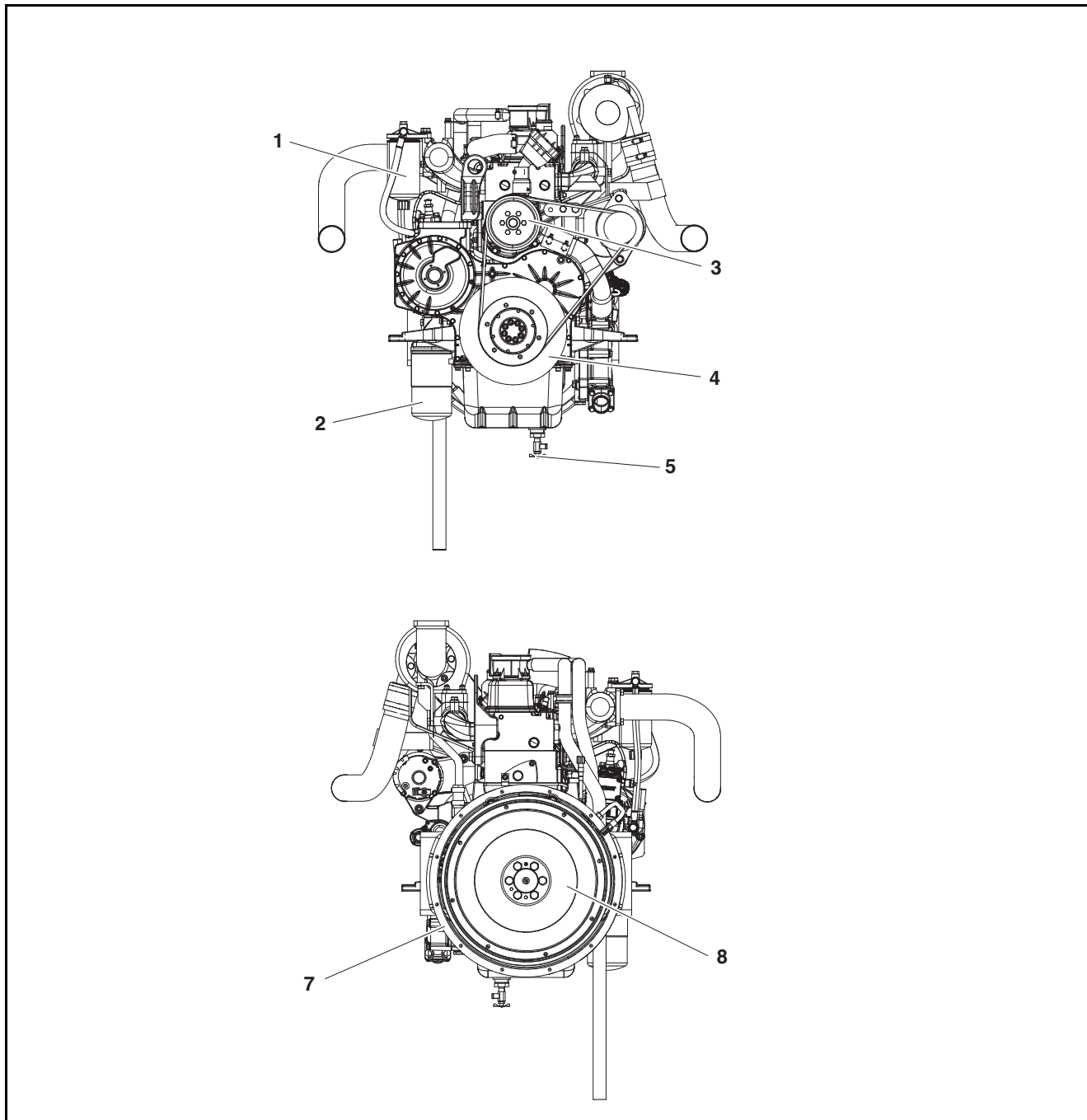
2. Breather

3. Performance and specifications

Exterior view drawing of the engine (DP086LA)

Note) The images shown represent the standard model; they do not include all models.

Front/Rear (DP086LA)



EK00348A

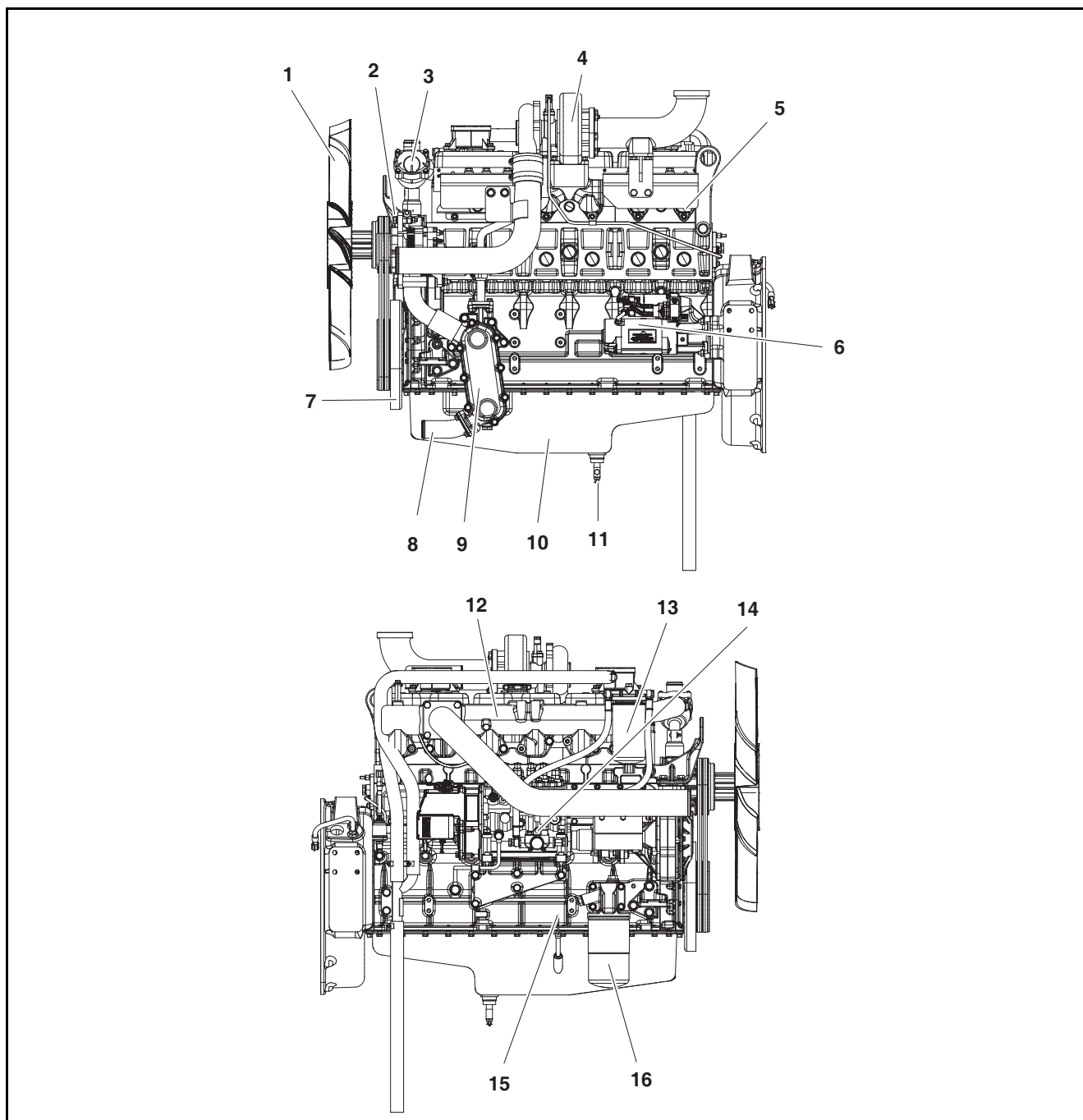
- 1. Fuel filter
- 2. Oil filter
- 3. Oil pan pulley

- 4. Crankshaft pulley
- 5. Oil drain plug
- 6. Oil pan

- 7. Flywheel housing
- 8. Flywheel

3. Performance and specifications

Left/Right (DP086LA)

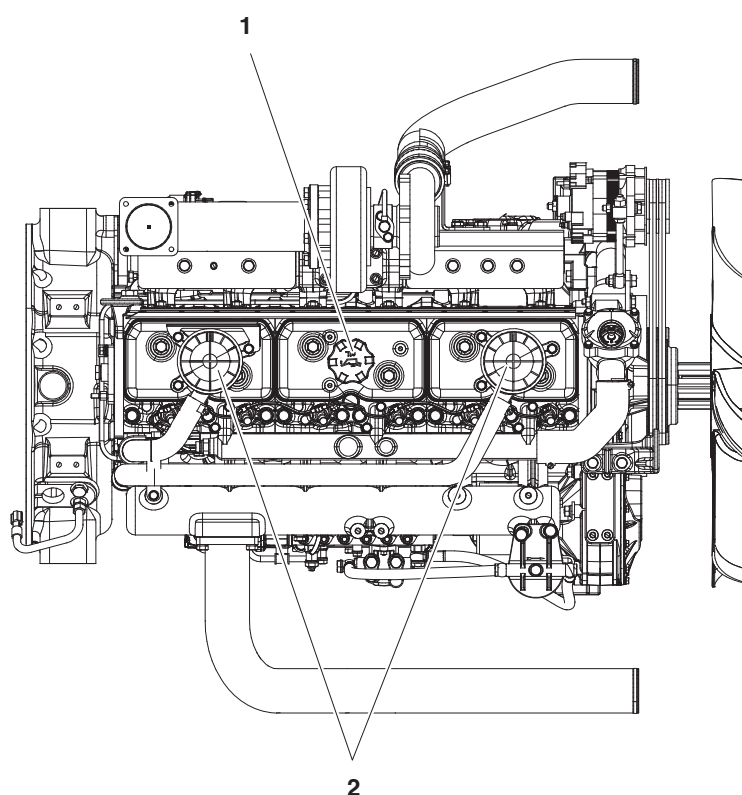


EDE08230004

- | | | | |
|-----------------|-----------------------|---------------------|-------------------------|
| 1. Cooling pan | 5. Exhaust manifold | 9. Oil cooler | 13. Fuel filter |
| 2. alternator | 6. Starter | 10. Oil pan | 14. Fuel injection pump |
| 3. Thermostat | 7. Vibration damper | 11. Oil drain valve | 15. Oil level gauge |
| 4. Turbocharger | 8. Cooling water pipe | 12. Intake manifold | 16. Oil filter |

3. Performance and specifications

Top (DP086LA)



EK00350A

1. Oil cap

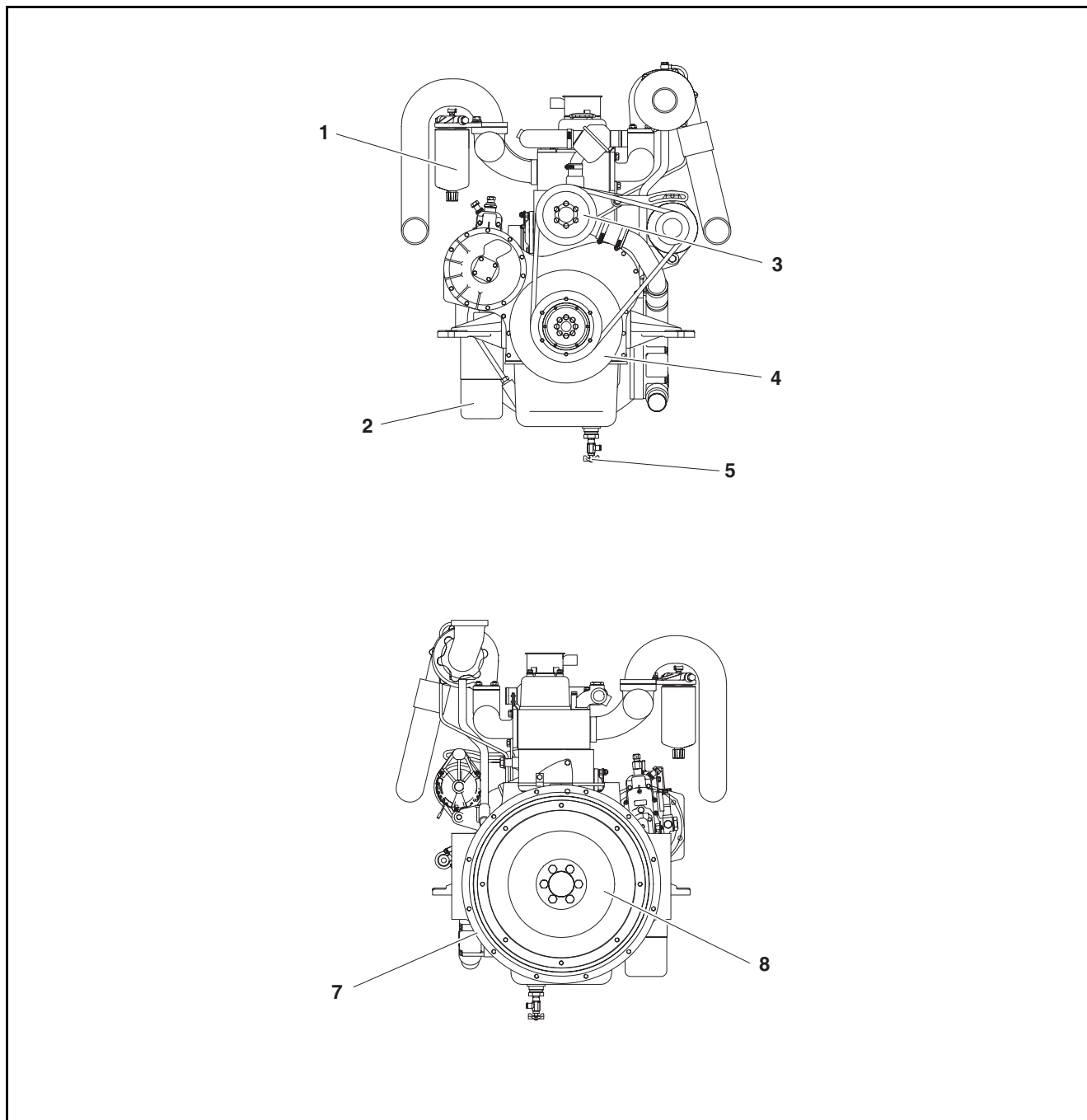
2. Breather

3. Performance and specifications

Exterior view drawing of the engine (PU086TI)

Note) The images shown represent the standard model; they do not include all models.

Front/Rear (PU086TI)

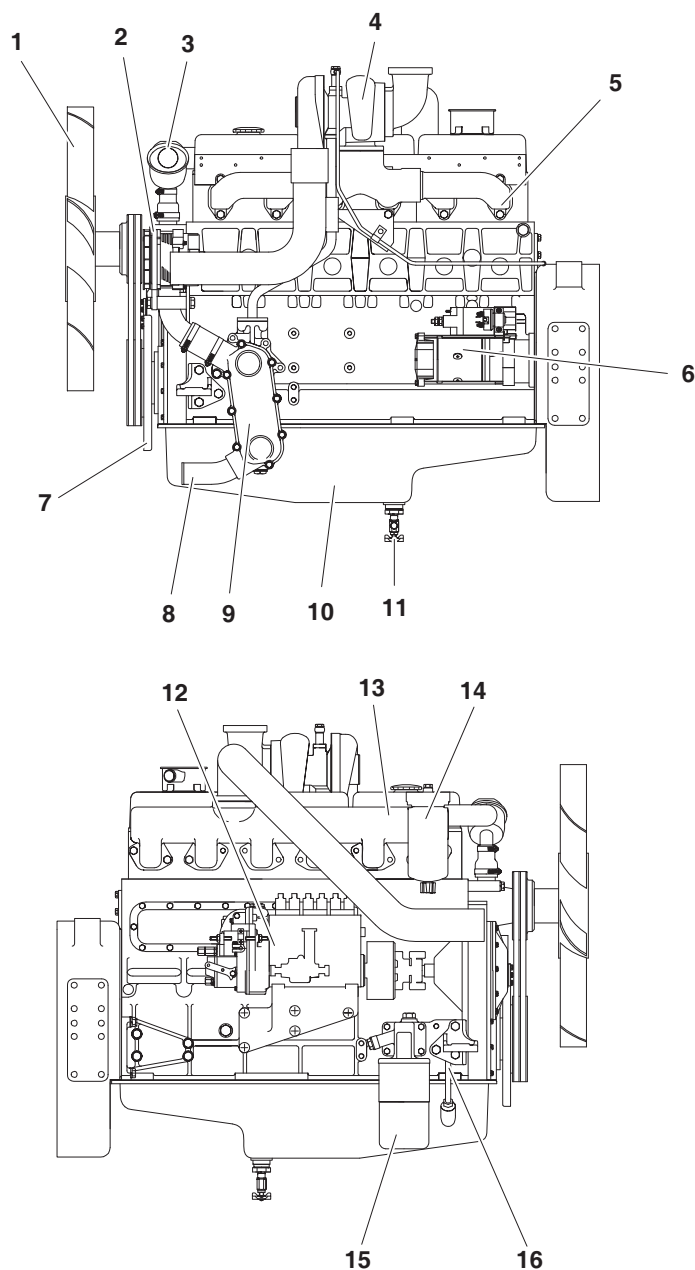


EDL08220184

- | | | |
|-------------------|----------------------|---------------------|
| 1. Fuel filter | 4. Crankshaft pulley | 7. Flywheel housing |
| 2. Oil filter | 5. Oil drain plug | 8. Flywheel |
| 3. Oil pan pulley | 6. Oil pan | |

3. Performance and specifications

Left/Right (PU086TI)

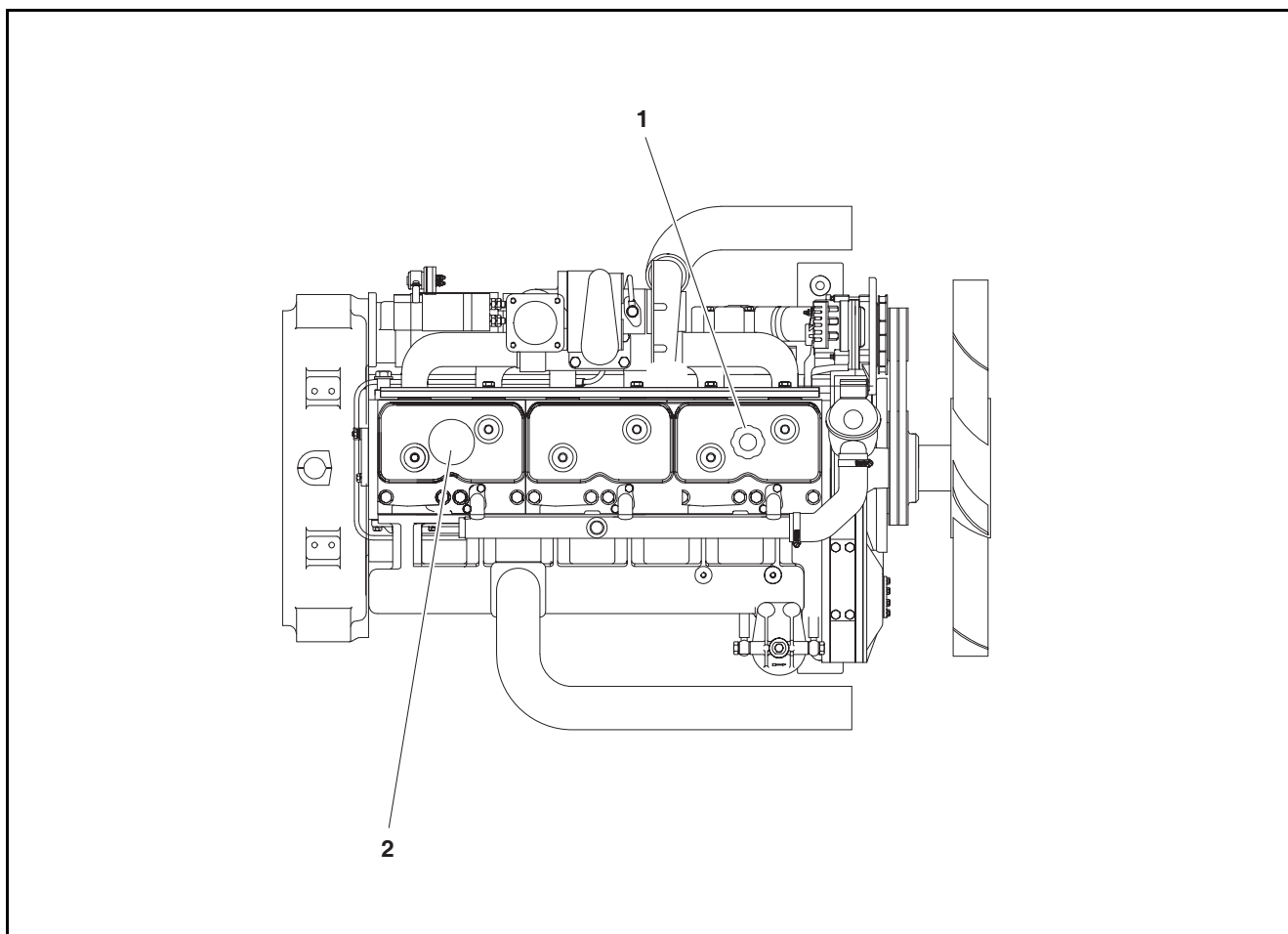


EDL08220185

- | | | | |
|-----------------|-----------------------|-------------------------|---------------------|
| 1. Cooling pan | 5. Exhaust manifold | 9. Oil cooler | 13. Intake manifold |
| 2. alternator | 6. Starter | 10. Oil pan | 14. Fuel filter |
| 3. Thermostat | 7. Vibration damper | 11. Oil drain valve | 15. Oil filter |
| 4. Turbocharger | 8. Cooling water pipe | 12. Fuel injection pump | 16. Oil level gauge |

3. Performance and specifications

Top (PU086TI)



EDL08220186

1. Oil cap

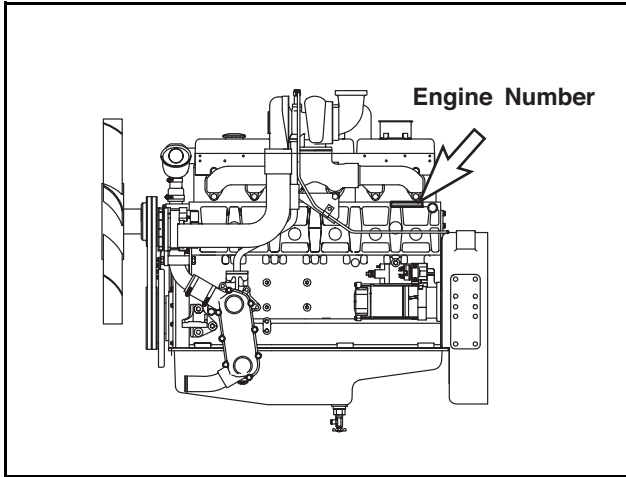
2. Breather

3. Performance and specifications

Engine identification number

Engine code and manufacturing number

The engine model and serial number is located on the engine as illustrated. These numbers are required when requesting warranty and ordering parts.



EA9O2001

Engine number engraving

- Type 1

(A)

(B)

(C)

- A. Engine model SUFFIX(5 digits)
- B. Production Year(1 digit)
- C. Serial Number(5 digits)

- Type 2

(A)

(B)

(C)

(D)

- A. Sales Model name(4~7 digits)
- B. Production Year(1 digit)
- C. Serial Number(5 digits)
- D. After engine model SUFFIX(2 digits)

- Type 3

(A)

(B)

(C)

(D)

(E)

- A. Sales Model name(5 digits)
- B. Engine output(3 digits)
- C. Production Year(1 digit)
- D. Serial Number(5 digits)
- E. After engine model SUFFIX(2 digits)

- Type 4

(A)

(B)

(C)

- A. New representative specification (9 digits)
- B. Production Year(1 digit)
- C. Serial Number(5 digits)

- Type 5

(A)

(B)

(C)

(D)

- A. Sales Model name(4~7 digits)
- B. Production Year(1 digit)
- C. Serial Number(5 digits)
- D. After new representative specification(3 digits)

- Type 6

(A)

(B)

(C)

(D)

(E)

- A. Sales Model name(5 digits)
- B. Engine output(3 digits)
- C. Production Year(1 digit)
- D. Serial Number(5 digits)
- E. After new representative specification(3 digits)

3. Performance and specifications

4. Regular inspection

General information	43
General Information	43
Routine Inspection	43
Regular inspection table	44
General conditions	44
Use of Genuine Parts.....	46
Cooling system	47
General Information	47
Coolant standards.....	47
Capacity of coolant	47
Checking the Coolant.....	47
Measurement of Coolant Concentration	47
Discharging the coolant	48
Charging the Coolant	49
Cleaning the cooling circuit	50
Inter cooler	51
Lubrication system	52
General Information	52
Engine oil standards	53
Engine Oil Capacity	54
Checking the Engine Oil	54
Replacement of Engine Oil	55
Replacement of Engine Filter.....	55
Fuel system	56
General Information	56
Fuel Standards.....	57
Water draining from fuel filter	58
Replacing fuel filter	58
Preventing fuel contamination.....	59
Fuel injection pump.....	59
Air bleeding in the fuel circuit	59
Fuel injection nozzle	60
Check fuel injection nozzle pressure.....	60
Removal of nozzle	61
Installation nozzle	61

Adjustment nozzle.....	61
Note for cleaning nozzle	61
Adjusting injection timing	61
Priming pump strainer cleaning.....	63
Intake/exhaust system	64
General Information	64
Air Filter.....	64
Disassembly of air filter.....	64
Cleaning of the Air Filter Element	65
Changing the air filter element	66
Turbocharger	66
Routine check and serving the turbocharger	66
Disassembly and cleaning a turbocharger.....	66
Cylinder block/head	67
Valve Clearance.....	67
How to adjust the valve clearance	67
Adjusting the Valve Clearance	67
Cylinder Compression Pressure	68
Electric system	69
Battery.....	69
Starter	69
Others/driving system	70
V-Belt	70

General information

General Information

As time passes after purchasing an engine, each of the engines parts age and initial engine performance cannot be maintained.

Regular inspection and replacement according to the recommended regular inspection table allows you to maintain an engine with the optimum conditions and best performance for a long period and prevent unexpected accidents in advance.

Users are responsible for the proper operation and maintenance of engines. Engines should be inspected and replaced by officially-certified technicians in a workspace with the specified tools and facilities. Observe the following instructions to perform inspections.

1. Perform inspections on a flat floor without a slope.
2. Excluding extreme circumstances, only perform inspection while the engine is stopped.
3. Disconnect the '-' terminal of the battery before performing an inspection.
4. Perform inspection in a well ventilated space.
5. Use a wooden prop or lift when working under the engine.

DANGER

- **Wait until the engine is sufficiently cooled before starting inspection after operating the engine. Otherwise, you may be burned.**
- **You may be poisoned by the emission when starting an engine in a closed space. Perform inspection at the well-ventilate space.**
- **Unless absolutely compelled, do not perform inspection under an engine.**
- **Do not be close to fire when inspecting an engine. Fuel, oil, or batteries may generate gas, causing fire.**
- **If inspecting the engine while it is running, do not wear accessories such as necklaces, rings, watches or gloves. Such accessories may become stuck in rotating parts while the engine is running and may cause serious bodily injury.**

CAUTION

- **Incorrect inspection methods may cause of engine faults.**
- **Cleaning an engine with liquids such as water or wax may cause breakdown of electrical parts.**
- **Be careful when handling batteries, cables, and electrical wirings because current flows through those parts.**
- **Do not put heavy things or apply excessive force or impact on the fuel-related units.**
- **Make sure that you connect the battery terminal ('+' and '-') to the right terminal. Connecting the '+' and '-' terminals to the wrong terminal may cause damage to the electrical unit parts and fire.**

Routine Inspection

Routine inspection is an inspection performed by an engine operator before operating the engine. It should be performed to protect operator's safety, as well as the engine.

The following is a minimal check list.

1. Check whether the engine smoothly starts and the levels of fuel, oil, and coolant are within the normal range.
2. Check if any discharged emissions are colored and if the exhaust contains toxic gas elements.
3. Check whether abnormal noise occurs after starting an engine or not.
4. Check whether oil or water is leaking.

4. Regular inspection

Regular inspection table

General conditions

Regular inspection and replacement according to the recommended regular inspection table allows you to maintain the engine with optimum conditions and best performance for a long period and prevent unexpected accidents in advance.

(○ : Inspection and Adjustment ● : Replacement)

Check Points		Daily	Inspection interval (Hours)					Remarks
			First 50	200	400	600	1,200	
Cooling system	Check for leakage(hoses, clamp)	○						
	Check the coolant water level	○						
	Change the coolant water						●	
	Adjust the V-belt tension	○						Every 2,000hrs
	Clean the radiator						○	
Lubrication system	Check for leakage	○						
	Check the oil level gauge	○						
	Change the lubricating oil		● a	●				
	Replace the oil filter cartridge		● a	●				
Fuel system	Check the leakage fuel line	○						
	Clean the fuel strainer of fuel feed pump			○				
	Remove sediment from fuel tank						○	
	Drain the water in separator			○				
	Replace the fuel filter element				●			
	Check fuel Injection timing			○				When necessary
	Check the injection nozzles			○				When necessary
Intake/Exhaust system	Check the leakage for intercooler (hoses, clamp)	○						
	Clean and change the air cleaner element			○ b	●			
	Clean the inter-cooler air fins					○		
	Clean the turbocharger							Every 2,000hrs

4. Regular inspection

Check Points		Daily	Inspection interval (Hours)					Remarks
			First 50	200	400	600	1,200	
Engine adjust	Check the state of exhaust gas	○						
	Check the battery charging	○						
	Check the compression pressure						○	When necessary
	Adjust Intake/Exhaust valve clearance		○ a					When necessary

a. First 50hr

b. Clean

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

4. Regular inspection

Use of Genuine Parts

An engine consists of many parts which are mechanically harmonized. To prevent engine faults in advance and use engines with best performance for a long period, maintenance and replacement of expendable parts should be conducted regularly.

Use of genuine parts is recommended. Using unauthorized or remanufactured parts may cause critical damage and faults to engine for which HD Construction Equipment shall not be held liable.

4. Regular inspection

Cooling system

General Information

The coolant should be replaced according to the cycle specified in the inspection interval table. If the coolant gets dirty, the engine is overheated, and the coolant overflows in the thermal expansion tank.

Coolant standards

We recommend you to inject the antifreeze about 40~50% of the entire coolant. The antifreeze prevents the freezing and corrosion of the system, and increases the boiling point of water. In winter, you may need to change the amount of antifreeze per ambient temperature as shown in the table below. The freezing point per antifreeze ratio shown in the table may differ slightly depending on the antifreeze type. For more information, see the specifications provided by the manufacturer.

Whenever you add coolant(water) to replenish the amount reduced by engine operation, the antifreeze portion is decreased. So, you need to increase the antifreeze level to the proper level after replenishing the coolant.

- concentration of antifreeze during winter

Ambient temperature (°C)	Coolant (°C)	Antifreeze (%)
Above -10	85	15
-10	80	20
-15	73	27
-20	67	33
-25	60	40
-30	56	44
-40	50	50

Capacity of coolant

Engine Mode	Coolant capacity (lit)
D1146	14/11
D1146T	
DP086TA	
P086TI	
DP086LA	
PU086	
PU086T	13.2
PU086TI	

Checking the Coolant

DANGER

If the radiator cap is opened to exchange or replenish coolant while the engine is overheated, hot water will spurt out and may cause serious burns. If it is absolutely necessary to open the radiator cap while the engine is overheated, wrap the radiator cap with a cloth and slowly open the cap in two steps until the steam pressure has been released from the inside. After the steam pressure has been completely released, remove the radiator cap.

1. For the engine coolant, you should use clean tap water.
2. To the engine coolant add 40% of antifreeze to prevent corrosion.
3. Periodically check coolant to maintain the concentration of antifreeze and additives.

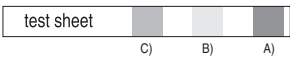
CAUTION

If you keep the antifreeze and corrosion inhibitor at a proper level, you can prevent the corrosion of engine effectively and keep the quality of the engine. Be careful that, if managed improperly, it can give a fatal impact on the coolant pump and cylinder liner.

4. You can check the concentration of antifreeze and corrosion inhibitor using the coolant test sheet.

Measurement of Coolant Concentration

- Special Tools

Figure	Product Number/Name
	60.99901-0038 Coolant test sheet

The coolant concentration can be measured as follows.

4. Regular inspection

1. If the engine coolant temperature is within a range of 10 ~ 55°C, drain the coolant and fill half a plastic cup with it.

CAUTION

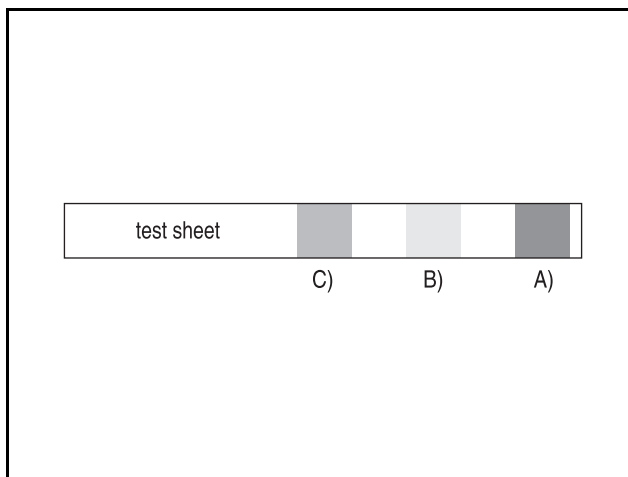
When taking out a sample of coolant from the supplementary tank, it is difficult to measure the precise concentration. Always take out sample by opening the drain plug of coolant.

2. Soak the test sheet in the coolant and take it out after 3 ~ 5 seconds. Shake the sheet to remove the remaining coolant.
3. Wait for about 45 seconds until the test sheet changes its color.

CAUTION

Measurement time should not exceed 75 seconds. The color changes as time passes.

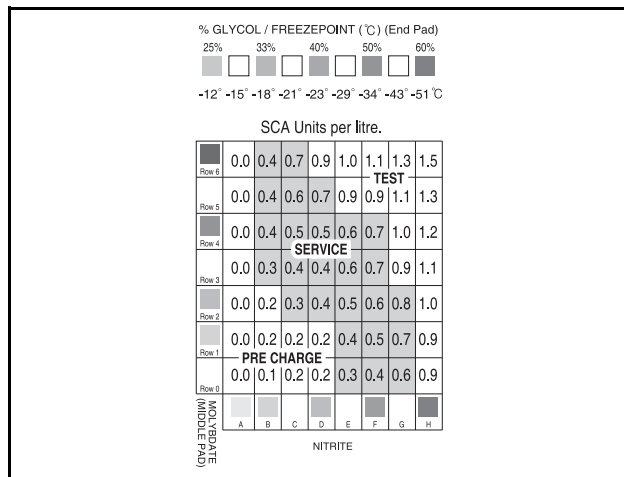
4. Check the color on test sheet.



EDL0213002A

- 1) Compare the color of part (A) on the test sheet to the color of GLYCOL/FREEZEPOINT (End pad) of the standard color table.
- 2) Compare the color of the test sheet (B) to the color of MOLYBDATE (Middle pad) of the standard color table.
- 3) Compare the color of the test sheet (C) to the color of NITRITE of the standard color table.

5. Compare and confirm the parts with identical colors on the test sheet and the standard color table.



EDL022154A

- 1) Compare the changed pink color part A of the test sheet with the GLYCOL/FREEZEPOINT (End pad) of the standard color table on top of the container and confirm the concentration. The concentration indication has to be within the color scope of 33~50%.
- 2) It should be maintained at the optimum range, in the green section between 0.3 to 0.8 where the color of MOLYBDATE (Middle pad) on the standard color table (which is identical with the Middle (B) of the test sheet) is crossed with the color of NITRITE on the standard color table (which is identical with the (C) of the test sheet).
- 3) If it is above 0.8 or, drain a little coolant and then add clean tap water to adjust the concentration.

CAUTION

- If the color on the test sheet does not match the color of the standard color table, find a middle color on the standard color table. For example, if the color of (C) of the test sheet matches D and F on the NITRITE of the standard color table, select E.
- To prevent corrosion inside of the engine cooling unit, drain the coolant and replace it with new coolant once a year.

Discharging the coolant

The coolant can be discharged as follows.

1. Make sure that engine and radiator are cooled.

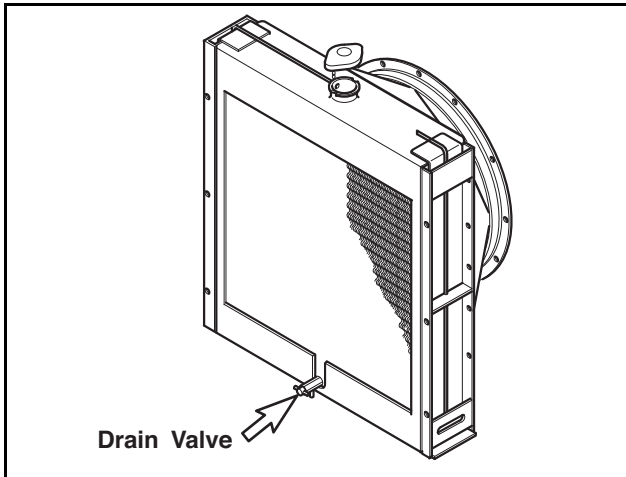
4. Regular inspection

2. Open the radiator cap.

CAUTION

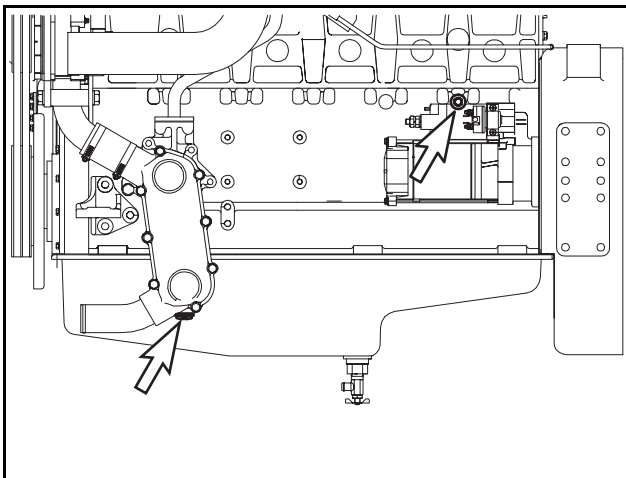
- Never open the radiator cap while the engine is overheated. If the radiator cap is opened while the engine is overheated, hot water will spurt out and may cause serious burns. Open the radiator cap after ensuring that the engine has been cooled sufficiently.
- Mark and separately manage the containers for storing coolant from beverage containers to avoid confusion. If coolant is ingested, see a doctor immediately.

3. Loosen the drain valve which is located under the radiator to discharge the coolant.



EA5O4002

4. Disassemble the coolant discharge plug of the cylinder block, and discharge it to a container.



EA9O4003

5. Drain cooling water in the oil cooler.

Charging the Coolant

1. Make sure that engine is cooled.
2. Open the radiator cap.

DANGER

- Never open the radiator cap while the engine is overheated. If the radiator cap is opened while the engine is overheated, hot water will spurt out and may cause serious burns. Open the radiator cap after ensuring that the engine has been cooled sufficiently.
- Mark and separately manage the containers for storing coolant from beverage containers to avoid confusion. If coolant is ingested, see a doctor immediately.

3. Put in the coolant slowly.

CAUTION

Be careful not to let foreign substances flow into the engine when replenishing coolant.

4. Be sure that the air is gone out from cooling system.
5. After checking the coolant level when the engine is warmed up, replenish coolant if necessary.

DANGER

If the engine is hot, wrap the coolant pressure cap with a cloth upon opening it so that the steam may be discharged. This can prevent you from burning by the hot steam coming out of the cap inlet.

CAUTION

- Do not mix antifreezes from different manufacturers.
- Do not mix the coolant with different concentrations.
- Do not add antirust which is not recommended by us.
- As insufficient coolant concentration may cause corrosion or freezing, on the other hand, an excessive concentration may degrade the cooling performance. Mix coolant with 40% antifreeze to prevent corrosion.

4. Regular inspection

WARNING

Discard exchanged coolant according to the regulations set forth by the relevant authorities. Disposing of exchanged coolant into the ground, sewers, drains, rivers, or the sea will cause serious environmental pollution. Violation of regulations regarding discard of coolant without observing the handling regulations, will be punished.

Cleaning the cooling circuit

If the internal coolant circuit is contaminated by corrosion or foreign substance, the cooling effect is reduced. The resistance in the coolant circuit may damage the mechanical seal of the coolant pump.

The negative impact on the cooling circuit may be caused by use of improper antifreeze or corrosion inhibitor, or by use of coolant without such ingredients. If the coolant pump leaks or the coolant is severely contaminated within short period of time (6 months) after start of using the operation (e.g., the coolant color becomes muddy - probably brown, grey or black depending on the degree of contamination), before removing the coolant pump, clean the cooling system in the following way.

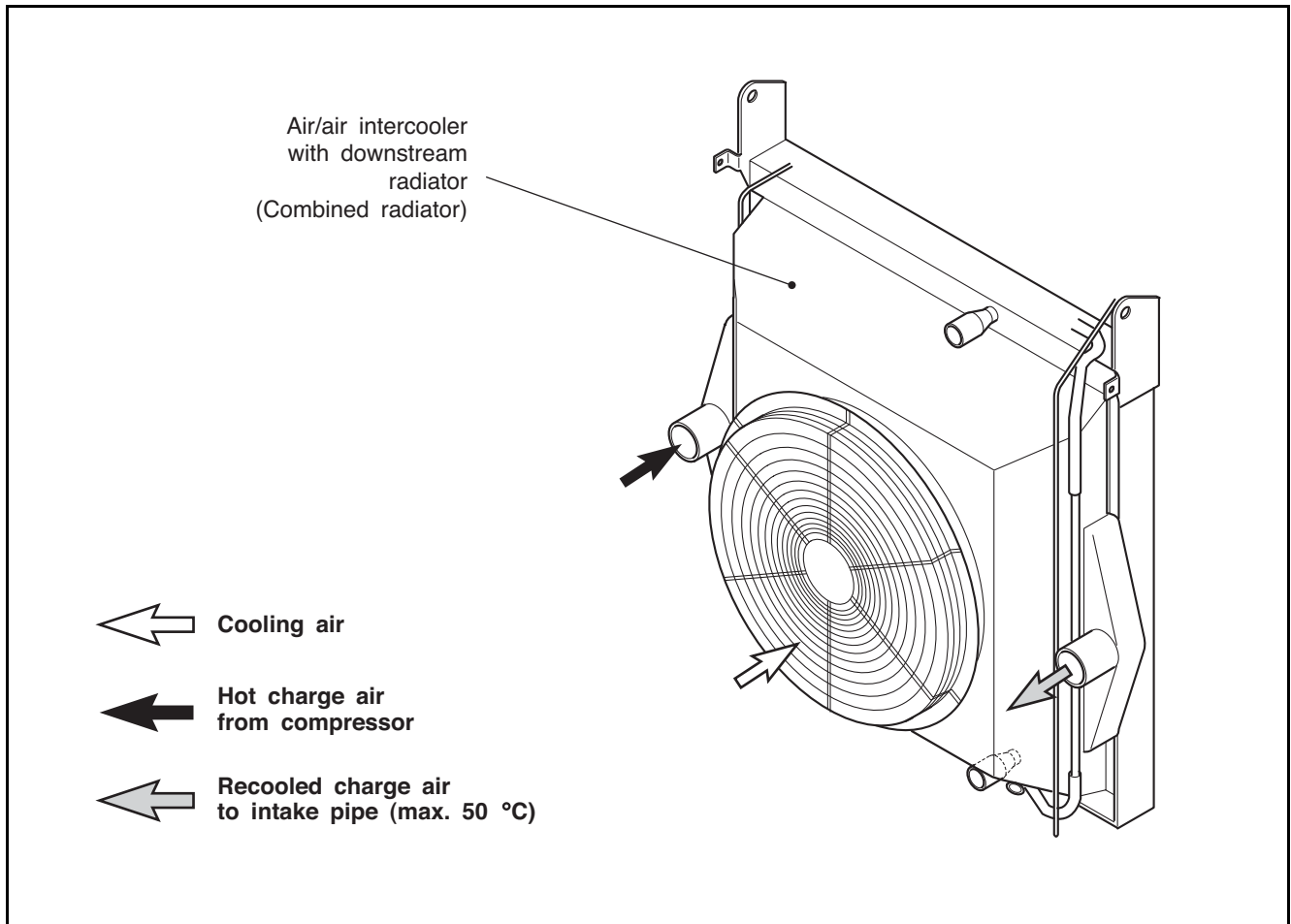
1. Discharge the coolant.
2. If you want to clean the cooling circuit swiftly, remove the thermostat.
3. Mix water and 1.5% of cleaning solution and fill the cooling circuit with this liquid.
4. Load the engine. When the coolant temperature reaches 60°C, run the engine for about 15 minutes.
5. Discharge the cleansing solution.
6. Repeat the step 3 and 4 above.
7. Fill the cooling circuit with hot water.
8. While running the engine at idle speed for 30 minutes, check if there is any leakage in the drain plug and coolant line. If the coolant is insufficient, replenish it.

CAUTION

Clean the cooling circuit regularly with cleansing solution.

Inter cooler

The air cooler adopts an air cooling fan, which has sufficient cooling capacity. The life and performance of an air cooler greatly depends on the intake air conditions. Dirty air may contaminate and clog the cooling pins. This results in reduced engine power or engine failure. So, always check the intake system for air leak, damage or contamination of air filter.



EA5O4003

CAUTION

To keep the optimum performance of the air cooler, clean it regularly.

4. Regular inspection

Lubrication system

General Information

Engine oil lubricates, cools, seals, prevents corrosion, and cleans engines, enhancing engine performance and extending the engine's lifetime. If a vehicle is continuously driven while engine oil is insufficient, the moving parts of the engine may get stuck, causing engine faults.

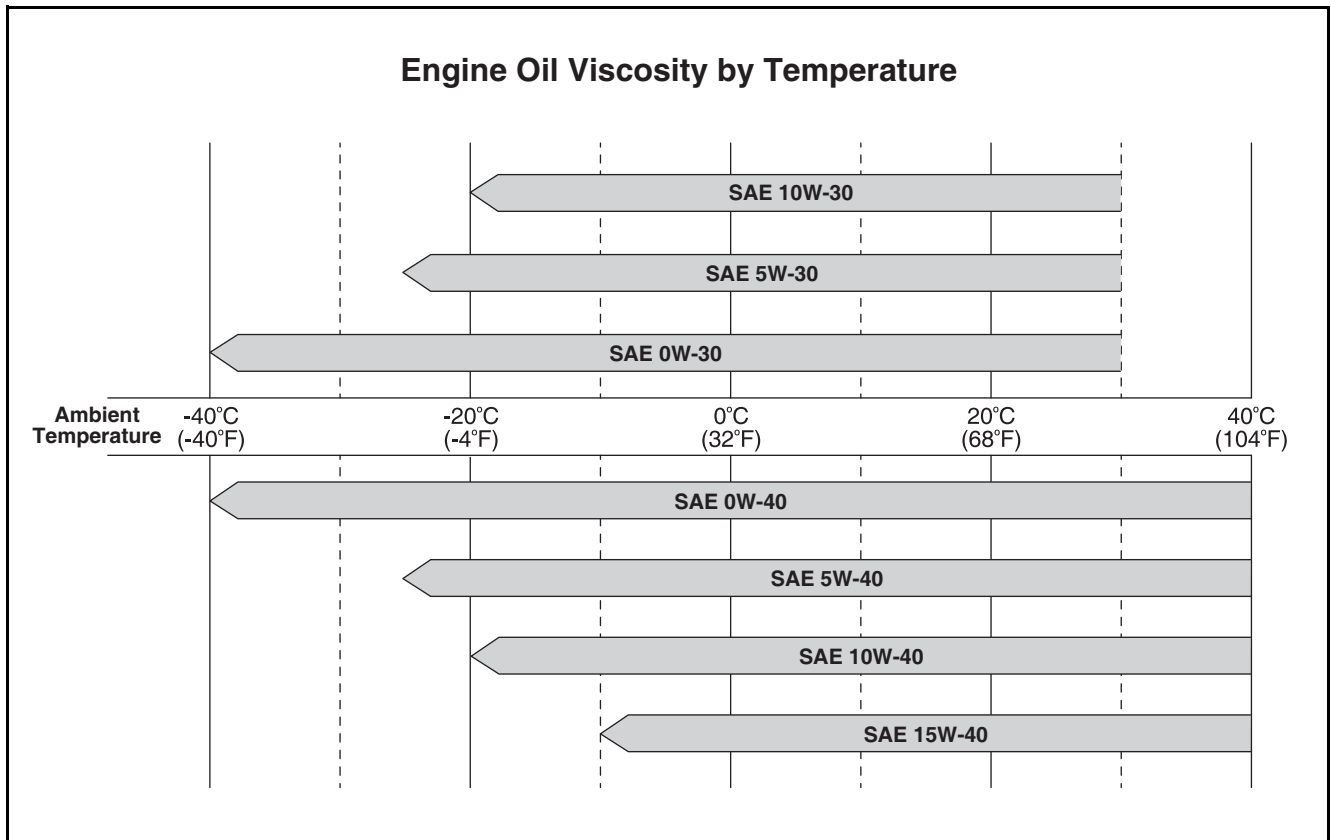
Engine oil should be checked through the oil level gauge and replenished if required. Oil level should be checked while the engine is stopped. To check the oil level, turn off the engine while it is running and wait for 5 ~10 minutes to allow the engine oil to flow back into the oil pan. The engine oil level should indicate between the upper limit and the lower limit of the oil level gauge.

Engine oil should be periodically replaced based on the regular inspection table and the oil filter and the cartridge should be replaced as the engine oil is replaced.

4. Regular inspection

Engine oil standards

Use the specified engine oil suitable for the environment and conditions of the site where the engine will be used.



EDL06200023

Please use the engine oil which satisfies the following recommended specifications.

Engine Model and Product Code	SAE Classification	Oil Class
D1146	SAE 10W40	API CI-4
D1146T		
P086TI		
DP086TA		
DP086LA		
PU086		
PU086T		
PU086TI		

Note) Use of HD Construction Equipment genuine engine oil is recommended.

4. Regular inspection

Engine Oil Capacity

Please replenish the engine oil based on the following recommended oil amount.

Engine Model and Product Code	Engine oil capacity (lit)	
	Engine only	
	Max.	Min.
D1146	15.5	12
D1146T	15.5	12
P086TI	15.5	12
DP086TA	15.5	12
DP086LA	15.5	12
PU086	15.5	12
PU086T	15.5	12
PU086TI	15.5	12

Checking the Engine Oil

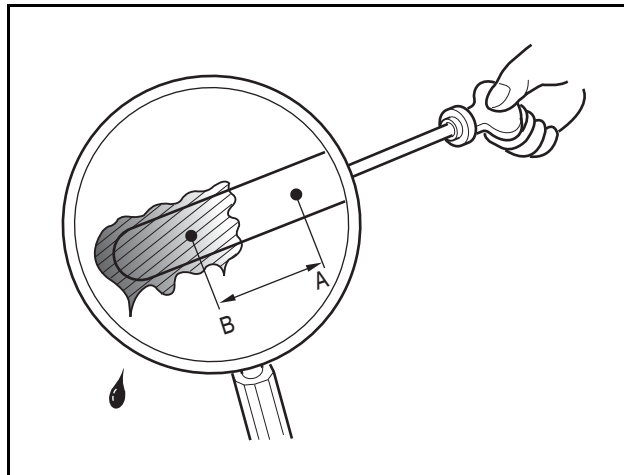
Check the oil level everyday using an oil level gauge.

1. The oil level should be checked when the engine is stopped and on an even level. If you started the engine, wait for 5~10 minutes to allow the engine oil to flow back into the oil pan.
2. Pull out the oil level gauge, and clean the indication line of the oil level gauge with clean cloth.

CAUTION

Cleaning the indication line of the oil level gauge with dirty cloth allows the foreign substances to get into the engine, causing damage to the engine.

3. Insert the oil level gauge, and then pull it out to check the engine oil level, viscosity, and contamination. Replenish or replace the engine oil if required.

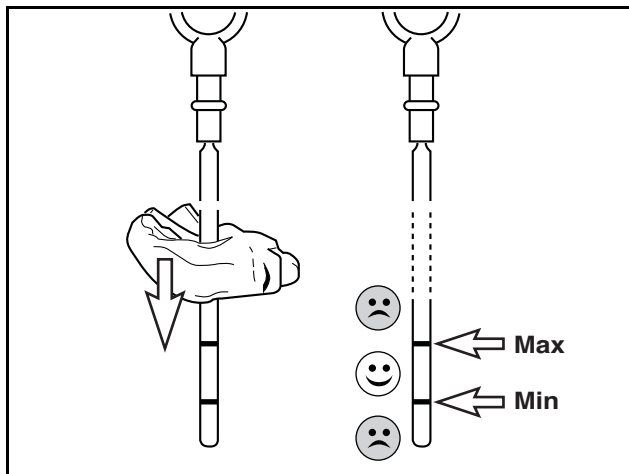


DV2213016A

- 1) Check the oil level everyday using an oil level gauge.
- 2) Check if the oil is smeared between the upper limit (A) and the lower limit (B) of the oil level gauge.
- 3) If engine oil is smeared below the lower limit (B) or not smeared on the gauge at all, replenish engine oil.
- 4) Check condition of engine oil. If it is polluted, replace it with new oil.

CAUTION

- Do not fill the engine oil above the upper limit. Exceeding the upper limit may damage the engine.
- Be careful not to let foreign substances flow into the engine when replenishing engine oil.

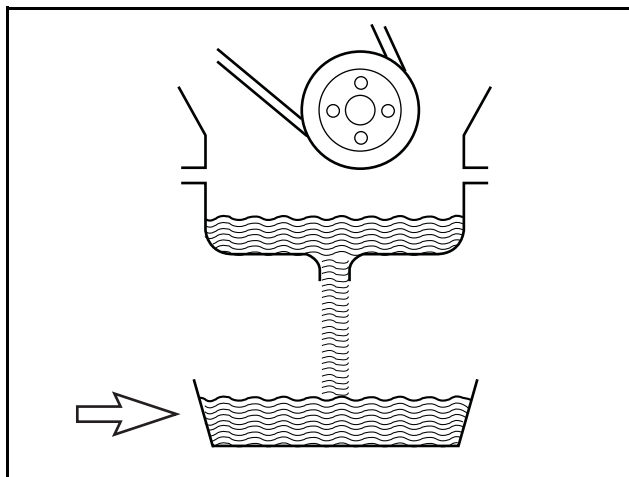


DV2213163A

Replacement of Engine Oil

Check the oil level using an oil level gauge and replenish it if required. Replace the engine oil in the following steps when the engine is warm by running it.

1. Pull out the oil level gauge.
2. Open the drain plug of the oil pan to discharge the engine oil from the container.



DV2213017A

3. After discharging the engine oil, assemble the drain plug of the oil pan again.
4. Fill the engine oil into the cartridge of the oil filter.
5. Through the oil filler cap, fill the engine oil.
6. Idle the engine for several minutes so that the oil circulate through the lubrication system.
7. Then, stop the engine, wait for about 10 minutes, check the oil level, and fill the oil if required.

DANGER

- Prolonged and repeated contact of skin with engine oil may lead to shrinking, dryness of skin and even cause dermatitis.
- Do not expose skin with exchanged engine oil for a long period.
- Always wear work clothes and gloves.
- When skin is stained with engine oil, immediately wash it with water, soap or hand cleaners.
- Do not clean skin with gasoline, fuel, thinner, or solvent.
- Apply a skin protective cream after cleaning from oil.
- Do not put oil-stained gloves or cloth in pockets.

WARNING

Discard exchanged oil according to the regulations set forth by the relevant authorities. Disposing of discharged oil into the ground, sewers, drains, rivers, or the sea will cause serious environmental pollution. Violation of regulations regarding discard of engine oil without observing the handling regulations, will be punished.

Replacement of Engine Filter

Check the oil pressure and leakage, and replace the oil filter if required. Whenever replacing the oil, the oil filter cartridge should be replaced with a new one.

1. Using an oil filter wrench, loosen the cartridge by turning it counterclockwise.
2. Wipe the oil filter head and cartridge contact thoroughly, and make sure that the oil filter cartridge is positioned properly.
3. Apply a little bit of oil to the o-ring area of the cartridge, assemble it until the O-ring surface may contact, and turn it 3/4 or 1 turn using a wrench to keep it air-tight.

CAUTION

When replacing the oil filter cartridge, be sure to use the genuine part of HD Construction Equipment.

4. Regular inspection

Fuel system

General Information

The fuel injection pump and nozzle are composed of very sophisticated components with high precision. If fuel is mixed with foreign substance, it may clog the nozzle or the fuel injection pump components may be seized. So, be sure to keep the fuel system clean all the time.

CAUTION

- **Use clean, certified and qualified fuel only. Using irregular or unspecified fuel may cause critical damage and faults to the engine.**
 - **Replenish fuel while the engine is stopped.**
-

4. Regular inspection

Fuel Standards

The quality of fuel is very important to satisfy the engine performance, extension of engine life and the allowable exhaust gas level. HD Construction Equipment engine is designed to use diesel fuel available in the local market. If you want the optimum engine performance, select the proper fuel referring to the fuel selection table below.

- Low Sulfur Diesel

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

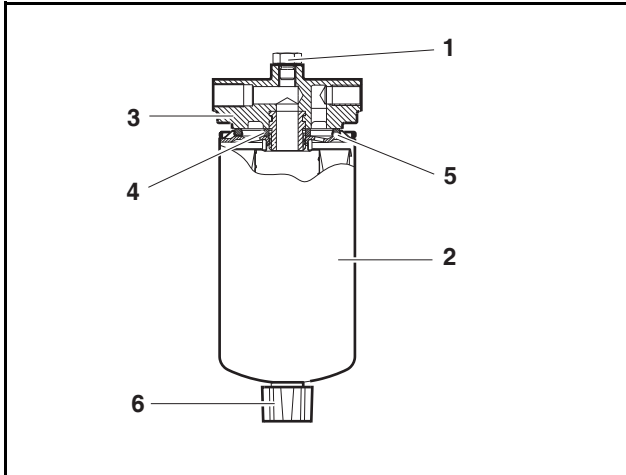
Note) If the sulfur content of the fuel is more than 0.5%, the replacement and inspection cycle should be cut in half.

4. Regular inspection

Water draining from fuel filter

An oil filter has two functions: oil filtering and water separation.

1. the water separation function of the fuel filter discharges water and sediment from the water separator.
2. Stop the engine, and loosen the drain plug for water separation manually.



DV2213019A

3. Turn the drain plug (6) for water separation counterclockwise 2~3 times until water is drained. Drain the water in the cartridge until fuel is discharged.
4. Tighten the drain plug for water separation by turning it clockwise.

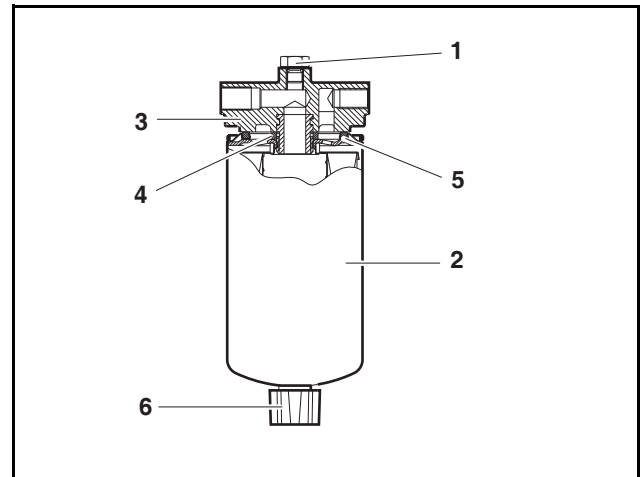
DANGER

Fuel may be drained when water is drained from the fuel filter. Fuel is highly inflammable. Fire may occur when you use fire near the engine when draining water from the fuel filter.

CAUTION

- Do not tighten the plug excessively because it may damage the screw.
- If you do not check the fuel filter regularly and drain the water in the fuel filter, water flows into the fuel system of the engine, causing serious failure in the fuel system, etc., and decrease in or damage to the fuel filter performance. Inflow of water to the fuel system may stop the engine.
- Use clean, specified, and qualified fuel only. using irregular or unspecified fuel may result in more water in the fuel filter.

Replacing fuel filter



DV2213019A

1. Clean the area around the fuel filter head(3).
2. Disassemble the cartridge(2) by turning it counterclockwise with a fuel filter wrench.

CAUTION

Do not reuse the cartridge; replace them with new ones.

3. Remove the fuel filter screw adapter seal ring(4).
4. Clean the gasket contact of the fuel filter head(3).
5. Check the position of the new cartridge adapter seal ring(4).
6. Assemble the cartridge to the fuel filter head.

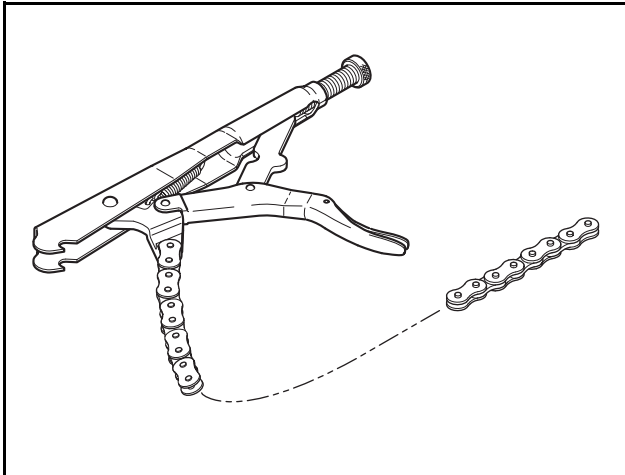
CAUTION

Assemble the new fuel filter without fuel. Do not inject fuel into the new fuel filter. After replacing the fuel filter, do air bleeding in the fuel circuit.

7. Tighten the cartridge with hand until the O-ring contacts the fuel filter head surface.

4. Regular inspection

8. Turn it by 3/4 to 1 turn with a fuel filter wrench.



DV2213020A

⚠ CAUTION

If you tighten the cartridge excessively, the screw may be distorted or O-ring damaged.

Preventing fuel contamination

Most of the fuel contaminations encountered while using the alternator engine are caused by water and propagation of microbes.

Usually, the contamination results from improper handling of fuel. Propagation of microbes requires water contained in the fuel. To prevent propagation of microbes, you have to keep the water to the minimum level possible in the storage tank.

Fuel injection pump

- Check the fuel injection pump housing, and replace it if crack or damage is found.
- Check if the idle operation and speed control lever's sealing device was not removed.
- Check if the idling or speed control lever's sealing line is not damaged.
- You should not modify the fuel injection pump if the sealing line is damaged, such engine cannot receive compensation.
- If the fuel injection pump is found abnormal, authorized personnel should handle it.

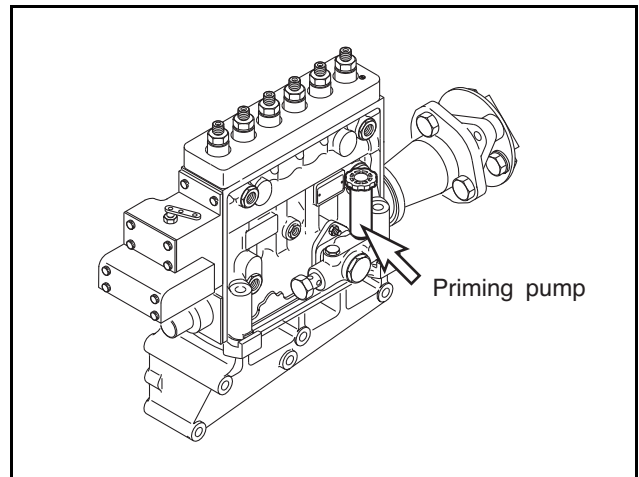
- The adjustment and test of the fuel injection pump must be conducted using a tester.

⚠ CAUTION

If you separate the parts where the seal ring (copper seal ring, rubber coating seal ring, etc.) is assembled, you should replace the seal ring with a new one. Otherwise, leakage may occur in the fuel filter connections, preventing normal functioning.

Air bleeding in the fuel circuit

When the engine stops due to replacement of fuel filter, fuel injection pump or insufficient fuel, you should perform air bleeding.



EA9O4005

1. Turn the priming pump cap.
2. Bleed the fuel by manually operating the priming pump with fuel filter outlet joint bolt and injection pump bleeder screw loosened.
3. Press the feed pump cap repetitively until the fuel without bubbles overflows from the bleeding plug screw.
4. After the whole air is pulled out, close the plug screws of the filter and the pump.
5. Confirm the resistance of fuel delivery by repetition pressing of the feed pump cap, Pressure and turn the priming pump cap simultaneously to close it.

⚠ DANGER

Fuel is highly inflammable. Fire may occur when you use fire near the engine when air bleeding in the fuel circuit from the priming pump.

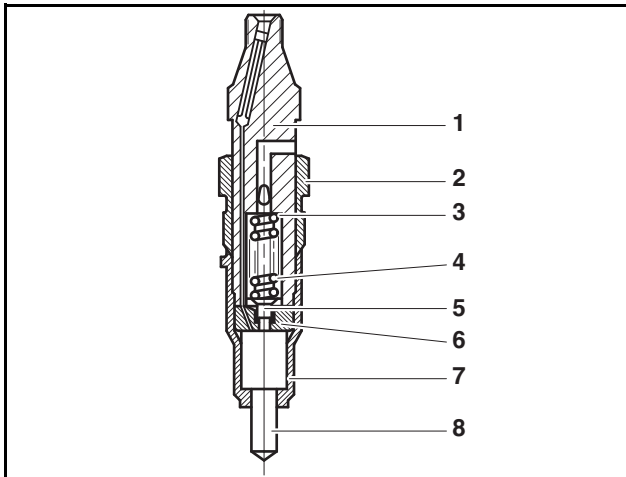
4. Regular inspection

CAUTION

If you separate the parts where the seal ring (copper seal ring, rubber coating seal ring, etc.) is assembled, you should replace the seal ring with a new one. otherwise, leakage may occur in the fuel filter connections, preventing normal functioning.

Fuel injection nozzle

- The injectors are designed to spray the fuel delivered by the injection pump directly into the spherical combustion chamber in the piston crown.
- The injector consists of the nozzle and the nozzle holder.

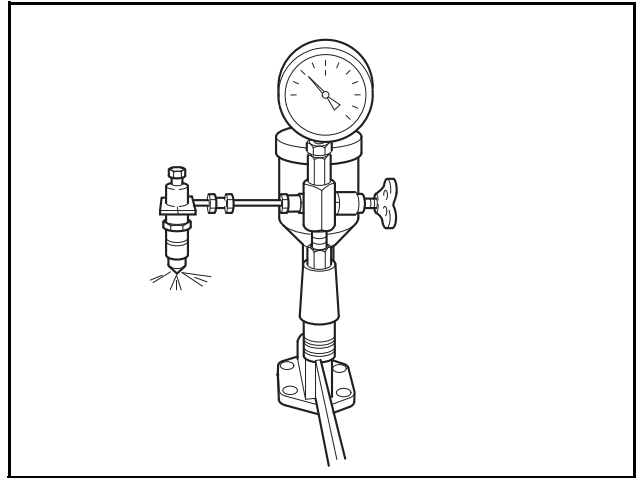


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- | | |
|------------------|---------------|
| 1. Nozzle holder | 5. Guide bush |
| 2. Union nut | 6. Washer |
| 3. Shim | 7. Cap nut |
| 4. Coil spring | 8. Nozzle |

Check fuel injection nozzle pressure

1. Install a nozzle to the nozzle tester.

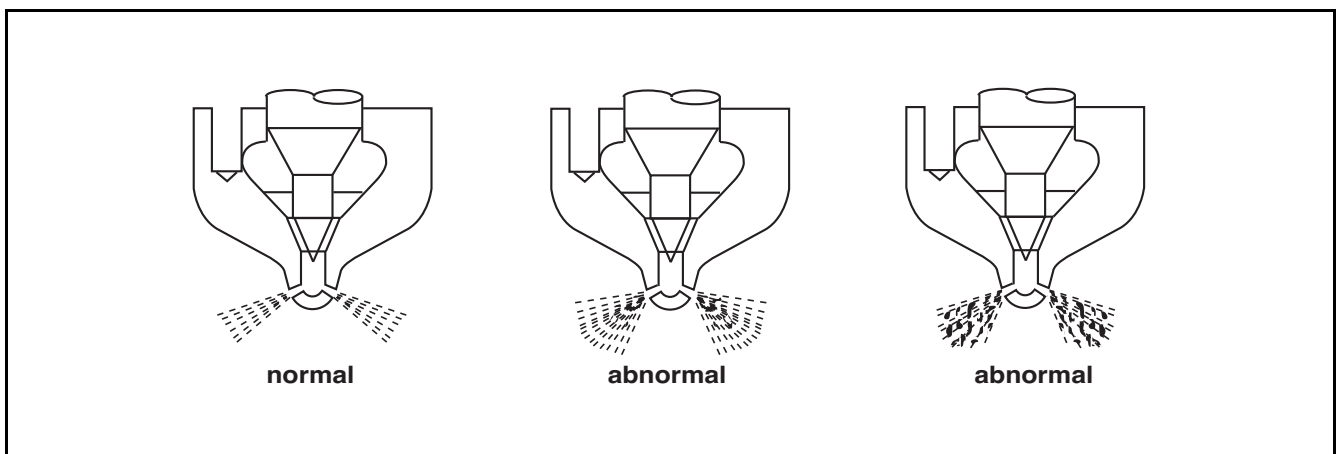


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2. Check injection pressure using cranking for meeting the correct pressure.
3. Check the nozzle spray status. If it is defective, replace the nozzle.

CAUTION

- As the nozzle injection nozzle is designed to operate under high pressure, you should handle it with special care.
- Do not hold your hands under the fuel jet, as there is a rise of injury. Do not inhale the atomized oil fuel. If possible, work under an extraction system.



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4. Regular inspection

Engine Model	Opening pressure (kg/cm ²)	Remarks
D1146	214	at 200 rpm
D1146T	214	at 200 rpm
P086TI	214	at 200 rpm
DP086TA	214	at 200 rpm
DP086LA	214	at 200 rpm
PU086	214	at 200 rpm
PU086T	214	at 200 rpm
PU086TI	214	

Removal of nozzle

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

Installation nozzle

1. After removing carbon deposit, submerge the nozzle in diesel oil and clean it.
2. Replace all the gaskets with new ones.
3. Assemble the parts and tighten them to specified torque.

Adjustment nozzle

1. the cap nut and assemble a nozzle to a nozzle tester.
2. With the adjusting screw loosened, operate the nozzle 2 ~ 3 times to bleed it.
3. Operate the nozzle tester lever at the specified rate.
4. Adjust the injection pressure to the standard pressure using the adjusting screw.
5. After adjusting the injection pressure, tighten the cap nut to specified torque.
6. Re-check the injection pressure and see if the spray pattern is normal. Spray pattern should be uniform and free of spattering.

Note for cleaning nozzle

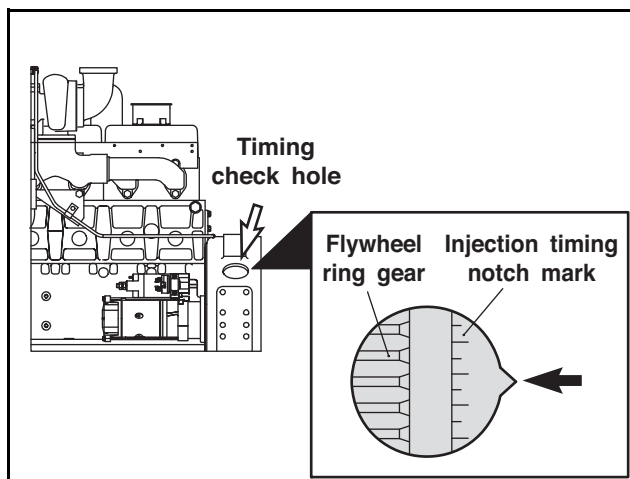
- Clean nozzle body externally from soot and carbon, When cleaning several nozzles at the same time, make sure nozzle bodies and needles are not mixed up. Visually inspect needle and body.
- Cleaning is useless if the seat of the needle is indented or the pintle is damaged and the nozzle should be replaced.
- Clean annular groove with scraper over full circumference. Wash out dislodged carbon deposits and dirt.

- Scrape needle seat with cleaning cutter, Dip cutter in test oil before use. The cutter can also be clamped in a lathe.
- Polish needle seat with wooden cleaning tool, preferably by chucking the needle in a lathe at the pintle end.
- Clean the spray holes of nozzles by chucking a cleaning needle of suitable diameter in the collect. If the carbon deposits in the spray holes cannot be removed by rotating and pressing, have the needle project only slightly from the collect and drive out the carbon by lightly tapping on the tool.
- Before reassembly thoroughly wash nozzle body and needle in clean test oil.
- Hold the needle at the pintle end only ; to avoid corrosion do not touch the lapped surfaces of the needle with you fingers.
- Thoroughly clean all other parts of the nozzle holder with clean fuel.
- Check nozzle discharge pressure in nozzle tester. The edge-type filter should not be pressed into the nozzle holder by more than about 5mm. If this depth is exceeded the injector must be replaced.

Adjusting injection timing

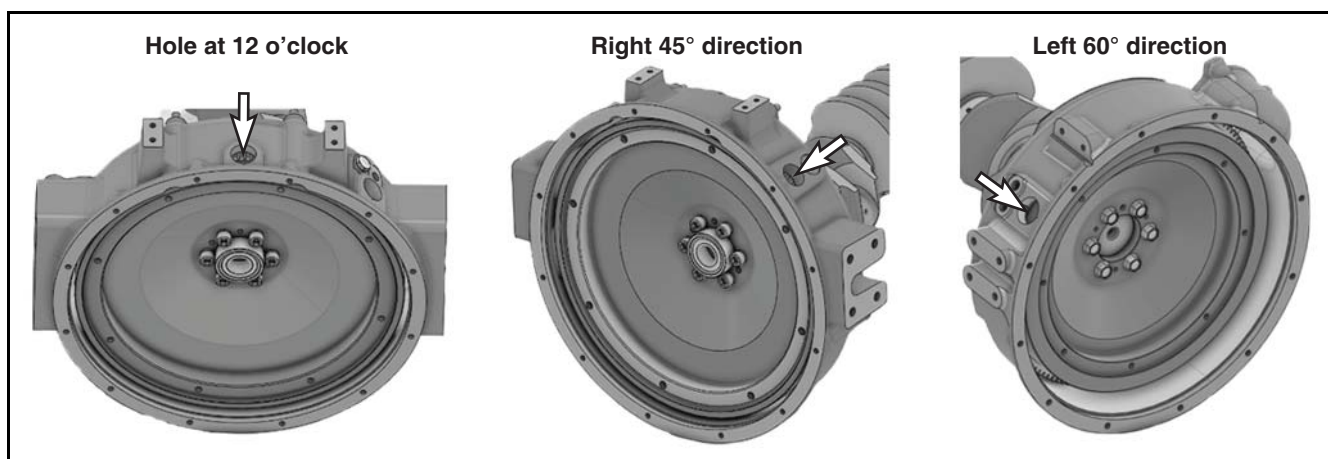
1. Adjust injection timing.
 - 1) Bring the piston of #1 cylinder to the compression TDC (OT) by turning the crankshaft. Again, turn 60° in the reverse direction of engine rotation.
 - 2) Disassemble the fuel injection pipe that connect the fuel injection pump and #1 injection nozzle.
 - 3) Disassemble the fuel injection pump delivery valve holder, and after removing the valve and valve spring, again assemble the valve holder and then, on it assemble the pipe of "U" shape on it.
 - 4) Operating the priming pump of supply pump, turn the crankshaft slowly in the direction of engine rotation until the fuel will drop at the rate of a drop for 6 ~8 sec.
 - 5) Confirm then whether the indication point at the flywheel housing inspection hole and the engraved specified injection angle are coincided or not, and if the injection timing is not correct, adjust as follows.

4. Regular inspection



EA9O5001

Engine model	Suffix	Injection timing check location
P086TI-1	DE08-PAG05, EBPOB	Hole at 12 o'clock
P086TI	DE08-PAG00, EBPOA, EBPOD	Hole at 12 o'clock
DP086LAF	DE08-OOG08	Hole at 12 o'clock
DP086TAF	DE08-OOG09	Hole at 12 o'clock
PU086TI	DE08-OOQ00	Fire pump
	EBPPA, EBPPB	Power unit
PU086T	EADPA, EADPE	Left 60° direction



EDE08240001

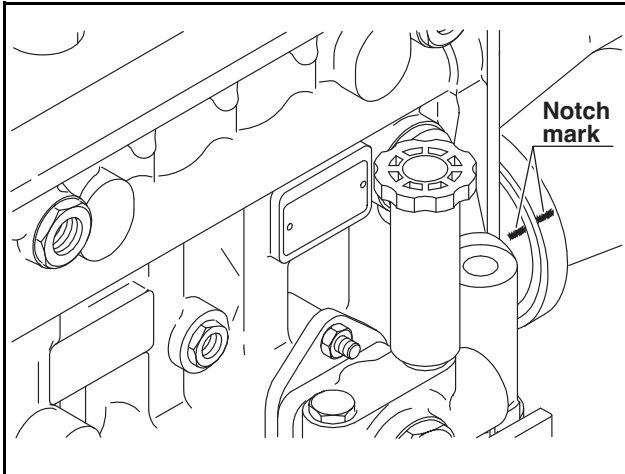
- a) As above adjusting method, Please coincide the indication point(← at the flywheel housing's inspection hole with the flywheel's inspection angle.

Engine Model	Injection timing	Remarks
D1146	18°	BTDC
D1146T	18°/12°	BTDC
P086TI	12°	BTDC
DP086TA	19°	BTDC
DP086LA	14°	BTDC
PU086	18°	BTDC
PU086T	18°/12°	BTDC
PU086TI (EBPPA)	15° ±1°	BTDC
PU086TI (EBPPB)	18° ±1°	BTDC

- b) Loosen the drive gear fixing bolt of injection pump a bit.

- c) After turning slowly the coupling of injection pump until the fuel will drop from #1 plunger at the rate of a drop for 6 ~ 8 sec., tighten the driving gear fixing bolt of fuel pump.
- 6) After the adjustment of injection timing, disassemble the "U" shape pipe, readjust the delivery valve and the valve spring.
- 7) Turn the coupling until the notch mark of the indicator plate attached to the fuel injection pump is aligned with the notch mark of the coupling.

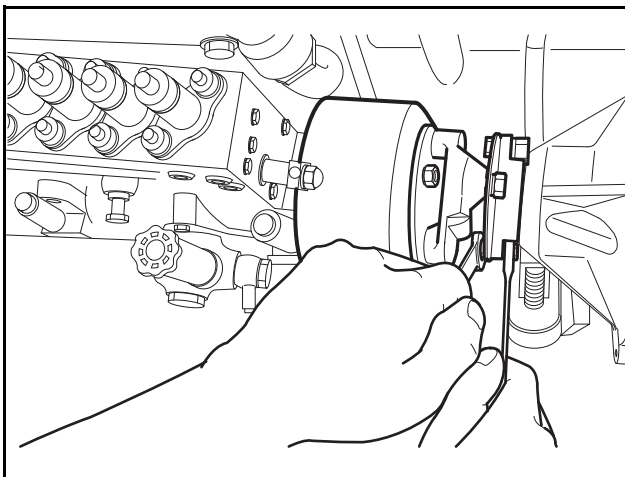
4. Regular inspection



EA9O5002

- 8) Tighten the Coupling fixing bolts and nuts to specified torque.

Torque	6.0 ~ 6.5 kgf·m
--------	-----------------

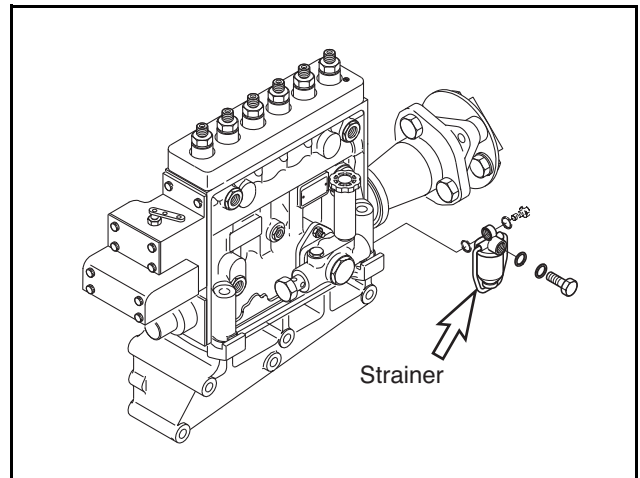


EAMD021I

- 9) Install the oil delivery pipe and return pipe.

Priming pump strainer cleaning

1. Clean the priming pump strainer filter frequently.
2. The strainer filter is incorporated in the priming pump inlet side.



EA9O4004

4. Regular inspection

Intake/exhaust system

General Information

The air filter purifies dust and foreign substances included in the air and supplies clean air into the engine. The air filter is directly related to engine lifetime, emissions, and engine output. Please periodically check, clean, and replace the air filter.

CAUTION

- **Do not operate the engine when the air filter is separated from the engine.**
- **Use specified air filters only. Using unauthorized or remanufactured air filters may result in critical faults.**
- **Foreign substances in the engine may cause abrasion inside the engine.**
- **Immediately exchange a damaged air filter with a new one.**
- **Be careful not to let foreign substances flow into engine or damage the air filterrelated electric apparatus when replacing an air filter.**
- **Be careful not let dust inside when assembling the air filter.**

Air Filter

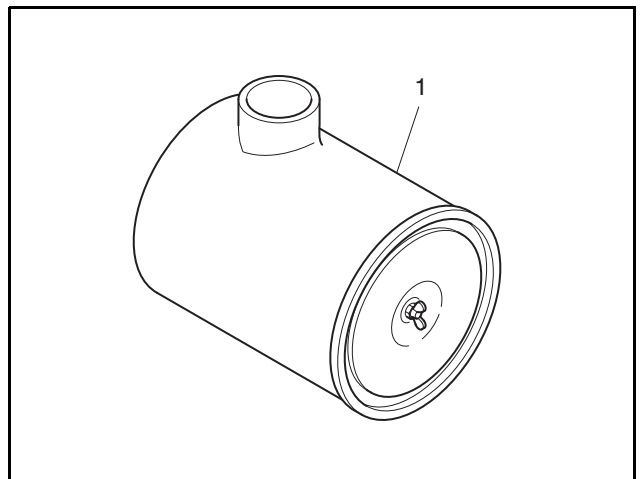
- Air cleaner is mounted on the engine to purify the air for combustion.
- The intervals at which the air cleaner requires servicing depend on the specific operating conditions encountered.
- Clogged air filters may cause black smoke and reduce power.
- A check should be made from time to time to see that the fastening elements securing the air cleaner to the intake manifold seal the connection tightly.
- Any ingress of unfiltered air is liable to cause a high rate of cylinder and piston wear.

Disassembly of air filter

DANGER

Allowed only when the engine is stopped.

1. Empty the dust bucket periodically. The dust should not exceed the half of the dust bucket capacity.
2. You can disassemble the dust bucket by removing two clamps. Remove the dust bucket cover and empty the dust inside.
3. Assemble the cover and dust bucket accurately with care.
4. For easy alignment, the cover has dent and the dust collector has a protrusion. Here is the position where a filter is mounted horizontally, check the "TOP" mark on the air filter canister.



DV2213029A

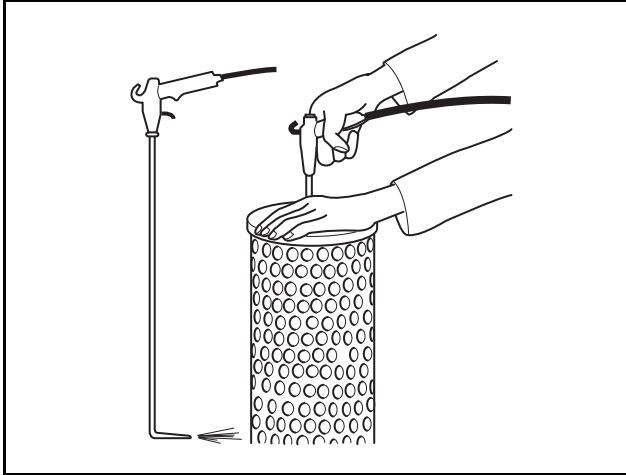
1. Air cleaner ass'y

4. Regular inspection

Cleaning of the Air Filter Element

Clean the air filter element by using the most suitable method for your work environment among the three methods stated below.

1. Use compressed air to clean the air filter element.



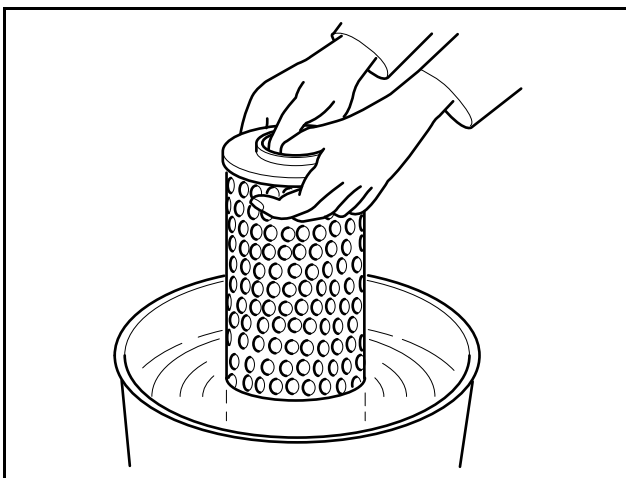
EDL022155A

- 1) To clean, let sufficient compressed air reach the inside bottom of the element at 90° direction with an air gun.
- 2) Move air gun up and down the element to blow air from inside to outside until no more dust is coming out from the element.
- 3) Do not use compressed air pressure exceeding 5 bars.

! DANGER

Always wear protective goggles before starting work. Otherwise, dust or foreign substances from the element may get in your eyes and cause injuries.

2. Clean the element by washing it.



EDL022156A

- 1) Before washing the element, clean the element by using compressed air as described above.

- 2) Soak the element in the warm cleaning solvent for 10 minutes and then shake it back and forth for about 5 minutes.
- 3) Rinse the element with clean water, drain the water, and then dry it at room temperature. Fully dry the element before reassembling it to the engine.

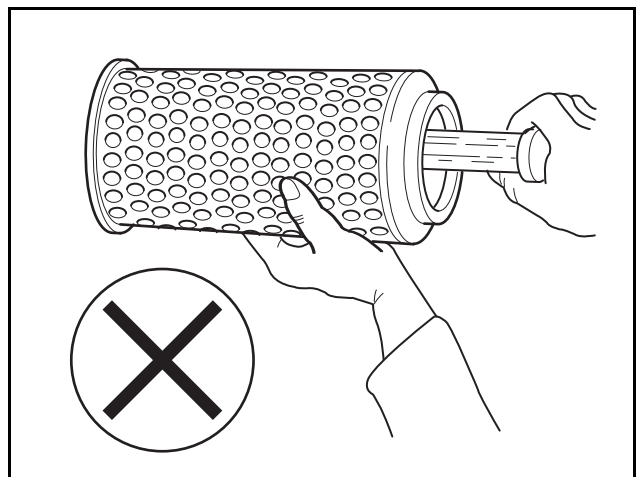
! CAUTION

Never use steam spray, gasoline, alkali or hot cleansing solution to cleansing the element.

3. In an emergency, temporarily clean the element by using the following method.
 - 1) Tab the end plate of the element with the thumb to clean it temporarily.

! CAUTION

- **This method should only be used in an emergency when cleaning of element is necessary and no compressed air or cleansing solution is available.**
- **Under no circumstances should the surface of the element be hit or beaten with a hard object to shake the dust off.**



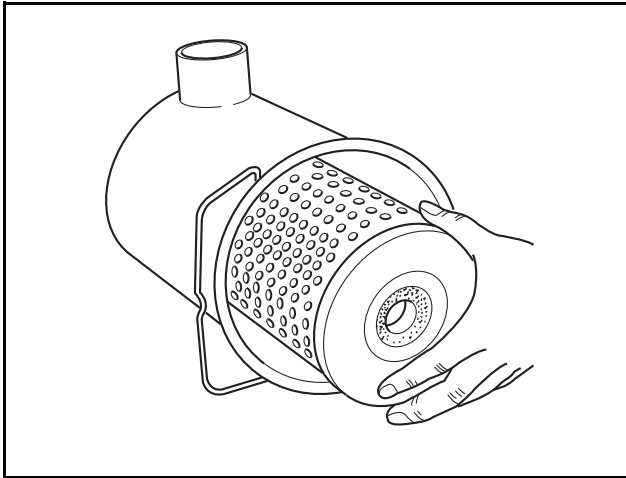
EDL022157A

- Note) Before reassembling the element, make sure that the filter paper is not wrinkled, the state of rubber sealing is good, and there is no deformed part in the element.
- Note) Under any circumstances, do not reuse damaged elements. When in doubt, replace the element with a new one.

4. Regular inspection

Changing the air filter element

1. Remove the hex nut, remove the dirty element.



DV2213030A

2. Replace with a new one or wash it.
3. Using a wet rag, wipe the inside of the filter housing.
4. The sealing contact of element.

DANGER

Do not let dust come into the end of air filter.

Turbocharger

The Turbocharger does not need a specific maintenance. Whenever replacing the engine oil, check oil pipe for leakage or clogging.

- You should handle the air filter with special care to prevent foreign substance from getting in.
- The turbocharged compressed air and exhaust gas pipe should be checked periodically. Air leakage causes engine overheat, so repair is required.

CAUTION

Be careful not to bend it.

- If the impeller is severely contaminated, soak only the wheel in a solvent and clean it with a rigid brush thoroughly. Here, be sure to soak only impeller, and the turbocharger should be supported by a bearing housing, not by an impeller.

Routine check and serving the turbocharger

The turbocharger performance is determined by maintenance state of the engine. So you should regularly perform inspection and check as specified.

1. Intake system

For the intake system, the air filter should be carefully managed. For a wet type air filter, the intake resistance should be small as possible.

2. Exhaust system

For the exhaust system, when exhaust gas leaks from the exhaust pipe or turbocharger joint, supercharging efficiency is lowered. So you need to pay attention to prevent gas leakage and burn. Heat resistant nuts are used for parts which are highly heated during operation, such as the turbine seal, and the nuts should not be mixed with other nuts. The screw burn prevention paint should be applied to the assembly nuts of the specified positions.

3. Fuel system

If the spray status of the fuel injection nozzle is not good, or the injection timing is not correct, the exhaust gas temperature increases to give a negative impact on the turbocharger. So, the nozzle should be tested.

4. Lubrication system

For the lubrication system, pay attention with the oil quality and the replacement time of the cartridge of the oil filter. Degradation of engine oil has bad effect on the turbocharger, as well as the engine body.

Disassembly and cleaning a turbocharger

You can disassemble the turbocharger from the engine to clean or inspect it. Here, be sure to seal the oil inlet and outlet with a tape, etc.

Cylinder block/head

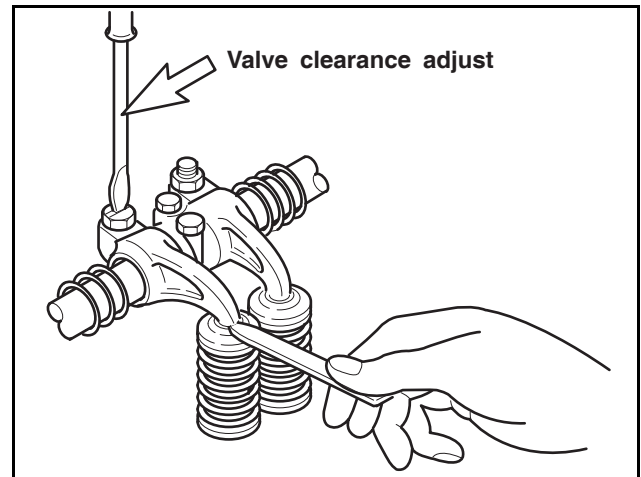
Valve Clearance

Adjust the valve clearance.

- When disassembling the engine or cylinder head.
- When there is excessive noise in the valve connection.
- When the engine runs abnormally even if the fuel injection system is normal.

How to adjust the valve clearance

1. Adjust the valve clearance.
 - 1) Loosen the lock nuts of rocker arm adjusting screws.
 - 2) Push the feeler gauge of specified value between a rocker arm and a valve stem (to measure the clearance of the valve and rocker arm contacting part)
 - 3) Adjust the clearance with adjusting screw respectively and then tighten with the lock nut.



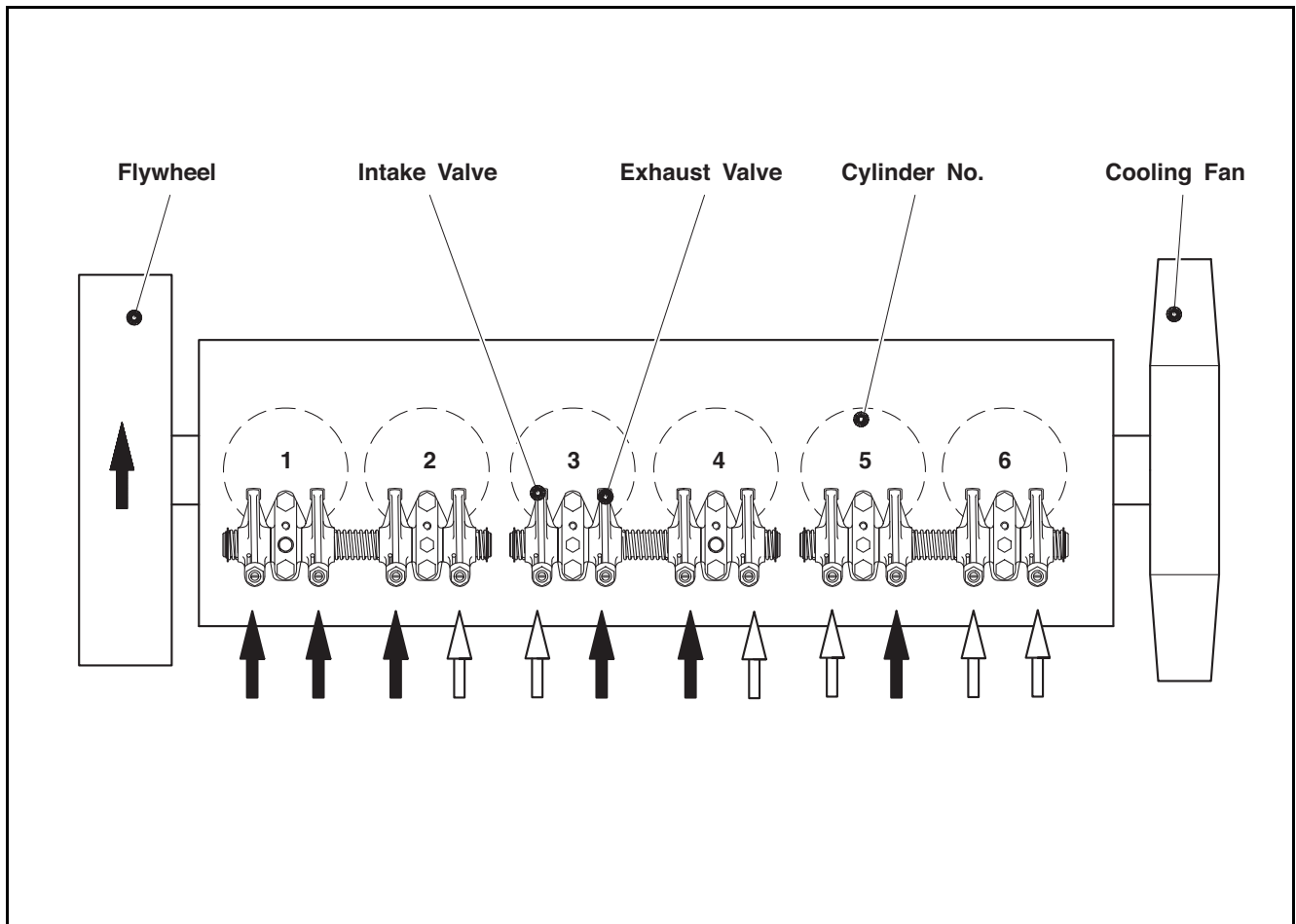
EA8M3007

- 4) Adjust valve clearance with a feeler gauge and tighten the fixing nuts to specified torque.

Torque	4.4 ±0.45 kgf·m
--------	-----------------

Adjusting the Valve Clearance

1. Guide for valve clearance adjustment



EA9O5005

4. Regular inspection

- 1) Rotate the crankshaft so that #1. cylinder may be positioned at the compression TDC (Top Dead Center). Then adjust the valves corresponding to mark “●” in the below table.

Note) #1. cylinder is located at the side where flywheel was installed.

Note) #6. cylinder is positioned at the valve overlap when #1. cylinder is positioned at the compression TDC (Top Dead Center).

- 2) Rotate the crankshaft one rotation (360°) so that #6. cylinder may be positioned at the compression TDC (Top Dead Center). Then adjust the valves corresponding to mark “○” in the below table.

Note) #6. cylinder is located at the side where cooling fan was installed.

Note) #1. cylinder is positioned at the valve overlap when #6. cylinder is positioned at the compression TDC (Top Dead Center).

(I: Intake, E: Exhaust)

Cylinder No.	#1		#2		#3		#4		#5		#6	
	I	E	I	E	I	E	I	E	I	E	I	E
#1 TDC	●	●	●			●	●			●		
#6 TDC				○	○			○	○		○	○

- 3) As for the valve clearance, adjust it when in cold.

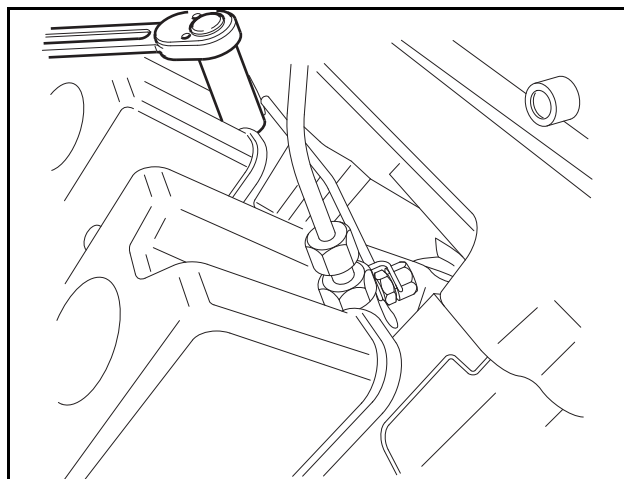
Specified value		Measurement tolerance	
Intake valve	Exhaust valve	Intake valve	Exhaust valve
0.3 mm	0.3 mm	±0.05 mm	

CAUTION

- Crankshaft revolution is done by hands without using a starting motor.
- Turn it to the direction of engine rotation, but do not use the installing bolts at the turn.
- The cylinder no. and the order of intake and exhaust can be determined from the flywheel housing.

Cylinder Compression Pressure

1. Start and warm up the engine.
2. Stop the engine and disassemble the fuel injection nozzle holder assembly.
3. Install a special tool, compression pressure gauge adapter in the fuel injection nozzle holder hole.

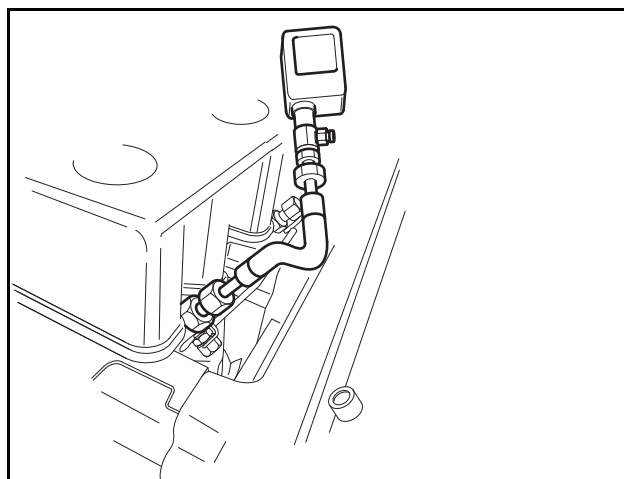


DV2213046A

4. Connect the compression pressure gauge to the adapter.

Standard	Above 28kg/cm ²
Tolerance limit	24kg/cm ²
Difference between each cylinder	Within ±10%

Note) Testing conditions: at water temperature of 20°C and speed of 200 rpm (10 turns)

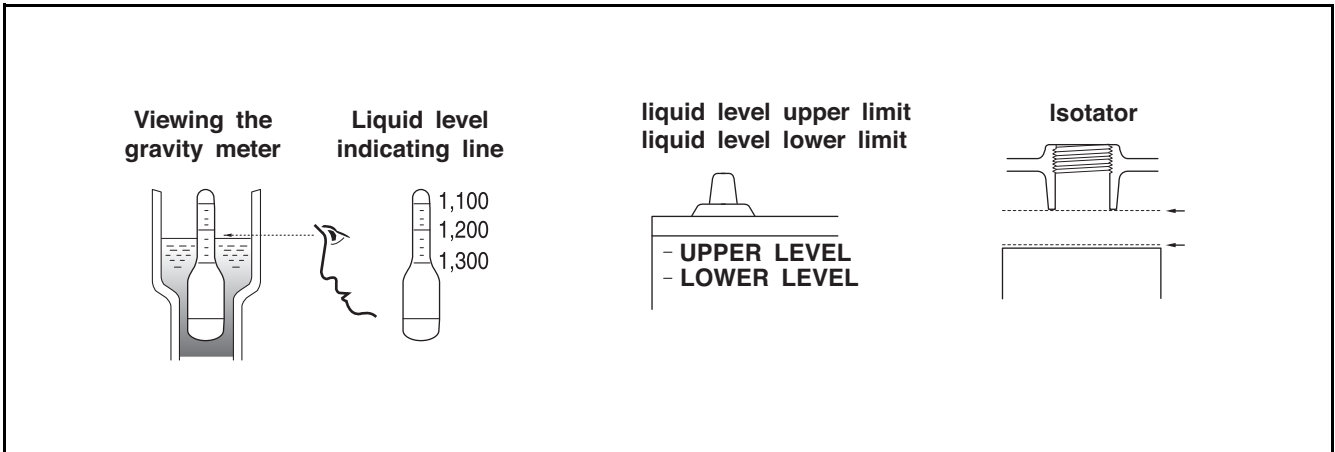


EA9O5004

Electric system

Battery

- Check for the electrolyte leakage by crack in the battery, and replace the battery if defective.
- Check the amount of electrolyte, and replenish distilled water if insufficient.
- Check the specific gravity of electrolyte. If it is below the specified value (1.12 ~ 1.28), replenish it.



DV2213040A_E

Starter

When servicing the engine, immerse the starter motor's pinion gear and ring gear in the fuel, wash them completely, and apply grease again. When you clean the surrounding of engine, be careful so that water may not enter the starter.

CAUTION

- Starter should be protected from humidity all the time.
- Before working on the electric system, be sure to disconnect the ground wire ("-" minus wire) of the battery. Short circuit may occur while working on the electrical system. Connect the ground wire last after completing all of work.

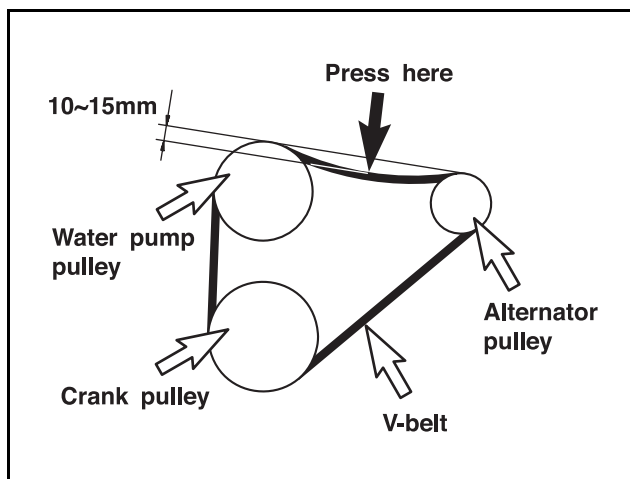
4. Regular inspection

Others/driving system

V-Belt

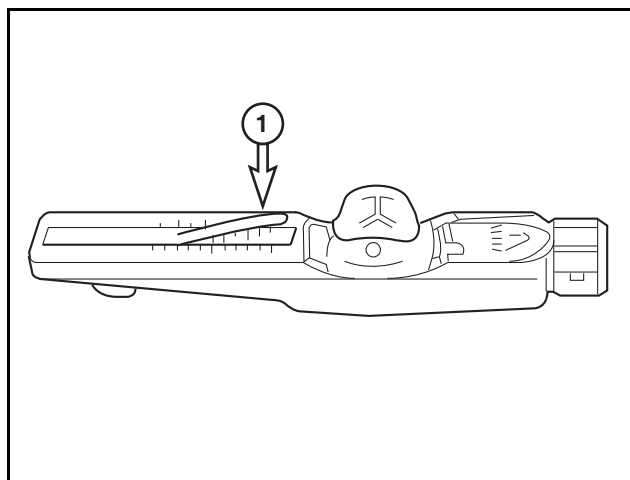
The tension of the V-belts should be checked daily .

1. Change the V-belts if necessary
 - 1) If in the case of a multiple V-belt drive, wear or differing tensions are found, always replace the complete set of V-belts.
2. Checking condition
 - 1) Check V-belts for cracks, oil, overheating and wear.
3. Testing by hand



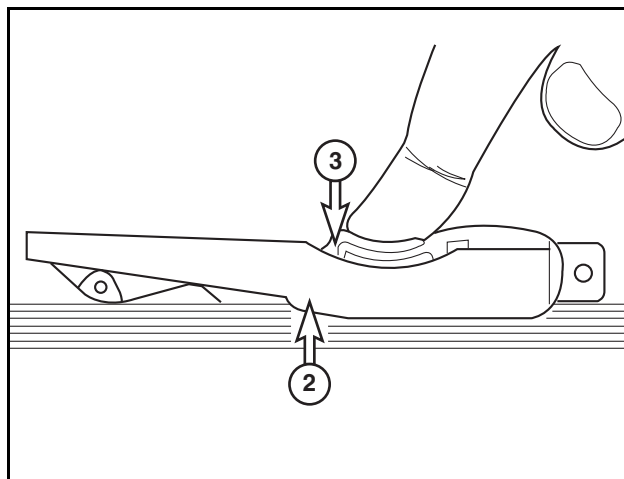
EA9O2006

- 1) For the V-belt tension, when you press the center between pulleys, if it is pressed by 10~15mm, it is normal.
- 2) To check the tension of V-belt more accurately, you can use a V-belt tension gauge.
4. Tension measurement
 - 1) Lower indicator arm (1) into the scale.



DV2213048A

- 2) Apply tester to belt at a point midway between two pulleys so that edge of contact surface (2) is flush with the V-belt.



DV2213049A

- 3) Slowly depress pad (3) until the spring can be heard to disengage. This will cause the indicator (1) to move upwards.

Note) If pressure is maintained after the spring has disengaged a false reading will be obtained.

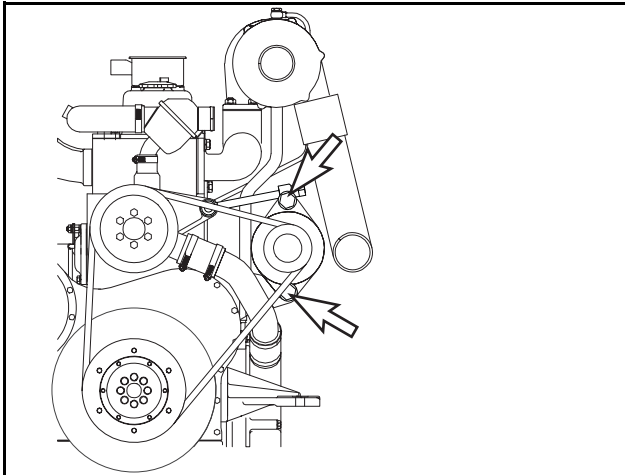
- 4) Read the tension value at the point that the top surface of indicator arm(1) intersects with the scale.
- 5) Before taking readings makes ensure that the indicator arm remains in its position.

Note) If the value measured devotes from the setting value specified, the V-belt tension must be corrected according to the following table.

Type	Belt width (mm)	Tension from a Tension Meter		
		New belt (kg)		Replacement required
		Upon installation	After 10 minute	
M	8.5	50	45	40
A	11.8	55	50	45
B	15.5	75	70	60
C	20.2	75	70	60
3V-2	18.8	90~100	70~80	60
3V-4	39.4	180~200	140~160	120
3V-6	60.0	270~300	210~240	180

4. Regular inspection

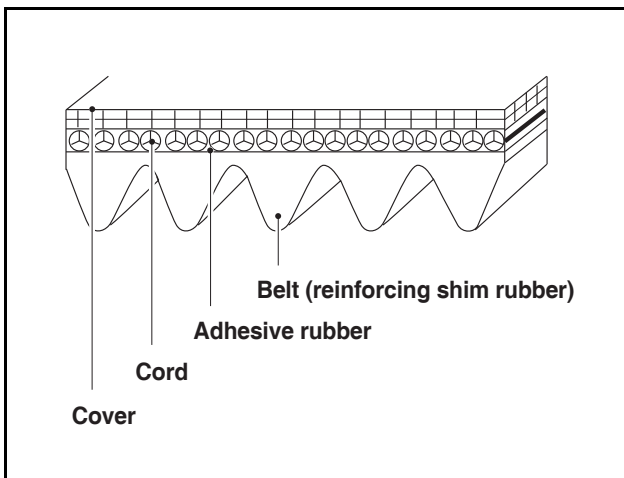
5. Tension adjustment and V-belt replacement



EDB58180011

- 1) Loosen fixing bolts and nuts.
- 2) Adjust the alternator until V-belts have correct tensions.
- 3) Tighten fixing bolts and nuts.
- 4) To change the V-belts loosen fixing bolts and nuts. Then push the alternator toward water pump pulley by hand.

6. Poly belt tension



EB5O6002

Number of belt folds (PK type)	Tension (kgf)
3	20 - 27
4	27 - 36
5	34 - 45
6	41 - 57
7	48 - 66
8	59 - 73

4. Regular inspection

5. About the engine

Marking system of units	75
Unit Conversion Methods.....	75
Tightening torque	76
Tightening torque of main parts	76
Tightening Torque of General Bolts	77
Tightening torque of plug screw	78
Hollow Screw (4-Hole) Tightening Torque	78
Engine Disassembly	79
Procedure of Disassembling an Engine	79
Engine Assembly	88
Procedure of Assembling Engine.....	88

Marking system of units

Unit Conversion Methods

The following methods show how to convert SI units to US units and vice versa.

1. To convert an SI unit to a US unit, multiply a SI unit with the number in the following table.

Note) (SI Unit) X (Number) = (US Unit)

Note) 1mm X 0.03937 = 0.03937 in

2. To convert a US unit to an SI unit, divide the US unit by the number in the following table.

Note) (US Unit) ÷ (Number) = (SI Unit)

Note) 1 in ÷ 0.03937 = 25.4 mm

Item	Number	SI Unit	US Unit
Length	0.03937	mm	in
	3.28084	m	ft
	1.093613	m	yd
	0.621371	km	mile
Area	0.00155	mm ²	in ²
	0.1550	cm ²	in ²
	10.76391	m ²	ft ²
	1.19599	m ²	yd ²
Weight	2.204623	kg	lb
	0.001	kg	t (ton)
Volume	0.061024	cc	in ³
	0.061024	ml	in ³
	0.061024	cm ³	in ³
	61.023744	L	in ³
	0.264172	L	gal
Force ^a	2.204622	kgf	lbf
	0.2248089	N	lbf
Acceleration	3.28084	m/s ²	ft/s ²
	39.37008	m/s ²	in/s ²
Torque ^b	7.233014	kgf·m	ibf·ft
	86.79619	kgf·m	ibf·in
	0.7375621	N·m	ibf·ft
	8.850748	N·m	ibf·in

Item	Number	SI Unit	US Unit
Power	1.340483	kw	Hp
Pressure	0.01	kPa	bar
	7.500615	kPa	mmHg
	20.88543	kPa	lb/ft ²
	14.2233	psi	kg/cm ²
Power	1.3596	kw	PS
	0.98635	ps	hp
Fuel Consumption	0.00162	g/kwh	lb/psh
Energy	0.000947817	J	BTU
	0.7375621	J	lbf·ft
	0.000277778	J	Wh
Luminous Flux	0.09290304	lm/m ²	lm/ft ²
Speed	0.6213712	km/h	mph
Temperature	°C	°C	°F

- 9.806 x (kgf) = (N)
- 9.806 x (kgf·m) = (N·m)
- {(9/5) x (°C) + 32} = (°F)
{(°F) - 32} x (5/9) = (°C)

5. About the engine

Tightening torque

Tightening torque of main parts

Major Parts	Screw (Diameter x pitch)	Strength (grade)	Tightening Torque	Remarks
Cylinder head bolt	M14 x 1.5	10.9T	1st: 6.0 kgf·m 2nd: 90° 3rd: 90° 4th: 90° Finished: 60° (Angle Method)	COLLARD DUO BOLT
Connecting rod bearing cap bolt	M14 x 1.5	12.9T	1st: 4 ±0.2 kgf·m 2nd: 60° ±3°	
Crankshaft main bearing cap bolt	M16 x 1.5	12.9T	1st: 15 kgf·m 2nd: 25 kgf·m 3rd: 30 kgf·m	
Crankshaft main bearing cap bolt	M12 x 1.5	10.9T	9.0 kgf·m	
Flywheel housing fixing bolt	M12 x 1.5	10.9T	11.2 kgf·m	
Flywheel fixing bolt	M14 x 1.5	10.9T	18.0 ±3.6 kgf·m	
Crankshaft pulley fixing bolt	M12 x 1.5	10.9T	13.4 kgf·m	
Oil spray nozzle	M14 x 1.5	-	4.5 ±0.45 kgf·m	
Injection nozzle nut	M28 x 1.5	-	7.0 ±0.5 kgf·m	
Injection pump bracket bolt	M10	8.8T	4.4 kgf·m	
Injection pump coupling bolt	-	-	6.0 ~ 6.5 kgf·m	
Injection pump driving gear nut	M24 x 1.5	8.8T	25.0 kgf·m	
Injection pipe nut	M14 x 1.5	8.8T	3.0 kgf·m	
Injection pump delivery valve holder	-	-	11.0 ~ 12.0 kgf·m	

5. About the engine

Tightening Torque of General Bolts

Please refer to the following tightening torque for the bolts which are not listed in Tightening Torque of Main Parts.

1. Tightening Torque of General Bolts

Nominal Diameter × Pitch (mm)	Strength Classification										
	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)
	Elastic Limit Value (kg/mm ²)										
	20	24	32	30	40	36	46	54	64	90	106
	Tightening Torque (kg·m)										
M5	0.15	0.16	0.25	0.22	0.31	0.28	0.43	0.48	0.5	0.75	0.9
M6	0.28	0.30	0.45	0.4	0.55	0.47	0.77	0.85	0.9	1.25	1.5
M7	0.43	0.46	0.7	0.63	0.83	0.78	1.2	1.3	1.4	1.95	2.35
M8	0.7	0.75	1.1	1	1.4	1.25	1.9	2.1	2.2	3.1	3.8
M8 x 1	0.73	0.8	1.2	1.1	1.5	1.34	2.1	2.3	2.4	3.35	4.1
M10	1.35	1.4	2.2	1.9	2.7	2.35	3.7	4.2	4.4	6.2	7.4
M10 x 1	1.5	1.6	2.5	2.1	3.1	2.8	4.3	4.9	5	7	8.4
M12	2.4	2.5	3.7	3.3	4.7	4.2	6.3	7.2	7.5	10.5	12.5
M12 x 1.5	2.55	2.7	4	3.5	5	4.6	6.8	7.7	8	11.2	13.4
M14	3.7	3.9	6	5.2	7.5	7	10	11.5	12	17	20
M14 x 1.5	4.1	4.3	6.6	5.7	8.3	7.5	11.1	12.5	13	18.5	22
M16	5.6	6	9	8	11.5	10.5	17.9	18.5	18	26	31
M16 x 1.5	6.2	6.5	9.7	8.6	12.5	11.3	17	19.5	20	28	33
M18	7.8	8.3	12.5	11	16	14.5	21	24.2	25	36	43
M18 x 1.5	9.1	9.5	14.5	12.5	18.5	16.7	24.5	27.5	28	41	49
M20	11.5	12	18	16	22	19	31.5	35	36	51	60
M20 x 1.5	12.8	13.5	20.5	18	25	22.5	35	39.5	41	58	68
M22	15.5	16	24.5	21	30	26	42	46	49	67	75
M22 x 1.5	17	18.5	28	24	34	29	47	52	56	75	85
M24	20.5	21.5	33	27	40	34	55	58	63	82	92
M24 x 1.5	23	25	37	31	45	38	61	67	74	93	103

Note) The standard torque values above are about 70% of the bolt elastic limit values.

Note) The tensile force has been calculated by multiplying the tensile strength with the screw cross-sectional area.

Note) A special screw should be tightened with 85% of the tightening torque of the standard value. For example, a MoS2-coated screw should be tightened with 60% of the tightening torque of the standard value.

5. About the engine

2. Tightening Torque of Key General Bolts

Nominal Diameter x Pitch (mm)	Strength Classification			Remarks
	8.8T	10.9T	12.9T	
	Tightening Torque (kgf·m) ±10%			
M6 x 1	1	1.25	1.5	
M8 x 1.25	2.2	3.1	3.8	
M8 x 1	2.4	3.35	4.1	
M10 x 1.5	4.4	6.2	7.4	
M10 x 1.0	5	7	8.4	
M12 x 1.75	7.5	10.5	12.5	
M12 x 1.5	8	11.2	13.4	
M14 x 1.5	13	18.5	22	

Tightening torque of 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

Hollow Screw (4-Hole) Tightening Torque

Material Classification	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 ^a	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

a. Applied to HD Construction Equipment Engines

Engine Disassembly

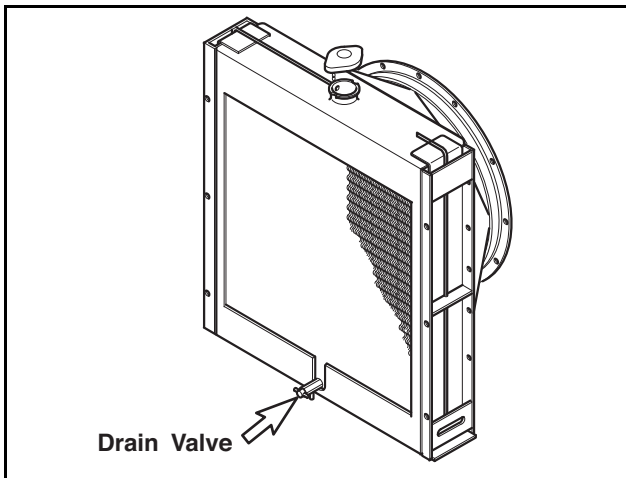
Procedure of Disassembling an Engine

CAUTION

- Prepare tools and genuine parts necessary before disassembling engine.
- Prepare a shelf for the storage of removed parts.
- Perform repairs in a light and clean space.
- Keep hands clean while performing repairs.
- Keep parts removed from the engine in the order of disassembly.
- Do not allow parts removed from the engine to touch each other or be mixed with other parts.

Disassemble the engine in the following order.

1. Remove the oil level gauge
 - 1) Pull out the oil level gauge.
2. Drain cooling water
 - 1) Remove the radiator cap. Open the drain plug at the radiator lower part to drain the coolant as the right figure.

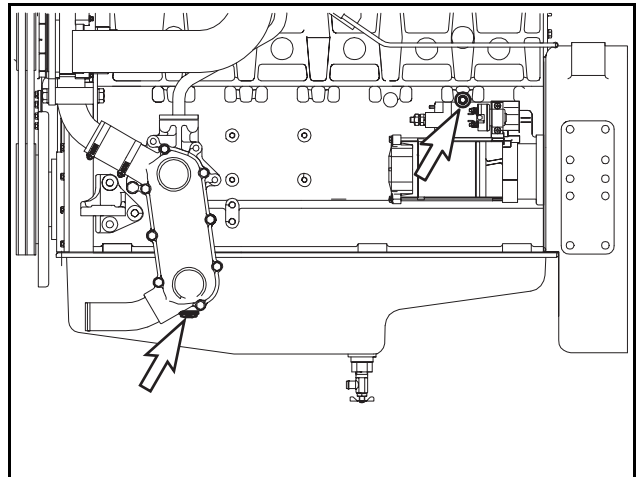


EA5O4002

CAUTION

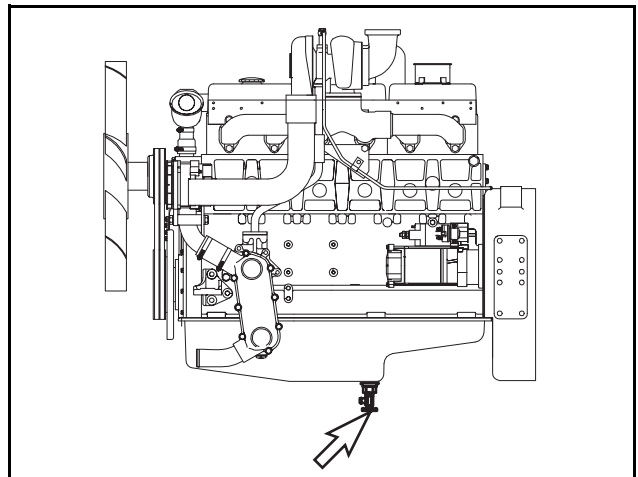
When removing radiator filler cap while the engine is still hot, cover the cap with a rag, then turn it slowly to release the internal steam pressure. This will prevent a person from scalding with hot steam spouted out from the filler port.

- 2) Remove the drain plug from the cylinder block and drain out the cooling water into a container.



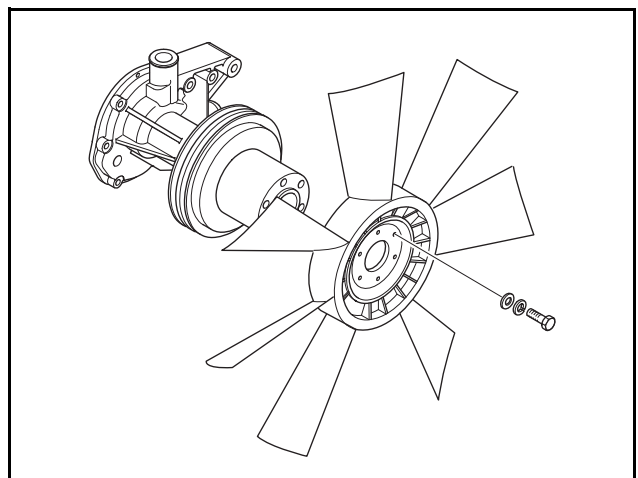
EA9O4003

3. Drain engine oil



EA9O4001

- 1) Remove the oil drain cock of oil pan and pour the engine oil into the prepared vessel.
4. Remove the cooling fan

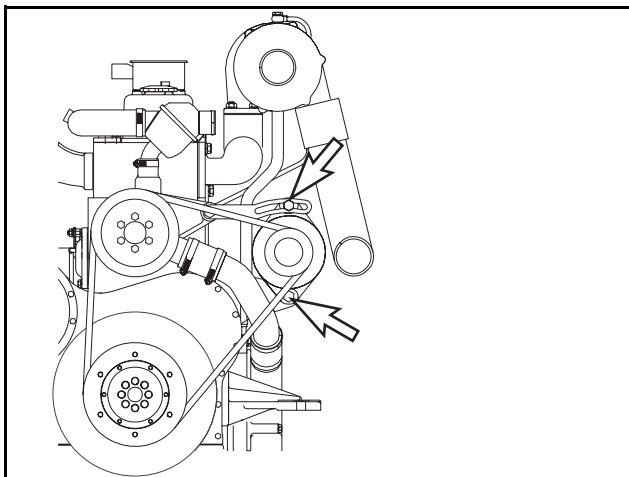


EA9M3001

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

5. About the engine

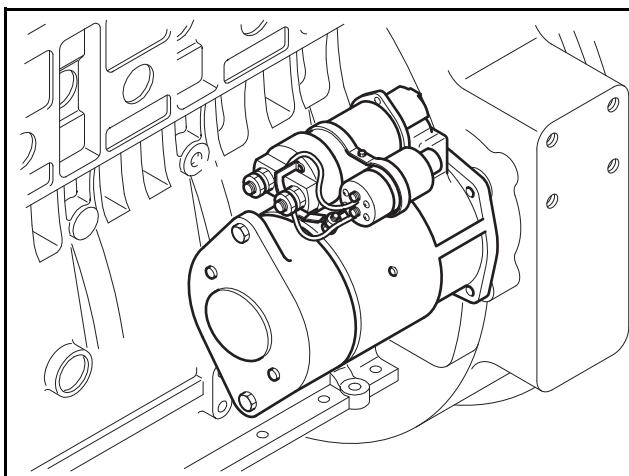
5. Remove the V-belt



EA9O2007

- 1) Remove the V-belt by loosening the alternator tension adjusting bolt and tighten the bolt.

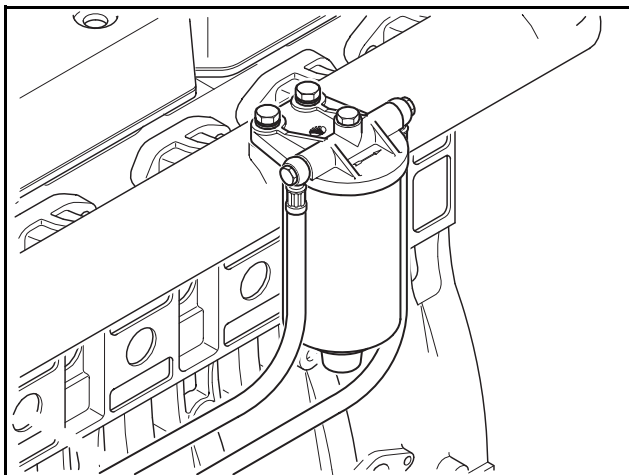
6. Remove the starter



ED7OM003

- 1) Loosen the starter assembling nuts and remove the starter being careful not to damage its gears.

7. Remove the fuel filter



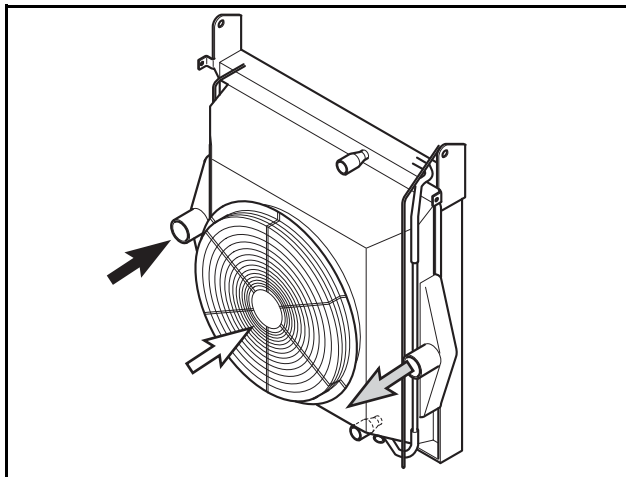
ED7OM009

- 1) Remove the hollow screws of filter and tear down fuel supply and discharge rubber hose.
- 2) Remove fuel filter assembling bolts and disassemble the fuel filter.

8. Remove the breather

- 1) Loosen the clamp screw to remove the rubber hose.

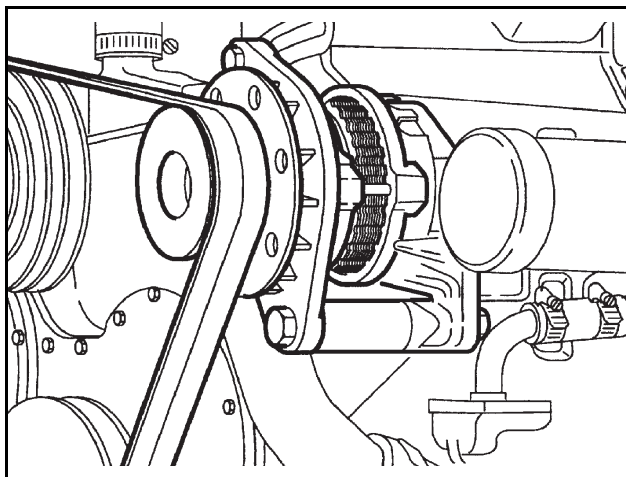
9. Remove the Inter cooler



EA6M2001

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

10. Remove the Alternator

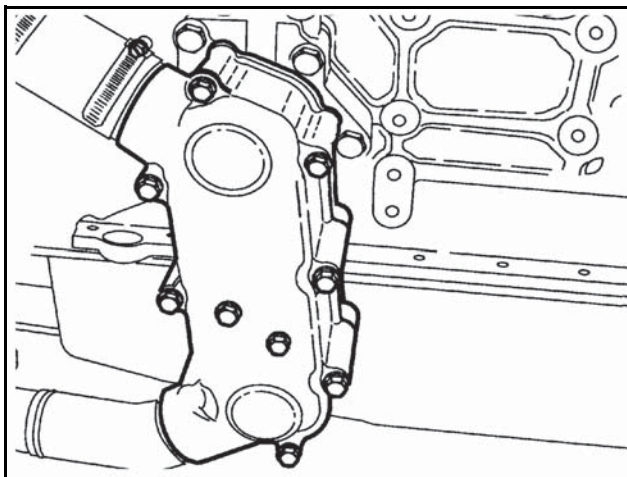


EA9M3004

- 1) Remove the alternator fixing bolts and disassemble the alternator.
- 2) Remove the tension adjusting bolts and bracket.

5. About the engine

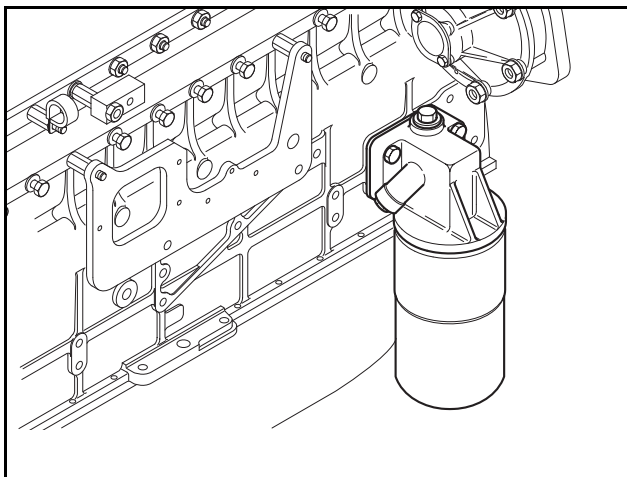
11. Remove the oil cooler



ED7OM012

- 1) Loosen the cooling water pump and the rubber hose clamps of connected pipes, and disassemble it.
- 2) Remove the oil cooler assembling nuts and disassemble it.

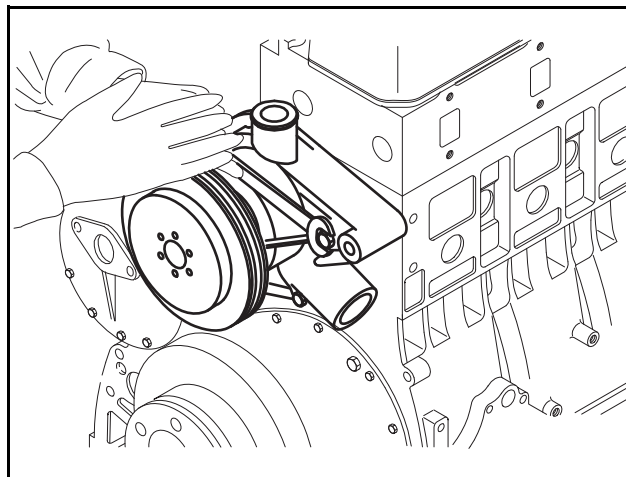
12. Remove the oil filter



EB8M3002

- 1) Remove the oil filter assembling bolts and disassemble the oil filter assembly.

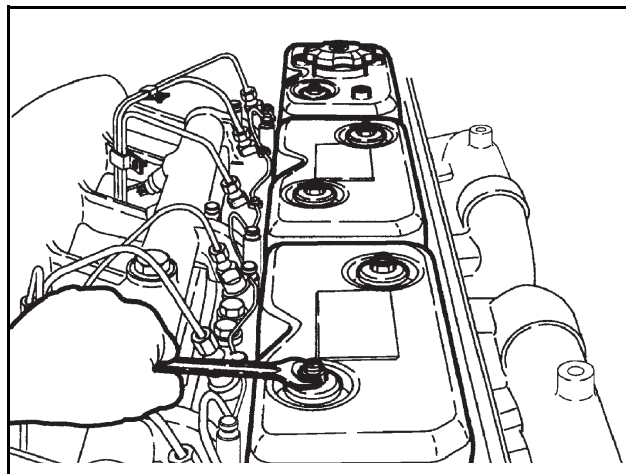
13. Remove the water pump



ED7OM008

- 1) Remove the water pump assembling bolts and disassemble the water pump.

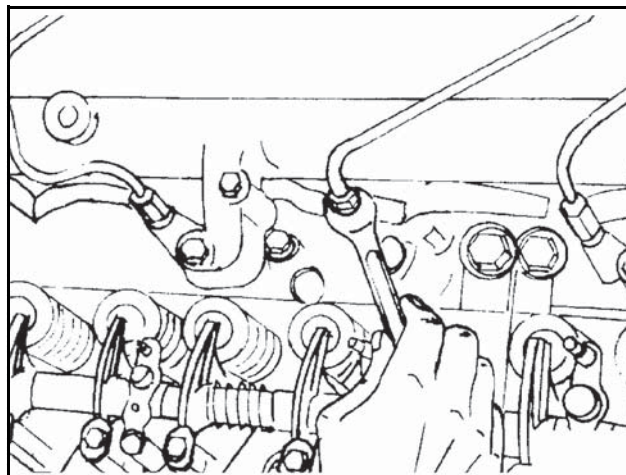
14. Remove the cylinder head cover



EB5M3012

- 1) Remove the head cover assembling bolts and lift the cover.

15. Remove the nozzle



ENM3013S

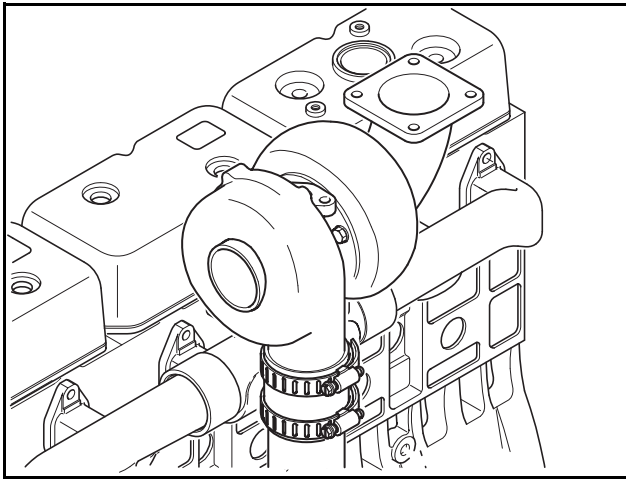
5. About the engine

- 1) Remove the fuel supply high pressure pipe and its assembling nuts that are connected between fuel injection pump and nozzle and disassemble the pipes.
- 2) After installing the special tool for removing nozzle temporarily, loosen the holder and then hammer up with a hammer which is a special tool so as for nozzle assembly to be disassembled.

CAUTION

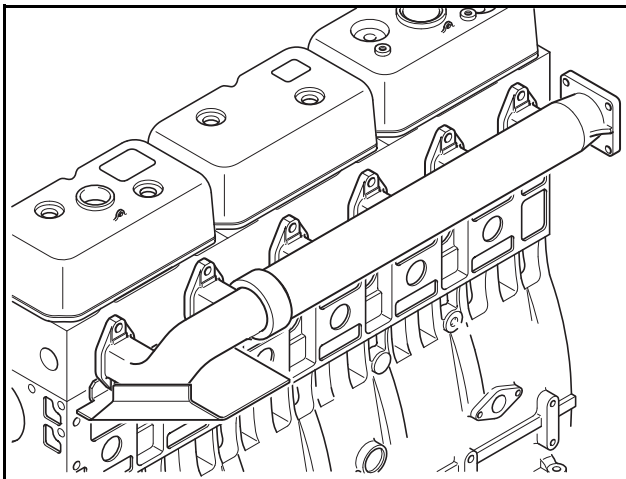
Be careful not to damage the nozzle at disassembled.

- 3) Pull the seal ring out through the nozzle hole of cylinder head and scrap it.
16. Remove the turbo charger



ED7OM010

- 1) Disassemble the oil supply pipe that supplies oil from cylinder block to turbo charger and the oil discharge pipe that discharges oil from turbo charger to cylinder block.
 - 2) Remove the turbo charger assembling nuts and disassemble it from the exhaust manifold.
17. Exhaust manifold



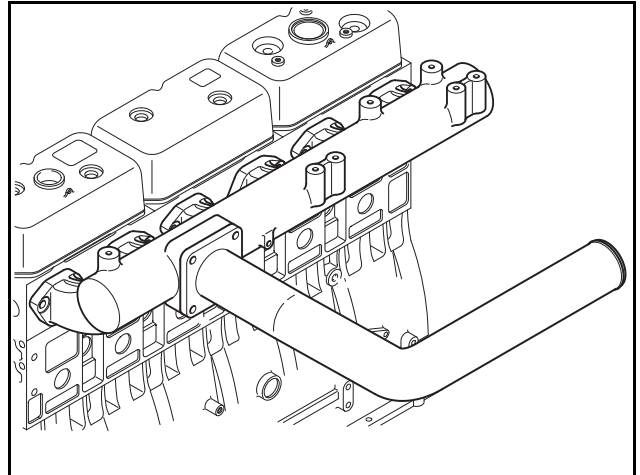
ED7OM011

- 1) Remove the exhaust manifold assembling nuts and disassemble the heat shield from the exhaust manifold.
- 2) Then disassemble the exhaust manifold and gasket.

CAUTION

Do not reuse the gasket.

- 3) Scrap the used gasket.
18. Remove the intake manifold



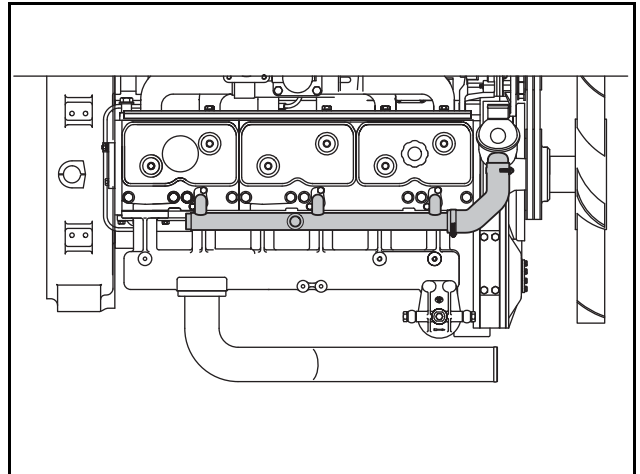
ED7OM005

- 1) Remove the cooling water pipe assembling bolts and disassemble the pipe for the cylinder head.
- 2) Remove the gasket of cooling water pipe with a scraper thoroughly.

CAUTION

Be careful for the gasket pieces not to get in the passage of cooling water.

19. Remove the cooling water pipe



ED7OM006

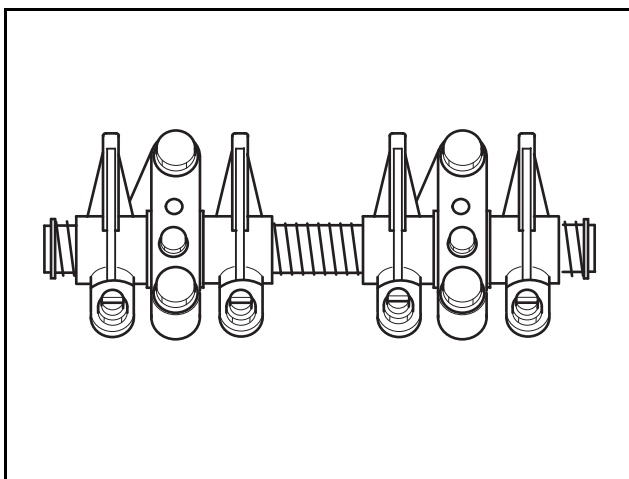
5. About the engine

- 1) Remove the cooling water pipe assembling bolts and disassemble the pipe for the cylinder head.
- 2) Remove the gasket of cooling water pipe with a scraper thoroughly.

CAUTION

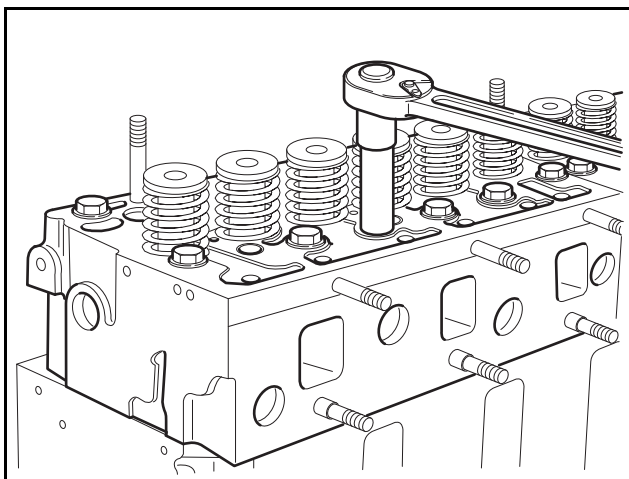
Be careful for the gasket pieces not to get in the passage of cooling water.

20. Remove the rocker arm



EA9M3011

- 1) Remove the rocker arm bracket assembling bolts in the reverse order (zigzag method) of assembling and disassemble the rocker arm.
 - 2) Disassemble the push rod.
21. Remove the cylinder head



EAMD1021

- 1) Remove the cylinder head bolts in the reverse order of tightening.
- 2) Remove it step by step.
 - First step: Loosen 1 ~ 2 threads

- Second step: Remove by loosening fully.

CAUTION

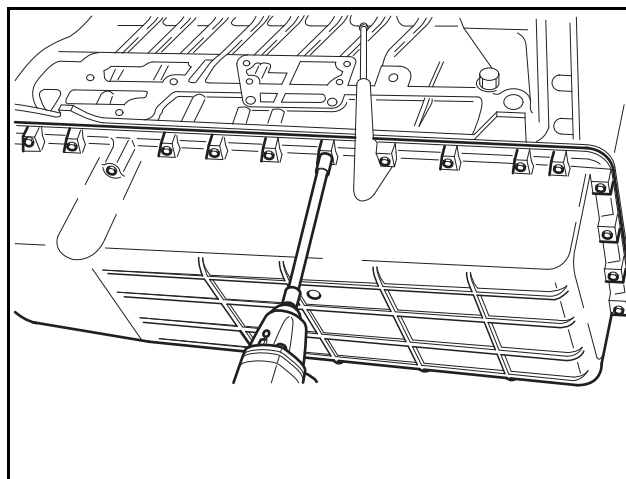
- Lay the removed bolts orderly not to damage the threads at all and store.
- Prevent a collision between the bolt thread each other.

- 3) Take out the cylinder head gasket and scrap it.
- 4) Remove the foreign residues from the cylinder head surface and block surface.

CAUTION

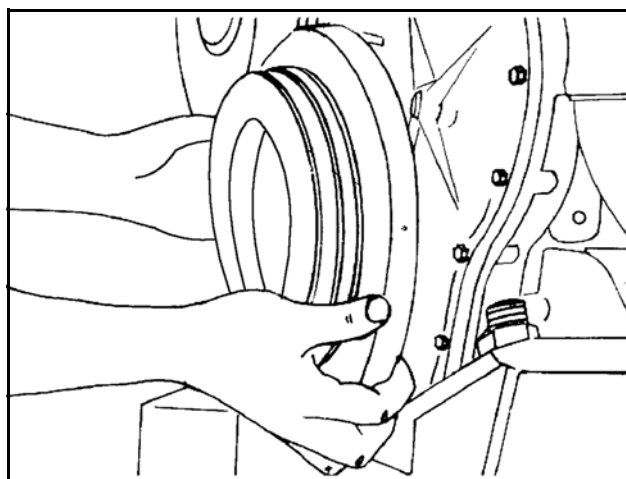
Try not to make any damage on the contact surfaces.

22. Remove the oil pan



EAMD0341

- 1) Remove the oil pan assembling bolts and disassemble the pan.
 - 2) After removing the oil pan gasket, scrap it.
23. Remove the Vibration damper

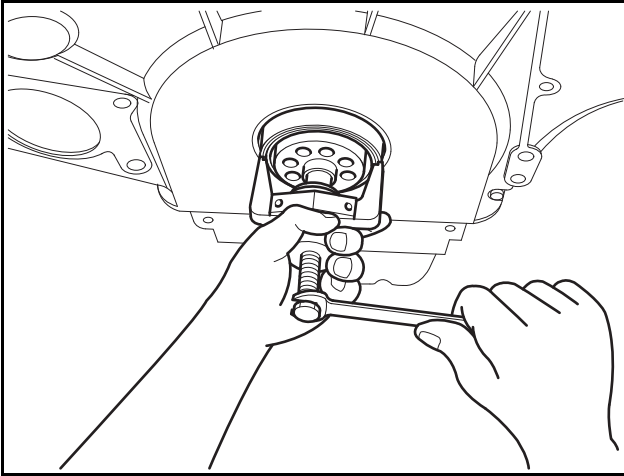


EA9M3012

5. About the engine

- 1) Remove the vibration damper assembling bolts in the reverse order of assembling and disassemble the damper assembly

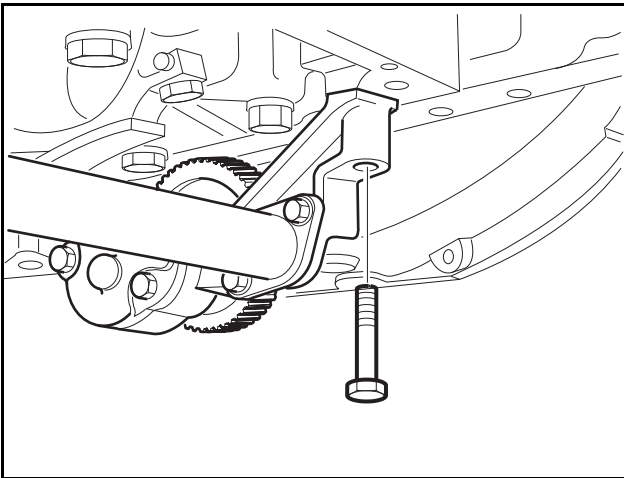
24. Remove the timing gear case cover



EAMD025I

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

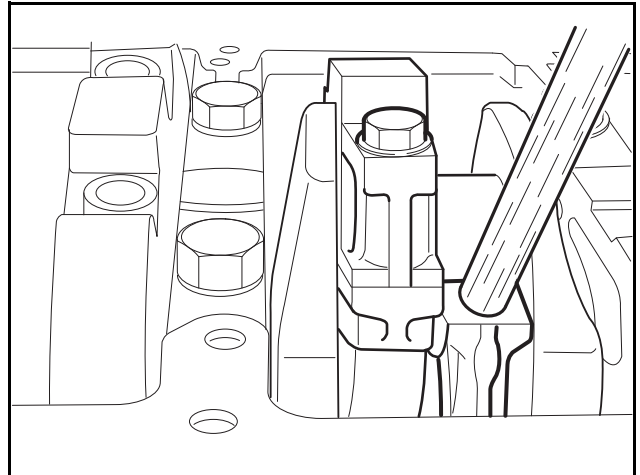
25. Remove the oil pump



EFM2025I

- 1) Remove the bracket fixing bolts of oil intake pipe.
- 2) Remove the pipe assembling bolts of oil pump and disassemble intake and supply pipe.
- 3) Remove the oil pump assembling bolts, and disassemble the oil pump.

26. Remove the piston assembly

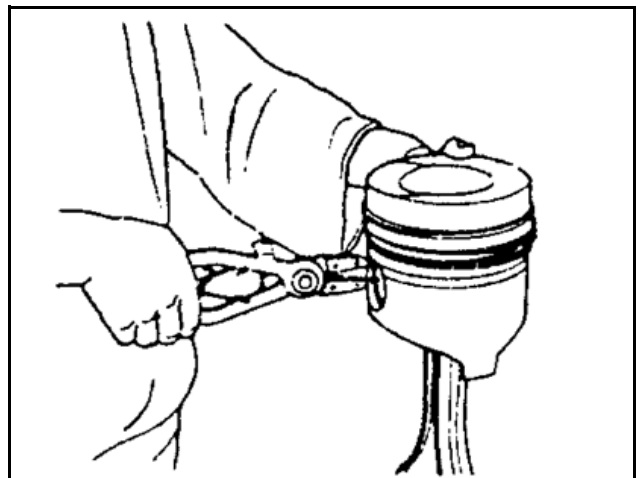


EFM2026I

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

27. Disassemble the piston assembly

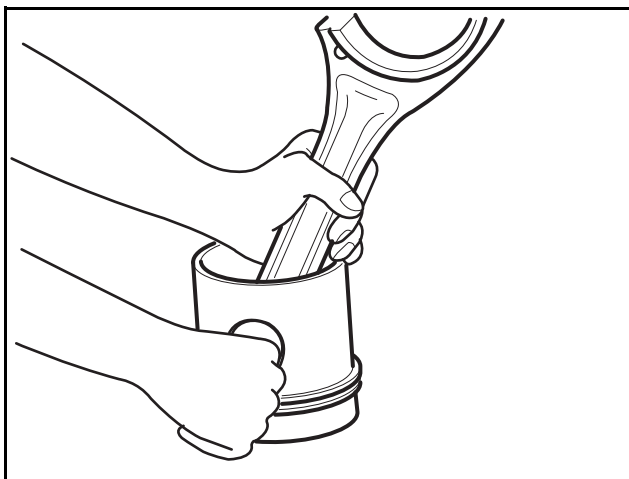
- 1) Remove the snap rings by means of a plier.



EAMD038I

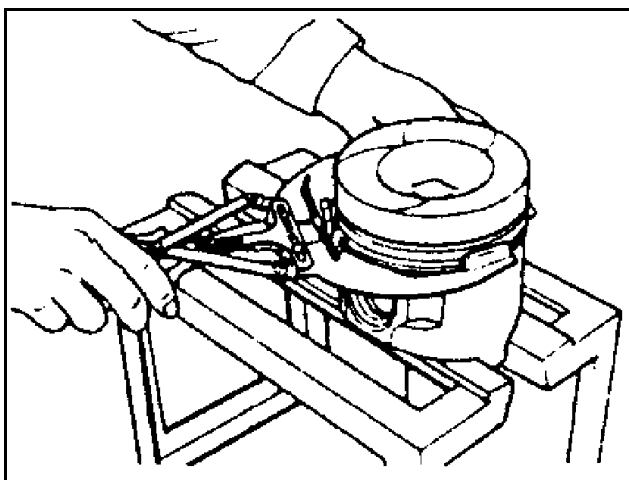
- 2) Heat the piston with a electric heater, then take out the piston pin from the piston as tapping it with a round wooden bar.

5. About the engine



EAMD088I

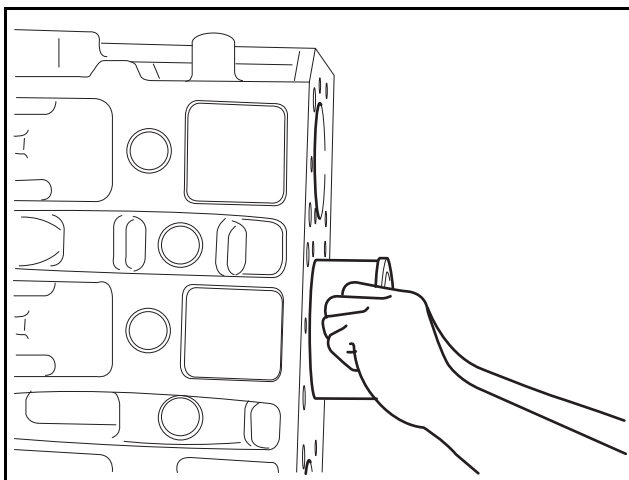
- 3) Remove the piston ring with a plier.



EAMD039I

- 4) Clean the piston thoroughly.

28. Remove the cylinder liner

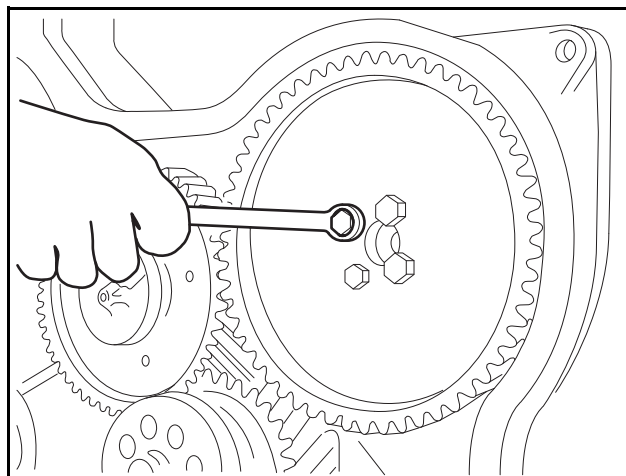


EAMD087I

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

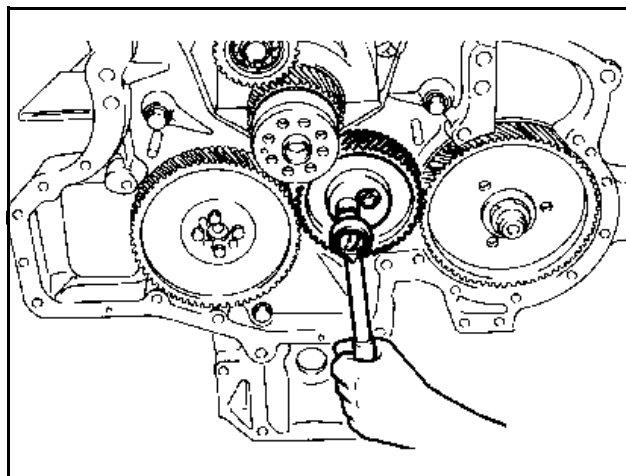
29. Remove the gear and idle gear pin

- 1) Remove the camshaft gear assembling bolts and disassemble the camshaft gear.



EDM2025I

- 2) Remove the idle gear assembling bolts and disassemble the idle gear pin.

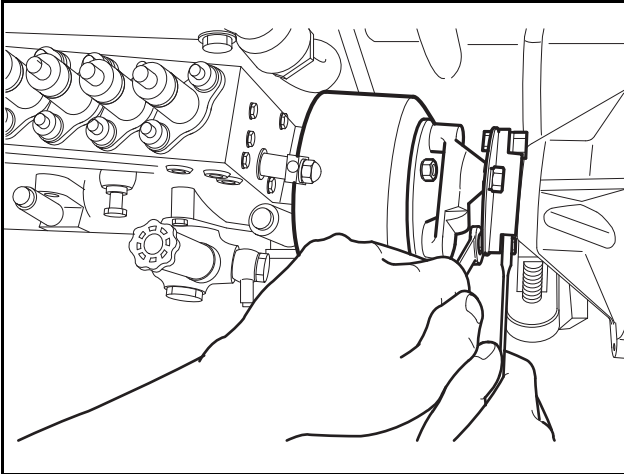


EAMD026S

30. Remove the fuel injection pump

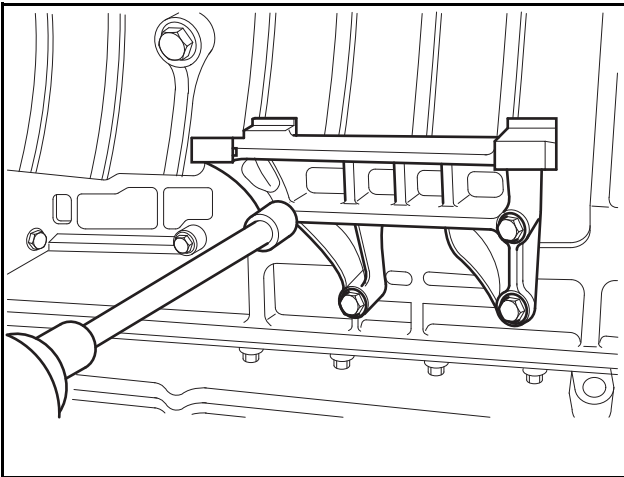
- 1) Disassembly the oil hose for lubrication.
2) Remove the injection pump flange assembling nuts.

5. About the engine



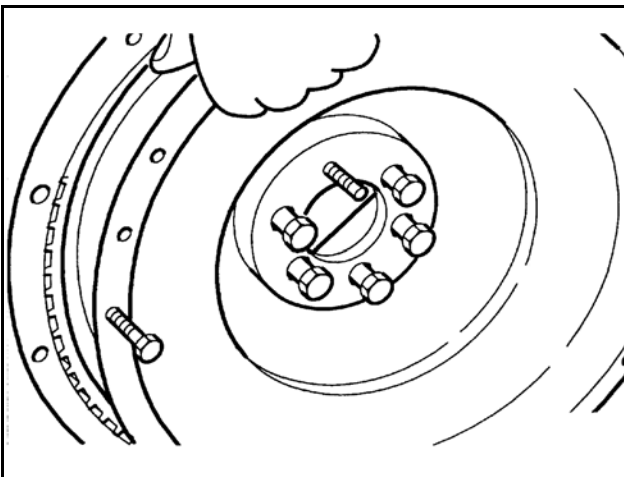
EAMD021I

- 3) Remove the bracket fixing bolts of injection pump, and disassemble by pulling the injection pump backward.



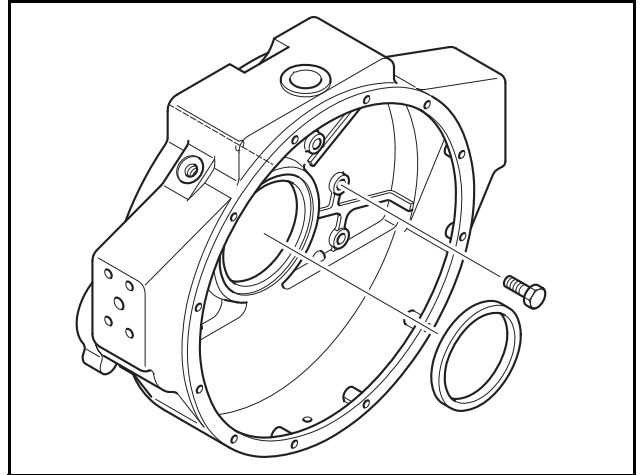
EAMD022I

31. Remove the water chamber cover
 - 1) Remove the assembling bolts and disassemble the water chamber cover.
 - 2) Remove the remnant gasket thoroughly.
32. Remove the flywheel



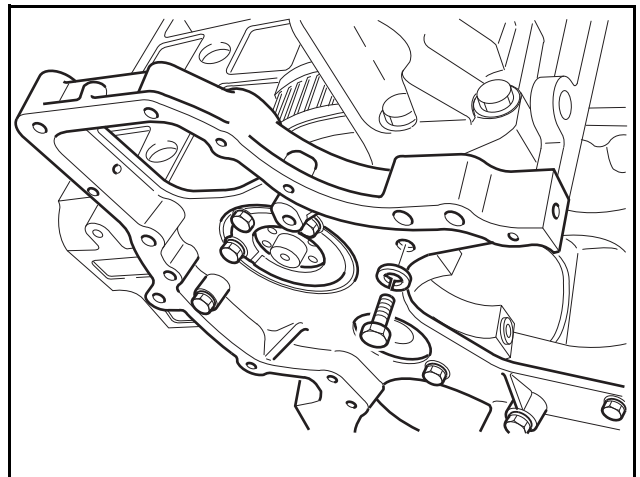
EDM2072I

- 1) Remove the flywheel assembling bolts and disassemble it.
 - 2) The bolt removal is done by the reverse order of assembling and by the steps.
33. Remove the flywheel housing



EA9M3013

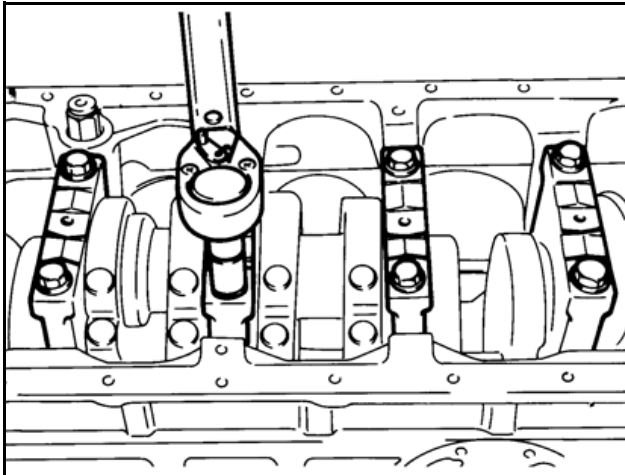
- 1) Remove the flywheel housing assembling bolts and disassemble the flywheel housing.
 - 2) Disassemble the oil seal of flywheel housing.
34. Remove the Injection pump drive gear
 - 1) Remove the assembling nuts of drive gear.
 - 2) Remove the drive gear housing assembling nuts and disassemble the gear assembly.
35. Remove the timing gear case



EAMD046I

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

36. Remove the Bearing cap



EAMD047S

- 1) Remove the bearing cap assembling bolts by the step in the reverse order of assembling, and disassemble the bearing cap.

Note) Remove by the sameway as the cylinder head bolts' removal.

- 2) Disassembled bearing caps are kept laid in order.

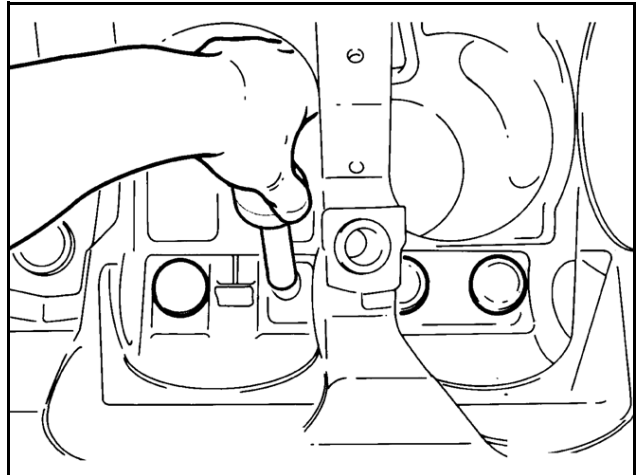
37. Remove the crankshaft

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

⚠ CAUTION

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.

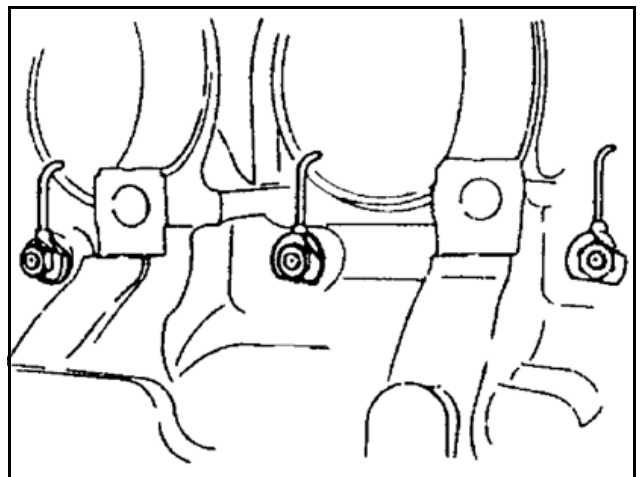
38. Remove the camshaft and tappet



EAMD072S

- 1) In order for camshaft not to be damaged, disassemble turning it.
- 2) In order for the disassembled camshaft to be prevented from bends or damage, put it on the special lathe and store.
- 3) Pull out the tappet.
- 4) As required, pull out the camshaft bush from the cylinder block by a press.
- 5) Check for damage, scratch, and wearing state and if abnormal, tear down.

39. Remove the oil spray nozzle



EAMD048S

- 1) Remove the valve screws of oil injection nozzle and disassemble it.

5. About the engine

Engine Assembly

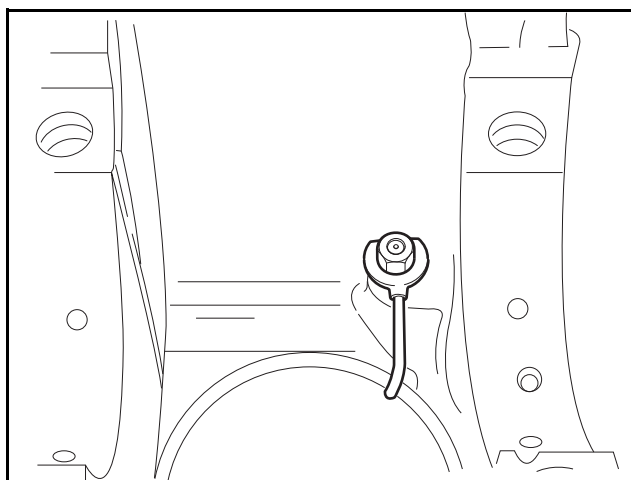
Procedure of Assembling Engine

CAUTION

- **Cleanse all disassembled and disconnected parts. Especially, clean the oil and coolant path with compressed air and check if there is any resistance.**
- **Arrange general tools and special tools for engine assembly.**
- **Prepare clean engine oil to be applied on each sliding component.**
- **Prepare repair materials such as sealant and gaskets.**
- **Replace used gaskets, seal rings, and expendable parts with new ones.**
- **Each bolt should be tightened with the specified tightening torque in the order of tightening; however, excessive tightening torque should be avoided.**
- **Ensure that all engine parts are successfully operating after reassembly.**
- **Check if any bolts are loose after the first assembly.**
- **Always keep hands clean during assembly.**

Assemble the engine in the following order.

1. Cover the floor of the workshop with wood plate or thick paper to prevent damage to the cylinder head and place the cylinder block with the head fitting surface facing downward.
2. Attach the oil spray nozzle.



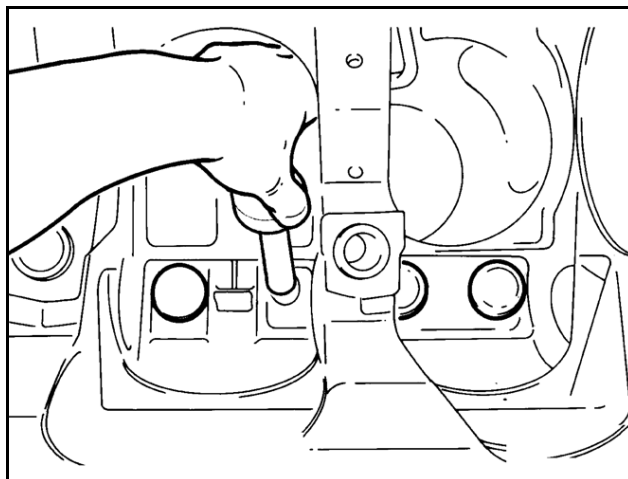
EDM3053I

- 1) Tighten and assemble the oil spray nozzle flange with fixing bolts using the spray nozzle jig.

Torque	8 kg·m
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3. Attach the tappet and cam shaft.

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



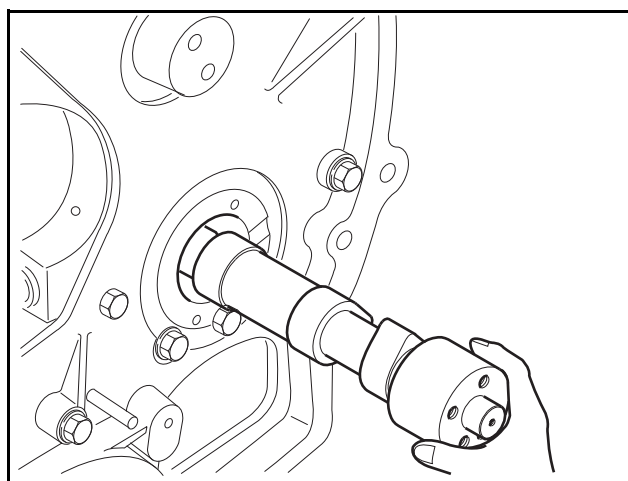
EAMD072S

- 3) Wet the cam bush inside diameter and camshaft with oil, and carefully assemble them while turning the camshaft.

CAUTION

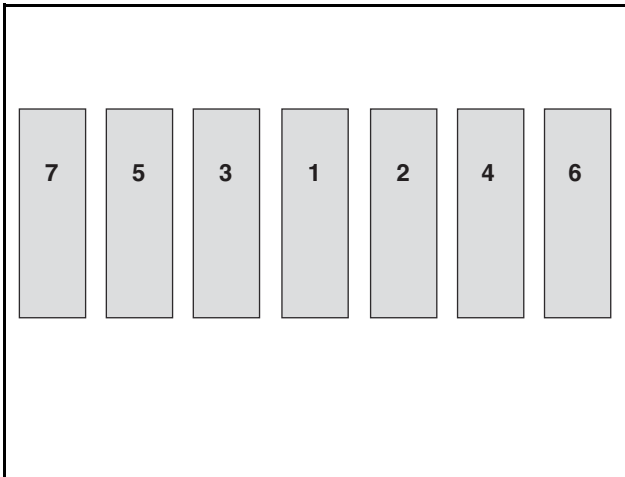
Be careful not to generate a damage to camshaft and bush.

- 4) Check to see that the camshaft rotates smoothly.



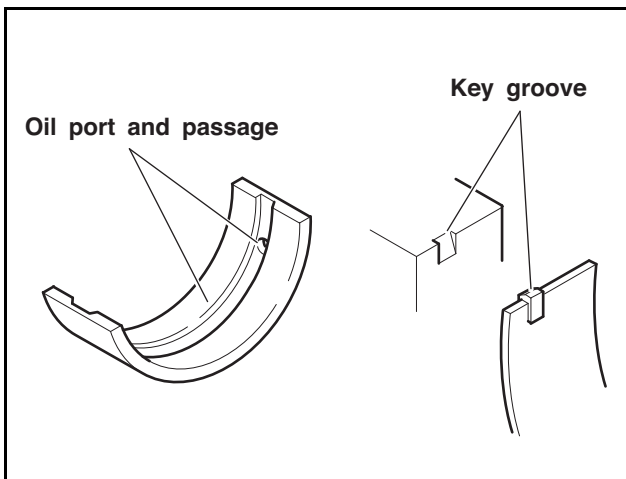
EDM2060I

4. Attach the crankshaft.



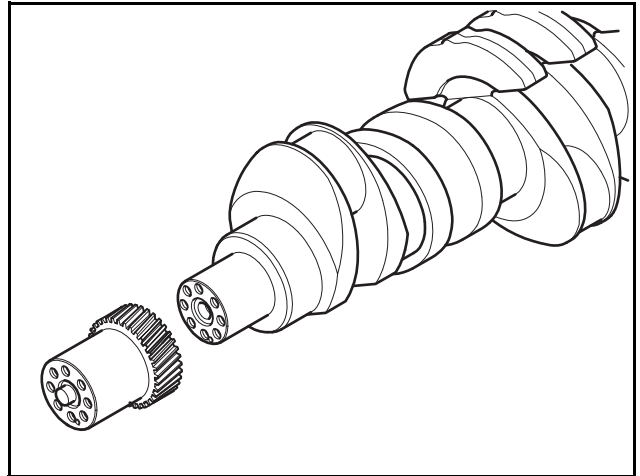
EFM20611

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



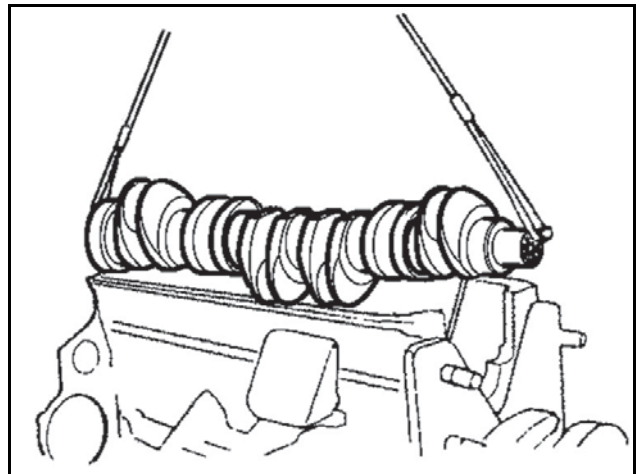
EA0M4083

- 2) Heat the crankshaft gear for at least 10 minutes to 120°C, then apply sealant (Loctite # 641) to the inside wall of the heated crankshaft gear evenly before inserting it to the end of crankshaft.



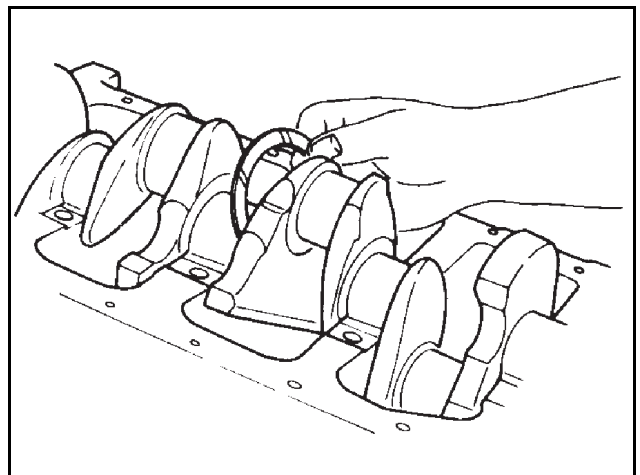
EA8M3014

- 3) Semi-tighten a bolt at both sides of the crankshaft, apply engine oil to journals and pins, then assemble the crankshaft with the cylinder block by tightening the fixing bolts.



EAMD075S

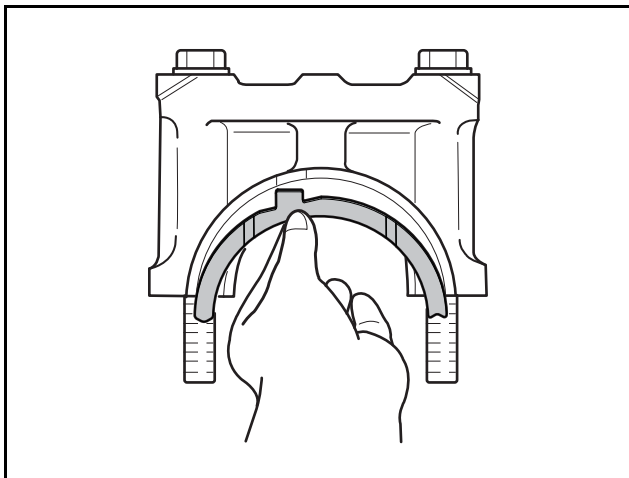
- 4) Coat engine oil to the pin and journal of crankshaft.
- 5) Install the oiled thrust washers with the oil groove facing outward.



EAMD076S

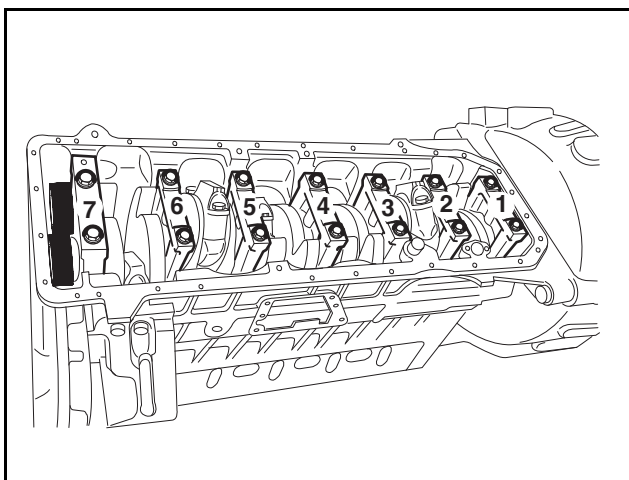
5. About the engine

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



EDL11180004

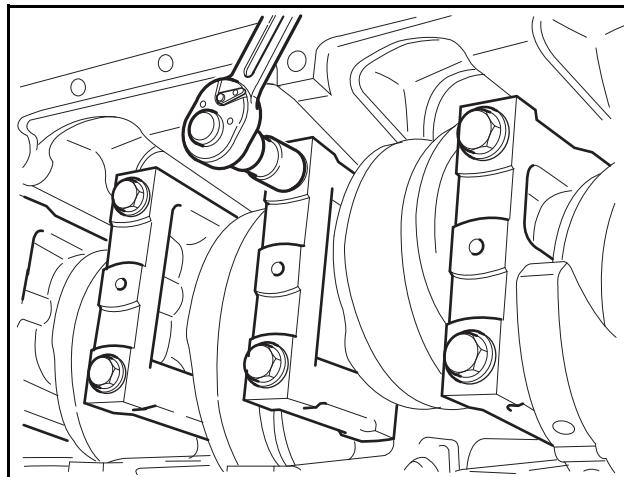
- 7) Install the bearing cap by matching the cylinder block No. with the bearing cap No.



EQM3058I

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

Torque	30 kgf·m
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EQM3059I

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

- 1st: Temporary bolt screwing about 1 ~ 2 threads.
- 2nd: With impact wrench, tighten up to about 15kgf·m.
- 3rd: With torque wrench, tighten up to about 25kgf·m.
- 4th: By means of torque wrench, tighten finally in the specified torque. (30kgf·m)

- 10) Tighten the bearing cap in the sequence of 4-3-5-2-6-1-7.

- 11) Check to see that the assembled crankshaft turns smoothly.

5. Attach the flywheel housing.

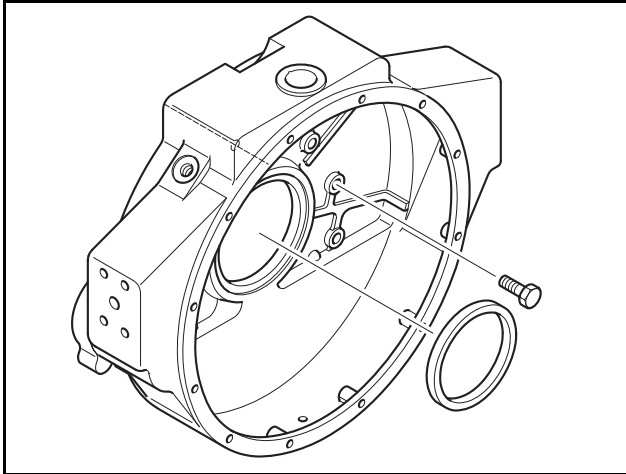
- 1) Temporarily install the guide bar on the cylinder block.
- 2) Apply gasket to the cylinder block.
- 3) Using the dowel pin and guide bar, install the flywheel housing and tighten the fixing bolts in a diagonal sequence to specified torque. (Zigzag method)

Torque	11.2 kgf·m
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- 4) When the bolts are tightened, remove the guide bar.

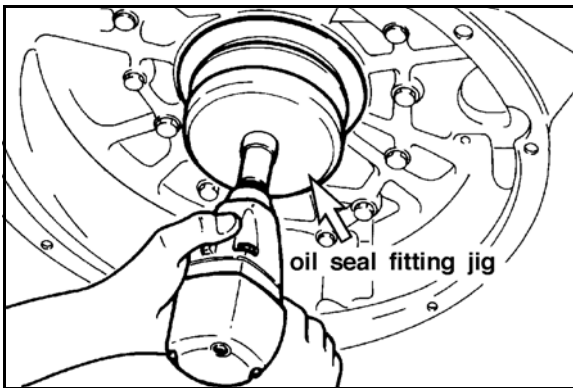
- 5) The flywheel housing is assembled after the new oil seal was pressed (Coat engine oil over the outside of oil seal) before in the housing by a press.

5. About the engine



EA9M3013

- 6) If any peripheral scar was generated due to oil seal at the oil seal contact surface of crankshaft, after inserting about 1 mm shim or thereabout in front of oil seal (Direction toward crankshaft.), measure and adjust.
6. Attach the rear oil seal.

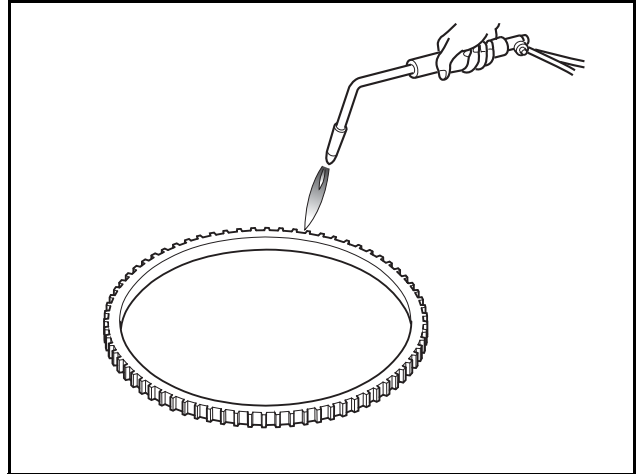


EA8M3003

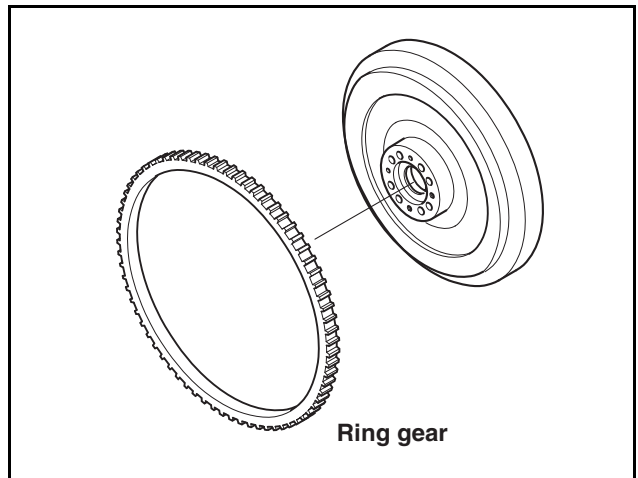
- 1) Apply lubricating oil to the outside of the oil seal and flywheel housing inside diameter and fit them over the crank shaft, then assemble the oil seal using an oil seal fitting jig.
7. Attach the flywheel.
- 1) Installation of flywheel ring gear With a gas burner, heat the ring gear evenly until heat expansion takes place, then install it using a hammer.

CAUTION

Do not allow the temperature of the ring gear to exceed 200°C

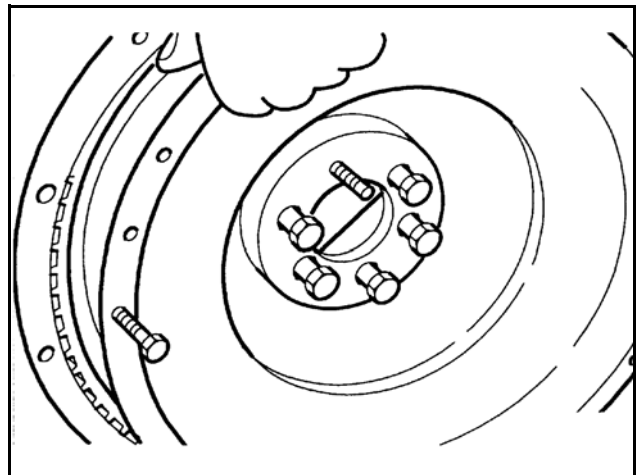


EA0M4029



EDB58180008

- 2) Install a guide bar into a bolt hole on the crank shaft, and lift the flywheel to align the dowel pin with the pin hole on the flywheel for temporary assembly operation.



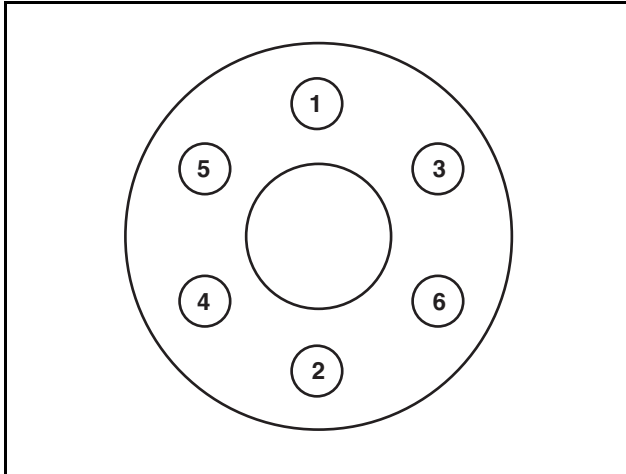
EDM20721

- 3) Coat the adhesive (#271 Loctite) over the assembling bolts and install bolts in the remaining holes. After that take out the guide bar, then install a bolt in the hole where the guide bar had been inserted.

5. About the engine

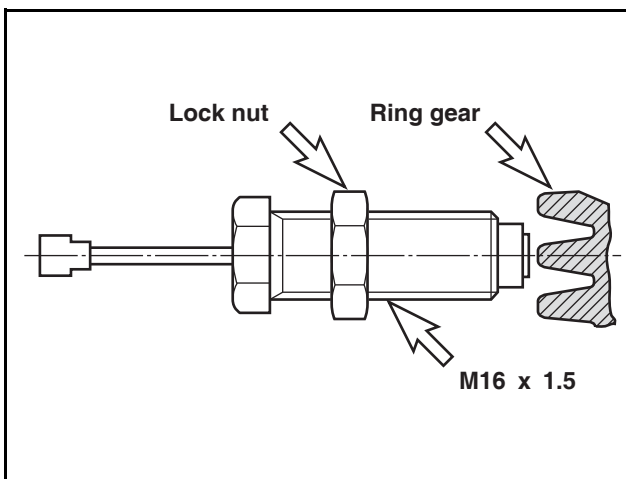
- 4) According to the order of tightening tighten the fixing bolts using a torque wrench in a diagonal sequence to specified torque.

Torque	18.5 kgf·m
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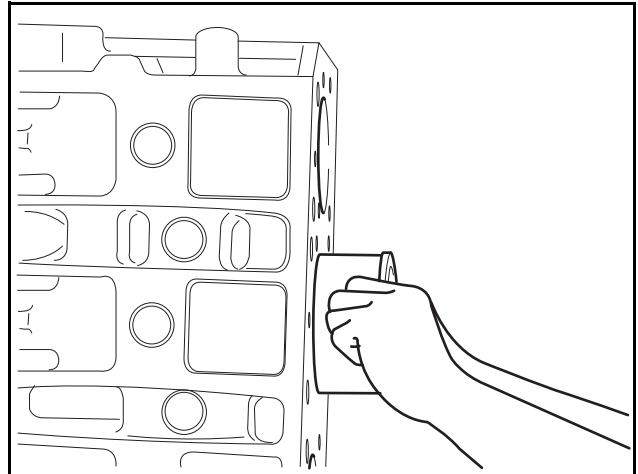
EDM2073I

8. Attach the Tacho sensor.



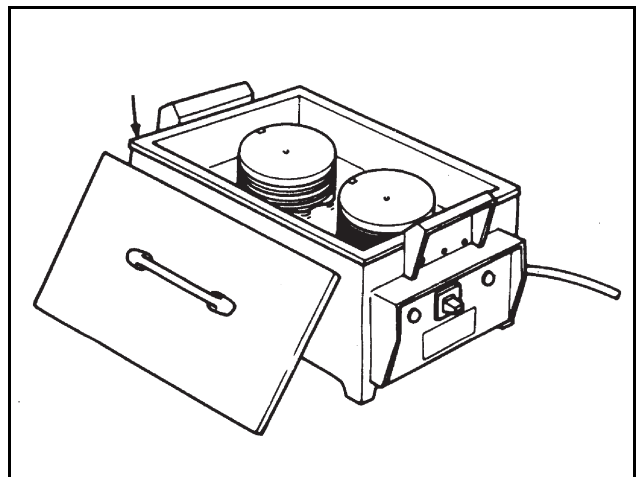
EPM2030I

- 1) Move the lock nut to hexagonal side of sensor completely.
- 2) Rotate (CW) the tacho sensor on fly wheel housing, until the end of it reach on fly wheel ring gear.
- 3) Rotate (CCW) the tacho sensor for 270° (gap 1.0 mm) and fix lock nut.
- 4) Tolerance limit is $\pm 27^\circ$. (gap ± 0.1 mm)
9. Attach the cylinder liner.
- 1) Stand the cylinder block so that the flywheel faces downward.
- 2) Thoroughly clean the liner flange fitting surface and bore inside with compressed air to prevent the entry of foreign substances.
- 3) After the cleaning operation, make the cylinder liner dried up and push it into the cylinder block by hand.



EAMD087I

- 4) Wet the liner inside diameter with engine oil.
10. Attach the water chamber cover.
- 1) Coat the adhesive over the water chamber cover (Particular around bolt holes) and after attaching the gasket, assemble it to the cylinder block using the bolts for assembling.
- 2) As for tightening of bolts, after primarily tightening the bolts located at the both ends of cover (4ea at both sides) and middle bolts (Upper, lower 2ea), tighten the rest.
11. Attach the piston and connecting rod
- 1) Use a piston heater to heat the piston approximately 100°C for 5 minutes.



DV2213156A

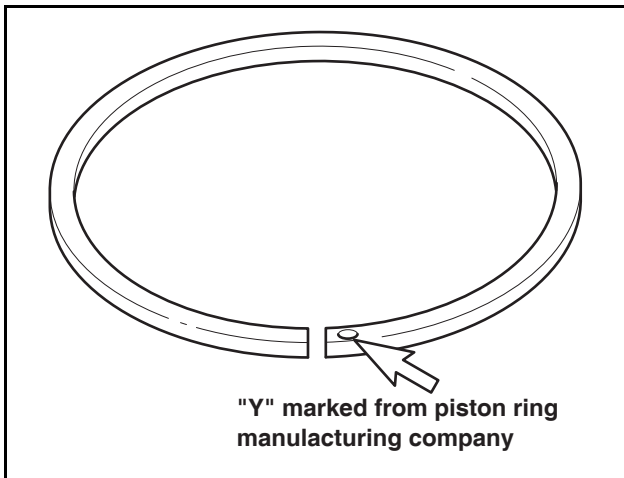
- 2) Align the piston pin hole with the oiled connecting rod small end and press the piston pin (by lightly tapping with a rubber hammer) to assemble the connecting rod with the piston.

5. About the engine



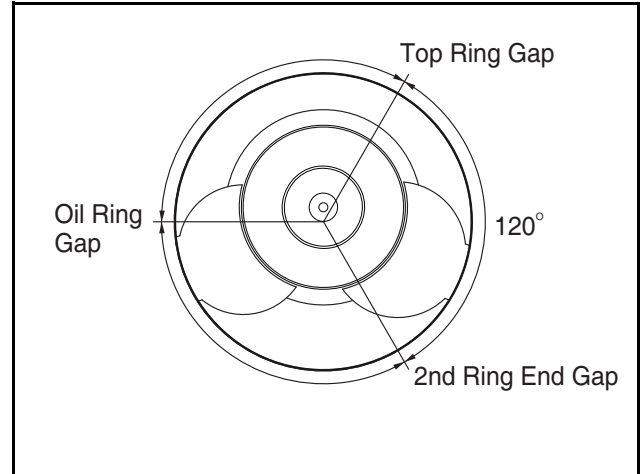
EAMD088I

- 3) Install the snap rings and check to see that it is securely assembled.
- 4) Install the piston ring in the piston using piston ring pliers.
- 5) 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" is upper surface.)



EAMD090I

12. Attach the piston assembly.
- 1) Adjust the angle among individual piston ring gaps to 90° and fit a piston assembling jig onto the piston. Use care not to match the ring gaps with the pin direction.

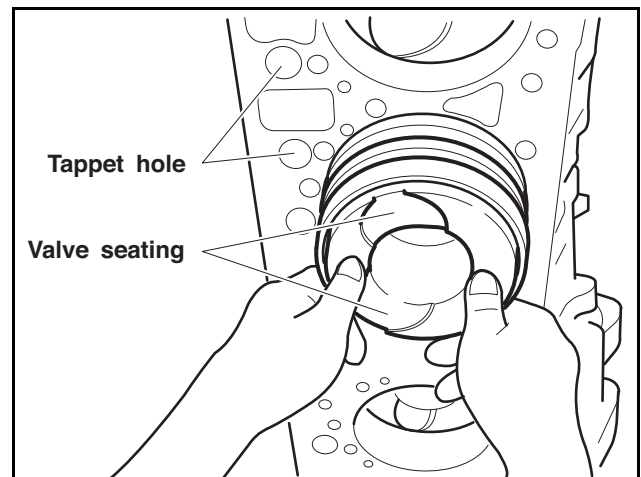


EDL11180005

- 2) Install the bearing by aligning it with the connecting rod key groove and apply oil to the bearing and piston.
- 3) Position the valve seating surface toward the tappet hole and insert the piston with hand.

CAUTION

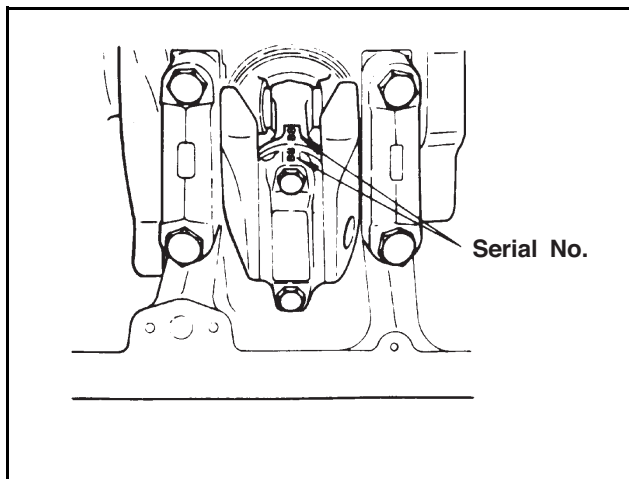
Use care not to damage the cylinder liner and piston, and slightly lift and insert the piston into the cylinder so that the ring may not be damaged by the fillet of the liner.



EAMD092I

- 4) Install the bearing in the connecting rod cap and apply oil.
- 5) Make sure that the manufacture serial numbers impressed on the connecting rod cap and connecting rod big end are identical, and install the connecting rod cap by aligning it with dowel pin.

5. About the engine



EA0M4092

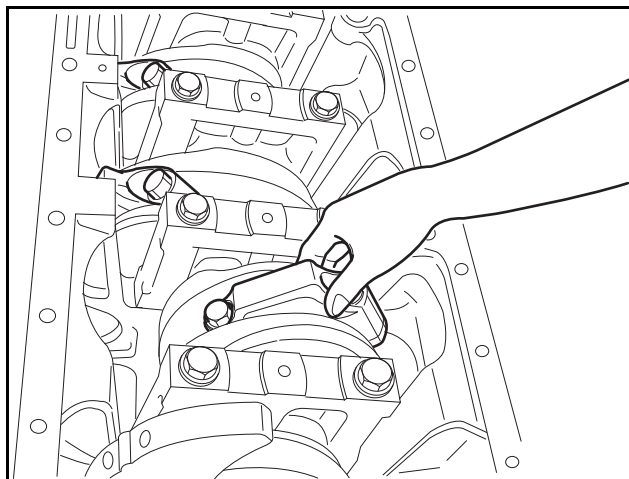
- 6) Tighten the fixing bolts to the specified torque using a torque wrench as follows.

<Connecting rod tightening torque>

Tightening torque	1st Step	4 ±0.2 kgf·m
	2nd Step	60° ±3°

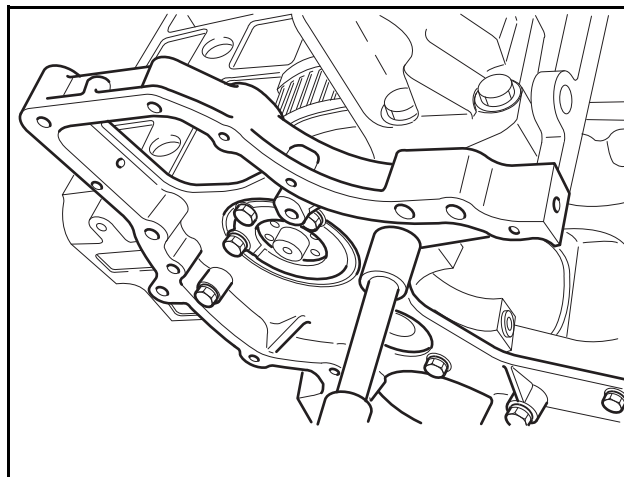
Note) Do not apply oil to the joint before bolting.

- 7) Move the bearing cap with hand, and release and reassemble it if no movement is detected.



EA8M094I

13. Attach the Timing gear case.

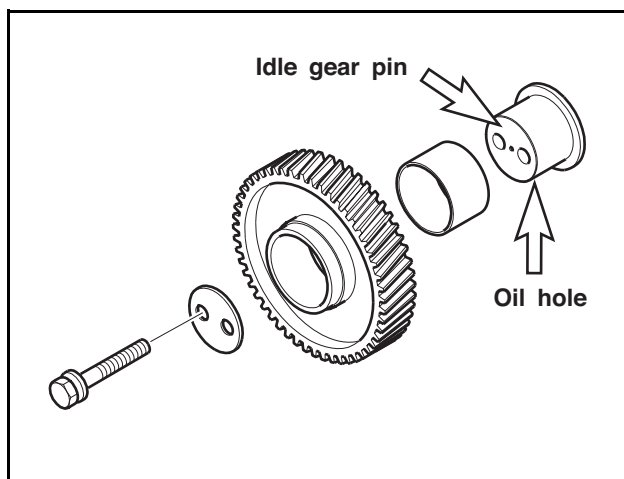


EA8M082I

- 1) Mount a new gasket using dowel pin on the cylinder block.
- 2) Put the time gear case to the cylinder block by aligning the dowel pin hole of timing gear case with its pin, and then assemble it by tapping lightly with an urethane hammer to the right and left (Particularly around dowel pin).
- 3) Tighten the bolts for assembling to the specified torque.
- 4) Tighten primarily the bolts of both end parts and then do the rest.

14. Attach the timing gear and idle gear pin.

- 1) Install the oil pump idle gear onto the No.7 bearing cap.
- 2) With the oil port on the idle gear pin facing the cylinder block, install the idle gear pin.



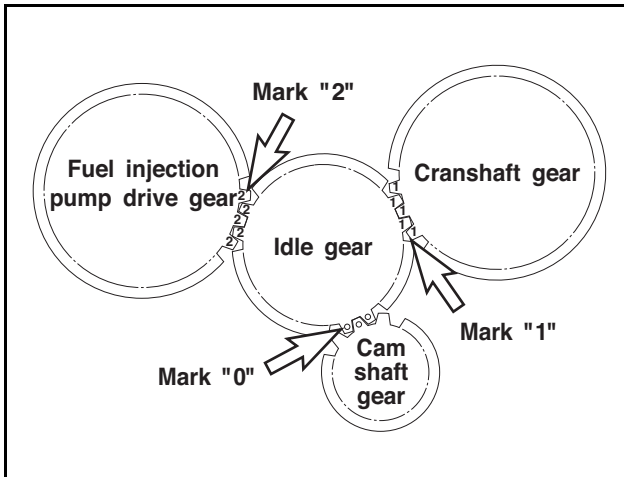
EA8M3004

- 3) With the oil port on the idle gear pin facing the cylinder block, install the idle gear pin.
- 4) Install a thrust washer over the camshaft and assemble the cam gear by aligning it with camshaft key groove. Tighten the cam gear assembling bolts to the specified torque. (Zigzag method)

5. About the engine

Torque	2.2 kgf·m
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- 5) Install the idle gear by coinciding the marks impressed on the crank gear, cam gear, fuel injection pump drive gear, and idle gear.



EA9M3015

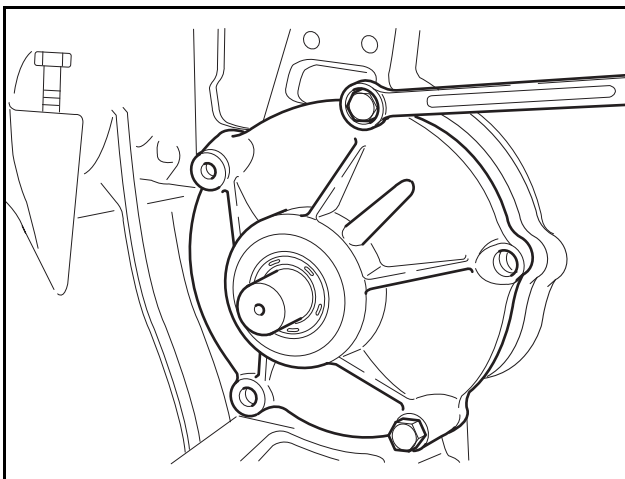
- 6) Install a thrust washer on the idle gear and tighten to specified torque.

Torque	3.1 kgf·m
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- 7) Check and adjust the amount of backlash between gears using a feeler gauge.

Measuring position (between)	Backlash (mm)	Limit (mm)
Cam gear & idle gear	0.16 ~ 0.28	0.35
Crank gear & idle gear	0.16 ~ 0.28	0.35
Injection pump & idle gear	0.16 ~ 0.28	0.35

15. Attach the injection pump flange.

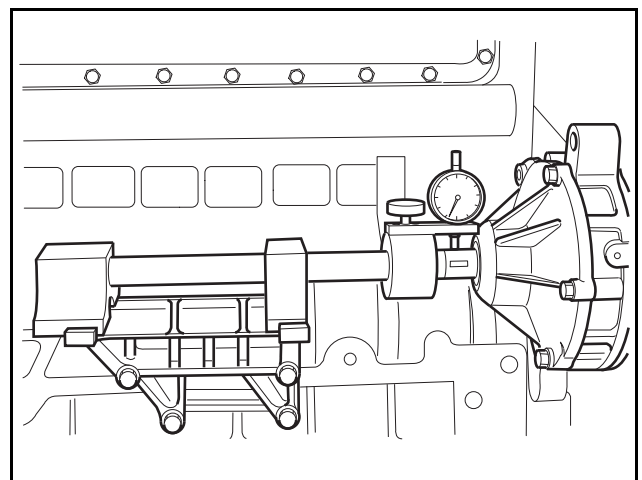


EA9M3021

- After assembling the fuel injection pump gear to the idle gear, tighten the assembling bolts of the injection pump flange.
- Mount gasket by aligning the bolt holes with the pin holes on the bearing housing.
- Turning the flywheel, adjust the pointer to the 16° position of the engraved scale.
- After adjusting the injection timing of fuel injection pump drive gear, tighten the fixing bolts in the direction of fuel injection pump.

16. Attach the injection pump.

- Install the injection pump bracket in the cylinder block.
- After measuring the amount of run-out with an alignment setting jig.



EAMD1071

- 3) Disassemble the bracket, adjust the shims, then reassemble it.

Run out	0.2 mm or less
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- Mount the top/bottom adjusting shims in the bracket and then mount the fuel injection pump.
- Tighten the fixing bolts in a diagonal sequence to specified torque.

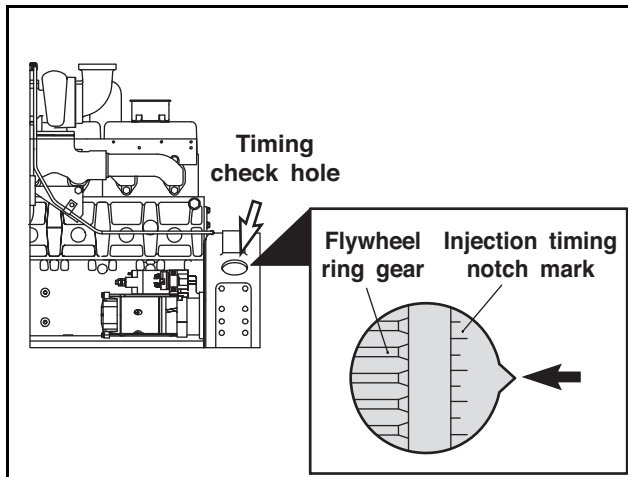
Torque	4.4 kgf·m
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17. Adjust injection timing.

- Bring the piston of #1 cylinder to the compression TDC (OT) by turning the crankshaft. Again, turn 60° in the reverse direction of engine rotation.
- Disassemble the fuel injection pipe that connect the fuel injection pump and #1 injection nozzle.
- Disassemble the fuel injection pump delivery valve holder, and after removing the valve and valve spring, again assemble the valve holder and then, on it assemble the pipe of "U" shape on it.

5. About the engine

- 4) Operating the priming pump of supply pump, turn the crankshaft slowly in the direction of engine rotation until the fuel will drop at the rate of a drop for 6 ~8 sec.
- 5) Confirm then whether the indication point at the flywheel housing inspection hole and the engraved specified injection angle are coincided or not, and if the injection timing is not correct, adjust as follows.



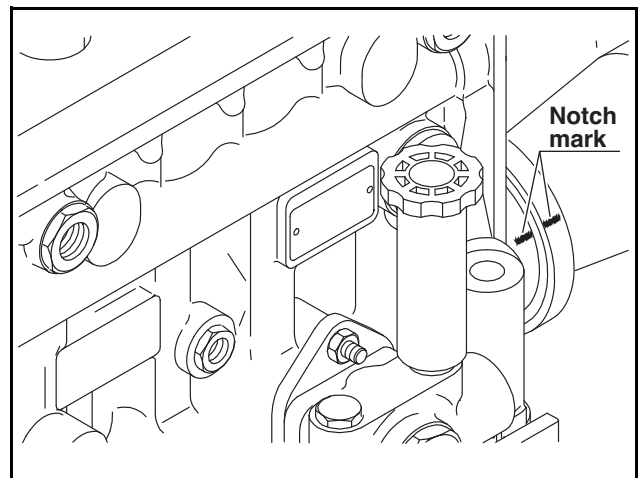
EA9O5001

- a) As above adjusting method, Please coincide the indication point(← at the flywheel housing's inspection hole with the flywheel's inspection angle.

Engine Model	Injection timing	Remarks
D1146	18°	BTDC
D1146T	18°/12°	BTDC
P086TI	12°	BTDC
DP086TA	19°	BTDC
DP086LA	14°	BTDC
PU086	18°	BTDC
PU086T	18°/12°	BTDC
PU086TI (EBPPA)	15° ±1°	BTDC
PU086TI (EBPPB)	18° ±1°	BTDC

- b) Loosen the drive gear fixing bolt of injection pump a bit.
- c) After turning slowly the coupling of injection pump until the fuel will drop from #1 plunger at the rate of a drop for 6 ~ 8 sec., tighten the driving gear fixing bolt of fuel pump.
- 6) After the adjustment of injection timing, disassemble the "U" shape pipe, readjust the delivery valve and the valve spring.

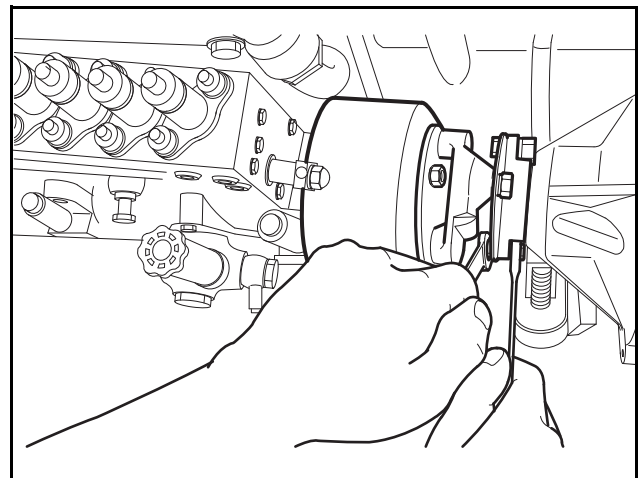
- 7) Turn the coupling until the notch mark of the indicator plate attached to the fuel injection pump is aligned with the notch mark of the coupling.



EA9O5002

- 8) Tighten the Coupling fixing bolts and nuts to specified torque.

Torque	6.0 ~ 6.5 kgf·m
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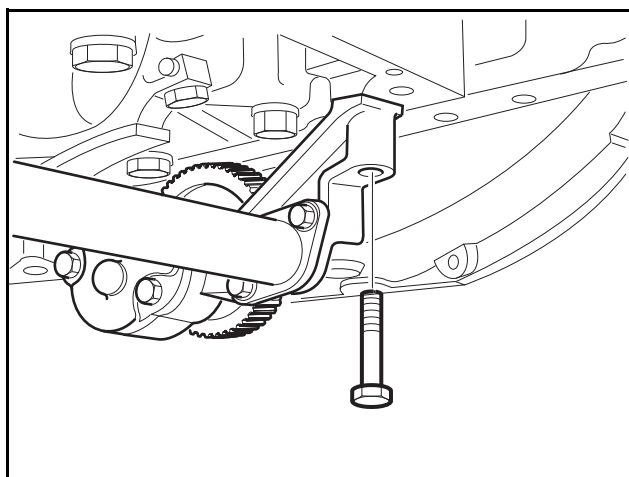


EAMD0211

- 9) Install the oil delivery pipe and return pipe.

5. About the engine

18. Attach the oil pump and oil pipe.



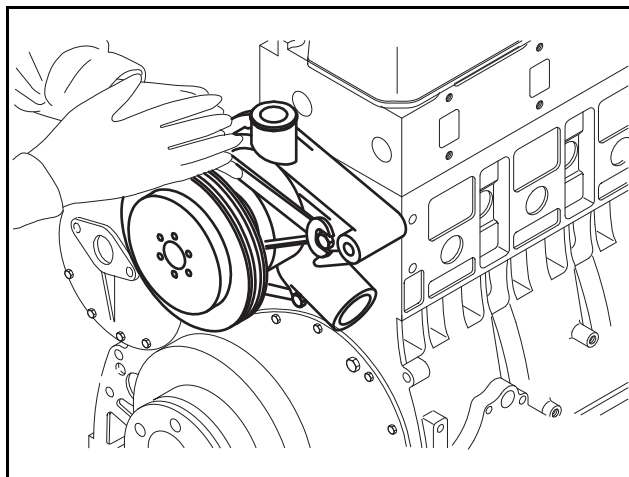
EFM2025I

- 1) Install a dowel pin in the No.7 bearing cap, then assemble the oil pump by tapping lightly with urethane hammer.
- 2) Insert the lock washers and tighten the assembling bolts with specified torque.

Torque	4.4 kgf·m
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- 3) Assemble the oil suction pipe with the delivery pipe to oil pump by the bolts.

19. Attach the water pump.



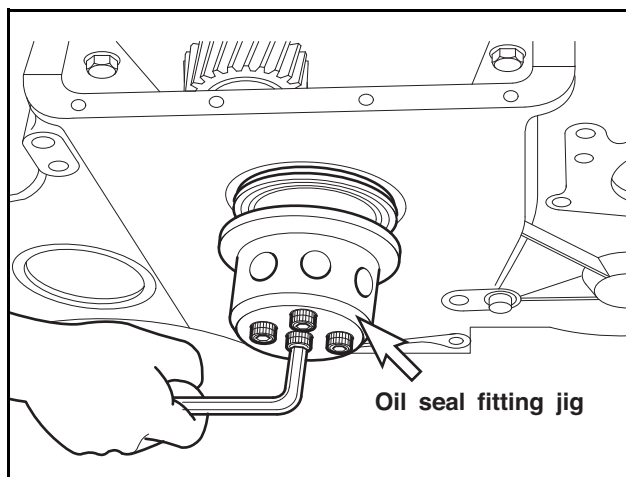
ED7OM008

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

Torque	2.2 kgf·m
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- 3) Connect water pipes and by-pass pipe to the water pump.
- 4) Connect a water pipe to the expansion tank.

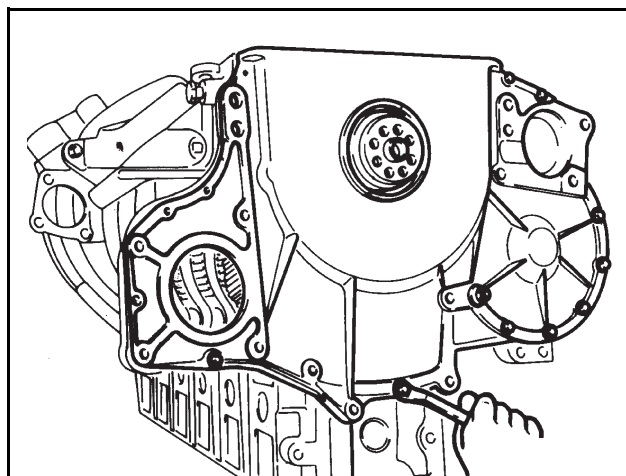
20. Attach the front oil seal.



EAMD086I

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

21. Attach the timing gear case cover.



EAMD085S

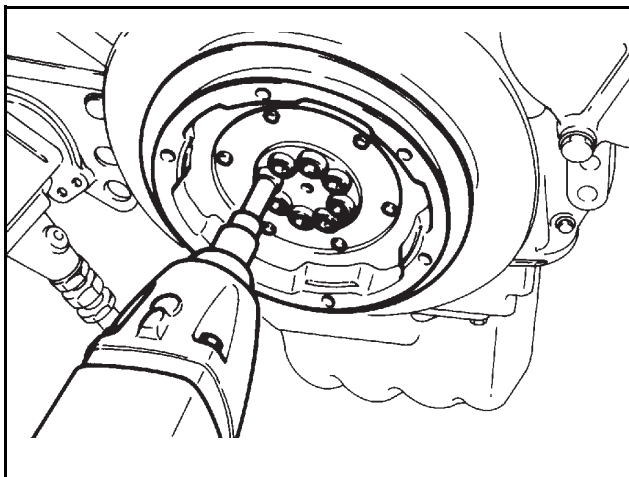
- 1) Install dowel pin on the timing gear case.
- 2) Mount a gasket by aligning the fixing bolt holes with those on the gasket.
- 3) Align the dowel pin with the cover pin hole, then install the cover with light tap.
- 4) Tighten the fixing bolts beginning with the oil pan fitting face.

⚠ CAUTION

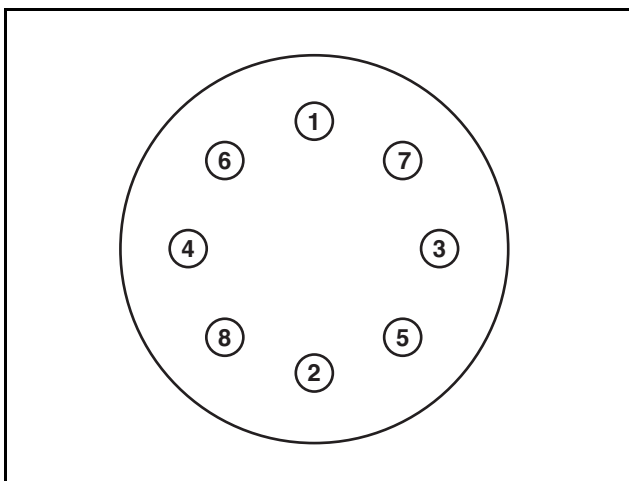
In the assembling, be careful not to be damaged by the crankshaft.

5. About the engine

22. Attach the vibration damper.



EAMD111S



EDM2089I

- 1) Insert the vibration damper to the crankshaft, and assemble by tightening the assembling bolts at the specified tightening torque according to bolt tightening order. (refer to right figure.)

Torque	13.4 ±2.6 kgf·m
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23. Attach the oil pan.

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

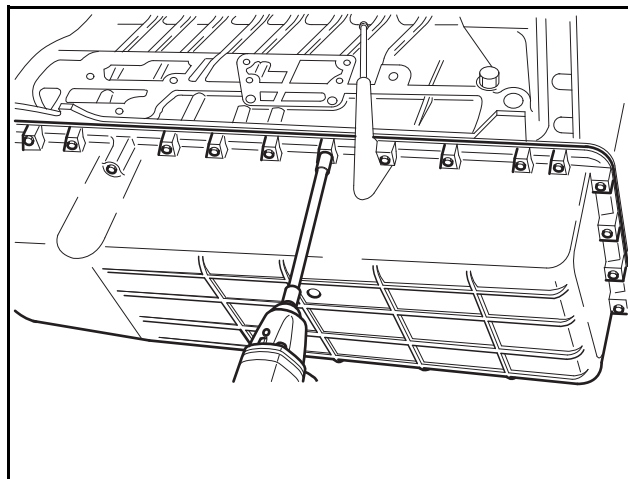
CAUTION

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

- 2) Coat the silicone at the gasket part that was removed (Contacting part), and attach the new oil pan gasket.

- 3) Assemble the oil pan by tightening the oil pan assembling bolts, and when tightening bolts, primarily tighten the bolts (4ea) at the both ends, and then tighten the rest bolts to specified torque.

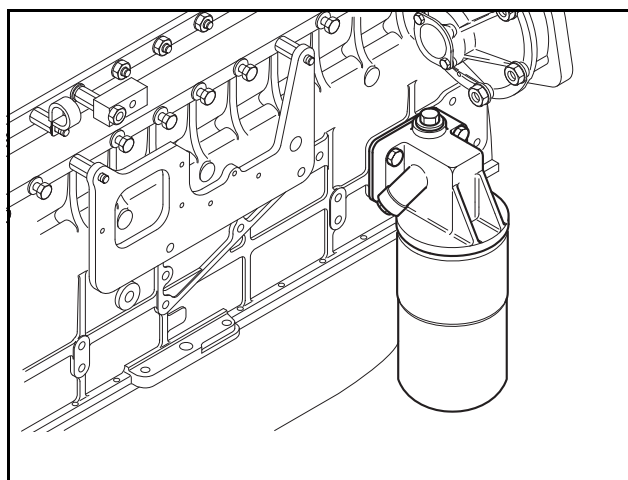
Torque	2.2 kgf·m
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EAMD034I

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

24. Attach the oil filter.



EB8M3002

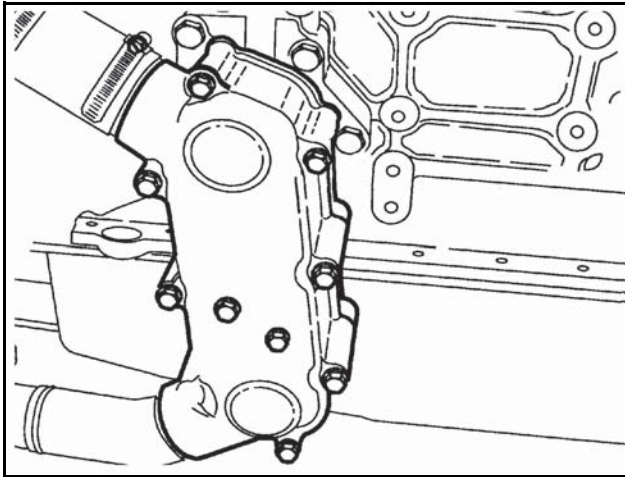
- 1) Install the oil filter onto the cylinder block, and tighten the fixing bolts.

Torque	2.2 kgf·m
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- 2) Install packing and assemble the cartridge using a filter wrench.

5. About the engine

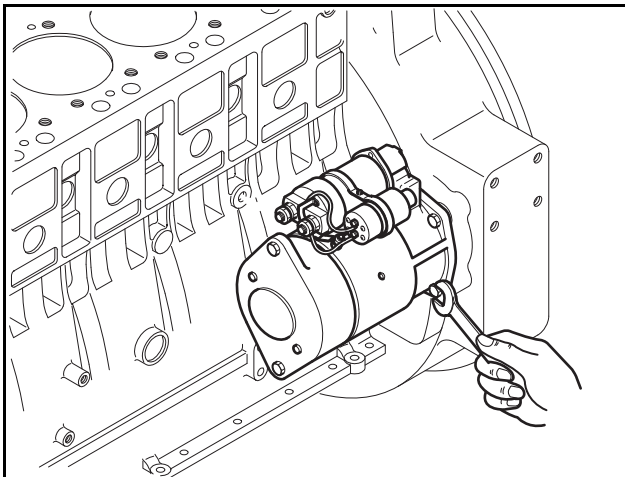
25. Attach the oil cooler.



ED7OM012

- 1) Assemble the oil cooler assembly by tightening the assembling nuts.
- 2) Connect the cooling water pipe with the cooling water pump and tighten a hose clamp.

26. Attach the starter.



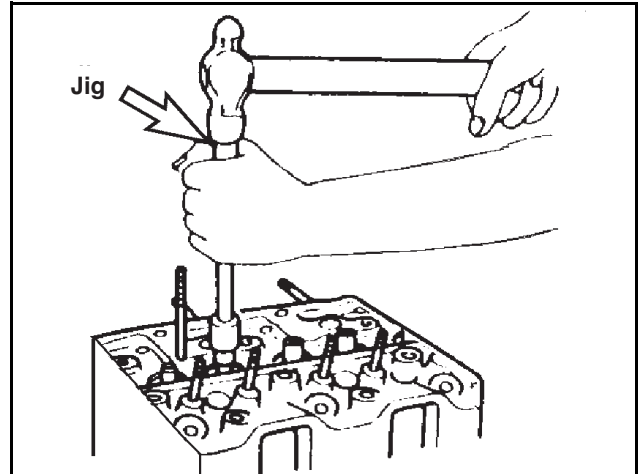
ED7OM004

- 1) Assemble the starter in position on the flywheel housing.

Torque	4.4 kgf·m
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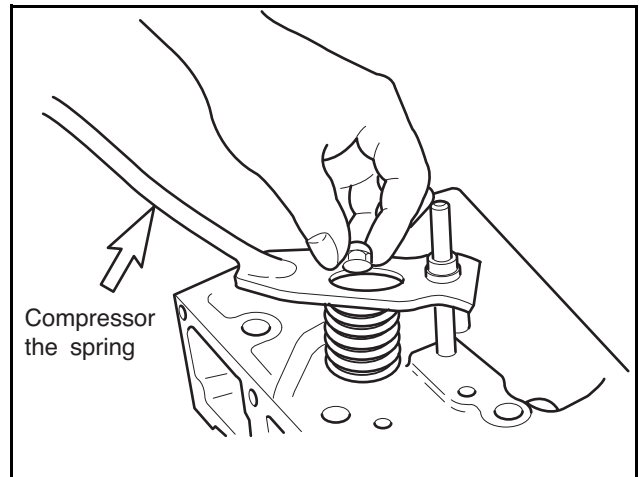
27. Attach the intake and exhaust valves.

- 1) Identify the marks of "IN" and "EX" impressed on the valve head before assembling the valve with the valve head.
- 2) With a valve stem seal fitting jig, assemble the valve stem seal with the valve guide.



EA9M3017

- 3) After installing valve springs and spring retainer, press the retainer with a jig, then install cotter pin.



EA0M4007

- 4) Tap the valve stem lightly with a rubber hammer to check that the valve is assembled correctly.

28. Attach the cylinder head.

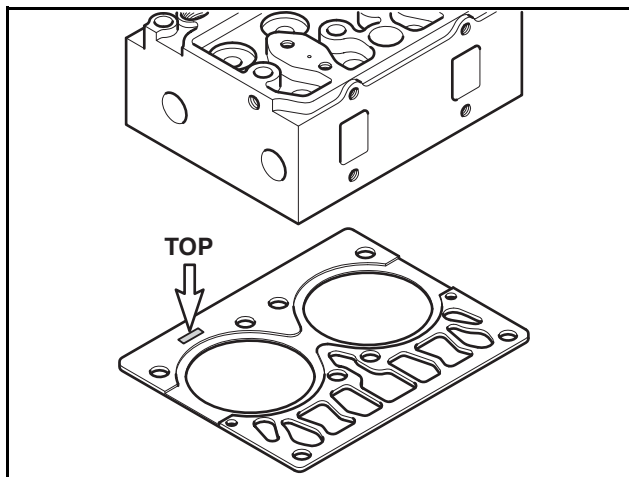
- 1) Blow the bolt holes of cylinder block with a compressed air and remove the foreign matter.
- 2) Clean the head gasket contact surface thoroughly.

CAUTION

Be careful for the foreign material not to enter into the combustion chamber.

- 3) Assemble the new head gasket by aligning the holes with dowels of cylinder block with 'TOP' mark facing upward.

5. About the engine



EB1M3025

- 4) Check the inside of combustion chamber for foreign substances, and carefully mount the cylinder head assembly in the block by aligning the dowel pin with the dowel pin hole.

CAUTION

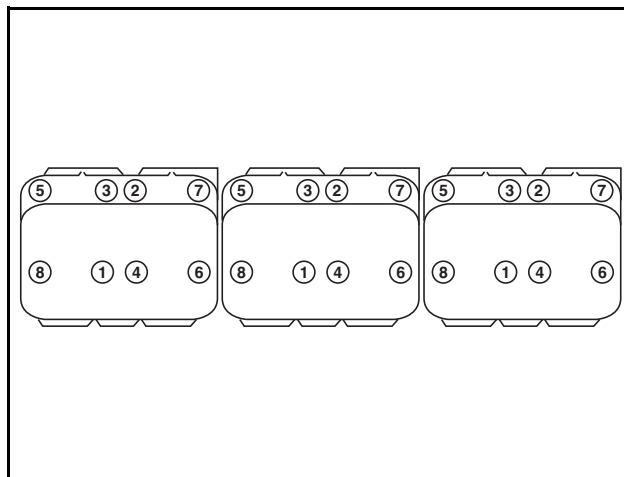
- Be careful not to damage the cylinder head gasket. If the dowel pin is not in alignment, lift the cylinder head again and then remount it.
- After tightening the cylinder head bolts, even at disassembling, the cylinder head gasket should be changed a new one.

	Type 5 (10.9T)
Specification	 COLLARD DUO BOLT M14 x 1.5 x 150
Torque	6 kgf·m + 90° + 90° + 90° + 60°

- 5) Tighten in proper sequence to the specified torque according to bolt tightening order.
- First stage: Coat the bolts with engine oil.
 - Second stage: Tighten 1 ~ 2 threads with hands.
 - Third stage: Tighten at about 6 kgf·m with a wrench.
 - Fourth stage: Tighten at rotating angle 90° with a wrench.
 - Fifth stage: Tighten at rotating angle 90° with a wrench.
 - Sixth stage: Tighten at rotating angle 90° with a wrench.
 - Seventh stage: Finally, tighten at rotating angle method 60° with a torque wrench.

CAUTION

- All bolts are tightened simultaneously by above steps.
- Before tightening bolts, the side parallel degree between cylinder heads should be adjusted.



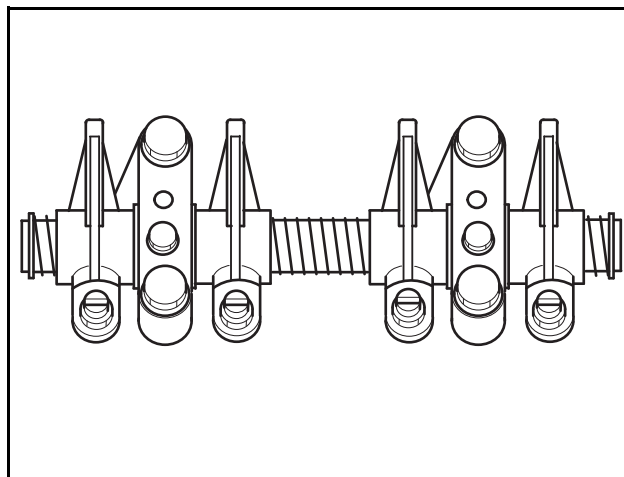
EDM2097I

29. Attach the push rod.

- 1) Coat the push rod with engine oil and insert it into the push rod hole.

30. Attach the rocker arm assembly.

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



EB1M3026

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

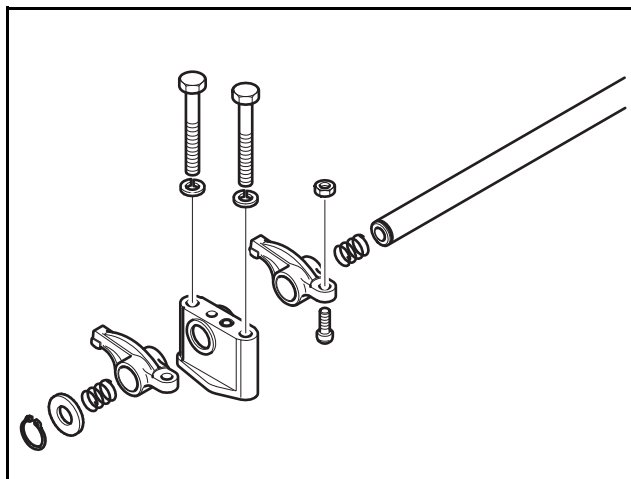
Torque	M10: 4.4 kgf·m M12: 8.0 kgf·m
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- 3) Semi-install valve clearance adjusting bolts onto the rocker arm.
- 4) Install the spring, rocker arm, bracket, rocker arm, spring, washer, and snap ring in the described sequence.

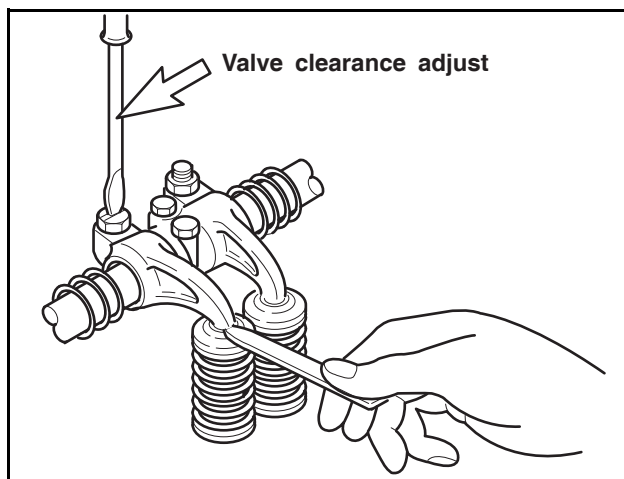
CAUTION

Install the rocker arm and bracket in the same direction.

5. About the engine



ED7OM002



EA8M3007

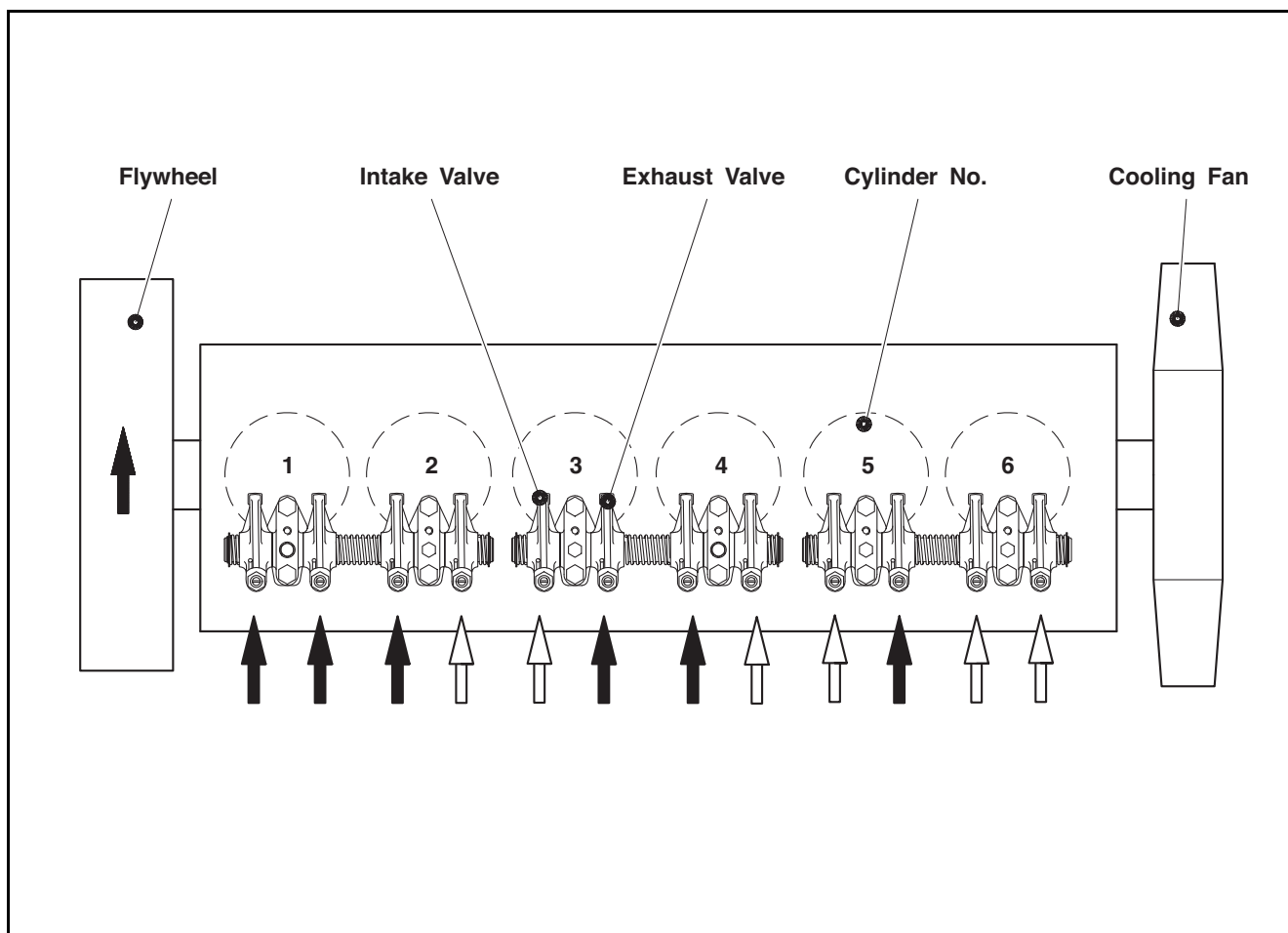
31. Adjust the valve clearance.

- 1) Loosen the lock nuts of rocker arm adjusting screws.
- 2) Push the feeler gauge of specified value between a rocker arm and a valve stem (to measure the clearance of the valve and rocker arm contacting part)
- 3) Adjust the clearance with adjusting screw respectively and then tighten with the lock nut.

- 4) Adjust valve clearance with a feeler gauge and tighten the fixing nuts to specified torque.

Torque	4.4 ±0.45 kgf·m
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32. Guide for valve clearance adjustment



EA9O5005

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

adjust the valves corresponding to mark “ • ” in the below table.

5. About the engine

Note) #1. cylinder is located at the side where flywheel was installed.

Note) #6. cylinder is positioned at the valve overlap when #1. cylinder is positioned at the compression TDC (Top Dead Center).

2) Rotate the crankshaft one rotation (360°) so that #6. cylinder may be positioned at the compression TDC (Top Dead Center). Then adjust the valves corresponding to mark “○” in the below table.

Note) #6. cylinder is located at the side where cooling fan was installed.

Note) #1. cylinder is positioned at the valve overlap when #6. cylinder is positioned at the compression TDC (Top Dead Center).

(I: Intake, E: Exhaust)

Cylinder No.	#1		#2		#3		#4		#5		#6	
	I	E	I	E	I	E	I	E	I	E	I	E
#1 TDC	●	●	●			●	●			●		
#6 TDC				○	○			○	○		○	○

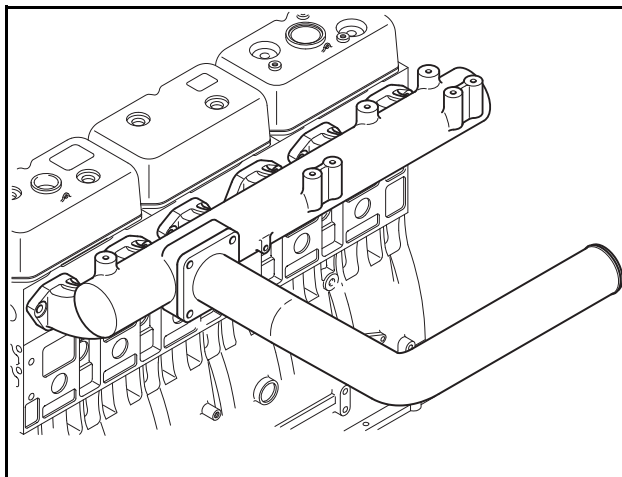
3) As for the valve clearance, adjust it when in cold.

Specified value		Measurement tolerance	
Intake valve	Exhaust valve	Intake valve	Exhaust valve
0.3 mm	0.3 mm	±0.05 mm	

CAUTION

- Crankshaft revolution is done by hands without using a starting motor.
- Turn it to the direction of engine rotation, but do not use the installing bolts at the turn.
- The cylinder no. and the order of intake and exhaust can be determined from the flywheel housing.

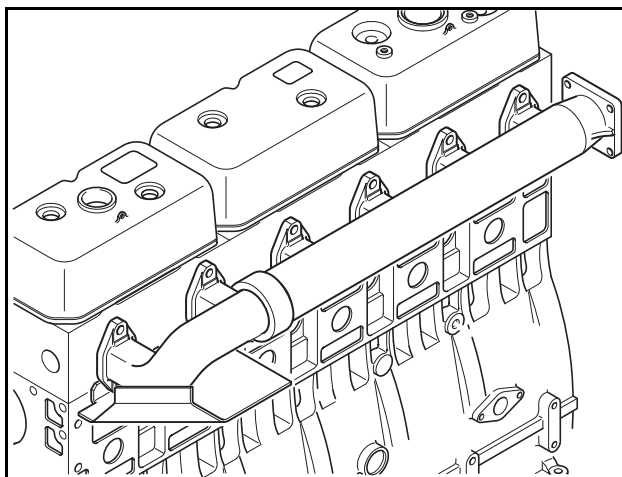
33. Attach the intake manifold.



ED7OM005

1) Put in the new gasket between the cylinder head and manifold, and assemble the intake manifold by tightening the assembling bolts.

34. Attach the exhaust manifold.



ED7OM011

1) Install the exhaust manifold gasket over the stud bolts by aligning the gasket with the exhaust port on the cylinder head.

CAUTION

Be careful to position the face and back of the gasket correctly.

2) Semi-assemble the exhaust manifold and install the heat resisting plate.

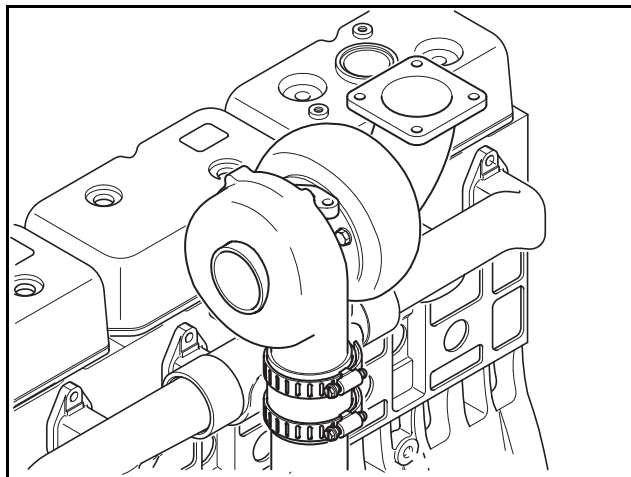
5. About the engine

- 3) Assemble them by tightening the assembling bolts. The tightening order of bolts is from the middle to left and right alternately.

CAUTION

For upper and lower bolts differ in the length, so use the correct bolts.

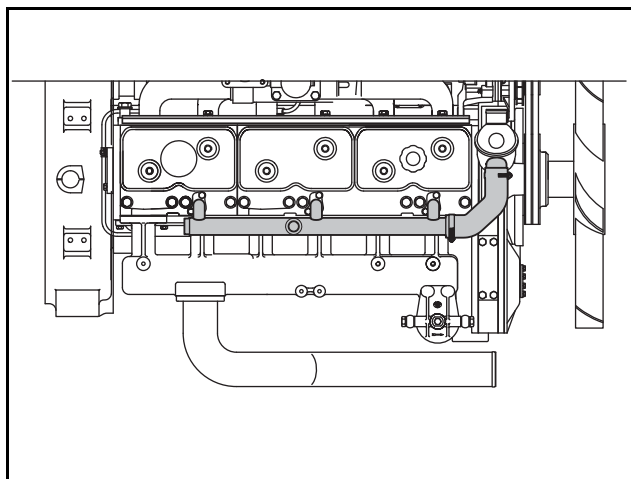
35. Attach the turbocharger.



ED7OM010

- 1) Fit a new gasket over the stud bolts of the exhaust manifold before tightening those turbocharger fixing bolts.
- 2) Install the oil supply pipe and return pipe.
- 3) Tighten the clamps of rubber hose that is connected air pipe to the intercooler.

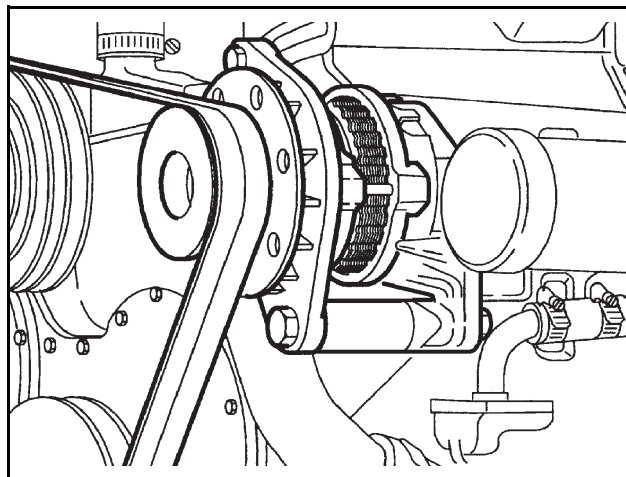
36. Attach the cooling water pipe.



ED7OM006

- 1) Attach new cylinder head gasket.
- 2) Assemble the cooling water pipe by tightening the assembling bolts.

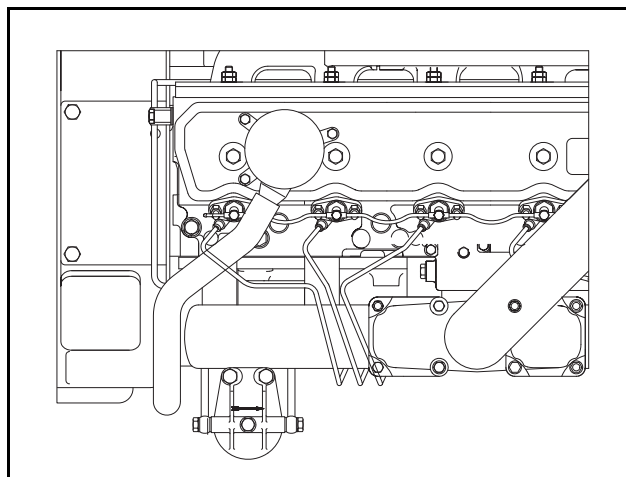
37. Attach the alternator.



EA9M3004

- 1) Install the alternator mounting bracket.
- 2) Install the alternator with fixing bolts to the mounting bracket.

38. Attach the fuel filter.

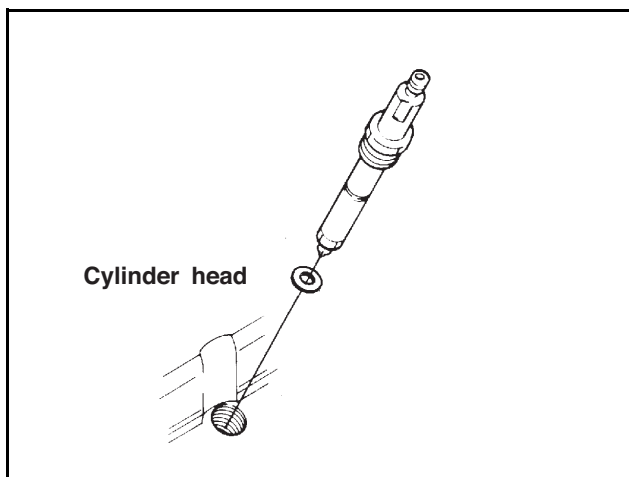


EA9M3019

- 1) Assemble the fuel filter with the intake manifold.
- 2) Assemble the fuel feed hose according to the direction of an arrow impressed on the fuel filter head so that fuel can be fed in the sequence of FUEL FEED PUMP FUEL FILTER FUEL INJECTION PUMP.

5. About the engine

39. Attach the Injection nozzle.

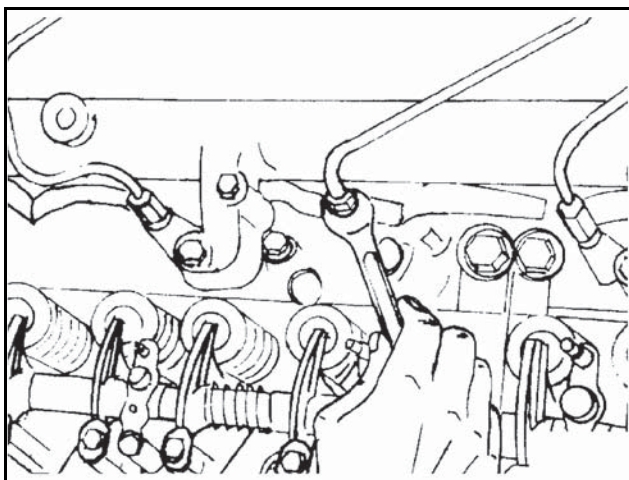


EB1M3024

- 1) Mount a seal ring on the seal ring seating surface of the cylinder head and assemble nozzle holder assembly with the nozzle pipe installing direction facing outward.
- 2) Be sure to follow the specified torque.

Torque	7.0 kgf·m
--------	-----------

40. Attach the injection pipe.



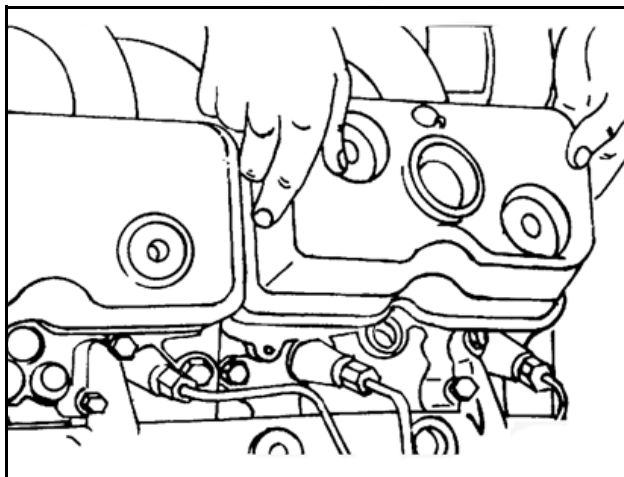
ENM3013S

- 1) Semi-assemble a nut at both ends of the fuel high pressure pipe and tighten them up one by one to specified torque.

Torque	3.0 kgf·m
--------	-----------

- 2) Tighten hollow screws to assemble the fuel return pipe.
- 3) Assemble the fuel return hose on the fuel injection pump.

41. Attach the cylinder head cover.



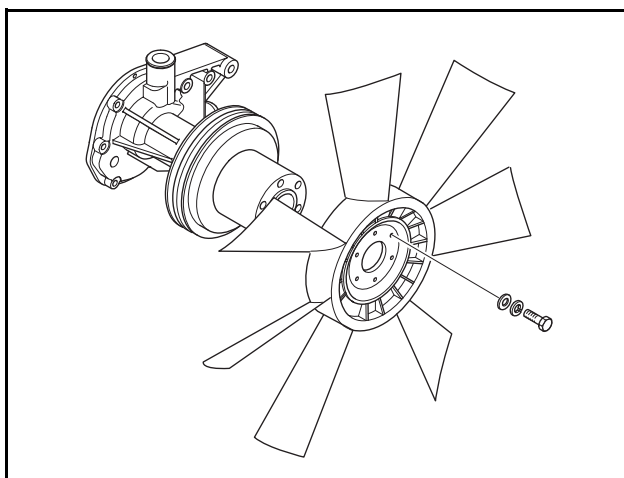
ENM3012S

- 1) Assemble the new gasket with the cylinder cover, install the cover on the cylinder head, then tighten the fixing bolts in sequence to specified torque.

Torque	1.5 kgf·m
--------	-----------

- 2) Assemble the breather hose with PCV valve.
- 3) Insert the oil filler cap in the cylinder head cover.

42. Attach the cooling fan.

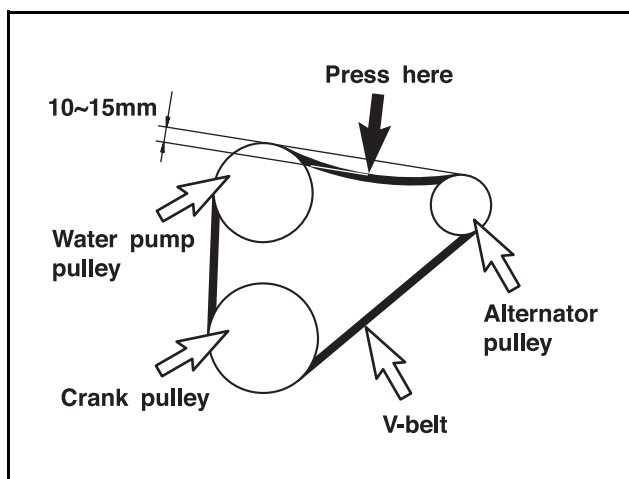


EA9M3001

- 1) Install the fan drive pulley onto the timing gear case cover.
- 2) Install the fan flange and cooling fan onto the cooling water pump.

Torque	4.4 kgf·m
--------	-----------

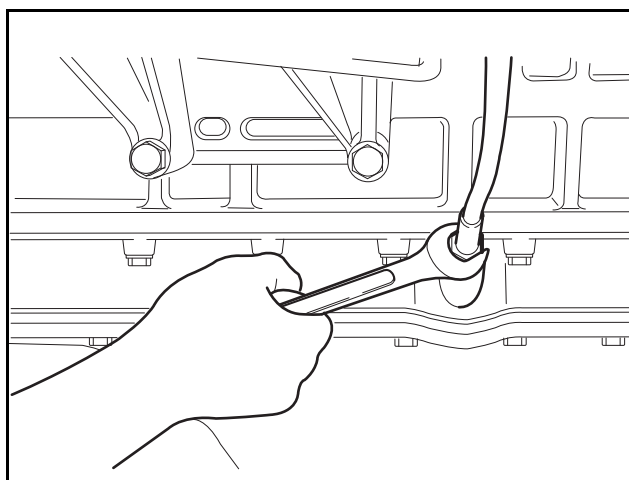
43. Attach the V- Belt



EA9O2006

- 1) Install the V-belt on the crank pulley, alternator pulley and water pump pulley.
- 2) Adjust the V-belt tension using the tension adjusting support.

44. Attach the oil level gauge



- 1) Apply sealant (Loctite #262) to the bottom side of the guide tube.
 - 2) Then assemble the guide tube and oil level gauge on the oil pan.
45. Assemble by connecting the other oil and fuel hoses.

5. About the engine

6. Cooling system

General information	109
General information	109
Failure Diagnosis	110
Thermostat	111
General Information	111
Check of the thermostat	111

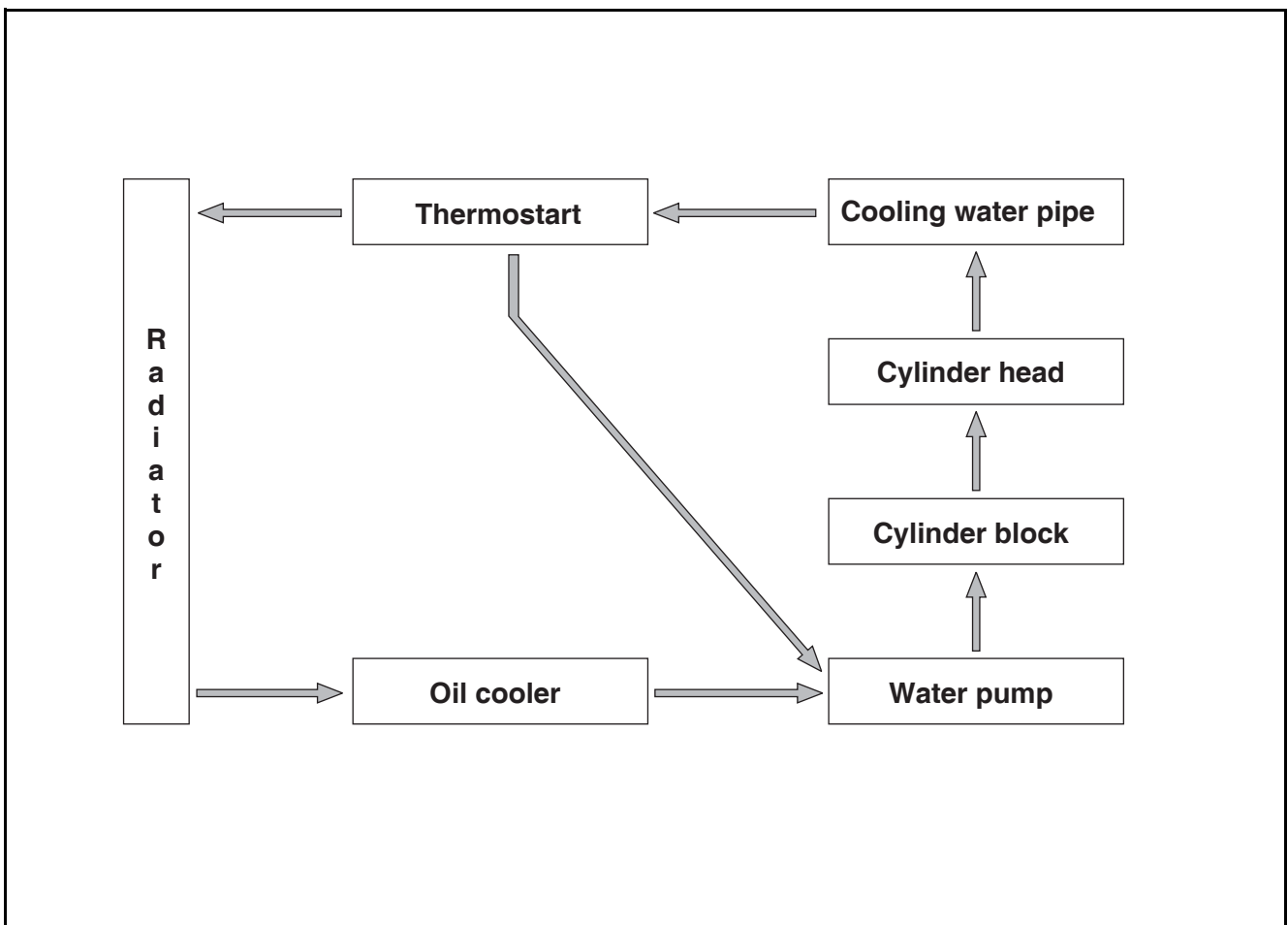
General information

General information

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

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

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



EQM40011

6. Cooling system

Failure Diagnosis

Phenomenon	Causes	Troubleshooting
Overheated engine	Not enough coolant	Replenish the coolant
	Defective radiator cap	Replace it
	Contaminated radiator	Clean the exterior of the radiator
	Defective V-belt offset	Adjust or replace it
	Contaminated or damaged V-belt	Replace it
	Damaged impeller	Replace the coolant pump
	Defective impeller fix	Replace the coolant pump
	Bad coolant pump operation	Replace it
	Bad water temperature controller operation	Replace it
	Bad coolant flow	Clean the coolant path
	Improper injection time	Check it with the failure diagnosis unit
	Damaged cylinder head gasket	Replace it
Overcooled engine	Bad water temperature controller operation	Replace it
	Too low ambient temperature	Heat the block
Leaking coolant	Damaged radiator	Repair or replace it
	Loosened or damaged radiator connection	Repair or replace the connection
	Defective radiator cap	Replace it
	Badly mounted coolant pump	Repair or replace it
	Bad or damaged coolant pump gasket	Replace the gasket
	Badly mounted water temperature controller	Repair or replace it
	Bad or damaged water temperature controller gasket	Replace the gasket
	Damaged cylinder head gasket	Replace the gasket
	Damaged cylinder head or block	Replace it
Noise	Bad coolant pump bearing	Replace the bearing
	Bad or damaged cooling fan	Repair or replace it
	Bad rotation of the cooling fan	Replace it
	Defective V-belt offset	Adjust or replace it

Thermostat

General Information

The thermostat maintains water temperature in the engine consistently and prevents heat loss to improve heat efficiency of the engine.

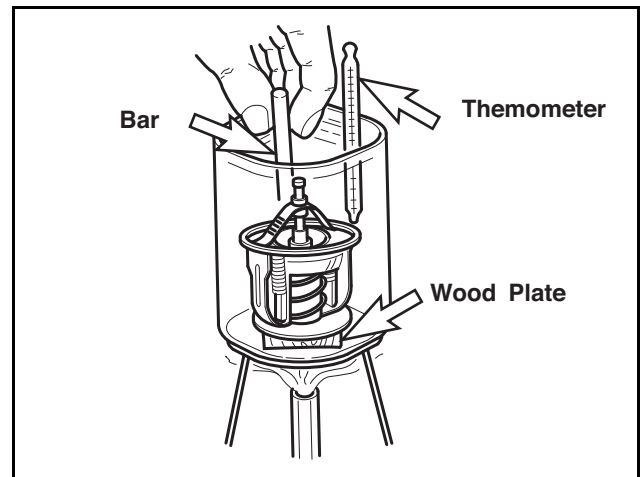
When the coolant temperature is below the normal temperature, the thermostat is closed and the coolant is bypassed and directly flows into the water pump. When the coolant temperature reaches the normal temperature or is higher than the temperature, the thermostat is fully open and the bypass circuit is closed. So the coolant flows into the radiator.

⚠ CAUTION

- The wax pellet type thermostat shows slower response to the change of cooling water than the bellows type thermostat. This happens because the heat capacity of the wax pellet type water temperature controller is larger than that of the bellows type water temperature controller. Therefore, to prevent rapid increase of engine coolant temperature, you must first operate the engine at idle until the engine is fully warmed up. When the weather is very cold, do not operate the engine in an overloaded condition or at high speed after starting the engine.
- When draining water from the engine cooler or injecting water to the engine cooler, work slowly to let the air in the cooler is fully exhausted.
- When a defect is found in the water temperature controller, replace it with a new one.

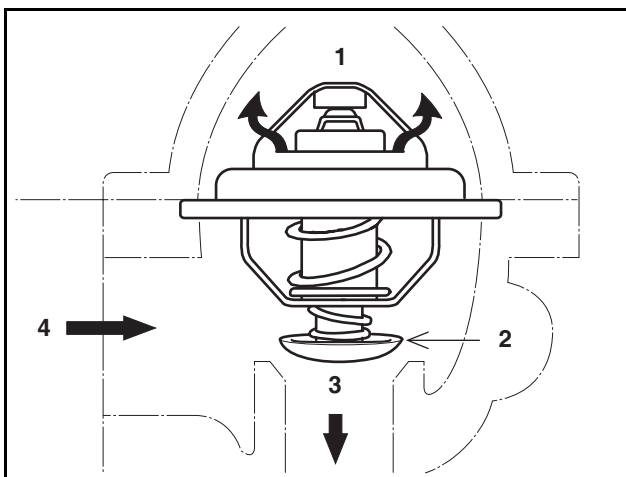
Check of the thermostat

1. Check whether the wax pellet and the spring are damaged or not.
2. Put the water temperature controller into water and heat the water slowly to check water temperature controller operation.
3. The water temperature controller is normal in the following case: it starts to be open at the water temperature of 82°C and it is fully open at the water temperature of 97°C.



DV2213100A_E

4. Check if there is any foreign substance in the water temperature controller.
Note) Clean the inside of the water temperature controller with an air gun.
5. Check if there are any foreign substance or damage part inside and outside of the hose.



DV2213099A

- | | |
|------------------|----------------------------|
| 1. To radiator | 3. To bypass tube |
| 2. By pass valve | 4. From cooling water pump |

6. Cooling system

7. Lubrication system

General information	115
General information	115
Failure Diagnosis	116
Oil pump	117
Oil pump disassembly	117
Oil pump assembly	117
Check of oil pump	117

General information

General information

This engine is the forced lubrication type of engine.

Oil pressure is generated and delivered by rotating the gear of the oil pump which is directly engaged with the crankshaft-gear on the front of the cylinder block.

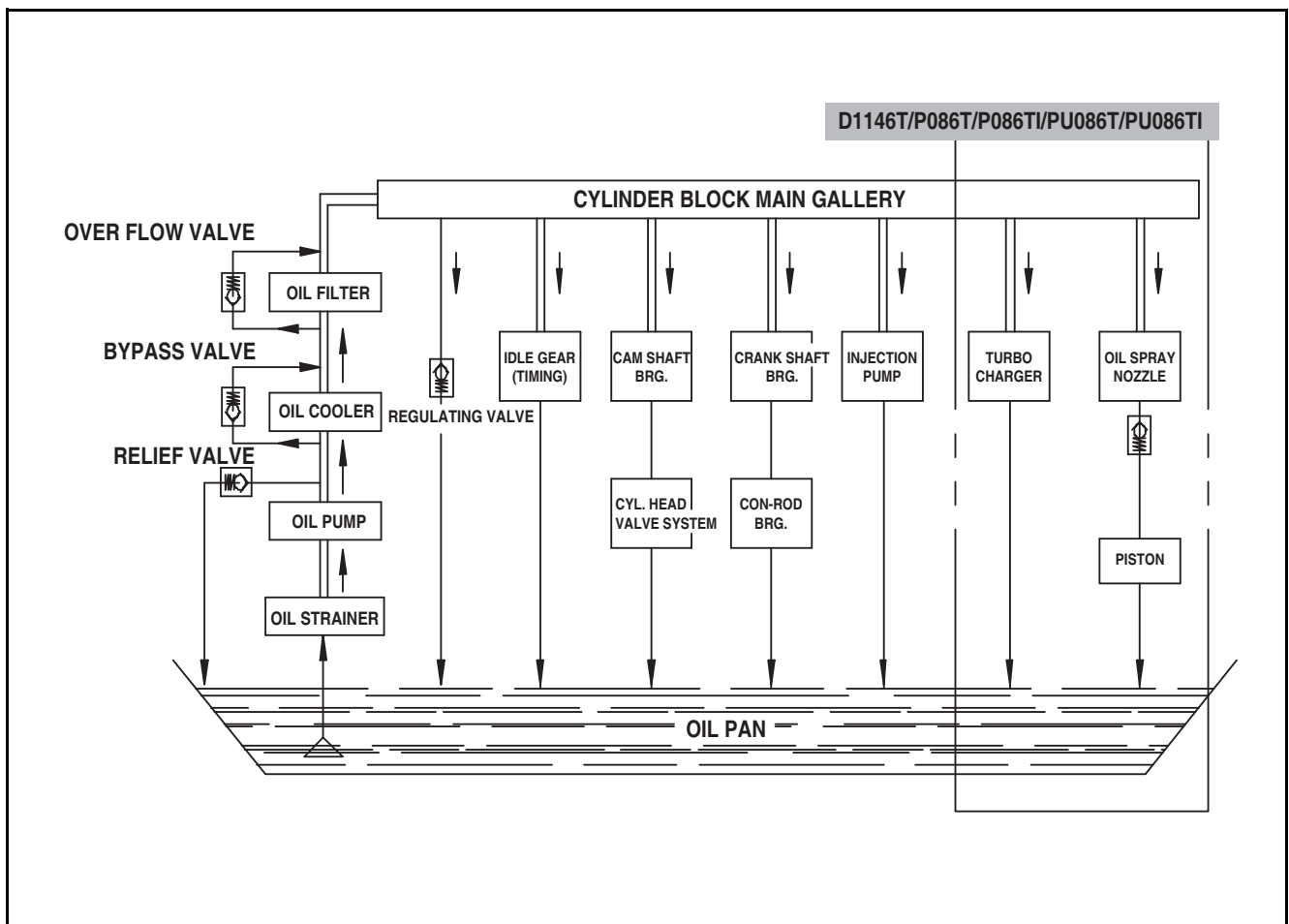
The oil pump delivers oil sucked from the oil pan with the suction pipe to the main path of the cylinder block through the oil cooler and oil filter. From the cylinder block, oil is delivered to the crankshaft bearings, camshaft bearings, and rocker arm for lubrication.

In addition, the turbocharger is connected to the engine lubrication circuit.

Around the cylinder block and the timing gear, lubricating oil is dispersed.

Each cylinder has an oil injection nozzle for cooling the bottom of the piston.

Engine oil is filtered through the oil filter and purified.



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7. Lubrication system

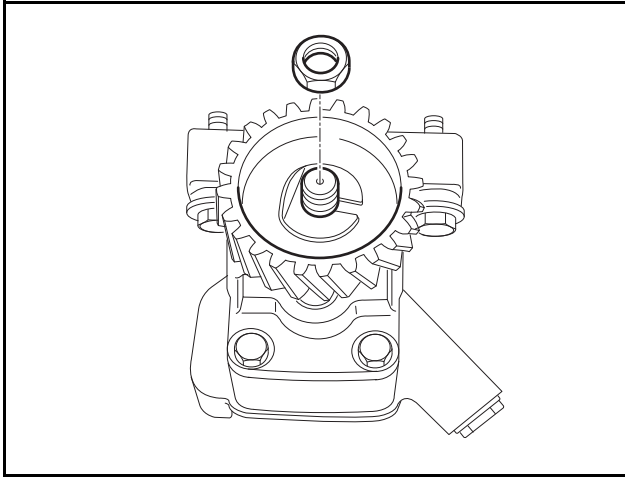
Failure Diagnosis

Phenomenon	Causes	Troubleshooting
Too much oil consumption	Bad oil	Replace oil with specified oil.
	Oil leakage from the oil seal ring and packing part	Replace it
	Worn or damaged piston and piston ring	Replace it
	Worn cylinder liner	Replace it
	Burnt piston ring	Replace it
	Worn valve guide oil seal, valve guide, or valve stem	Replace it
Low oil pressure	Bad oil	Replace oil with specified oil.
	Burnt oil pump relief valve	Replace it
	Clogged oil pump strainer	Cleanse the strainer
	Worn oil pump gear	Replace it
	Cracked oil delivery pipe of the oil pump	Replace it
	Defect oil pump	Repair or replace it
	Oil pressure gauge fault	Repair or replace it
	Worn bearings	Replace it
Contaminated oil	Clogged oil filter	Replace the oil filter with a new one
	Gas leakage	Replace piston ring with a new one
	Bad oil	Replace oil with specified oil.

Oil pump

Oil pump disassembly

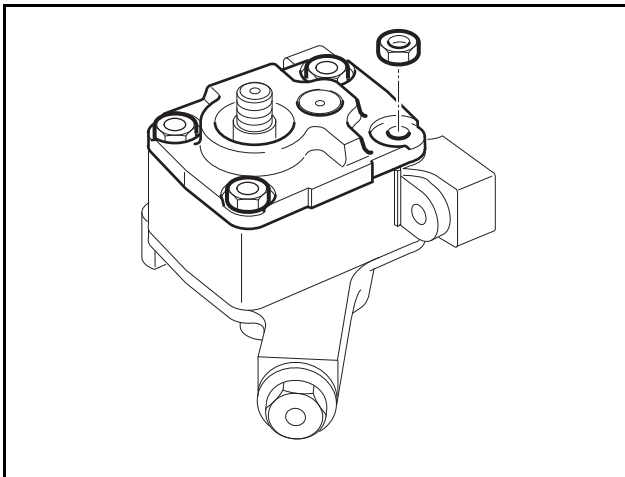
1. Disassembly of oil pump drive gear



EQM4006I

- 1) Unscrew the screw and disassemble the oil relief valve.
- 2) Unfold the washer for the oil pump drive gear fixing nut and remove the nut.
- 3) Disassemble the drive gear.
2. Remove the oil pump cover fixing nuts and disassemble the oil pump cover.

Note) The oil pump cover is fixed with the two dowel pins.



EQM4007I

3. Disassemble the drive gear and driven gear.

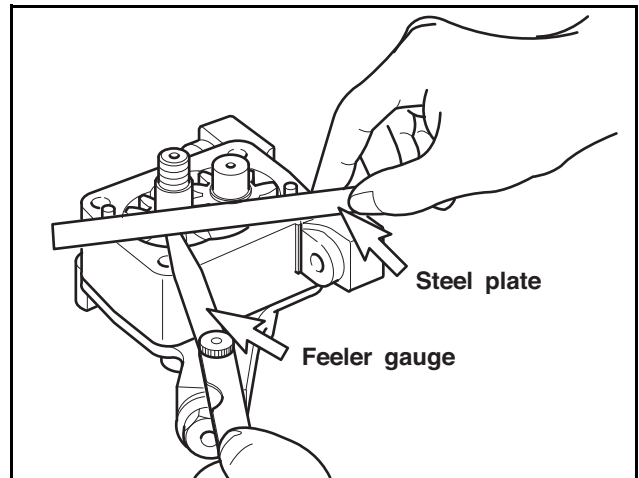
Oil pump assembly

1. For reassembly, reverse the disassembly sequence.

Check of oil pump

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.

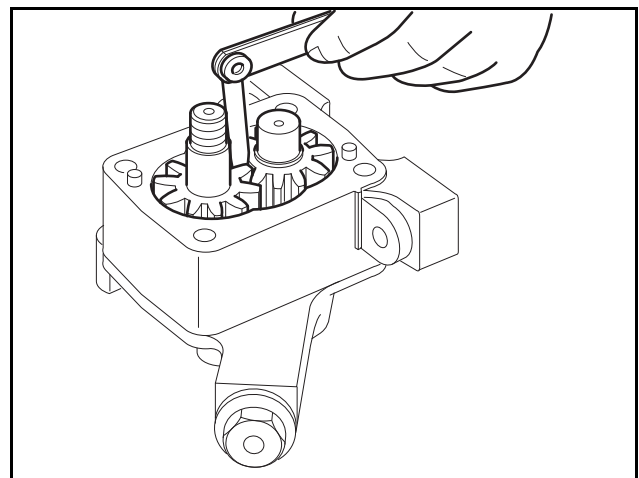
End play Limit	0.025 ~ 0.089mm
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EQM4008I

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 ~ 0.64mm
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EQM4009I

3. Measuring clearance between drive shaft and bushing

- 1) Measure the outside diameters of the drive shaft and driven shaft, and replace if the measured values are less than the limit (Ø16.95mm)

Standard	Ø16.95 ~ Ø16.968mm
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- 2) 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 not.

Clearance	0.032 ~ 0.077mm
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7. Lubrication system

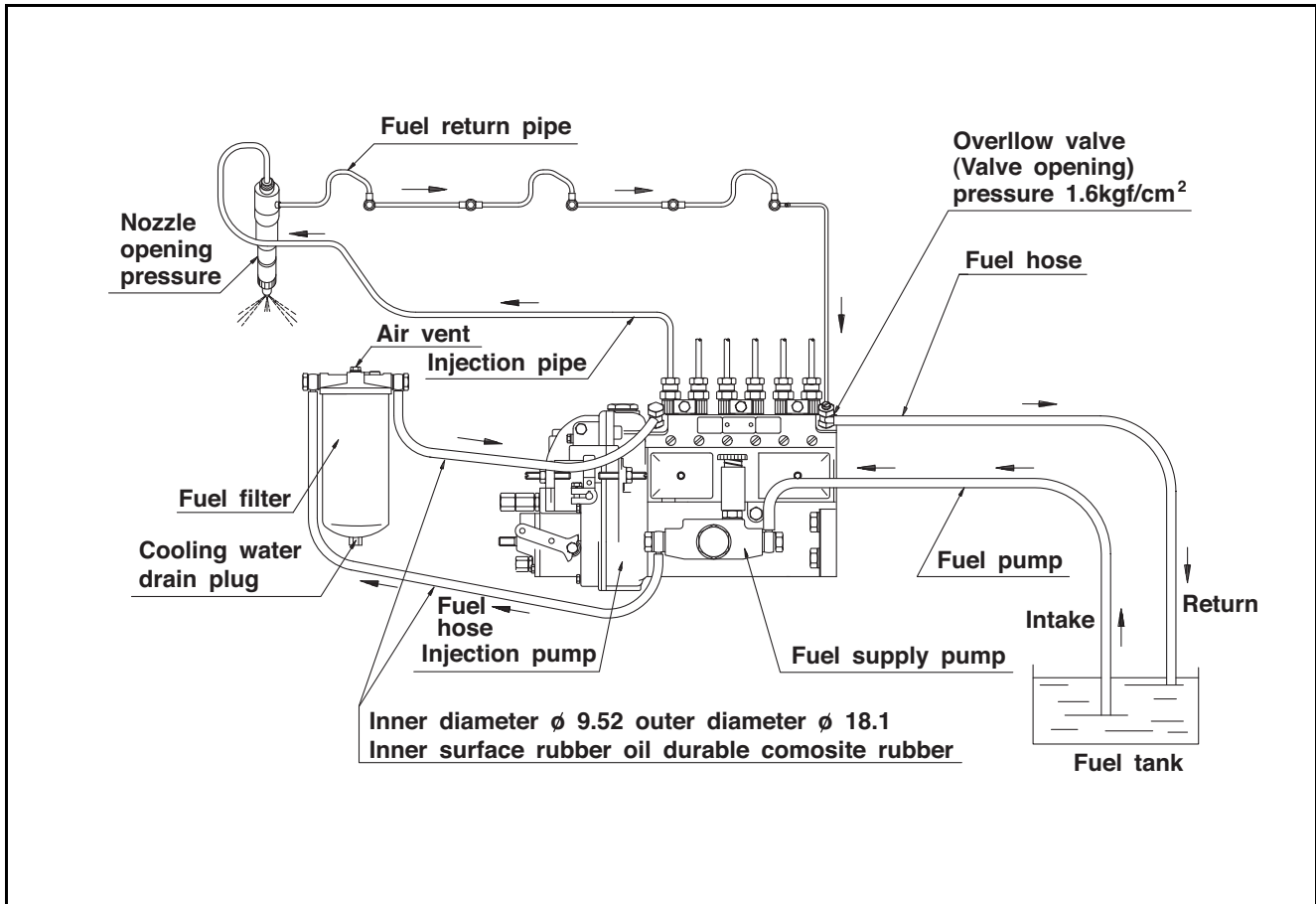
8. Fuel system

General information	121
General information	121
High Sulfur content in diesel fuel	122
Water (Moisture) in diesel fuel	122
Failure Diagnosis	123
Fuel injection pump	124
General Information	124
Adjustment fuel injection pump	125
Fuel feed pump	140
General descriptions and construction.....	140
Fuel feed pump disassembly	142
Fuel feed pump assembly	142
Fuel feed pump inspection	142
Fuel feed pump testing	143

General information

General information

The fuel system consists of the fuel tank, injection pump, injection nozzle, fuel filter, and fuel lines such as pipes and hoses necessary to connect those components.



EDO8006I

CAUTION

- The fuel lines should have a sufficient inner diameter.
- The fuel lines should be routed so that the fuel is not excessively heated by the heat radiation from the engine. The pipes should be laid as straight as possible without sharp bends.
- Make sure the pipes are protected against mechanical wear and well fastened to avoid vibrations.
- It is important that there are no fuel leakages or air infiltration neither on the suction or return line installation. Therefore securely fasten all the connections of fuel line.
- The return line back to the fuel tank must not be adjoin the suction line. In case of diesel fuel containing high water content due to insufficient fuel quality, maintenance difficulty or environmental adversity, an extra water separator with adequate capacity must be installed as user supply scope.

8. Fuel system

High Sulfur content in diesel fuel

HD Construction Equipment diesel engines can be operated with fuels Whose sulfur content is max. 0.05wt%.

Fuels with a sulfur content of > 0.05wt% are not Permitted as they result in increased corrosion and Hence greatly reduce the service life of the engines.

The oil and oil filter change intervals must be halved If the sulfur content is > 0.02wt%.

Water (Moisture) in diesel fuel

Water in the fuel causes;

- Incomplete combustion
- Iammed or clogged nozzle
- Damaged to the injection pump
- Piston damage
- Destruction of engine

In case of diesel fuel containing high water content due to insufficient fuel quality, maintenance difficulty or environmental adversity, an extra water separator with adequate capacity must be installed as user supply scope.

Failure Diagnosis

Symptom	Causes	Troubleshooting
1. Engine does not start A. Fuel is not supplied from the fuel delivery pump	• Clogged fuel pipe, or air entered the fuel pipe line • Defective delivery pump valve • Seized delivery pump piston or push rod	• Correct • Replace • Disassemble / correct
B. Fuel is not injected from the fuel injection pump	• Clogged fuel filter cartridge • Air entered to the fuel filter or injection pump • Seizure or defect in the plunger or delivery valve	• Clean / replace • Bleed • Disassemble / correct
C. Improper fuel injection timing	• Defective installation of fuel injection pump bracket • Defective adjustment of the fuel injection pump tappet • Excessively worn cam of camshaft	• Inspect / correct • Inspect / correct • Replace
D. Fuel injection nozzle not working	• Seizure of needle valve of nozzle • Fuel leakage between nozzle and needle valve • Improper fuel injection pressure	• Service or replace • Service or replace • Adjust
2. Engine starts but stops immediately	• Clogged fuel filter or clogged pipe between fuel delivery pump and injection pump • Air entered into fuel • Insufficient supply of oil by fuel delivery pump • Clogged air breather in fuel tank, causing insufficient fuel supply.	• Clean or replace • Air bleeding • Disassemble / correct • Replace breather
3. Insufficient engine power	• Excessively work plunger • Improper injection timing • Defective delivery valve • Excessive fuel leakage in injection nozzle • Nozzle not working properly	• Replace • Adjust • Replace • Service or replace • Disassemble / correct
4. Engine knocking occurs	• Early injection timing • High nozzle injection pressure • Nozzle not working properly	• Adjust • Adjust • Disassemble / correct
5. Excessive engine smoke and knocking	• Defective injection timing • Too low nozzle injection pressure • Broken nozzle spring • Nozzle not working properly • Excessively work plunger • Defective delivery valve seat • Excessive fuel supply	• Adjust • Adjust • Replace it • Replace it • Adjust • Replace it • Check feed pump
6. Unstable engine power	• Insufficient fuel supply • Air entered into fuel • Water entered into fuel • Defective plunger operation • Defective actuator operation • Defective nozzle • Injection start pressure different between cylinders • Defective controller	• Check feed pump • Air bleeding • Replace fuel • Disassemble / correct • Disassemble / correct • Disassemble / correct • Adjust • Adjust
7. Engine cannot reach the max. speed	• Nozzle not working properly • Defective operation of actuator or controller	• Disassemble / correct • Adjust
8. Unstable engine idling	• Defective controller operation • Defective plunger operation • Defective magnetic pickup sensor	• Adjust • Disassemble / correct • Inspect or replace

8. Fuel system

Fuel injection pump

General Information

The fuel injection pump is driven by the crankshaft gear. It is connected to the forced lubrication system, so separate connection is not required.

The governor of electric fuel injection pump is consist of the actuator that is operated by the signal of the control system and the control system that maintain the engine RPM as the changing load.

Adjustment fuel injection pump

1. D1146
 - 1) Injection pump : 65.11101 -7269A
 - Model : KP-PES6AD95B410RS2 (101061-8820 ZEXEL)
 - Governor : KP-EP/RSV200-1350AQ49C311(105419-3930)
 - Plunger & barrel : 131153-1720
 - Delivery valve : 131110-5120
 - Feed pump : KP-FP/KE-ADS(105210-5280)
 - Prestroke : 4.6 ± 0.05 mm
 - 2) Nozzle holder assembly : 65.10101-7050 (9134-153C LUCAS)
 - 3) Nozzle : 65.10102-6026 (9135-143 LUCAS)
 - 4) Injection pipe : 65.10301-6048
 - 5) Injection order : 1 - 5 - 3 - 6 - 2 - 4
 - 6) Injection timing : BTDC 18°

(A) Test condition for injection pump	Nozzle & Holder ass'y	105780-8140	Opening pressure: 175 kg/cm ²
	Injection pipe (ID, OD, L)	-	Ø2.0 X Ø6.0 - 600 mm
	Test oil	ISO4113	Temperature: 40 ± 5 °C
(B) Engine standard parts	Nozzle & holder ass'y	65.10102-6026	Nozzle (5 X Ø0.29)
		65.10101-7050	Opening pressure: 214 kg/cm ²
	Injection pipe (ID, OD, L)	65.10301-6048	Ø2.0 x Ø6 - 650 mm

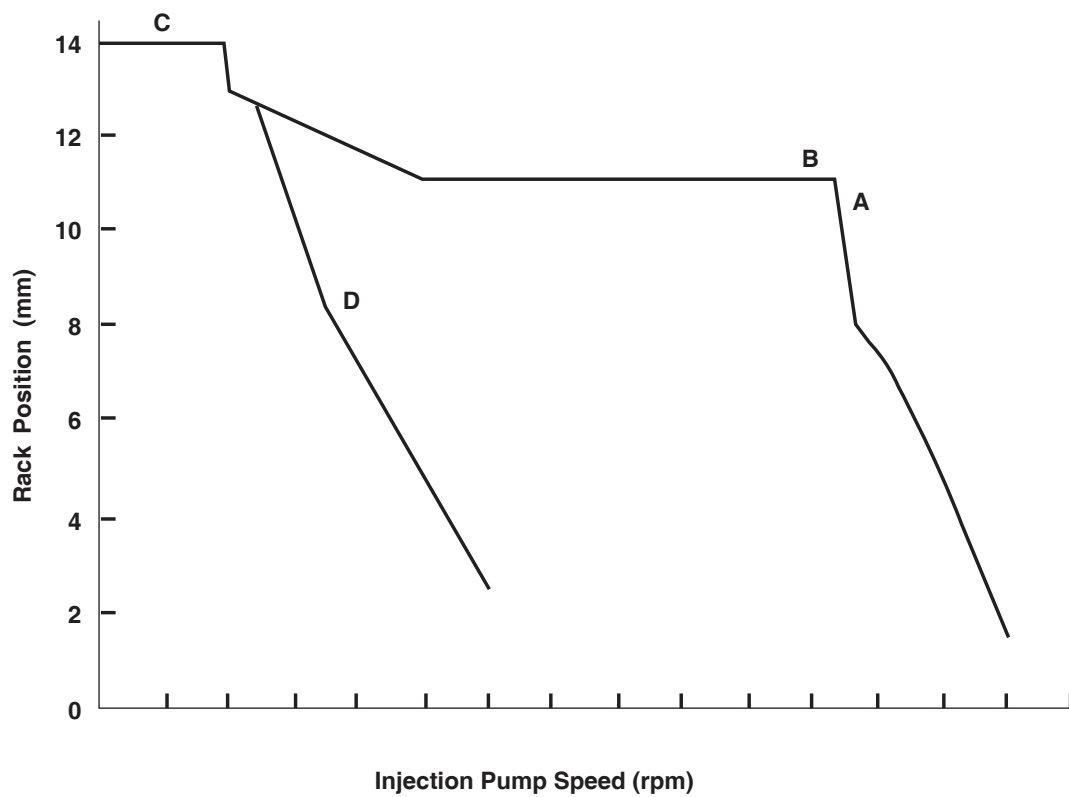
Rack diagram and setting valve at each point

	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q'ty on RIG (mm ³ /1,000st)		Press (mmHg)
				(A) Test condition for injection pump	(B) Engine standard parts	
Stand by power	A	-	900	-	93.5 $\pm$ 2	-
	B	-	875	-	(103)	-
	C	-	100	-	(135)	-
	D	≈ 7.7	370	-	± 2	-
	-	-	-	-	-	-

- Governor weight: 740 g
- Governor spring: $k=10.0$ kgf/mm
- Idle spring: $k=1.9$ kgf/mm
- Start spring: $k=0.01$ kgf/mm
- Feed pump: 105210-5280
- Lever ratio (min/max): 1 : 2
- Plunger: Ø9.5 Left hand 20 + 45 lead
- Delivery valve
 - Retraction pressure: 70 mm³/st, t-0.11
 - Opening pressure: 23.1 kgf/cm²
 - Spring: $k=1.63$ kgf/mm

8. Fuel system

Rack Diagram



EA9M4002

8. Fuel system

2. D1146T

1) Injection pump : 65.11101 -7271A

- Model : KP-PES6AD95B410RS2 (101061-8820 ZEXEL)
- Governor : KP-EP/RSV200-1350AQ49C311(105419-3930)
- Plunger & barrel : 131153-1720
- Delivery valve : 131110-5120
- Feed pump : KP-FP/KE-ADS(105210-5280)
- Prestroke : 4.6 ± 0.05 mm

2) Nozzle holder assembly : 65.10101-7050 (9134-153C LUCAS)

3) Nozzle : 65.10102-6026 (9135-143 LUCAS)

4) Injection pipe : 65.10301-6048

5) Injection order : 1 - 5 - 3 - 6 - 2 - 4

6) Injection timing : BTDC 18°

(A) Test condition for injection pump	Nozzle & Holder ass'y	105780-8140	Opening pressure: 175 kg/cm^2
	Injection pipe (ID, OD, L)	-	$\varnothing 2.0 \times \varnothing 6.0$ - 600 mm
	Test oil	ISO4113	Temperature: $40 \pm 5^\circ \text{C}$
(B) Engine standard parts	Nozzle & holder ass'y	65.10102-6026	Nozzle (5 X $\varnothing 0.29$)
		65.10101-7050	Opening pressure: 214 kg/cm^2
	Injection pipe (ID, OD, L)	65.10301-6048	$\varnothing 2.0 \times \varnothing 6$ - 650 mm

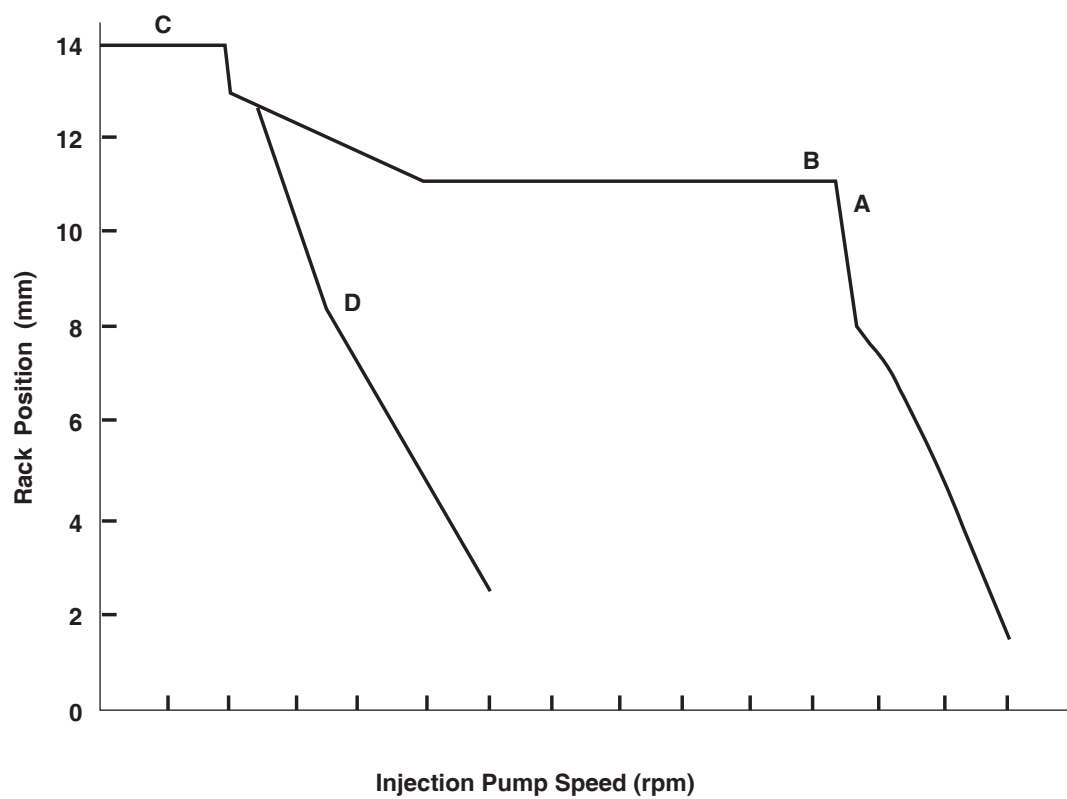
Rack diagram and setting valve at each point

	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q'ty on RIG ($\text{mm}^3/1,000\text{st}$)		Press (mmHg)
				(A) Test condition for injection pump	(B) Engine standard parts	
Stand by power	A	-	900	-	114.3 ± 2	-
	B	-	875	-	(126)	-
	C	14 or more	100	-	(140)	-
	D	≈ 7.7	370	-	12.8 ± 2	-
	-	-	-	-	-	-

- Governor weight: 740 g
- Governor spring: $k=10.0 \text{ kgf/mm}$
- Idle spring: $k=1.9 \text{ kgf/mm}$
- Start spring: $k=0.01 \text{ kgf/mm}$
- Feed pump: 105210-5280
- Lever ratio (min/max): 1 : 2
- Plunger: $\varnothing 9.5$ Left hand 20 + 45 lead
- Delivery valve
 - Retraction pressure: $70 \text{ mm}^3/\text{st}$, $t=0.11$
 - Opening pressure: 23.1 kgf/cm^2
 - Spring: $k=1.63 \text{ kgf/mm}$

8. Fuel system

Rack Diagram



EA9M4002

8. Fuel system

3. P086TI

- 1) Injection pump : 65.11101-7309 (106674-4120 ZEXEL)
 - Model : NP-PE6P120/700RS3S (106067-6010 ZEXEL)
 - Governor : Ghana electric control
 - Plunger & barrel : 134153 -2020
 - Delivery valve : 134110 - 1420
 - Feed pump : NP-FP/KD-PS(105237-5470)
 - Prestroke : 3.9 ± 0.05 mm
- 2) Nozzle holder assembly : 65.10101-7055 (9135-293A LUCAS)
- 3) Nozzle : 65.10102-6049 (9135-291 LUCAS)
- 4) Injection pipe : 65.10301-6049 , 65.10301-6052
- 5) Injection order : 1 - 5 - 3 - 6 - 2 - 4
- 6) Injection timing : BTDC 12°

(A) Test condition for injection pump	Nozzle & Holder ass'y	9135-293A	Opening pressure: 214 $\pm$ 8 bar
	Injection pipe (ID, OD, L)	-	$\varnothing 2.2 \times \varnothing 6.35$ - 650 mm
	Test oil	ISO4113	Temperature: 40 $\pm$ 5 $^\circ$ C
(B) Engine standard parts	Nozzle & holder ass'y	65.10102-6049	Nozzle (5 X $\varnothing 0.34$)
		65.10101-7055	Opening pressure: 214 kg/cm ²
	Injection pipe (ID, OD, L)	65.10301-6049 65.10301-6052	$\varnothing 2.0 \times \varnothing 6.35$ - 650 mm

Rack diagram and setting valve at each point

	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm ³ /1,000st)		Press (mmHg)
				(A) Test condition for injection pump	(B) Engine standard parts	
Stand by power	A	12.2	900	-	189 $\pm$ 2	-
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-

- Governor weight: 26 g
- Governor spring: -
- Idle spring: -
- Start spring: -
- Feed pump: 105210-5280
- Lever ratio (min/max): 1 : 2
- Plunger: $\varnothing 12$ Left hand 30 lead
- Delivery valve
 - Retraction pressure: 100 mm³/st, t-0.09
 - Opening pressure: 18.5 kgf/cm²
 - Spring: k=0.87 kgf/mm

8. Fuel system

4. PU086

1) Fuel injection pump : 65.11101-7269A

- Model type : PES6AD
- Governor type : RSV
- Fuel feed pump : 105210-4830
- Cam lift : 11 mm

2) Rotating direction : Clockwise (Viewed at driving gear side)

3) Injection order : 1-5-3-6-2-4

4) Injection timing: BTDC $18^{\circ} \pm 1^{\circ}$

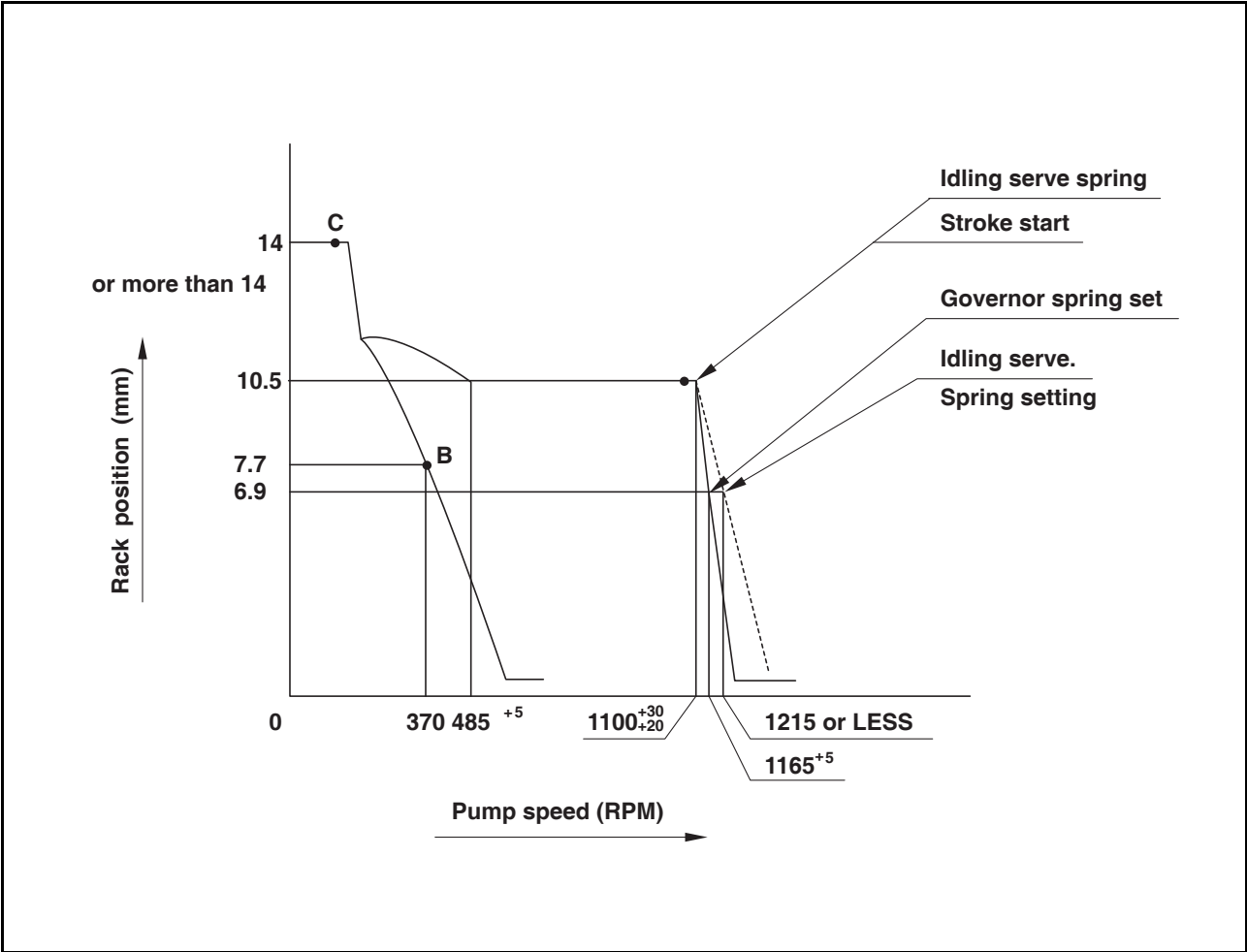
(A) Test condition for injection pump	Nozzle & Holder ass'y	105780-8140	Opening pressure: 175 kg/cm ²
	Injection pipe (ID, OD, L)	-	Ø2.0 X Ø8.0 - 600 mm
	Test oil	ISO4113	Temperature: 40 ±5 °C
(B) Engine standard parts	Nozzle & holder ass'y	-	Nozzle (5 X Ø0.36)
		65.10101-7050	Opening pressure: 214 + 8 kg/cm ²
	Injection pipe (ID, OD, L)	-	Ø2.2 x Ø6.0 - 650 mm

Rack diagram and setting valve at each point

	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm ³ /1,000st)		Press (mmHg)
				(A) Test condition for injection pump	(B) Engine standard parts	
Stand by power	A	10.5	1,100	88.5 ±2	±2.5	Full
	B	7.7	370	11.5 ±2	±25	Idle
	C	≈	100	(135)	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-

- Balance weight: 740 g
- Governor spring: k= 7.2 kg/mm
- Idle spring: k= 1.9 kg/mm
- Idle sub spring: k= 3.0 kg/mm
- Start spring: k= 0.01 kg/mm
- Max. discharge pressure: k= 3.4 kg/mm²
- Lever ratio(min/max): 1 : 1.2
- Plunger: Ø9.5, 20 + 45 lead
- Delivery valve
 - Retraction volume: 70 mm³/st, t=0.11
 - Opening pressure: 23.1 kgf/cm²
 - Spring: k=1.63 kgf/mm
- Feed pump: 105210-5280(KP-FP/KE-ADS)

Rack Diagram



EDM5001I

8. Fuel system

5. PU086T

1) Fuel injection pump : 65.11101-7271A

- Model type : PES6AD
- Governor type : RSV
- Fuel feed pump : 105210-4830
- Cam lift : 11 mm

2) Rotating direction : Clockwise (Viewed at driving gear side)

3) Injection order : 1-5-3-6-2-4

4) Injection timing: BTDC $12^\circ \pm 1^\circ$

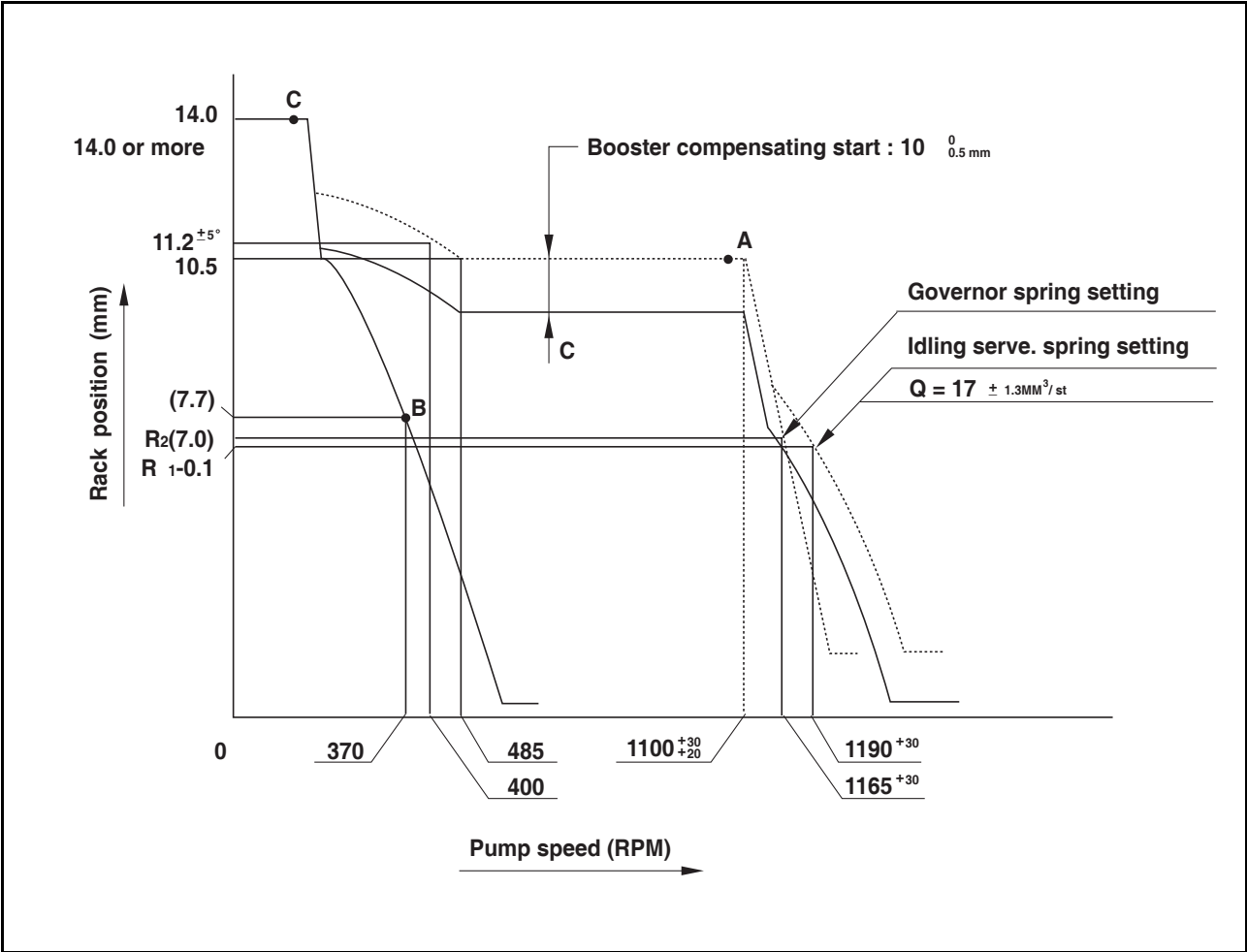
(A) Test condition for injection pump	Nozzle & Holder ass'y	105780-8140	Opening pressure: 175 kg/cm ²
	Injection pipe (ID, OD, L)	-	Ø2.0 X Ø8.0 - 600 mm
	Test oil	ISO4113	Temperature: 40 ±5 °C
(B) Engine standard parts	Nozzle & holder ass'y	-	Nozzle (5 X Ø0.36)
		65.10101-7050	Opening pressure: 214 + 8 kg/cm ²
	Injection pipe (ID, OD, L)	-	Ø2.2 x Ø6.0 - 650 mm

Rack diagram and setting valve at each point

	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm ³ /1,000st)		Press (mmHg)
				(A) Test condition for injection pump	(B) Engine standard parts	
Stand by power	A	10.5	1,100	113.5 ±2	±2.5	Full
	B	7.7	370	11.5 ±2	±25	Idle
	C	≈	100	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-

- Balance weight: 740 g
- Governor spring: k= 7.2 kg/mm
- Idle spring: k= 1.9 kg/mm
- Idle sub spring: k= 3.0 kg/mm
- Start spring: k= 0.01 kg/mm
- Max. discharge pressure: k= 3.4 kg/mm²
- Lever ratio(min/max): 1 : 1.2
- Plunger: Ø9.5, 20 + 45 lead
- Delivery valve
 - Retraction volume: 70mm³/st, t=0.11
 - Opening pressure: 23.1kgf/cm²
 - Spring: k=1.63 kgf/mm
- Feed pump: 105210-5280(KP-FP/KE-ADS)

Rack Diagram



EDM5003I

8. Fuel system

6. DP086LAF

- 1) Injection pump : 400912-00278
 - Model : 006PH609
 - Governor : Electric governor
 - Plunger & barrel : -
 - Delivery valve : -
 - Fuel feed pump : 006PH613
 - Prestroke : 3.9 ± 0.05 mm
- 2) Nozzle holder assembly : 65.10101-7055A
- 3) Nozzle : 65.10102-6049A
- 4) Injection pipe : 65.10301-6052B, 420208-00002
- 5) Injection order : 1 - 5 - 3 - 6 - 2 - 4
- 6) Injection timing : BTDC 14°

(A) Test condition for injection pump	Nozzle & Holder ass'y	-	Opening pressure:
	Injection pipe (ID, OD, L)	-	-
	Test oil	-	Temperature: -
(B) Engine standard parts	Nozzle & holder ass'y	65.10102-6049A	Nozzle (5 x $\varnothing 0.34$)
		65.10101-7055A	Opening pressure: 214 kg/cm ²
	Injection pipe (ID, OD, L)	65.10301-6052B, 420208-00002	$\varnothing 2.2 \times \varnothing 6.5 \times 650$ mm

Rack diagram and setting valve at each point

	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm ³ /1,000st)		Press (mmHg)
				(A) Test condition for injection pump	(B) Engine standard parts	
Stand by power	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-

- Governor weight: -
- Governor spring: -
- Idle spring: -
- Start spring: -
- Feed pump: 006PH613
- Lever ratio (min/max): -
- Plunger: $\varnothing 12$ Left hand 30 lead
- Delivery valve
 - Retraction pressure: 105 mm³/st, t=0.1 mm
 - Opening pressure: -
 - Spring: k=1.2 kgf/mm

8. Fuel system

7. DP086TAF

- 1) Injection pump : 400912-00282
 - Model : 006PH612
 - Governor : Electric governor
 - Plunger & barrel : -
 - Delivery valve : -
 - Fuel feed pump : 006PH613
 - Prestroke : 3.9 ± 0.05 mm
- 2) Nozzle holder assembly : 65.10101-7080A
- 3) Nozzle : 65.10102-6040A
- 4) Injection pipe : 65.10301-6052B, 420208-00002
- 5) Injection order : 1 - 5 - 3 - 6 - 2 - 4
- 6) Injection timing : BTDC 19°

(A) Test condition for injection pump	Nozzle & Holder ass'y	-	Opening pressure:
	Injection pipe (ID, OD, L)	-	-
	Test oil	-	Temperature: -
(B) Engine standard parts	Nozzle & holder ass'y	65.10102-6049A	Nozzle (5 x Ø0.3)
		65.10101-7055A	Opening pressure: 214 kg/cm ²
	Injection pipe (ID, OD, L)	65.10301-6052B, 420208-00002	Ø2.2 x Ø6.5 x 650 mm

Rack diagram and setting valve at each point

	Check point	Rack position (mm)	Pump speed (rpm)	Injection Q`ty on RIG (mm ³ /1,000st)		Press (mmHg)
				(A) Test condition for injection pump	(B) Engine standard parts	
Stand by power	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-

- Governor weight: -
- Governor spring: -
- Idle spring: -
- Start spring: -
- Feed pump: 006PH613
- Lever ratio (min/max): -
- Plunger: Ø12 Left hand 30 lead
- Delivery valve
 - Retraction pressure: 105 mm³/st, t=0.1 mm
 - Opening pressure: -
 - Spring: k=1.2 kgf/mm

8. Fuel system

8. PU086TI (EBPPA)

1) Parts of pump

- Pump speed limit : 1,400 rpm
- Pump housing : 05B131-00
 - Cradle
 - Pressure-feed lubrication
- Cam sequence/rotate direction (Viewed from driving end) : 1 - 5 - 3 - 6 - 2 - 4/Clockwise
- Tolerance of injection angle : $\pm 30^\circ$ (Relate No.1 cylinder)
- Prestroke : $H=4.5 \pm 0.05$ mm
- Camshaft : 05B168-0201-1YM
 - Cam lift : 12 mm
 - Diameter : $\varnothing 30$ mm
- Plunger and barrel ass'y : 05U1001-00
 - $\varnothing 12$ mm
 - Right, 30LEAD
- Delivery-valve : 05F232-00
 - D/V retraction $VR=105 \text{ mm}^3$ ($\varnothing 8 \times 2.1$ mm) $t=0.1$ mm
- Delivery-valve spring : 1.2 kgf/mm
- Holder delivery valve with damping valve : Orifice Dia. $\varnothing 0.65$ mm

2) Parts of governor

- Governor : RSV
- Lever ratio : 1 : 1.2
- Flyweight : 610 g
- Governor spring : $k=7.2$ kg/mm
- Idle spring : $k=1.9$ kg/mm
- Idle sub spring : $k=1.03$ kg/mm
- Start spring : $k=0.009$ kg/mm
- Boo. com spring : $k=1.02$ kg/mm

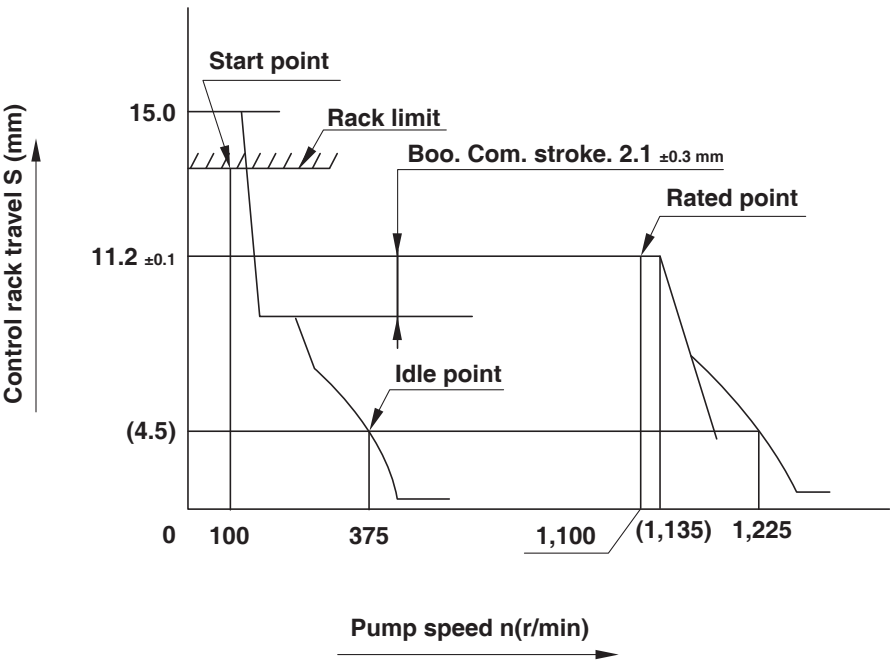
3) Feed pump

- Order No. : 05LS2035A
- Pressure : $P=1.5$ kgf/cm²
- Piston spring : $k=1.15$ kgf/mm

4) Bench test data

Attribute	Inspection tolerances					
	Speed	L.D.A pressure	Fueling	Fueling tolerance	Max SP. CYL/CYL	Rack travel
	r/min	kPa	mm ³ /st	mm ³ /st	mm ³ /st	mm
Rated	1,100	140	140	± 4.5 ●	9	11.2 ± 0.1
Torque peak	800	140	153	± 8	15	11.2 ± 0.1
Governor break	$1,135 \pm 10$	140				11.1 ± 0.2
High idle	$1,225 \pm 10$	140	21	± 4		(4.5)
Boost control	500	0	102	± 6	10	9.1 ± 0.3
Start fuel	100	0	190 ○	± 10		
Low idle	375	0	10 ○	± 2 ○	3.4	(4.5)

Rack Diagram



EDL08220188

8. Fuel system

9. PU086TI (EBPPB)

1) Parts of pump

- Pump speed limit : 1,400 rpm
- Pump housing : 05B131-00
 - Cradle
 - Pressure-feed lubrication
- Cam sequence/rotate direction (Viewed from driving end) : 1 - 5 - 3 - 6 - 2 - 4/Clockwise
- Tolerance of injection angle : $\pm 30^\circ$ (Relate No.1 cylinder)
- Prestroke : $H=4.5 \pm 0.05$ mm
- Camshaft : 05B168-0201-1YM
 - Cam lift : 12 mm
 - Diameter : $\varnothing 30$ mm
- Plunger and barrel ass'y : 05U1001-00
 - $\varnothing 12$ mm
 - Right, 30LEAD
- Delivery-valve : 05F232-00
 - D/V retraction $VR=105 \text{ mm}^3$ ($\varnothing 8 \times 2.1$ mm) $t=0.1$ mm
- Delivery-valve spring : 1.2 kgf/mm
- Holder delivery valve with damping valve : Orifice Dia. $\varnothing 0.65$ mm

2) Parts of governor

- Governor : RSV
- Lever ratio : 1 : 1.2
- Flyweight : 610 g
- Governor spring : $k=7.2$ kg/mm
- Idle spring : $k=1.9$ kg/mm
- Idle sub spring : $k=1.03$ kg/mm
- Start spring : $k=0.009$ kg/mm
- Boo. com spring : $k=1.02$ kg/mm

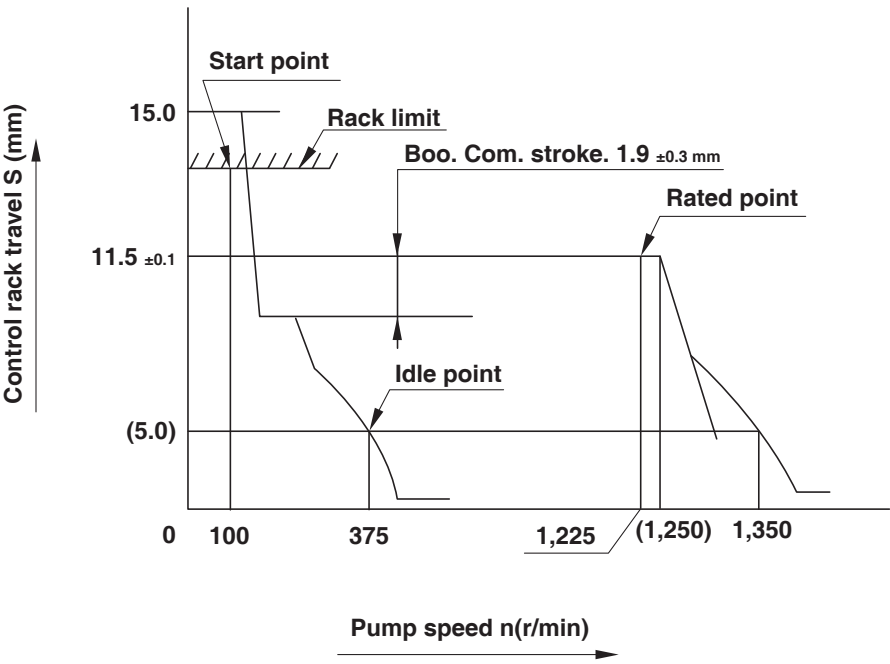
3) Feed pump

- Order No. : 05LS2035A
- Pressure : $P=1.5$ kgf/cm²
- Piston spring : $k=1.15$ kgf/mm

4) Bench test data

Attribute	Inspection tolerances					
	Speed	L.D.A pressure	Fueling	Fueling tolerance	Max SP. CYL/CYL	Rack travel
	r/min	kPa	mm ³ /st	mm ³ /st	mm ³ /st	mm
Rated	1,225	140	143	± 4.5 ●	9	11.5 ± 0.1
Torque peak	750	140	157	± 8	15	11.5 ± 0.1
Governor break	$1,250 \pm 10$	140				11.4 ± 0.2
High idle	$1,350 \pm 10$	140	25	± 4		(5.0)
Boost control	500	0	113	± 6	11	9.6 ± 0.3
Start fuel	100	0	190 ○	± 10		
Low idle	375	0	15 ○	± 3 ○	5.2	(5.0)

Rack Diagram

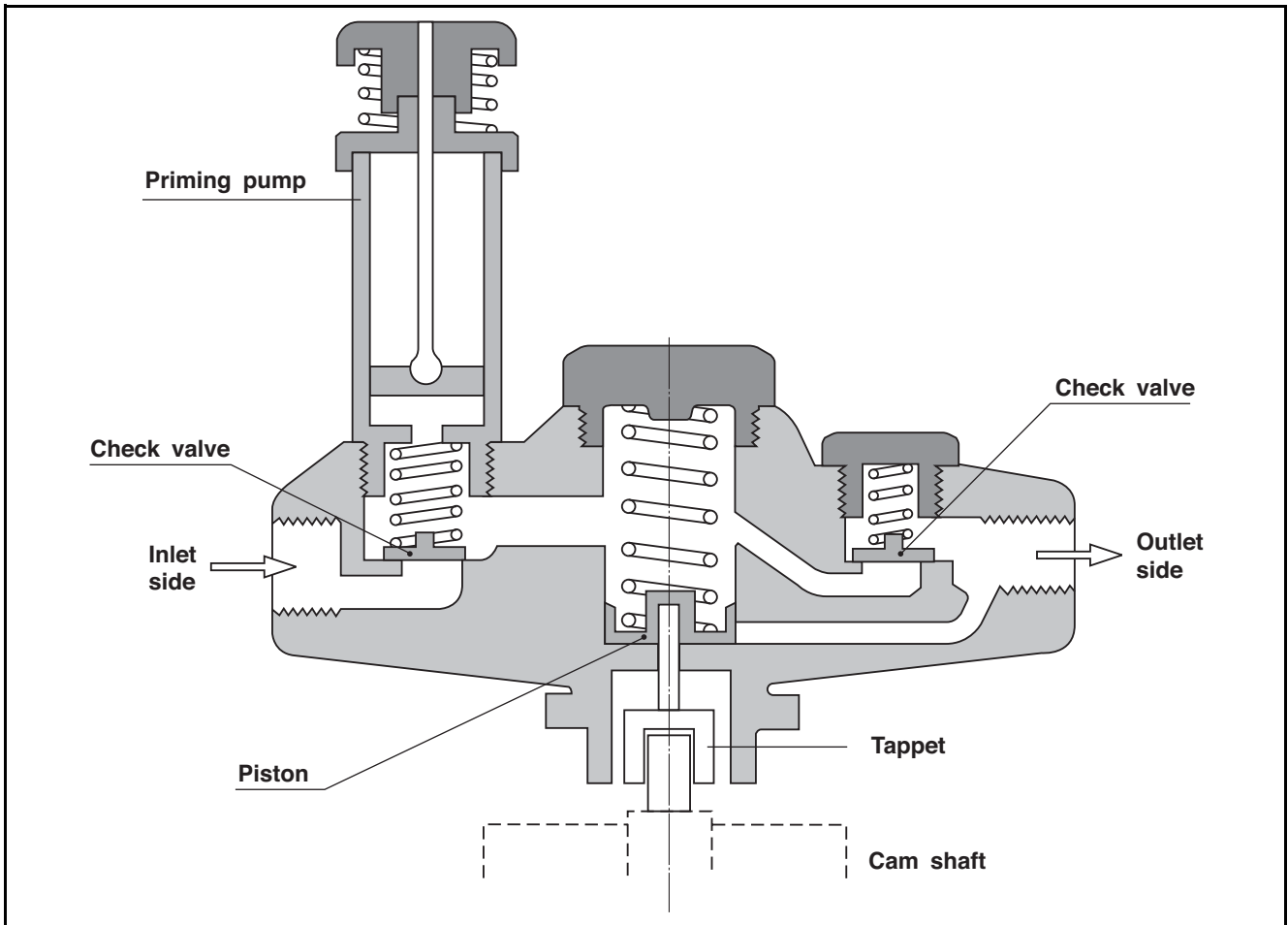


EDL08220189

8. Fuel system

Fuel feed pump

General descriptions and construction

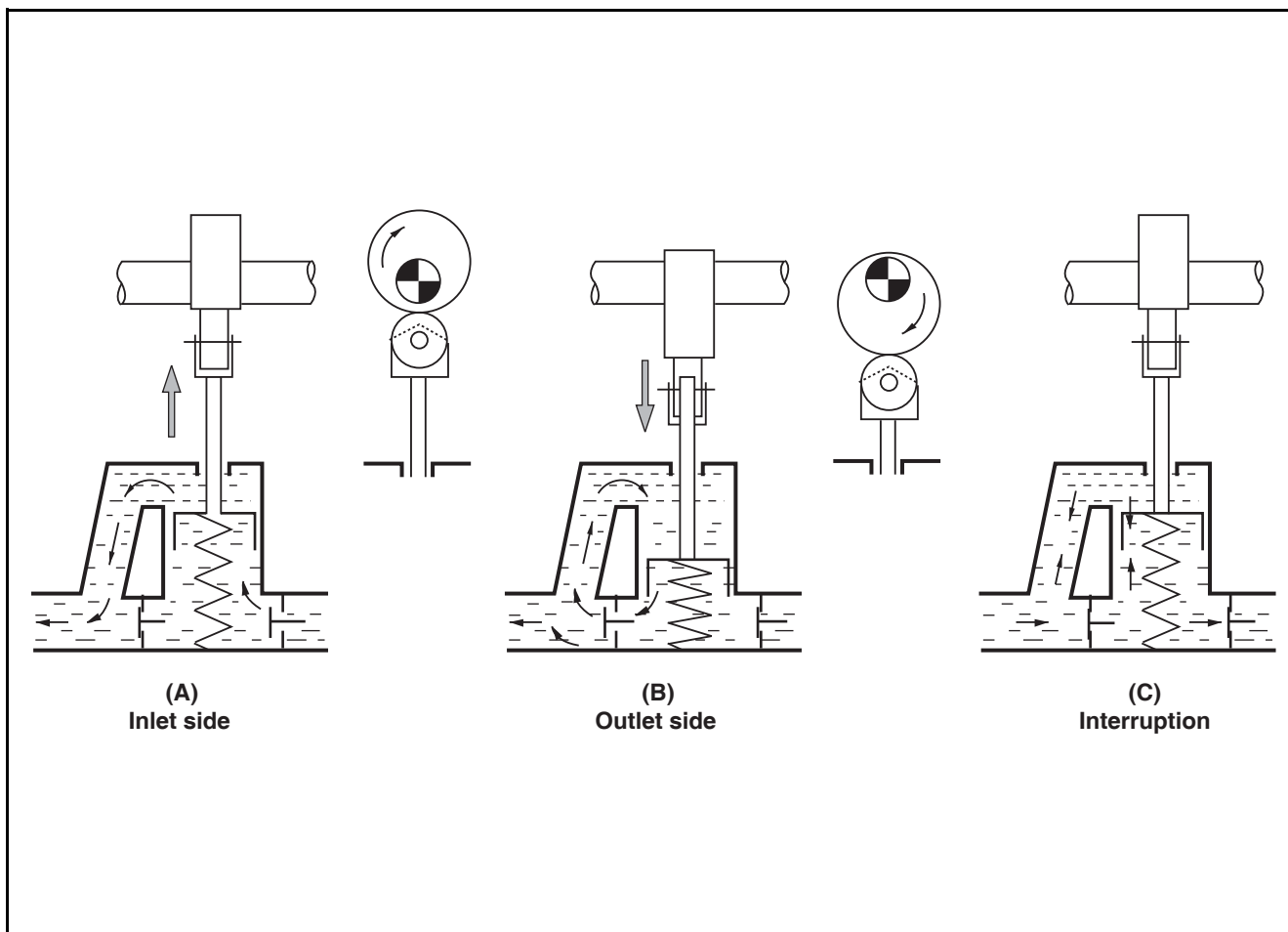


EQM4019I

The P-type injection pump is mounted with K-ADS or KP type feed pump. These pumps have the same basic construction and operation, and the general descriptions of the KP type pump are given below.

The figures show its construction (above figure) and operation (following figure). The piston in the fuel feed pump is driven by the push rod and tappet via the camshaft of injection pump and performs reciprocating operation to control the suction and delivery of fuel. When the cam reaches the Bottom Dead Center as shown in the figure, the fuel is drawn in through the check valve on the inlet side.

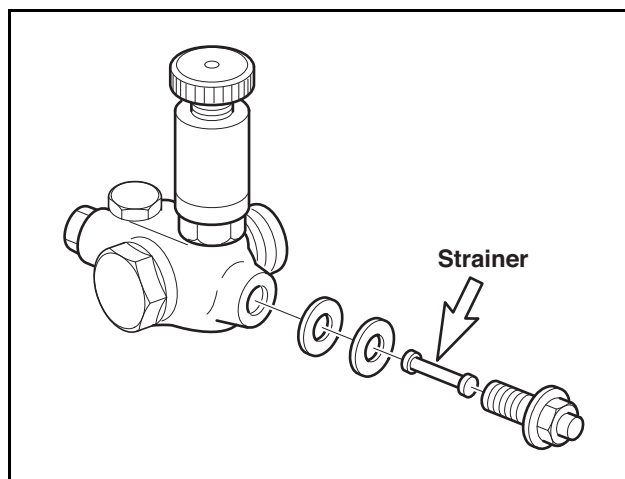
The fuel pressurized as the cam rotates on flows through the check valve on the outlet side as shown in (B). If the feeding pressure increases abnormally, the spring is compressed, resulting in interrupting further delivery of fuel as shown in (C).



EQM4020I

This feed pump is mounted with a priming pump designed to permit manual feeding of fuel from the fuel tank with the injection pump mounted in the engine. During the manual feeding operation, air must be bled from the fuel lines. When using the priming pump, fix it securely to prevent the possible entry of moisture or other foreign substances in the inside of feed pump.

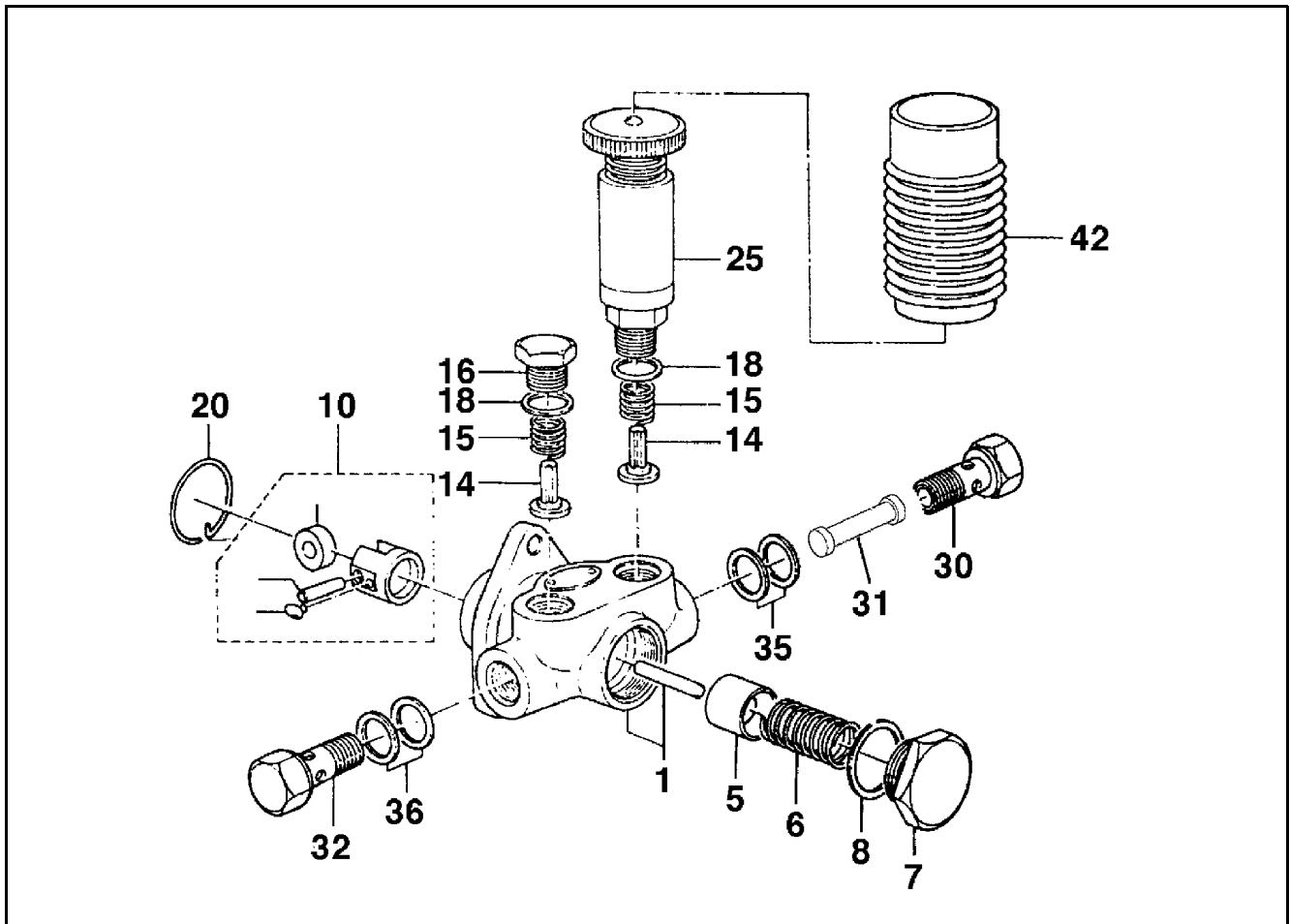
In addition, a strainer is fitted into joint bolt on the inlet side of the fuel feed pump to filtrate any foreign substances possibly mixed in fuel.



EB1M4003

8. Fuel system

Fuel feed pump disassembly



EQM4021S

1. Clamp the feed pump with a vise and disassemble the plugs (30, 32), strainer (31) and gaskets (35, 36).
2. Take off the priming pump (25), plug (16), both gaskets (18), spring (15), and check valve (14).
3. Take off the prigr (7), gasket (8), spring (6), and piston (5) on the piston side.
4. Pull out the snap ring (20) holding the tappet (10).
5. Disassemble the snap ring, then take off the tappet (10) and push rod (1).
4. The inspection for wear should be performed in the same procedure as for suction pressure test described below.

Fuel feed pump assembly

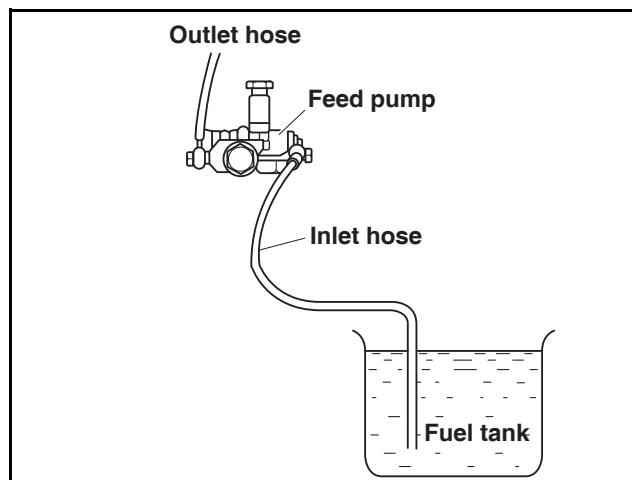
Reassembly operation is performed in reverse order of disassembly. All the gaskets must be replaced with new ones at reassembly.

Fuel feed pump inspection

1. If the check valve is damaged or scored on its seat face, replace it with a new one.
2. Inspect the piston and tappet for damage.
3. Replace the push rod if excessively worn, and replace together with the pump housing if required.

Fuel feed pump testing

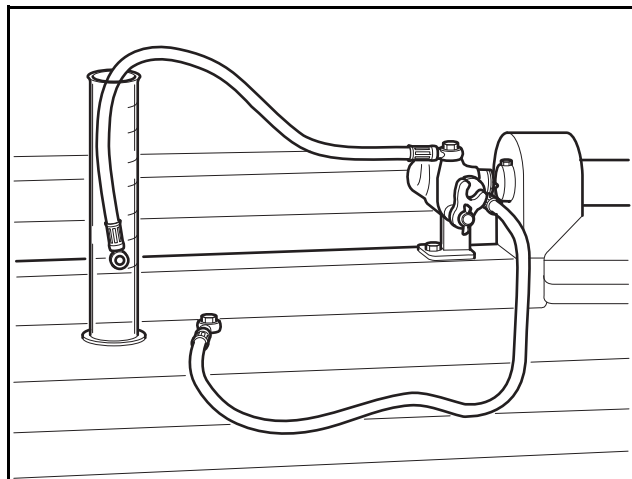
1. Suction capacity test



EQM4022I

- 1) Connect one end of a hose to the inlet side of the feed pump and immerse the other end of it into the fuel tank as illustrated.
- 2) Hold the feed pump in position about 1m above the level of fuel in the fuel tank.
- 3) Operate the tappet at the rate of 100rpm and check to see if fuel is drawn in and delivered for 40seconds or so.

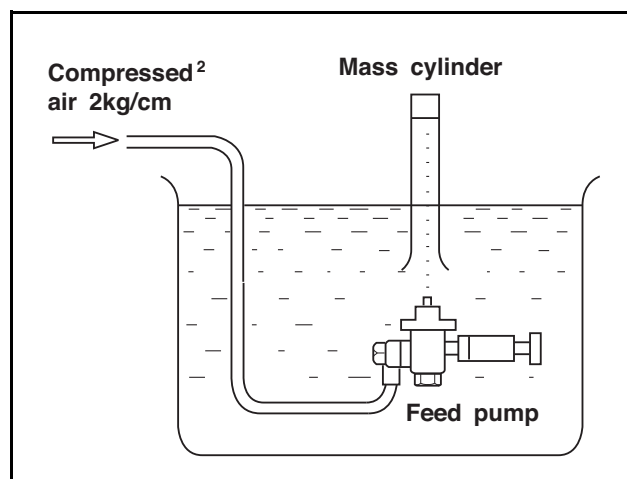
2. Delivery test



EAMC016I

- 1) Make a test with the feed pump mounted on a pump tester as illustrated.
- 2) Operate the pump at the rate of 1,000rpm and check to see if the pump delivery is more than 405 cc/15 seconds.

3. Sealing test



EQM4023I

- 1) Plug up the delivery port on the feed pump and apply compressed air of 2 kg/cm² into the inlet side.
- 2) Submerge the feed pump in a container of diesel fuel and check for air leak.

8. Fuel system

9. Intake/exhaust system

General information	147
General Information	147
Turbocharger	148
Construction	148
Function	149
Failure Diagnosis	150
How to Maintain Turbocharger	154
Special inspection of turbocharger	155

General information

General Information

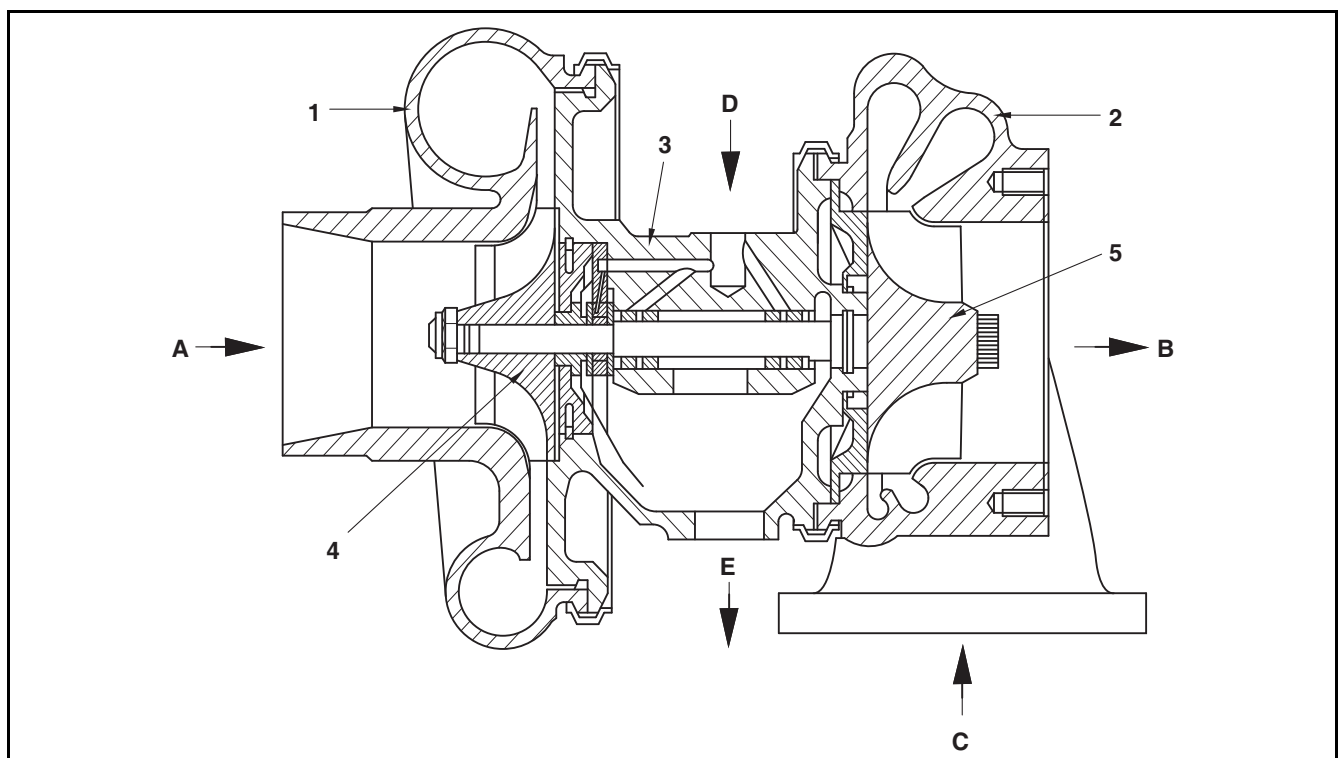
The exhaust gas of the engine passes through the turbine wing of turbocharger to rotate the turbine. At the same time, the impeller air of the compressor mounted on the other end of same shaft rotates to suck in the fresh air through air filter, and delivers it to the cylinder through inter cooler with high pressure.

The turbocharger is air-cooled. The bearing is lubricated by the lubricant supplied from the engine lubrication system.

The engine power depends on the supplied fuel amount and engine efficiency.

In order to make the supplied fuel burned completely to work for the engine efficiently, the sufficient air should be delivered to the cylinder. That is, the engine power is virtually determined by the size of cylinder. If compressed air is delivered to the cylinder with a given capacity, the air amount in the cylinder increases to burn more fuel, thereby increasing the engine power.

The method of compressing the air to supply it into the engine cylinder is called supercharging; and the method of using the exhaust gas discharged from the combustion chamber for the same purpose is called turbocharging.



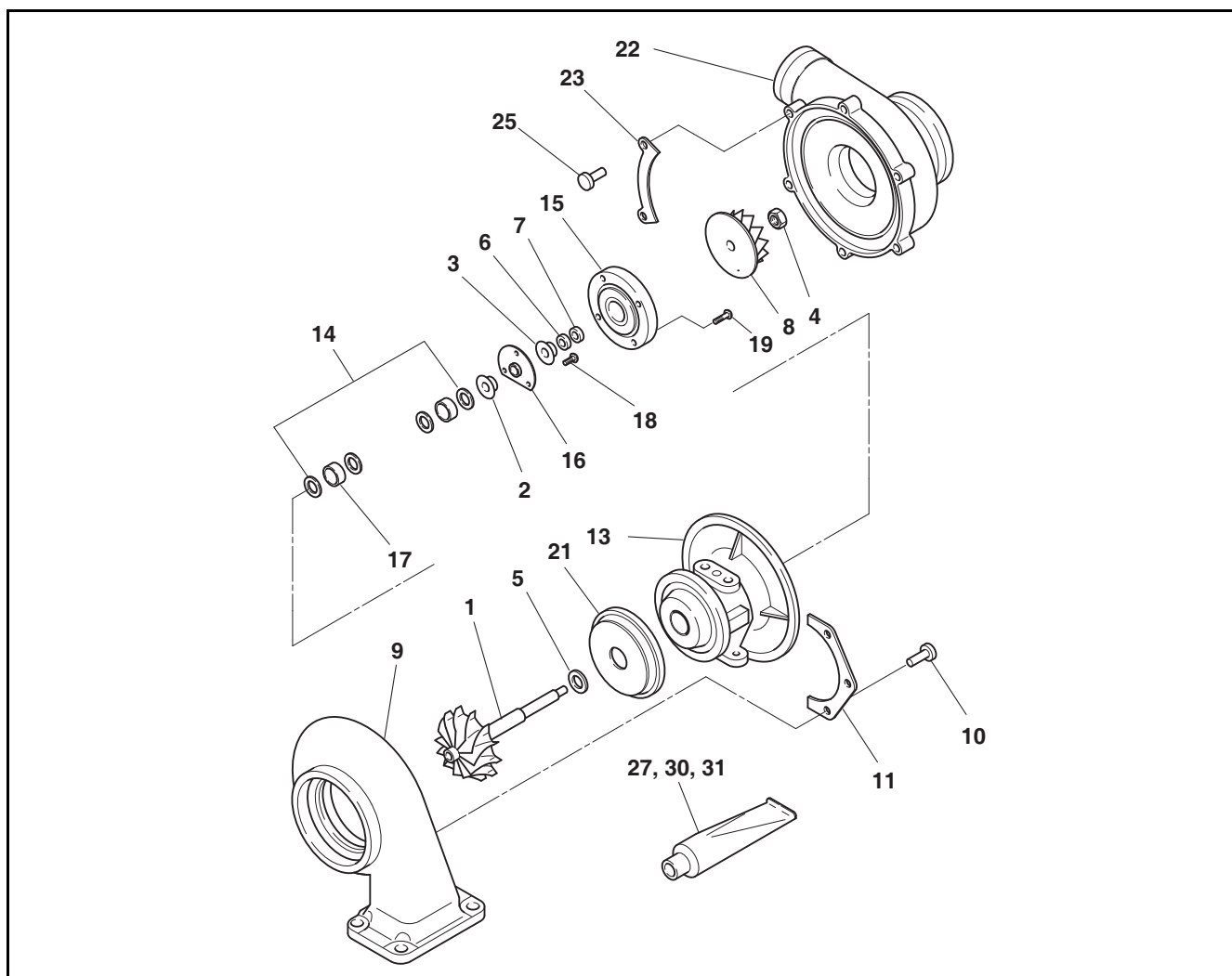
DV2213107A

No.	Name	No.	Name
1.	Compressor casing	A.	Air inlet
2.	Turbine casing	B.	Exhaust gas outlet
3.	Compressor wheel	C.	Exhaust gas inlet
4.	Impeller	D.	Engine oil delivery
5.	Turbine	E.	Engine oil recovery

9. Intake/exhaust system

Turbocharger

Construction



DV2213108A

No.	Name	No.	Name	No.	Name
1.	Turbine shaft	10.	Bolt	21.	Heat screen
2.	Thrust bush	11.	Clamp	22.	Compressor housing
3.	Oil shut off	13.	Bearing housing	23.	Clamp
4.	Fixing nut	14.	Retainer ring	24.	Bolt
5.	Seal ring	15.	Seal plate	27.	Liquid gasket
6.	Seal ring	16.	Thrust bearing	30.	Loctite
7.	Seal ring	17.	Journal bearing	31.	Liquid anti-burn agents
8.	Compressor wing wheel	18.	Screw		
9.	Turbine housing	19.	Screw		

Function

1. Turbine

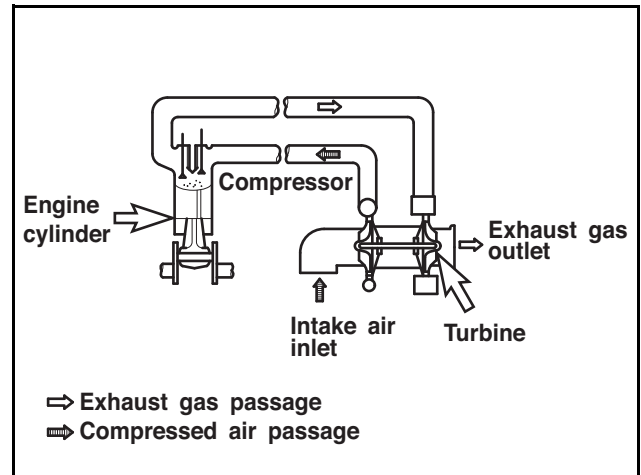
The exhaust gas that is discharged from combustion chamber passes through turbine housing conveying an energy to turbine wings to give the rotating power, This is called as the turbine and in order not to influence a bad effect at bearing part, there are the seal ring and heat dissipator.

2. Compressor

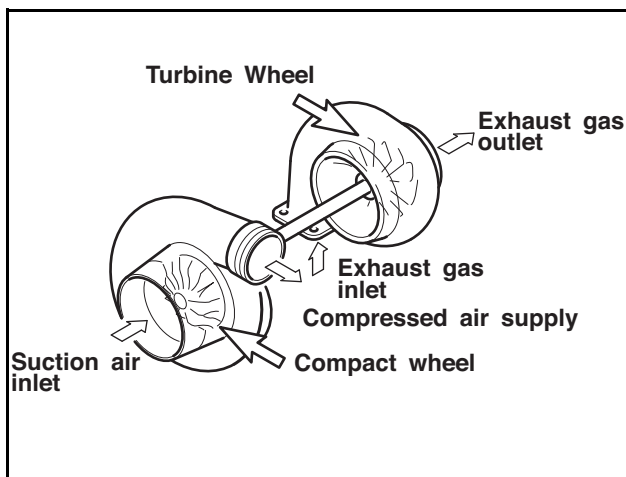
It is connected to the same shaft with the turbine to make a revolving assembly, and receive the revolving force of turbine, and sends air to the suction manifold by suctioning and compressing it. This is called as the compressor.

3. Bearing

- 1) Thrust bearing force is applied to the turbine wheel and an arrangement is made for the shaft not to shift.
 - 2) journal bearing (floating bearing) is adopted and it forms the double oil films at the in out surfaces in comparison to the general stationary type so that the bearing may be able to rotate independently and consequently the double layers of films act as the damper to make the slipping speed on the bearing surface less than the rotating speed of shaft so that the dynamic stability may be obtained.
4. Sealing at compressor shaft
- In order for the compressed intake air and lubricating oil not to leak, a seal plate and a seal ring are made to the double structures.



DV2213110A_E



DV2213109A_E

9. Intake/exhaust system

Failure Diagnosis

Phenomenon	Causes	Troubleshooting
Noise or vibration	Rotating part is contacted	Repair or replace it
	Unbalanced rotation of a rotor	Repair or replace it
	Burn	Repair or replace it
	Loose joint	Check or repair it
	Deformed or damaged intake system hose	Replace it
	Poor clamping state	Adjust and tighten the clamp
	Contaminated or damaged air filter	Replace and check if the impeller of the turbocharger is damaged
	Leakage of coolant from the turbocharger or oil from the oil hose	Replace the hose and the gasket
	Leakage of gas from the exhaust manifold	Replace the gasket or tighten the fixing nut
	Poor turbo actuator operation	Replace the turbocharger
	Leakage from the engine block and the exhaust manifold	Check the engine
	Contaminated blowby gas and abnormal oil amount	Check the turbo impeller and the turbo intake outlet
	Large gap of the turbocharger wheel, causing interference with the wall	Check if there is any sand or metallic foreign substance
	Damaged turbocharger wheel	Check if there is any sand or metallic foreign substance
	Damaged wheel and shaft of the turbocharger	Check if there is any sand or metallic foreign substance
	Poor rotating force of the turbocharger wheel	Check if there is any sand or metallic foreign substance

9. Intake/exhaust system

Phenomenon	Causes	Troubleshooting
Lowered output	Leakage of gas from each part of the exhaust system	Check or repair it
	Clogged air filter element	Replace or clean it
	Contaminated or damaged turbocharger	Repair or replace it
	Leakage of air from the discharging part of the compressor shaft	Check or repair it
	Deformed or damaged intake system hose	Replace it
	Poor clamping state	Adjust and tighten the clamp
	Contaminated or damaged air filter	Replace and check if the impeller of the turbocharger is damaged
	Poor turbo actuator operation	Replace the turbocharger
	Leakage from the engine block and the exhaust manifold	Check the engine
	Contaminated blowby gas and abnormal oil amount	Check the turbo impeller and the turbo intake outlet
	Large gap of the turbocharger wheel, causing interference with the wall	Check if there is any sand or metallic foreign substance
	Damaged turbocharger wheel	Check if there is any sand or metallic foreign substance
	Damaged wheel and shaft of the turbocharger	Check if there is any sand or metallic foreign substance
	Poor rotating force of the turbocharger wheel	Check if there is any sand or metallic foreign substance
Oil leakage	Deformed or damaged intake system hose	Replace it
	Poor clamping state	Adjust and tighten the clamp
	Contaminated or damaged air filter	Replace and check if the impeller of the turbocharger is damaged
	Leakage of coolant from the turbocharger or oil from the oil hose	Replace the hose and the gasket
	Poor turbo actuator operation	Replace the turbocharger

9. Intake/exhaust system

Phenomenon	Causes	Troubleshooting
Oil leakage	Leakage from the engine block and the exhaust manifold	Check the engine
	Contaminated blowby gas and abnormal oil amount	Check the turbo impeller and the turbo intake outlet
	Large gap of the turbocharger wheel, causing interference with the wall	Check if there is any sand or metallic foreign substance
	Damaged turbocharger wheel	Check if there is any sand or metallic foreign substance
	Damaged wheel and shaft of the turbocharger	Check if there is any sand or metallic foreign substance
	Poor rotating force of the turbocharger wheel	Check if there is any sand or metallic foreign substance
Oil consumption	Poor clamping state	Adjust and tighten the clamp
	Leakage of coolant from the turbocharger or oil from the oil hose	Replace the hose and the gasket
	Leakage from the engine block and the exhaust manifold	Check the engine
	Contaminated blowby gas and abnormal oil amount	Check the turbo impeller and the turbo intake outlet
	Large gap of the turbocharger wheel, causing interference with the wall	Check if there is any sand or metallic foreign substance
	Damaged turbocharger wheel	Check if there is any sand or metallic foreign substance
	Damaged wheel and shaft of the turbocharger	Check if there is any sand or metallic foreign substance
	Poor rotating force of the turbocharger wheel	Check if there is any sand or metallic foreign substance

9. Intake/exhaust system

Phenomenon	Causes	Troubleshooting
Black and white emissions	Deformed or damaged intake system hose	Replace it
	Contaminated or damaged air filter	Replace and check if the impeller of the turbocharger is damaged
	Leakage of coolant from the turbocharger or oil from the oil hose	Replace the hose and the gasket
	Poor turbo actuator operation	Replace the turbocharger
	Contaminated blowby gas and abnormal oil amount	Check the turbo impeller and the turbo intake outlet
	Large gap of the turbocharger wheel, causing interference with the wall	Check if there is any sand or metallic foreign substance
	Damaged turbocharger wheel	Check if there is any sand or metallic foreign substance
	Damaged wheel and shaft of the turbocharger	Check if there is any sand or metallic foreign substance
	Poor rotating force of the turbocharger wheel	Check if there is any sand or metallic foreign substance
Blue emissions	Leakage from the engine block and the exhaust manifold	Check the engine
Too much fog	Oil leakage to the turbine or compressor	Repair or replace it
	Worn or damaged seal ring due to worn bearing	Repair or replace it
Too much exhaust emissions	Clogged air filter element	Replace or clean it
	Clogged air duct	Check or repair it
	Air leakage from the intake system	Check or repair it
	The turbocharger cannot rotate because of burning	Repair or replace it
	A turbine blade or compression wing contacts with the other one or is damaged	Repair or replace it
	Deformed or clogged exhaust system pipe	Check or repair it

9. Intake/exhaust system

How to Maintain Turbocharger

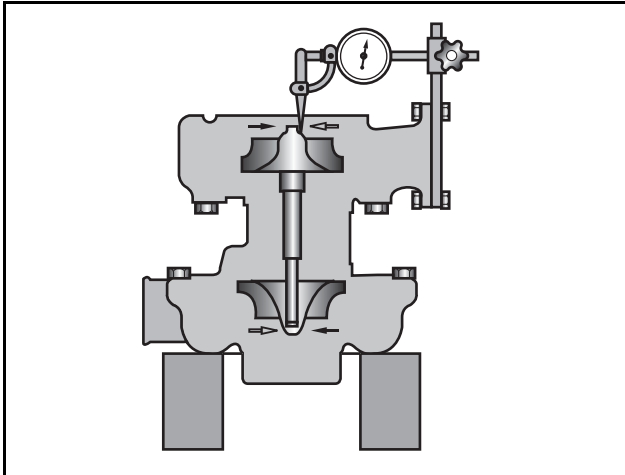
1. Cautions for engine operation

- 1) Observe the followings when starting, operating, and stopping an engine.

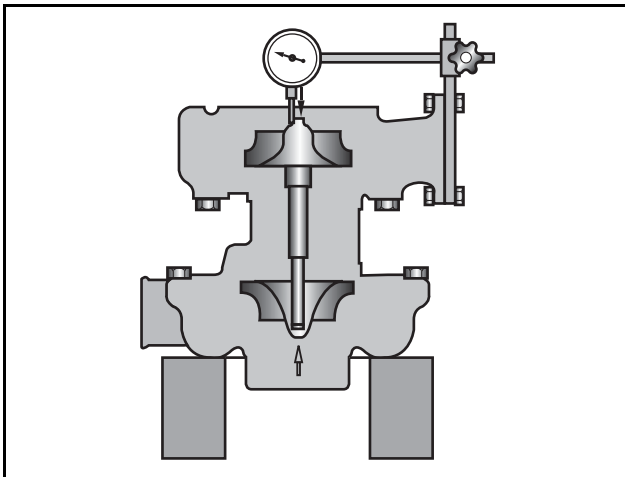
Item	Cautions	Reasons
Starting an engine	1) Check the oil amount	
	2) Therefore, start the engine with the starter motor to check the rise of oil pressure (until the gradation of the oil pressure gauge moves or the pressure indicator lamp is turned on).	2) Overhasty start of engine leads to engine rotation without lubricating turbocharger and other engine parts, causing abnormal wear or burning of bearings.
	3) If you replace oil, oil filter cartridge, or lubrication system parts or use an engine in cold areas, or the engine has stopped for a long period, loosen the oil pipe joint at the inlet of the turbocharger and run the starter motor until oil flows out. After completing the work, tighten the oil pipe joint again and start the engine.	3) When an engine has stopped or kept cold for a long period, circulation of oil in the pipe gets poor.
After starting an engine	1) Operate the engine at idle for five minutes from starting it.	1) When the engine is suddenly loaded while the engine and the turbocharger have not been smoothly rotated after starting the engine, parts with insufficient oil may be burnt.
	2) Check if oil, gas, or air is leaked from each part. If so, take proper action.	2) Leakage of oil, gas, or air (especially oil) reduces oil pressure and loss of oil cause burning of bearings.
During Operation	check the following.	
	1) Oil pressure At idle: 1.5 ~ 3.0 kg/cm ² Fully loaded: 3.0 ~ 5.5 kg/cm ²	1) Too low oil pressure causes abnormal wearing or burning of bearings. Too high oil pressure causes oil leakage.
	2) When abnormal noise or vibration occurs, slowly reduce the rotate count until the engine stops and then figure out the causes.	2) Operating an engine with noise or vibration may cause irreversible damage of the engine.
Stopping an Engine	1) Operate the engine at idle for five minutes before stopping it.	1) Sudden engine stop after operating the engine under high load allows the heat from the red-heated turbine blade to be delivered to the bearing system. Then oil burns and the bearing metal and rotation shaft are burnt.

Special inspection of turbocharger

You should check the radial and axial clearance of a rotor. This preventive action is to find the bearing wear status of the axial clearance so as to prevent the severe damage to the rotor and bearing.



DV2213034A

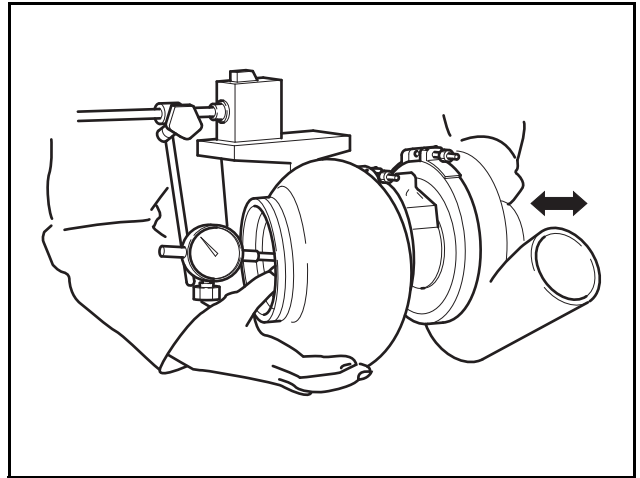


DV2213035A

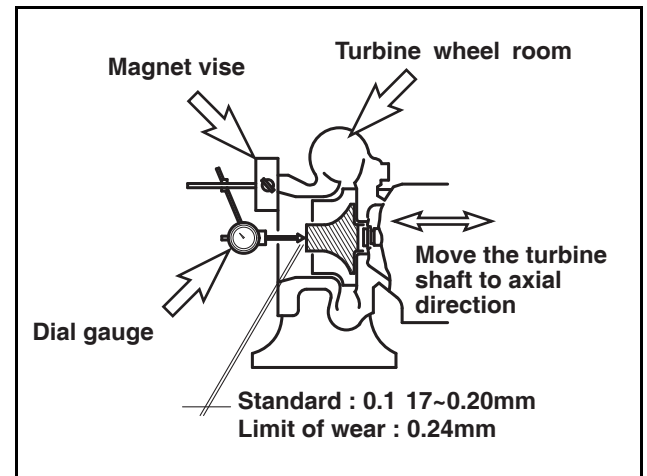
1. Guide for checking the rotor for rotating condition
The inspection of the rotor assembly for rotating condition should be performed by the degree of unusual sound. If a sound detecting bar is used, install its tip on the turbocharger housing and increase the engine revolutions slowly. If a high-pitch 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 play

Limit of wear	0.24 mm
---------------	---------



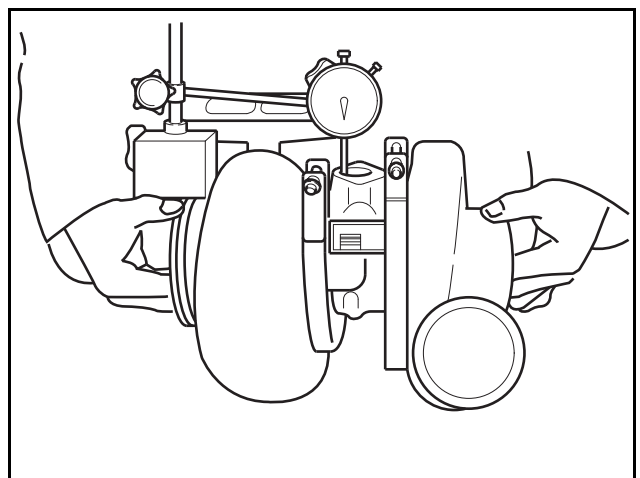
DV2213036A



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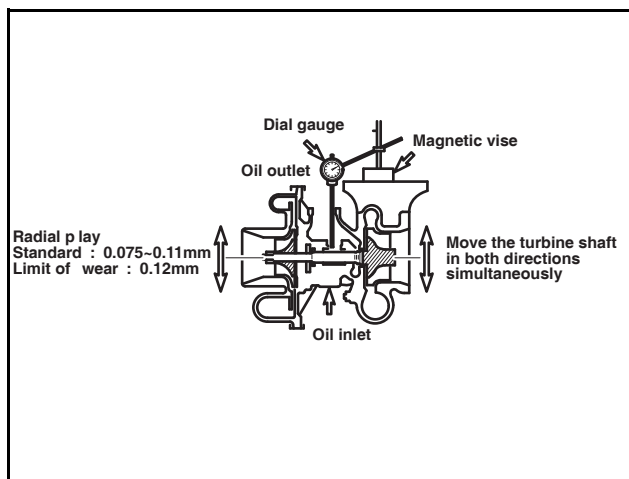
2) Rotor radial play

Limit of wear	0.12 mm
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DV2213038A

9. Intake/exhaust system



EA8M4004

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

10. Cylinder block/head

General information	159
General Information	159
Cylinder block	160
Check of Cylinder Block	160
Measurement of Cylinder Liner	160
Cylinder head	161
Disassembly of cylinder head	161
Assembly of cylinder head	161
Check of cylinder head	161
Valve	163
General Information	163
Check of Valve	163
Check of Valve Guide	163
Valve seat	163
Valve Spring	164
Rocker arm	166
Disassembly rocker arm	166
Assembly rocker arm	166
Check of rocker arm	166
Check of rocker arm shaft	166
Tappet and push rod	168
Tappet clearance	168
Visual inspection of tappet	168
Outside diameter of tappet	168
Warpage of Push Rod	168
Camshaft	169
Camshaft end play	169
Check of camshaft	169
Check of cam	169

General information

General Information

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

10. Cylinder block/head

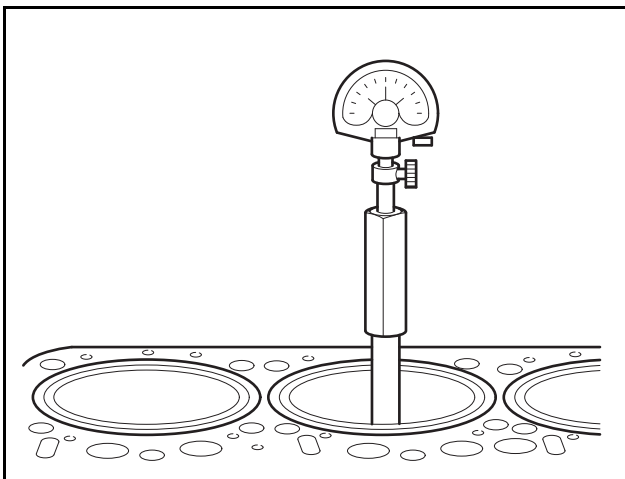
Cylinder block

Check of Cylinder Block

1. Cleanse the cylinder block and check if there is any cracked or damaged part with naked eye.
2. Replace the cylinder block if it is seriously cracked or damaged. Repair tiny cracks if existing.
3. Check if the oil path or coolant path is clogged or corroded.
4. Perform the hydrostatic test to check whether there is a crack or an air leakage.
5. Block the discharging outlets of the cooling water path and the oil path of the cylinder block and put pressure of 4 kg/cm² on the inlet. Then sink the cylinder block in the 70 °C water for 1 minute and check if air leaks.

Measurement of Cylinder Liner

1. Assemble the cylinder liner at the cylinder block and measure inner diameter at upper, middle, lower that is, 3 step by 45° interval.



DV2213111A

2. Calculate the average values after eliminating the maximum and minimum values.
3. If the measured values are very close to the limit value or beyond, replace it.

Standard	Limit
Ø111.000 ~ Ø111.022mm	Ø111.122mm

Cylinder head

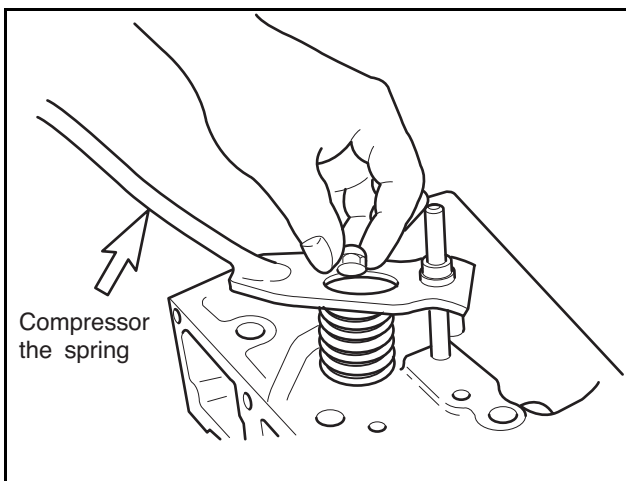
Disassembly of cylinder head

1. Disassemble the cylinder assembly, and put it on the shelf for assembly or clean lathe.

CAUTION

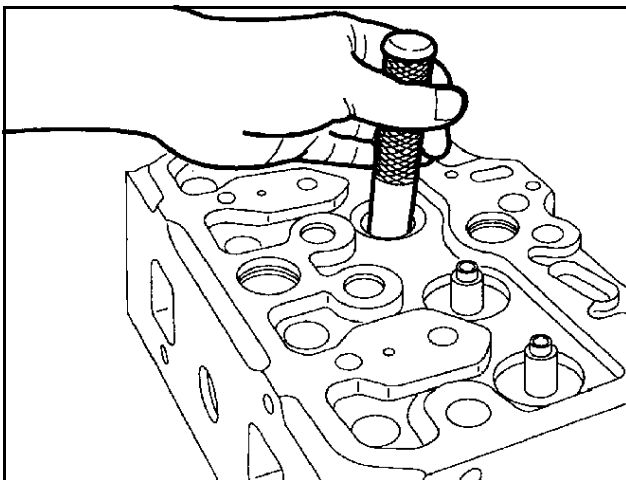
Prevent any damage to gasket's contact surface of the cylinder head.

2. Disassemble the cotter pin, spring, spring seat pushing valve spring by a special tool.



EA0M4007

3. Pull out the intake and exhaust valves.
4. The disassembled parts are kept laid in turn.
5. Disassemble the valve stem seal.
6. By means of the special tool, punch, pull out a valve guide.



EB5M3019

Assembly of cylinder head

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

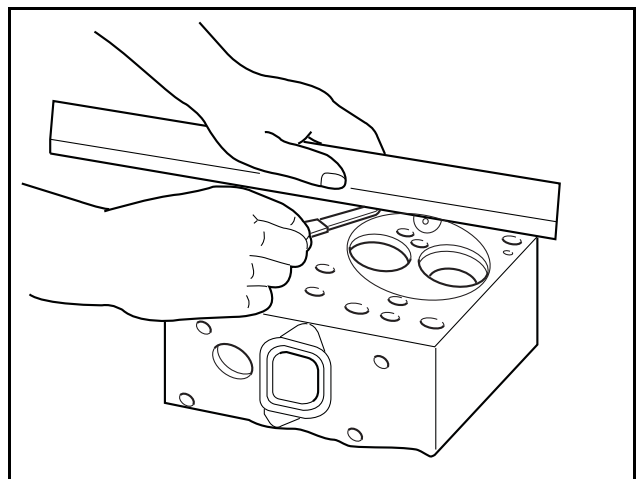
Check of cylinder head

1. Check for the cylinder head
 - 1) Remove carbon from the cylinder head lower surface.
 - 2) Check any crack or damage that can not found by naked eyes through the hydraulic or magnetic particle test.

CAUTION

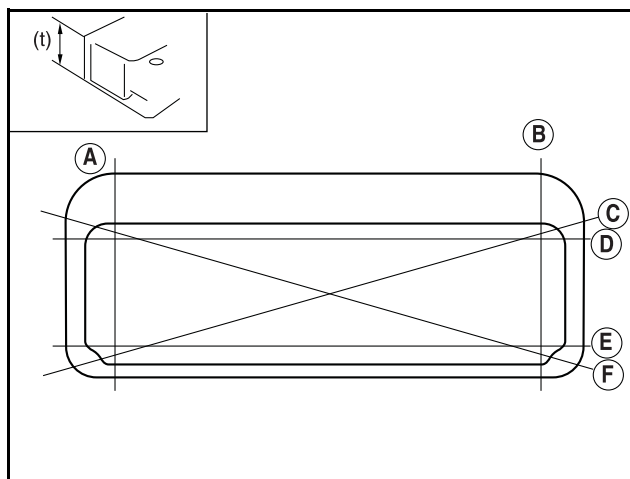
Be careful to magnetic particle test.

2. Distortion of lower surface



DV2213115A

10. Cylinder block/head



DV2213116A

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

	Standard	Limit
Warp	0.2 mm or less	0.3mm
Thickness : t (reference)	109.9 ~ 110.1mm	108.4mm

3. Flatness

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

Standard	Limit
0.05mm	0.2mm

4. The hydraulic test

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

Valve

General Information

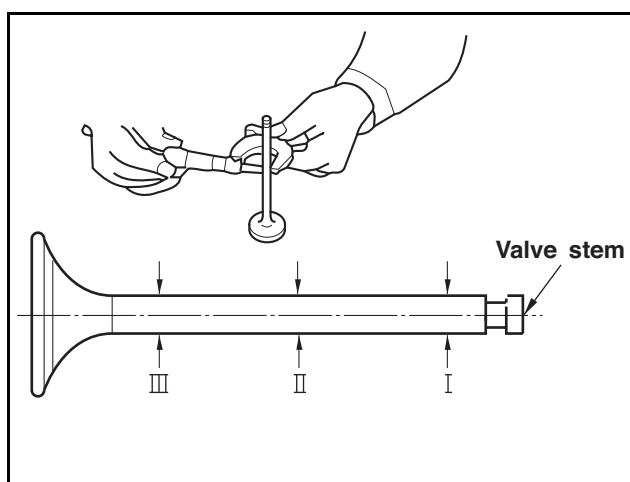
The overhead valves are actuated via chilled cast iron tapets, push rods and rocker arms from the camshaft.

Check of Valve

After cleaning the valves with clean diesel oil, measure the valve as follow.

1. Valve stem outer diameter
 - 1) Measure the valve stem's outside diameter at upper, middle, and lower to determine the wears and when the wear limit is more than limit, replace the valves.

Item	Standard	Limit
In.	Ø8.950 ~ Ø8.970 mm	Ø8.92 mm
Ex.	Ø8.935 ~ Ø8.955 mm	Ø8.895 mm



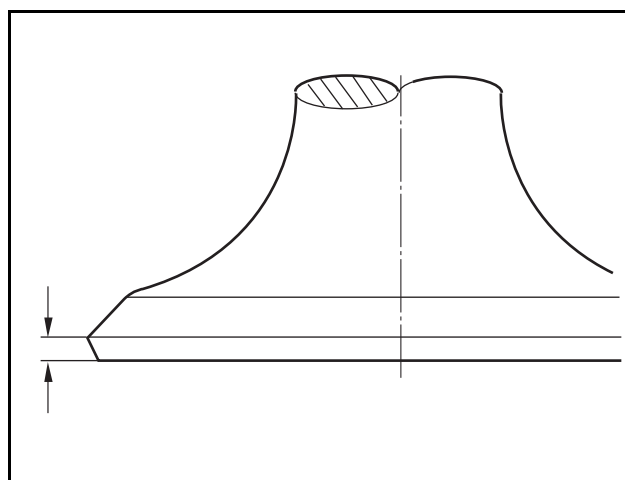
DV2213117A_E

2. Valve seat contacting faces
 - 1) inspect the scratch and wear of valve stem seal contacting face, and if necessary correct with the grinding paper but if severe replace it.
3. Valve head thickness
 - 1) if valve head thickness becomes less than limit, replace the valve.

Item	Standard	Limit
In.	2.7 mm	0.5 mm or less
Ex.	2.2 mm	0.5 mm or less

⚠ CAUTION

If the damage is severe, replace new one.

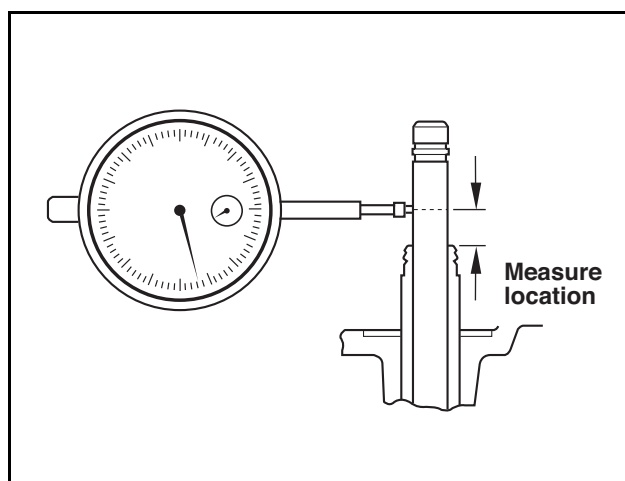


DV2213118A

Check of Valve Guide

1. 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.

Item	Standard	Limit
In.	0.04 ~ 0.07 mm	0.1 mm
Ex.	0.06 ~ 0.09 mm	0.15 mm



DV2213119A_E

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

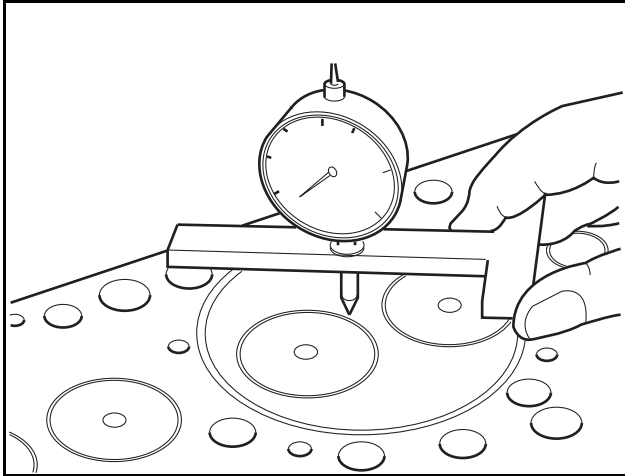
Valve seat

1. Contacting face amount
 - 1) As for the valve seat's wear, measure the width of the contact surface with intake valve seat and exhaust valve seat. If beyond the limit value, replace the valve seat.

10. Cylinder block/head

2. Valve depression

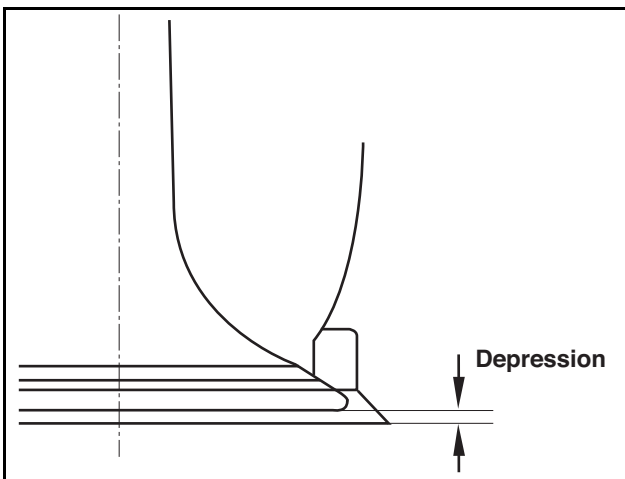
- 1) Assemble the valve at the valve seat of the cylinder head, and check the amount of depression of the valve from the lower portion of the cylinder head using a dial gauge.



EDM2032P

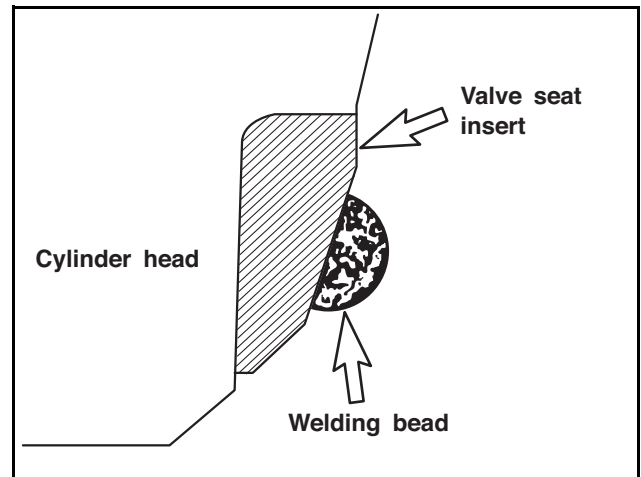
- 2) If the amount of depression is beyond the specified limit, replace the valve seat.

	Standard	Limit
Intake & Exhaust	0~0.3mm	0.55mm



EA0M4046

3. Valve seat disassembly



EA3M2032

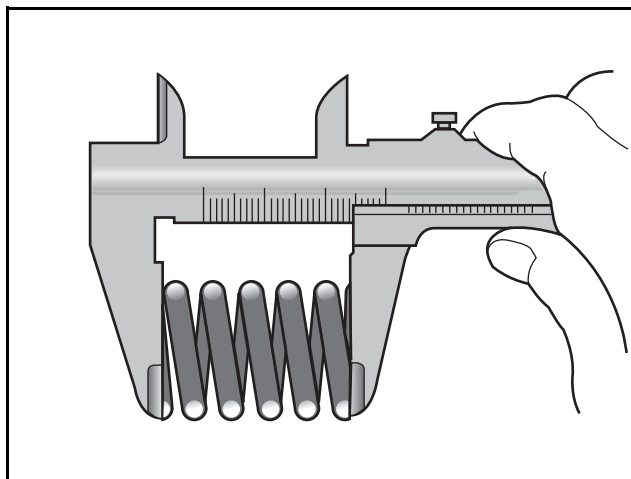
- 1) For the disassembling of valve seat, by welding the welding bead to a valve seat rotating tool or valve seat, pull it out with a special tool.
4. Valve seat assembly
 - 1) For the assembling of a new valve seat, by putting it among the dry ices of an ice box previously for about 2 hours for the cold shrinkage, and press it in the cylinder head by a special tool. (bench press)
 - 2) Apply valve lapping compound to the valve head seating face on the valve seat and lap the valve seat by turning it until it is seated in position, then wipe out the lapping compound.

Valve Spring

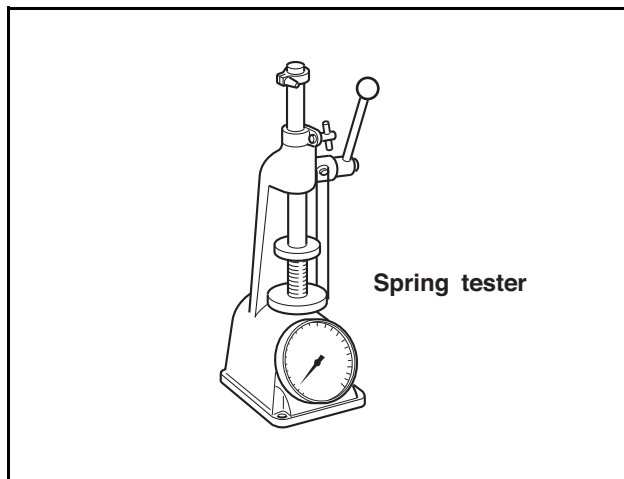
1. Visual check
 - 1) Check the appearance of valve spring and if necessary replace the spring.
2. Valve spring free length
 - 1) Use a vernier caliper to measure the valve spring free length.
 - 2) If the measured value is less than the specified limit, the valve spring must be replaced.

Spring free Length		Standard
Intake valve		64 mm
Exhaust valve	Inner	60 mm
	Outer	71 mm

10. Cylinder block/head



DV2213123A

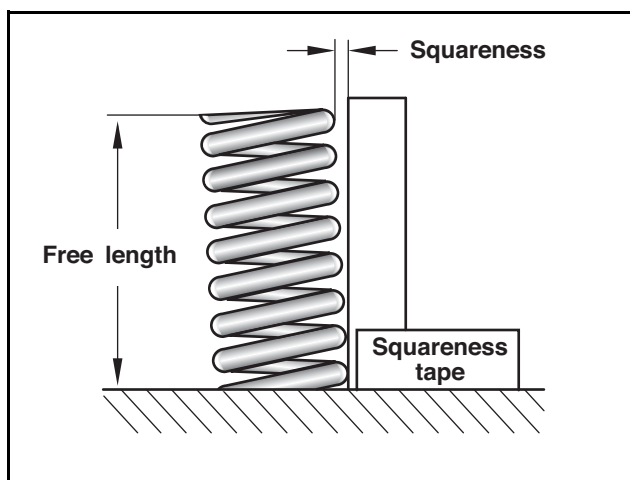


DV2213125A_E

3. Valve spring inclination

- 1) Use a surface plate and a square to measure the valve spring inclination.
- 2) If the measured value exceeds the specified limit, the valve spring must be replaced.

	Standard	Limit
Valve Spring Inclination	less than 1.8 mm	2.7 mm



DV2213124A_E

4. Valve spring tension

- 1) Use a spring tester to measure the valve spring tension.
- 2) If the measured value is less than the specified limit, the valve spring must be replaced.

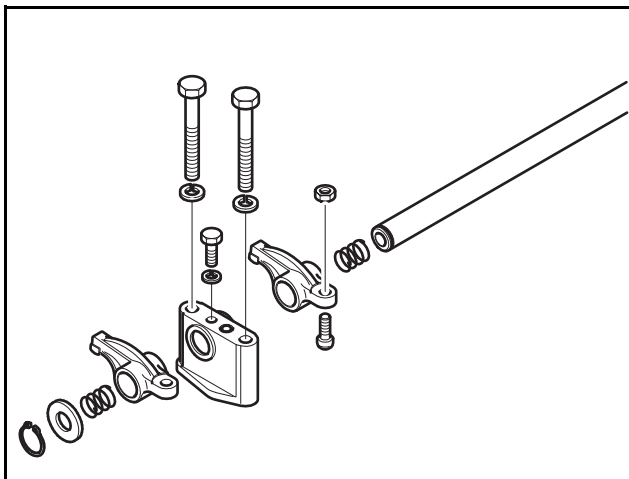
	Set Length		Spring force	Limit
Intake valve	Valve spring tension at 41mm set length		70kg	±3%
Exhaust valve	Inner	38mm	28.6kg	±6%
	Outer	41mm	66kg	±5%

10. Cylinder block/head

Rocker arm

Disassembly rocker arm

1. Disassemble the snap rings that are located at both ends of rocker arm shaft by a plier.
2. Disassemble in the order of washer, rocker arm bracket, rocker arm spring, rocker arm.



EA8M3008

Assembly rocker arm

1. Reassembling can be done in the reverse order of disassembling and following things should be heeded.

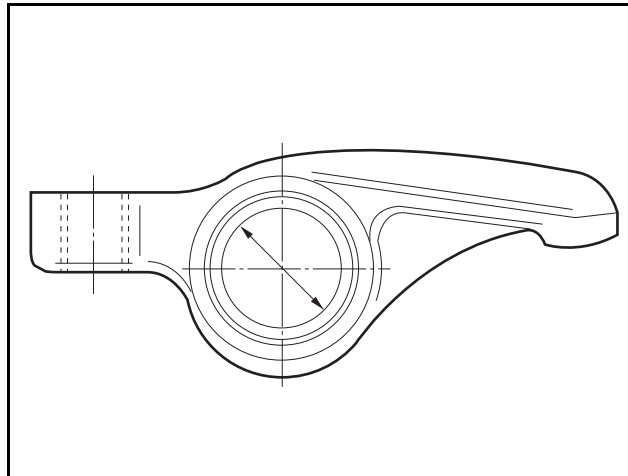
⚠ CAUTION

- Check the oil supply hole of rocker arm shaft for any clog and clean thoroughly.
- Be careful not to occur any swap of position and reverse assembly.

Check of rocker arm

1. Visual check
 - 1) Visually check the face of the rocker arm in contact with the valve stem end for scores and step wear.
 - 2) If the wear is small, correct it with an oil stone or grinding paper of fine grain size. Rocker arm with a considerable amount of step wear should be replaced.
2. Rocker arm bushing diameter
 - 1) Measure the inside diameter of the rocker arm bushing with an inside micrometer or vernier calipers, and compare the measured values with the rocker arm shaft diameter.
 - 2) If the clearance exceeds the limit, replace either bushing or shaft, whichever worn more.

Standard	Limit
0.040~0.113 mm	0.226 mm or less

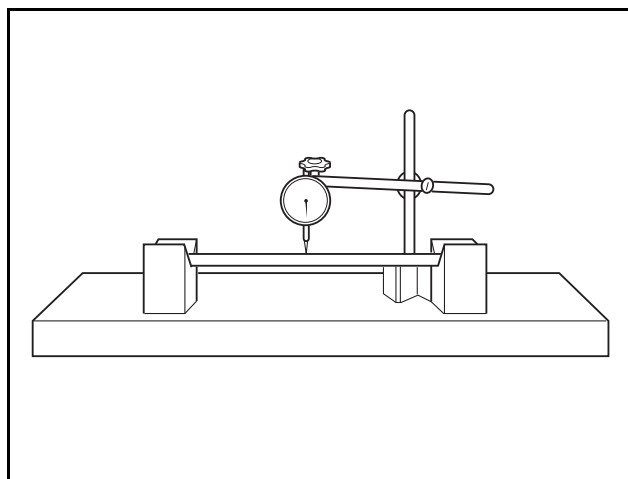


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Check of rocker arm shaft

1. Rocker arm shaft run-out
 - 1) Place the rocker arm shaft on two V blocks and inspect the shaft for bend using a dial gauge.
 - 2) If the amount of this run-out is small, press the shaft with a bench press to correct the run-out. Replace the shaft if the measured value exceeds the limit.

Limit	0.2 mm
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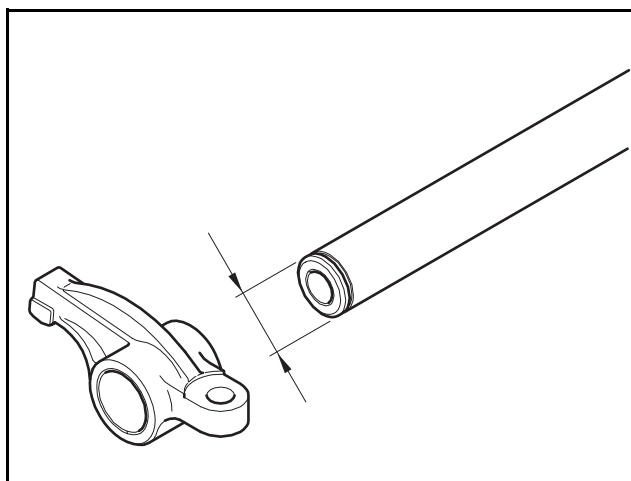


EDM2037I

2. Rocker arm shaft diameter
 - 1) With an outside micrometer, measure the rocker arm shaft diameter at the point where the rocker arms have been installed. Replace the rocker arm if the amount of wear is beyond the specified limit.

10. Cylinder block/head

Standard	Limit
Ø23.978 ~ Ø23.959 mm	Ø23.90 mm



EA9M3014

10. Cylinder block/head

Tappet and push rod

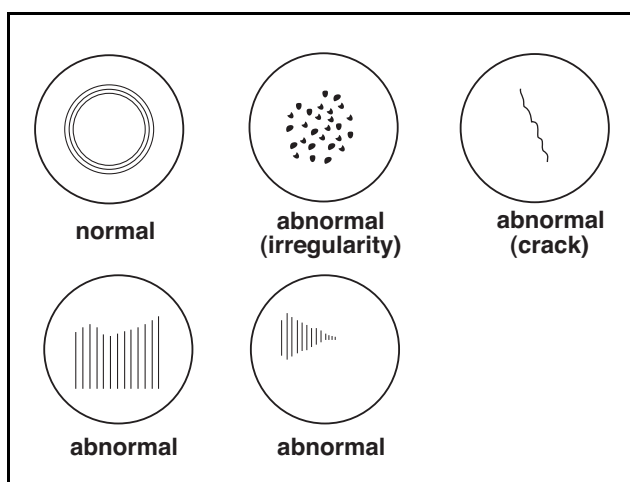
Tappet clearance

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

Standard	Limit
0.035mm ~ 0.077mm	0.15mm

Visual inspection of tappet

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

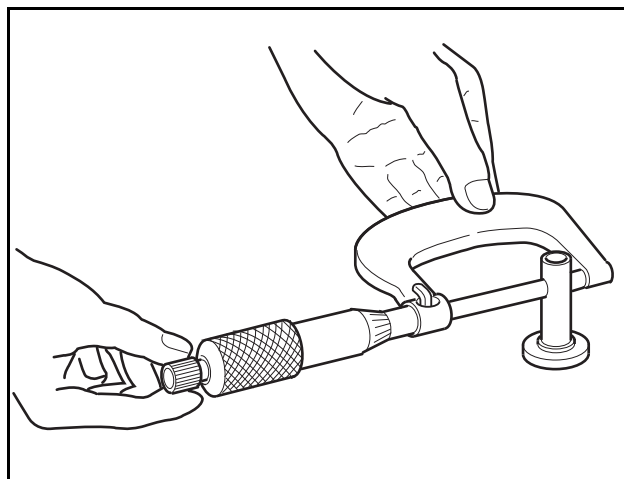


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Outside diameter of tappet

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

Standard	Ø19.944 ~ Ø19.965mm
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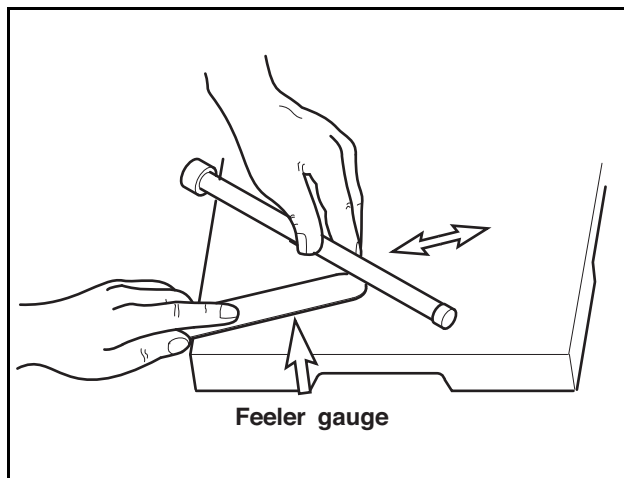


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Warpage of Push Rod

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

Limit	Below 0.3mm
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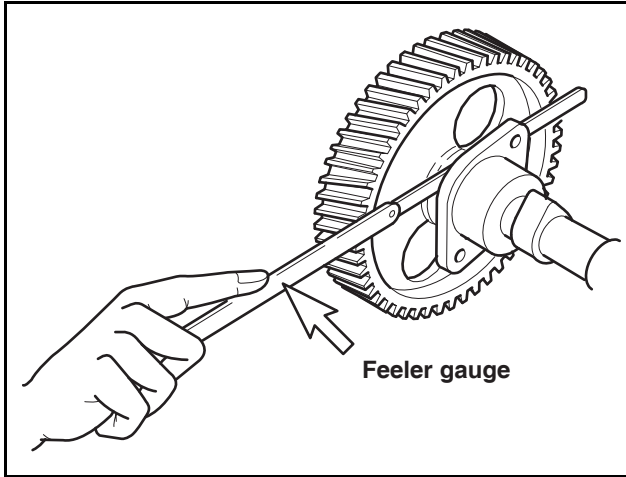


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Camshaft

Camshaft end play

1. Push the thrust plate toward the cam gear.
2. With a feeler gauge, measure the clearance between the thrust plate and camshaft journal.



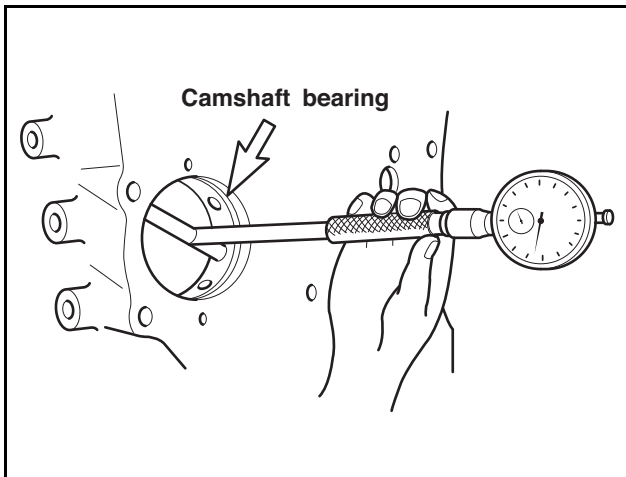
EA0M4067

3. If the end play is excessive, replace the thrust plate.

Standard	Limit
0.28 ~ 0.43mm	0.6 mm

Check of camshaft

1. Clearance between camshaft journal and camshaft bush

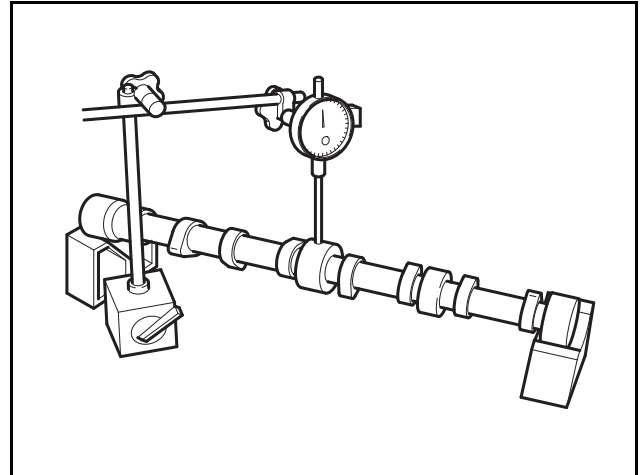


EA0M4063

- 1) With an outside micrometer, measure the camshaft journal diameter.
- 2) Measure the inside diameter of the camshaft bushing on the cylinder block using a cylinder bore indicator, and compare the measured value with the camshaft outside diameter to determine the clearance.
- 3) Replace the bushing if the measured value is beyond the specified limit.

Standard	Limit
0.060~0.115 mm	0.230 mm

2. Run-out



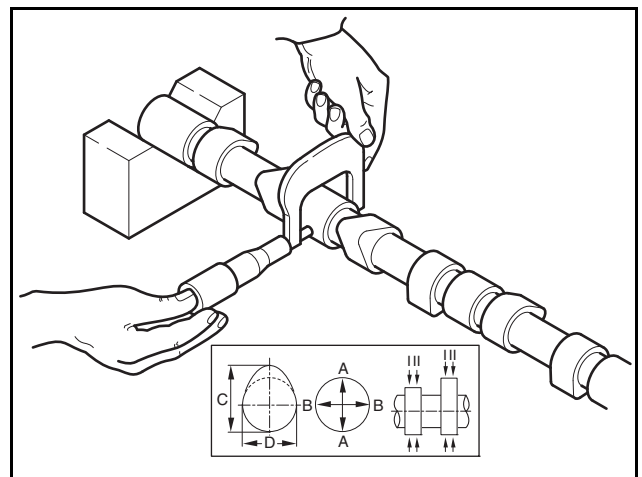
DV2213136A

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

Standard	Limit
0.05 mm	0.5 mm

Check of cam

1. Cam lobe height



DV2213132A

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

10. Cylinder block/head

		Standard	Limit
Cam lobe height (C)	Intake	49.15 mm	48.85 mm
	Exhaust	49.32 mm	49.00 mm
Cam journal diameter (A,B)		Ø57.86 ~ Ø57.88 mm	Ø57.52 mm

2. Cam surface

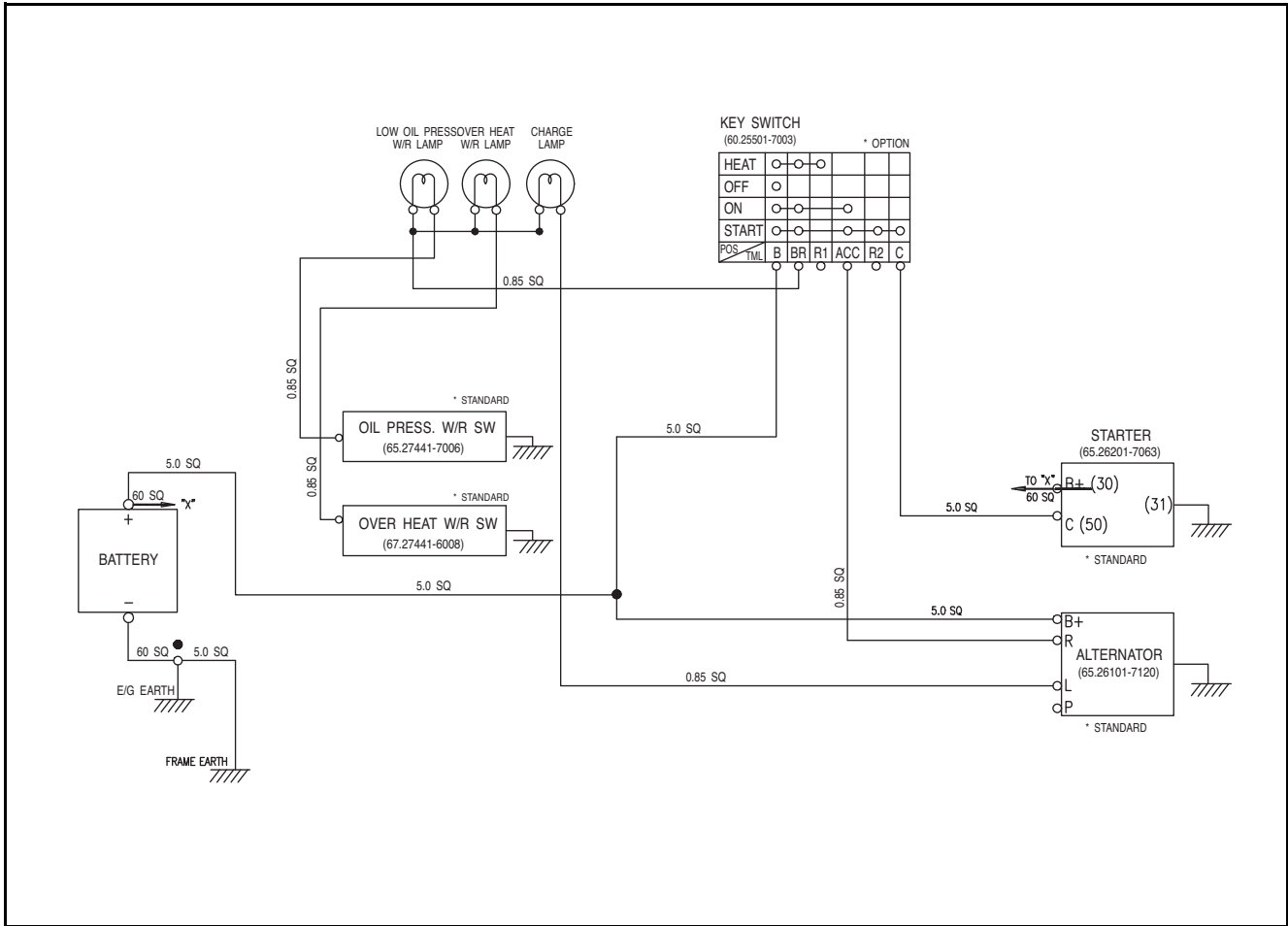
- 1) Inspect the cam face for scratch or damage. Slight step wear or damage on the cam face may be corrected with oil stone or oiled grinding paper. But, replace if severely damaged.

11. Electric system

General information	173
Electronic wiring diagram	173
Starter	174
General Information	174
Views	174
Wiring diagram	176
Alternator	178
General Information	178
Views	178
Wiring diagram	179
Air Heater	180

General information

Electronic wiring diagram



EA9O2008

11. Electric system

Starter

General Information

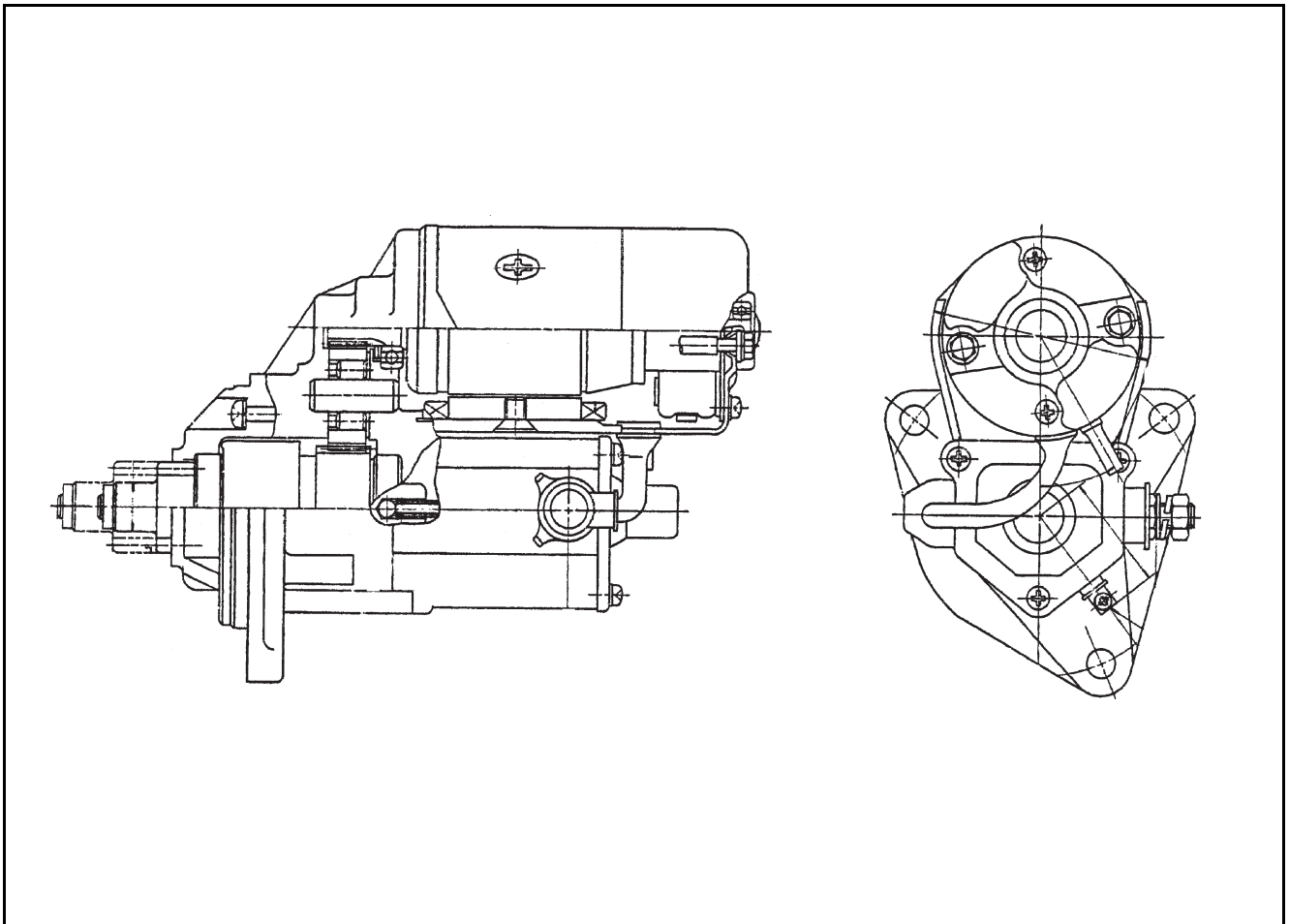
The starter is attached to the back of the flywheel housing. When disassembling the engine, immerse the pinion gear and ring gear of the starter in fuel, brush them, and then apply greases to them in order to prevent rust.

CAUTION

- Starter should be protected from humidity all the time.
 - Before working on the electric system, be sure to disconnect the ground wire("-" minus wire) of the battery. Short circuit may occur while working on the electrical system. Connect the ground wire last after completing all of work.
-

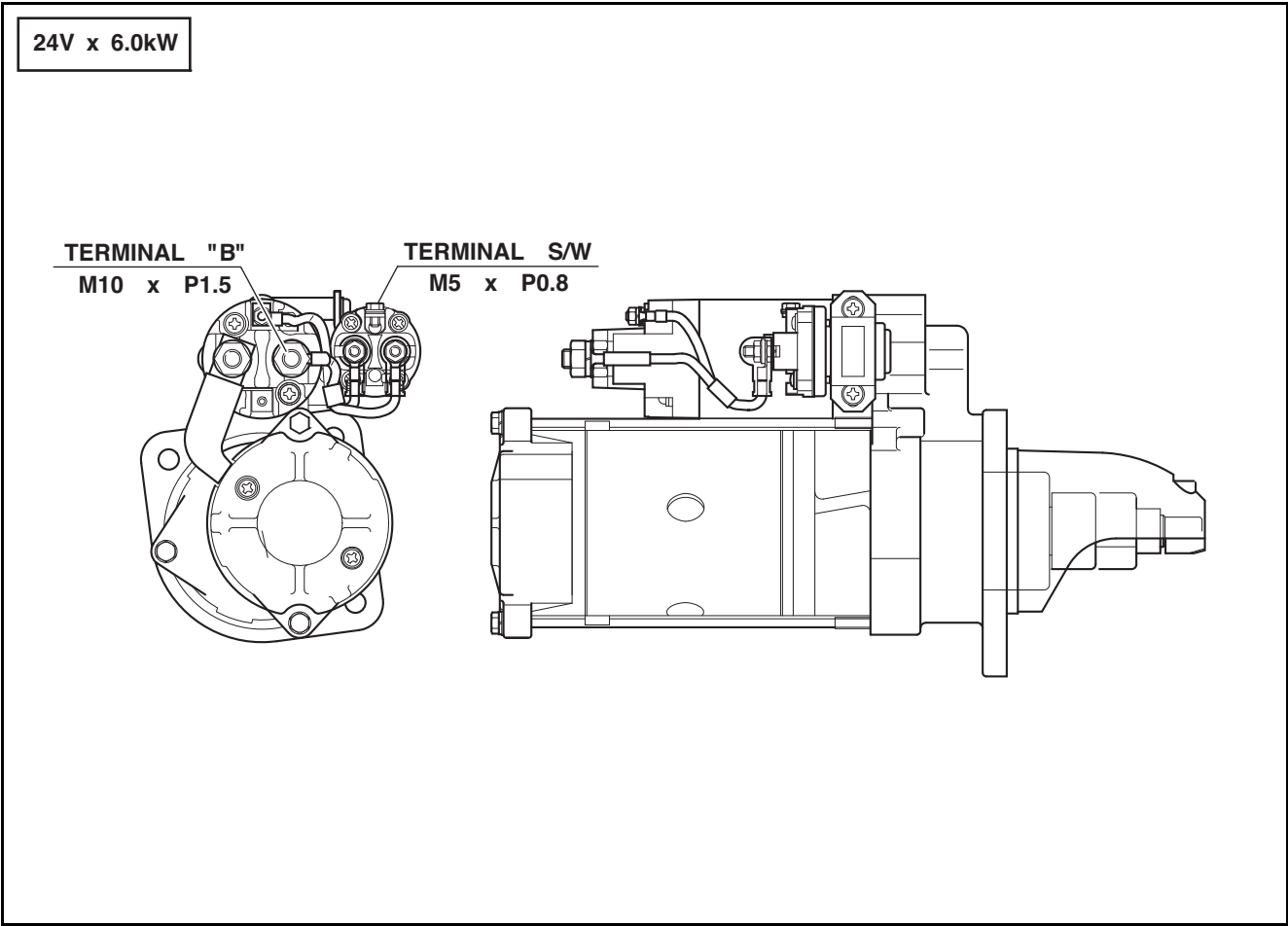
Views

- D1146/D1146T/PU086/PU086T

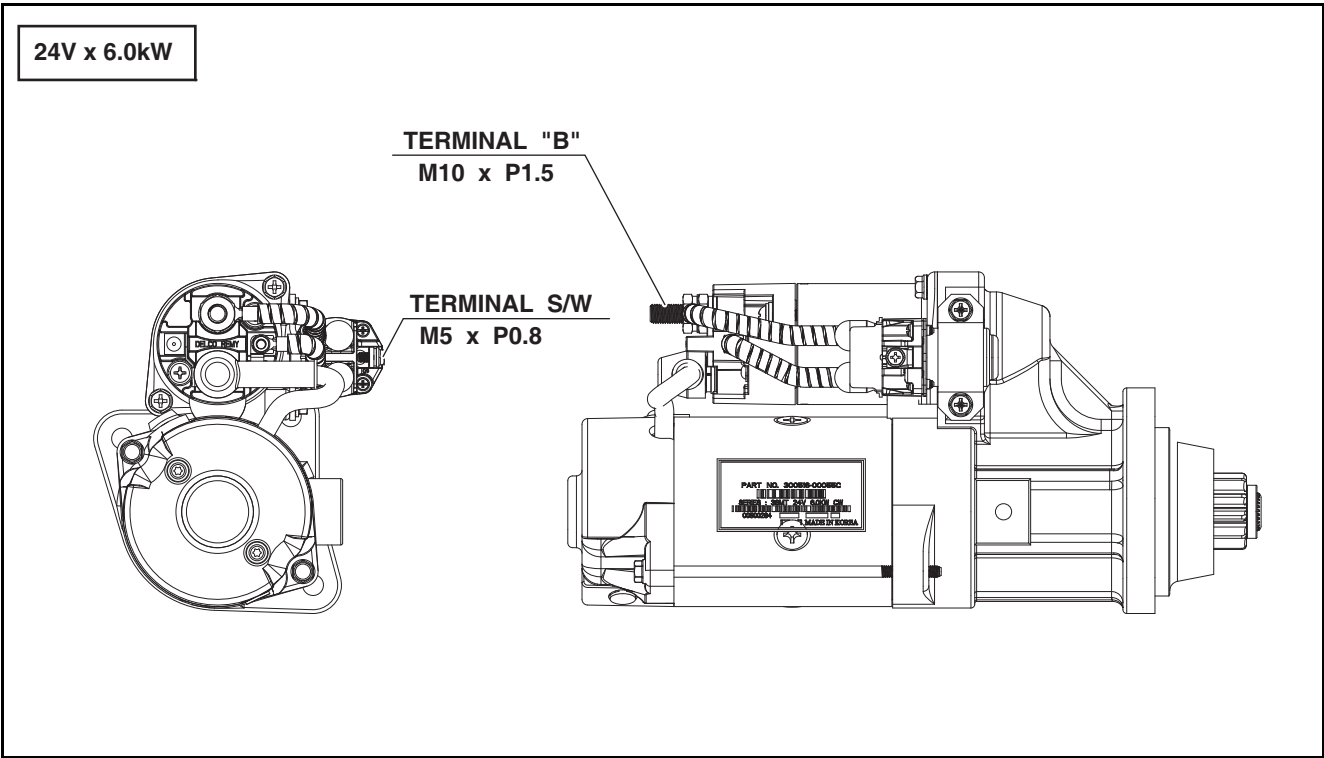


EA902009

- P086TI



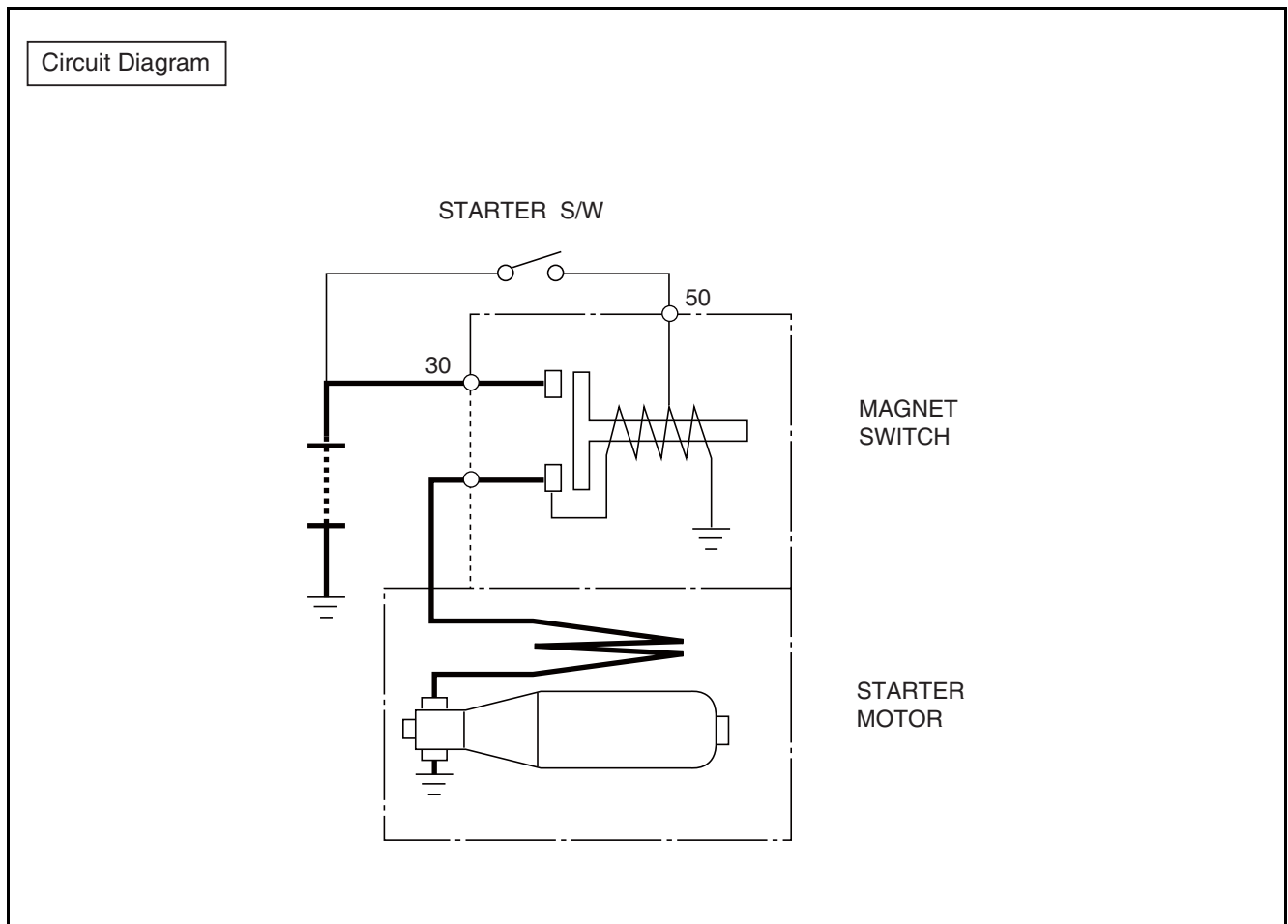
- PU086TI



11. Electric system

Wiring diagram

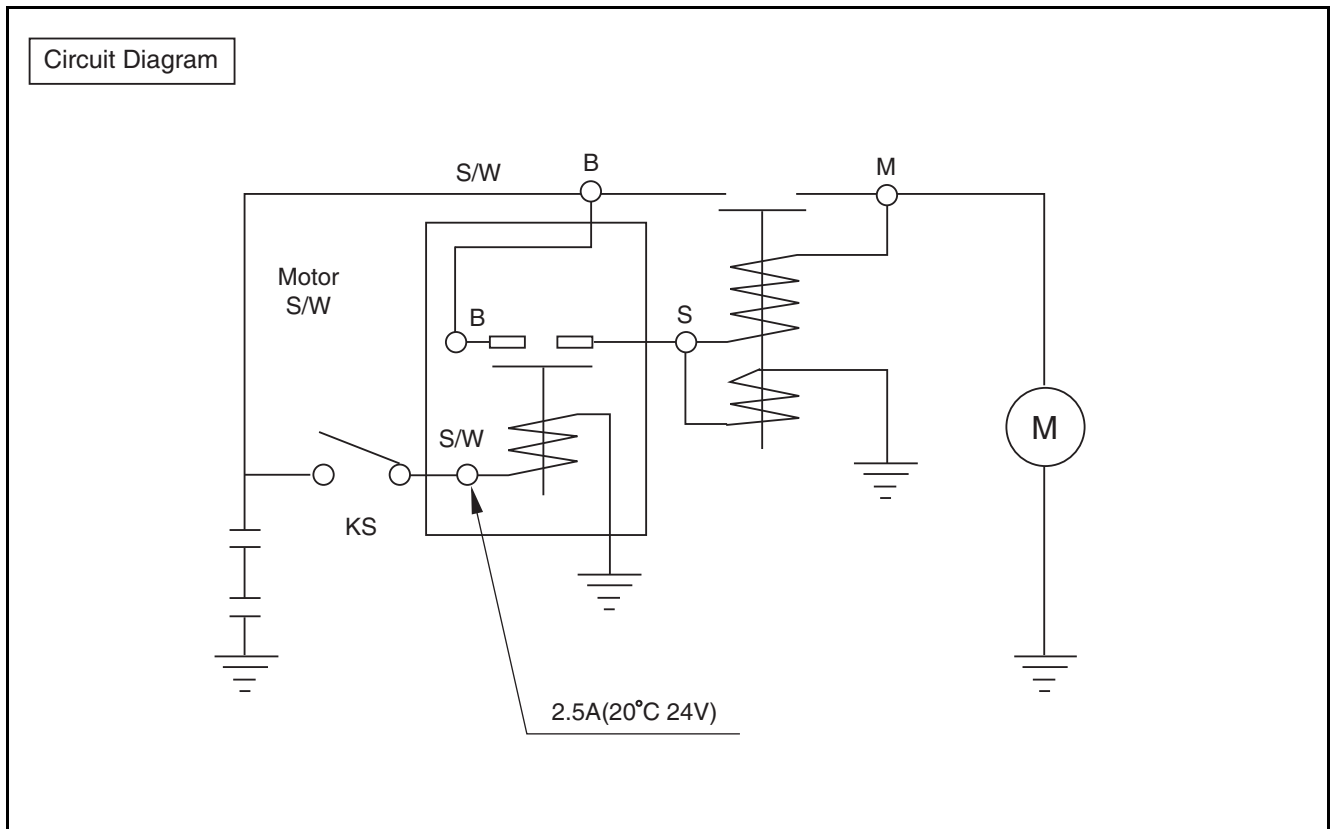
- D1146/D1146T/PU086/PU086T



EDE08220005

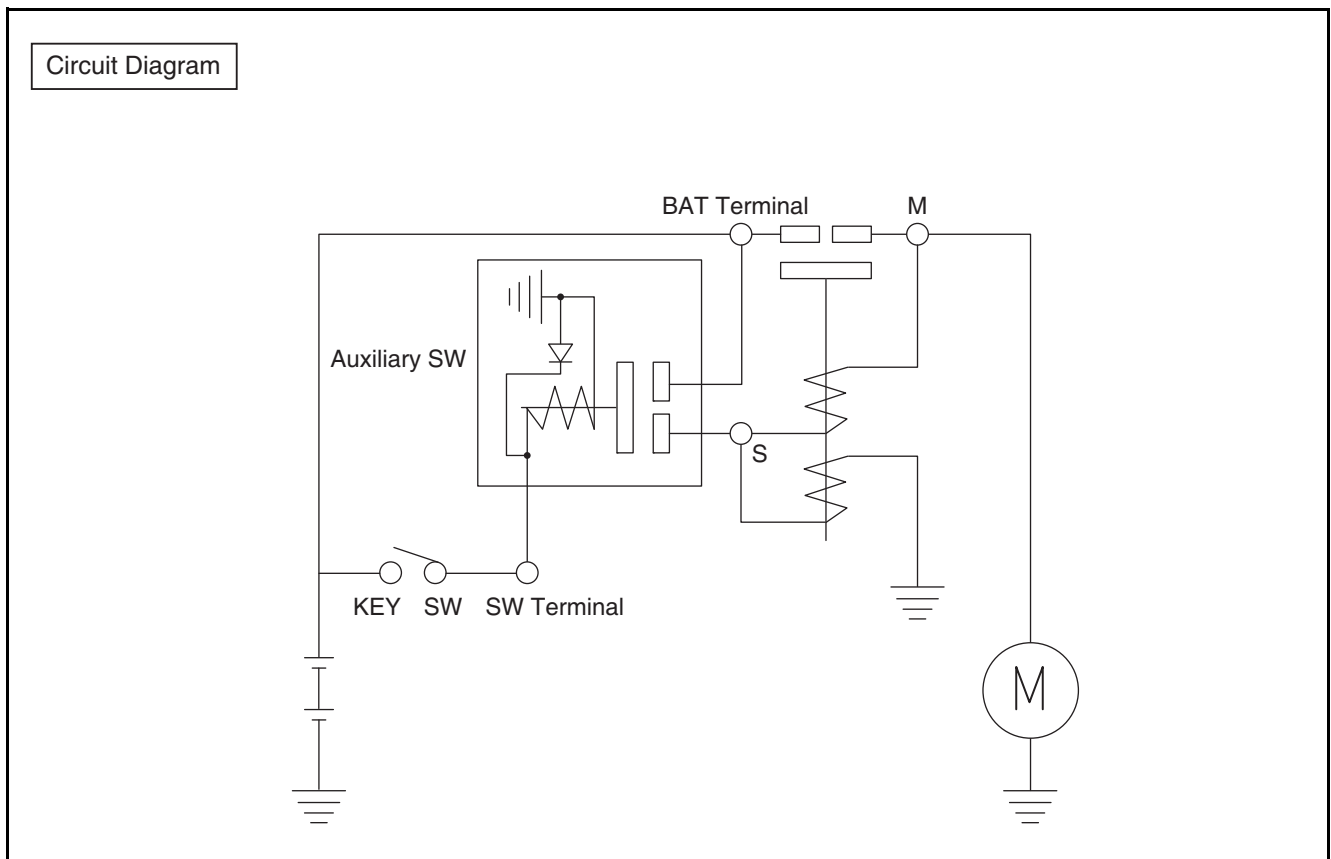
11. Electric system

- P086TI



EDE08220006

- PU086TI



EDL08220027

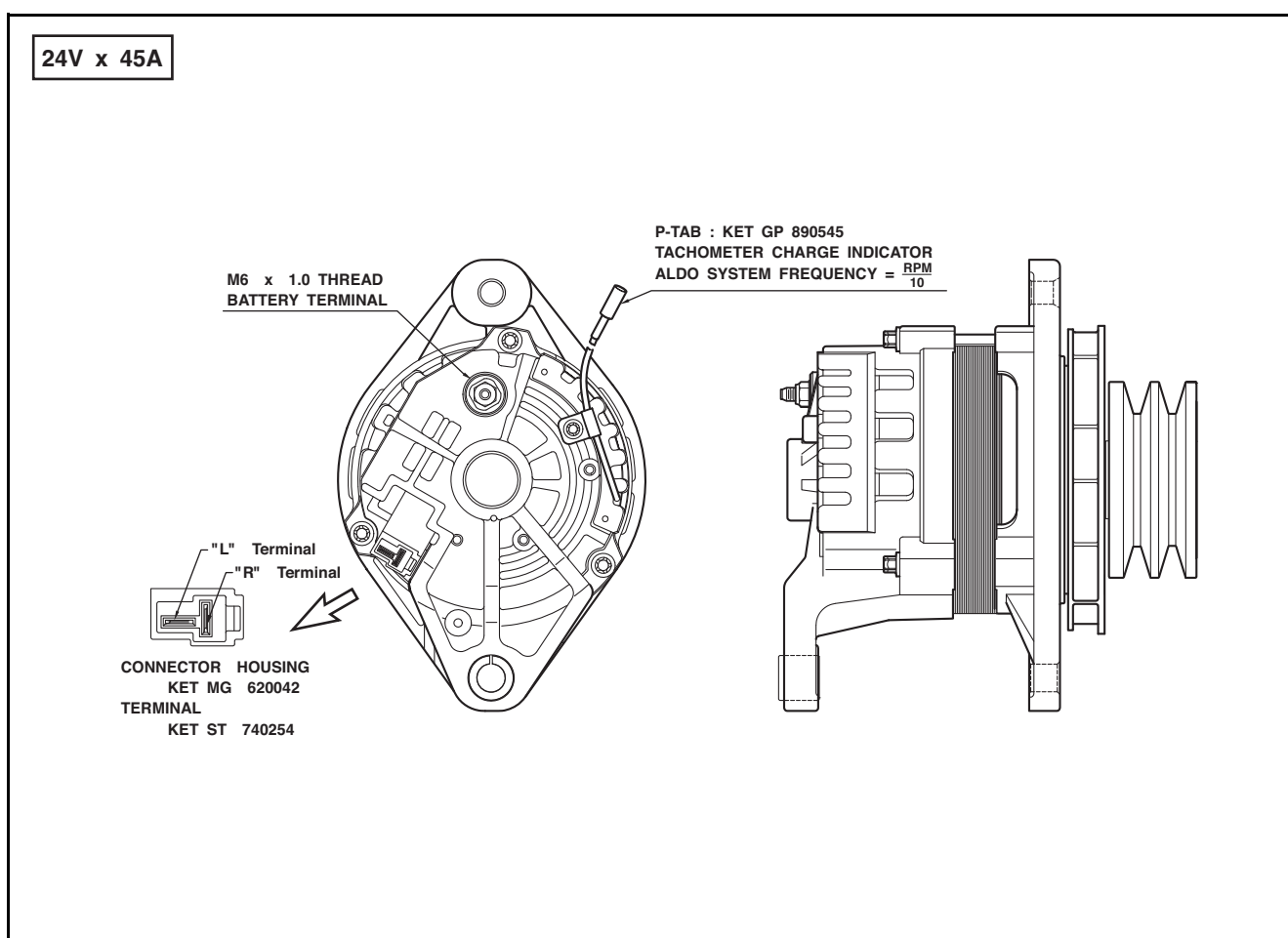
11. Electric system

Alternator

General Information

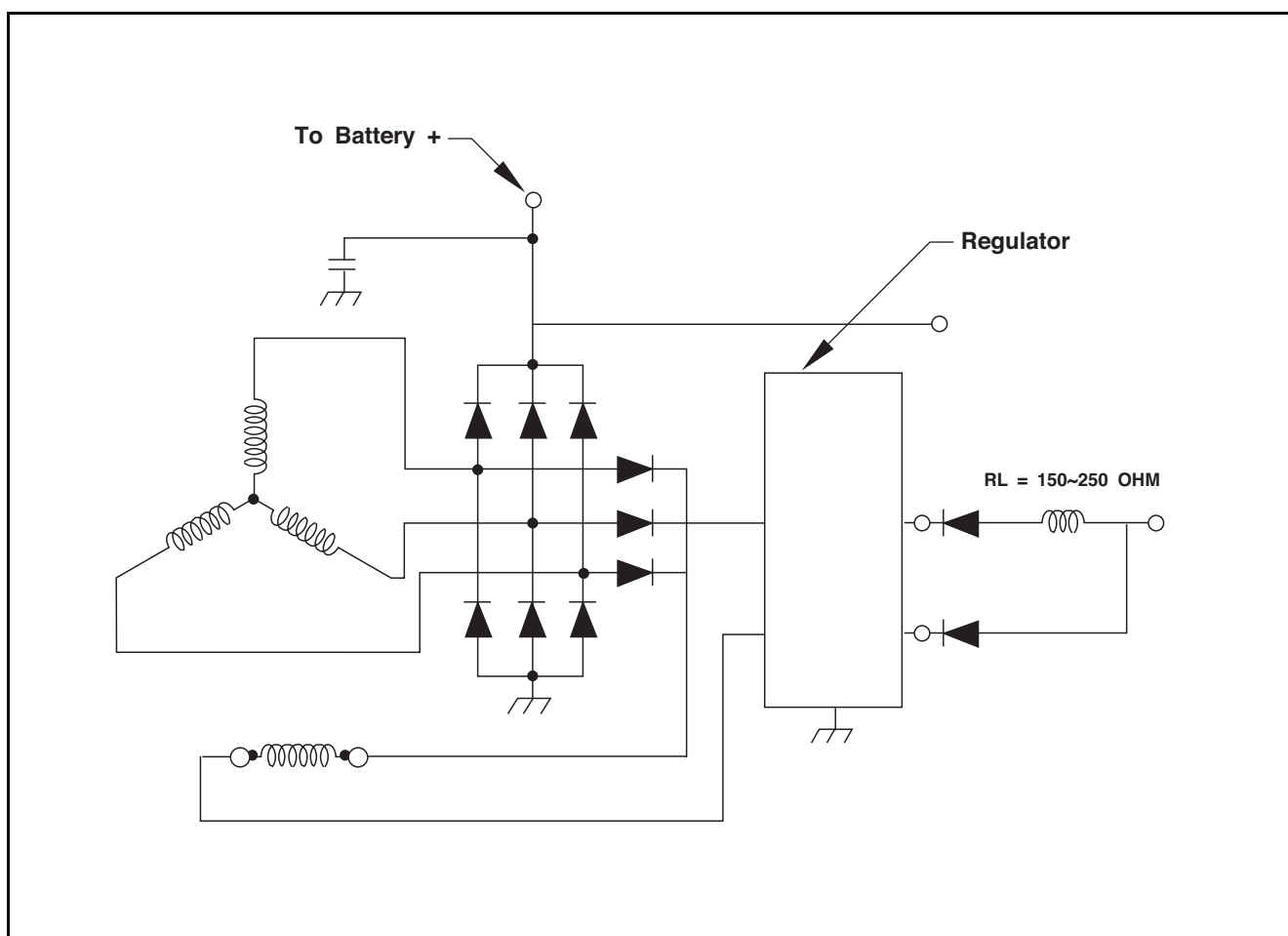
The alternator is fitted with integral silicon rectifiers. A transistorized regulator mounted on the alternator body interior limits the alternator voltage. The alternator should not be operated except with the regulator and battery connected in circuit to avoid damage to the rectifier and regulator. The alternator is maintenance-free, nevertheless, it must be protected against dust and, above all, against moisture and water.

Views



EA8O3006

Wiring diagram



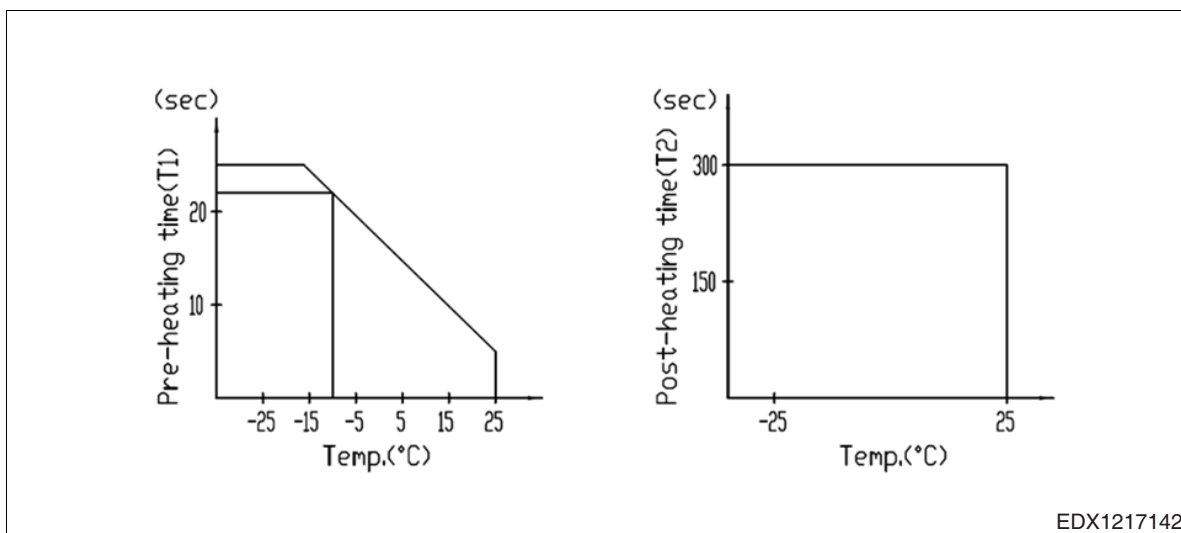
EA8O3007

11. Electric system

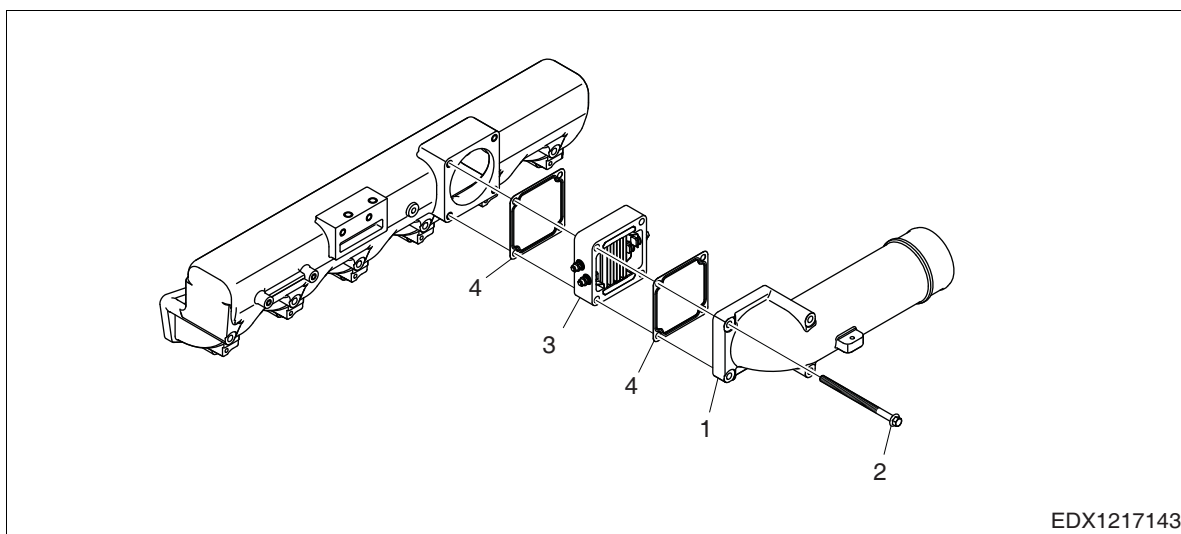
Air Heater

1) Air heater Operating Conditions

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



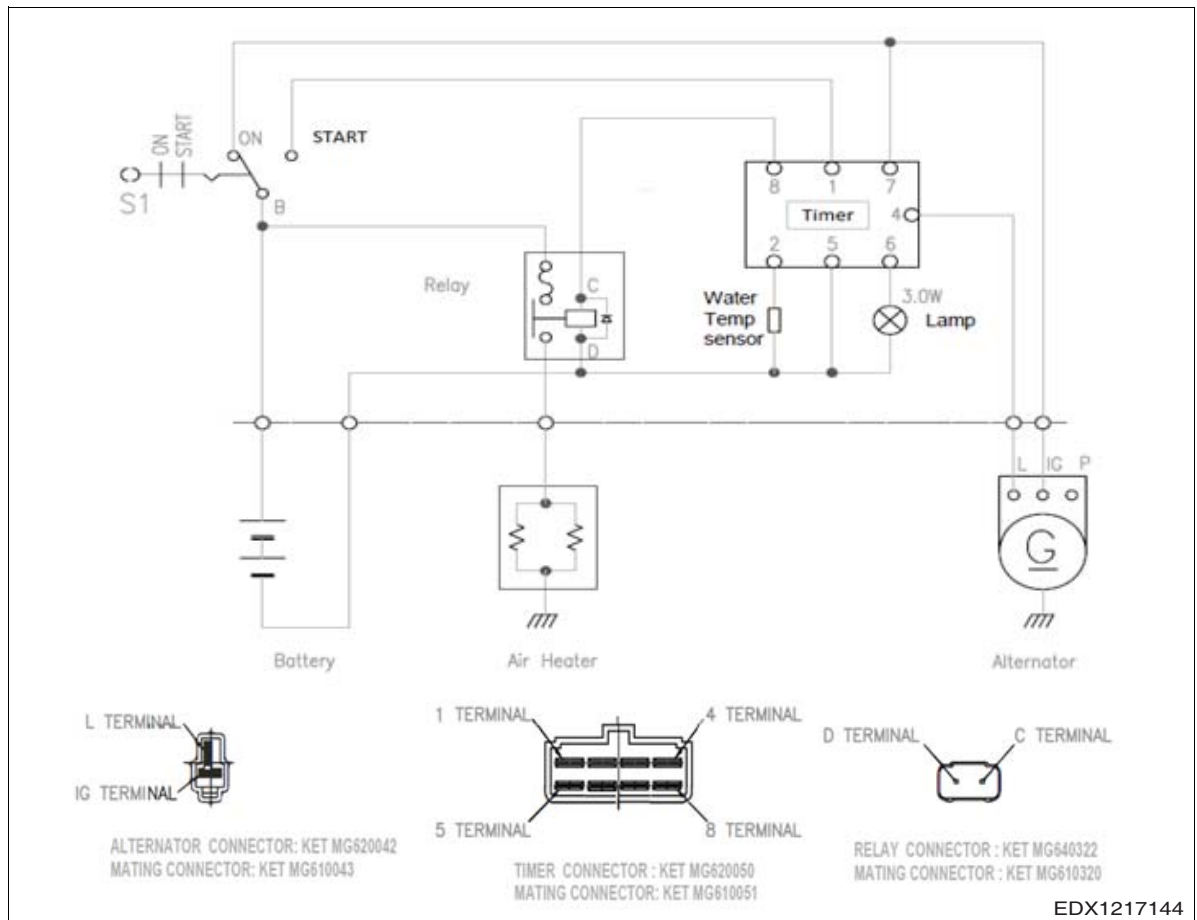
2) Air heater Mounting parts



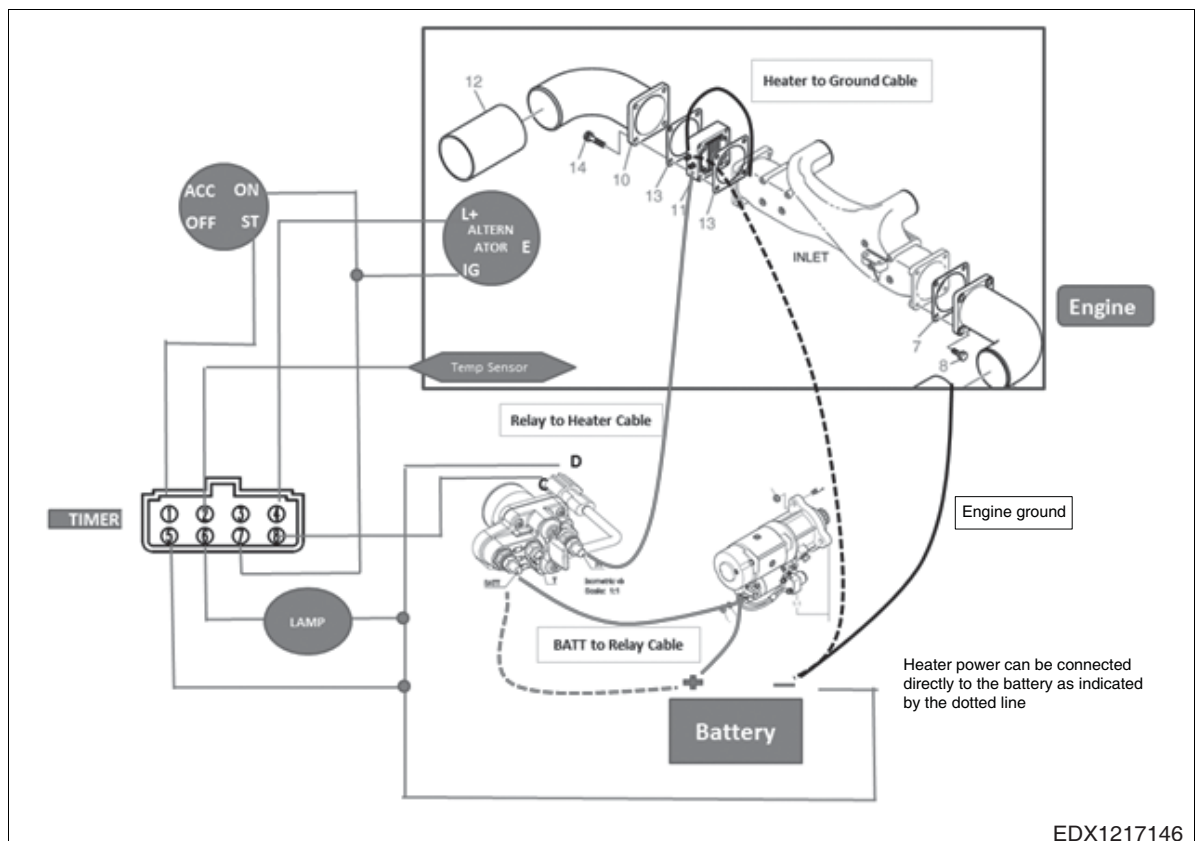
NO.	Description	Qty
1	PIPE, INLET	1
2	BOLT, COLLARED HEX	4
3	HEATER ASSY, AIR	1
4	GASKET, AIR PIPE	2

11. Electric system

3) Air heater Diagram



4) Air heater schematic



12. Others/driving system

General information	185
General Information	185
Crankshaft	186
Measurement of Crankshaft.....	186
Measurement of Crankshaft Bearing and Connecting Rod Bearing	187
Piston	189
Disassembly of Piston.....	189
Assembly of Piston	189
Piston Inspection.....	190
Piston Ring and Ring Groove	191
Piston pin	191
Connecting rod	193
Inspecting the connecting rod	193
Others	194
Engine timing	194

General information

General Information

The forged crankshaft has screwed-on counterweights.

The oil seal installed between the crankshaft and flywheel prevents oil leakage into the flywheel housing.

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 bearings.

12. Others/driving system

Crankshaft

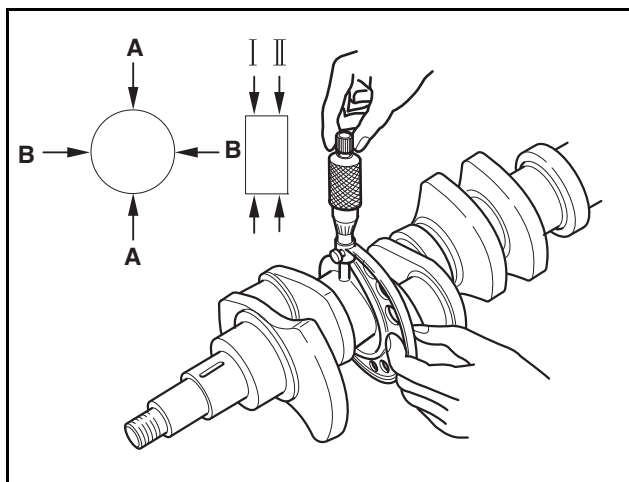
Measurement of Crankshaft

1. Inspection and measurement

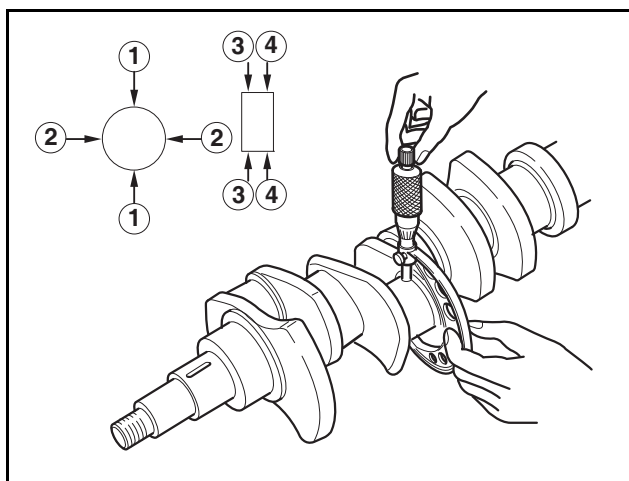
- 1) Visually inspect whether there is any crack or scratch on the journal and pins of the crankshaft.
- 2) Perform the magnetic particle testing or the liquid penetrant testing (color check) to check the cracks on the crankshaft. If cracks are found, replace the crankshaft with a new one.

2. Measuring journal and pin diameter

- 1) Using an outer diameter micrometer, measure the crankshaft journals and pins toward the direction as shown in the figure to determine the amount of wear.



DV2213147A



DV2213148A

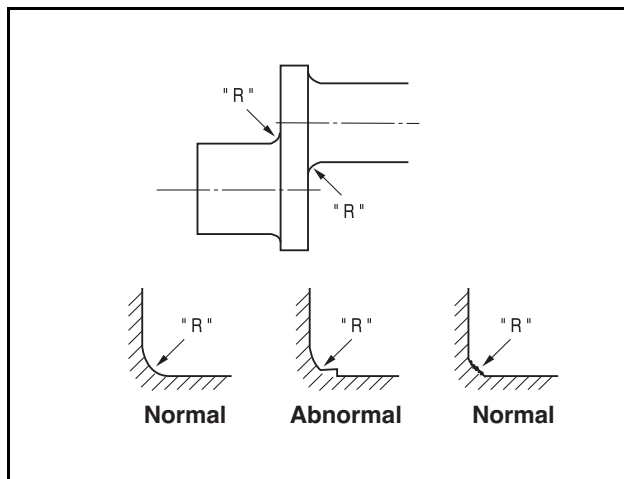
	Standard	Limit
Journal diameter	Ø83.966 ~ Ø83.988 mm	Ø83.000 mm
Pin diameter	Ø70.971 ~ Ø70.990 mm	Ø70.000 mm

- 2) If the amount of wear exceeds the tolerance limit, grind the crankshaft and assemble an under-size bearing.
- 3) There are 4 kinds as below, and the crankshaft also can be used by regrinding as below.

- Standard
- 0.25 (Inside diameter 0.25 mm less than standard)
- 0.50 (Inside diameter 0.50 mm less than standard)
- 0.75 (Inside diameter 0.75 mm less than standard)
- 1.00 (Inside diameter 1.00 mm less than standard)
- 4) "R" part standard value
 - Crank pin "R": 4.3 ~ 4.5
 - Crank journal "R": 3.8 ~ 4.0

CAUTION

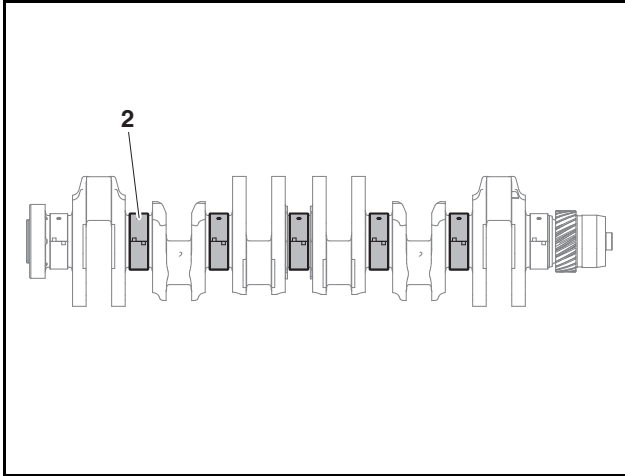
In case of crankshaft regrinding, the "R" part at the end of bearing must accurately be ground without fail and should avoid any processed jaw or coarse surface.



DV2213149A_E

3. Warpage of crankshaft

- 1) Put the crankshaft on the V block.
- 2) Put the dial gauge on the surface plate and measure the warpage of the crankshaft as spinning the crankshaft.



EDB58180012

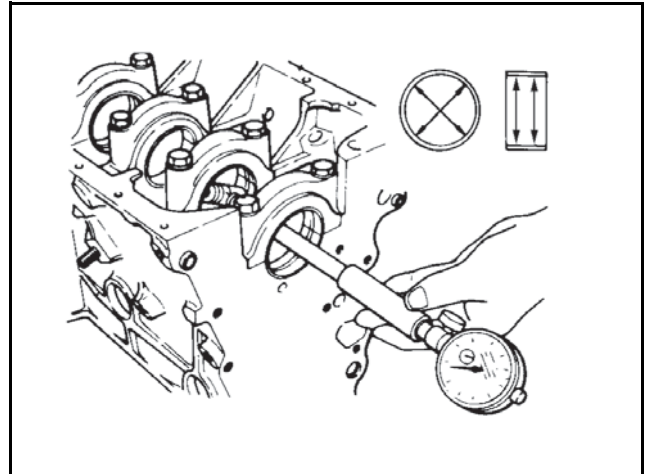
No	Standard	Limit
4	0.1 mm	0.15 mm
3, 5	0.06 mm	0.1 mm
2, 6	0.03 mm	0.05 mm

Measurement of Crankshaft Bearing and Connecting Rod Bearing

1. Visual inspection
Visually inspect the crankshaft bearing and connecting rod bearing for scratch, unusual wear or damage.
2. Oil clearance between crankshaft and bearing (Method 1: Dial gauge)
 - 1) Assemble the main bearing to the cylinder block, tighten the bearing cap to the specified torque.

Item	Standard
Tightening torque	30 kgf·m

- 2) Measure the inner diameter.



DV2213151A

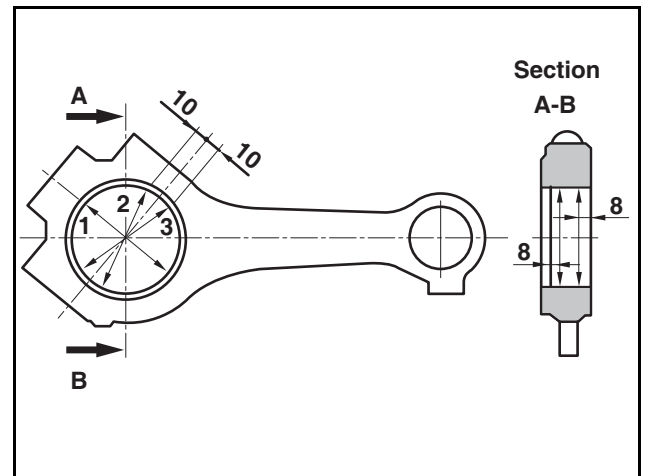
- 3) Assemble the bearing to the connecting rod, tighten the bearing cap to the specified torque.

<Connecting rod tightening torque>

Tightening torque	1st Step	4 ±0.2 kgf·m
	2nd Step	60° ±3°

Note) Do not apply oil to the joint before bolting.

- 4) Measure the connecting rod bearing journal inner diameter.



DV2213152A

- 5) if the clearance exceeds the tolerance limit, grind the crankshaft journal and pin, and assemble under size bearing.

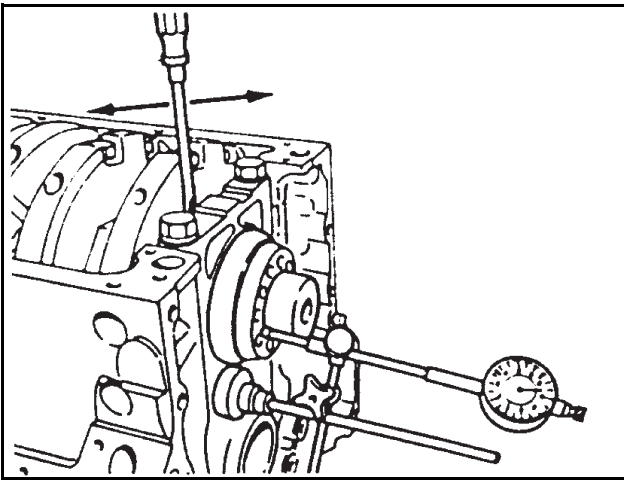
Item	Standard	Limit
Clearance	0.052~0.122mm	0.25mm

3. Oil clearance between crankshaft and bearing.
(Method 2: Plastic gauge)

- 1) Assemble the crankshaft to the cylinder block.
- 2) Place the plastic gauge on the crankshaft journal and pan.

12. Others/driving system

- 3) Assemble the bearing cap and tighten the bolt to the specified torque.
 - 4) Loosen the bolt, remove the bearing cap.
 - 5) Measure the width of the plastic gauge at the widest point using the ruler for plastic gauge measurement. This is the oil clearance.
 - 6) Measure the oil clearance of connecting rod as the same procedure.
4. End play
- 1) Assemble the crankshaft in the cylinder block.
 - 2) Install the dial gauge, and measure the end play of crankshaft by pushing the crankshaft to axial direction.



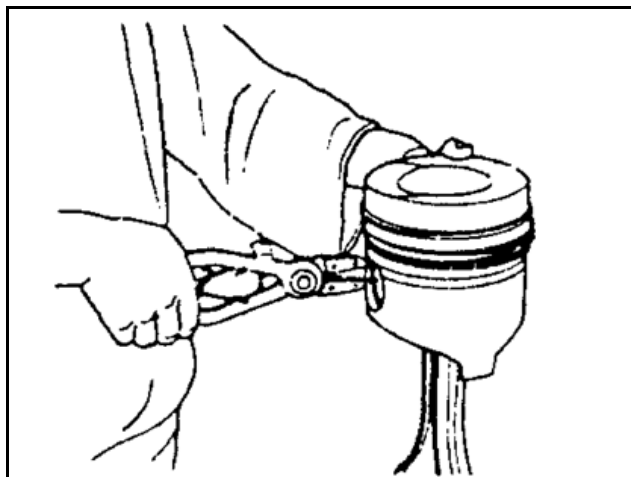
EAMD065S

Item	Standard	Limit
Axial end play	0.1~0.289 mm	0.5 mm

Piston

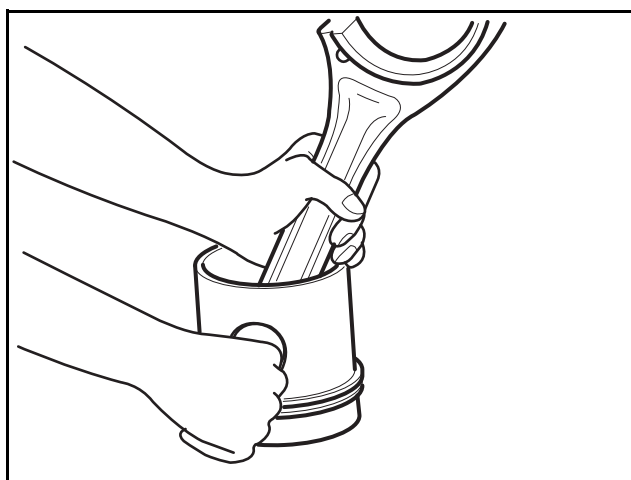
Disassembly of Piston

1. Disassemble the piston assembly
- 1) Remove the snap rings by means of a plier.



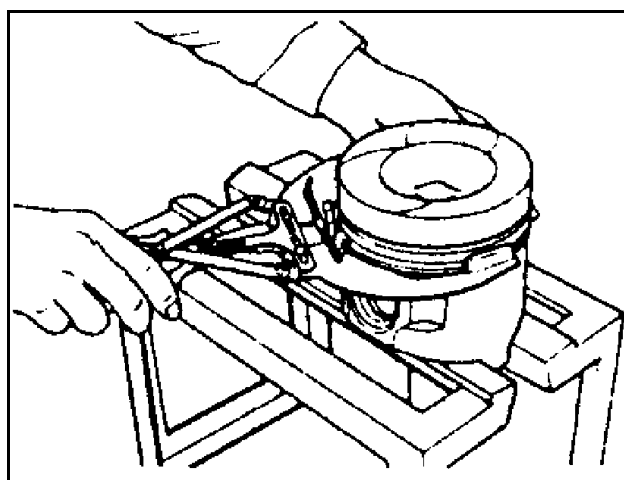
EAMD038I

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



EAMD088I

- 3) Remove the piston ring with a plier.

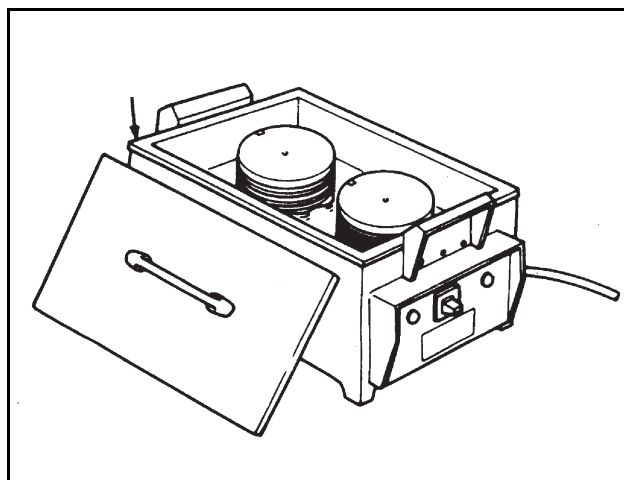


EAMD039I

- 4) Clean the piston thoroughly.

Assembly of Piston

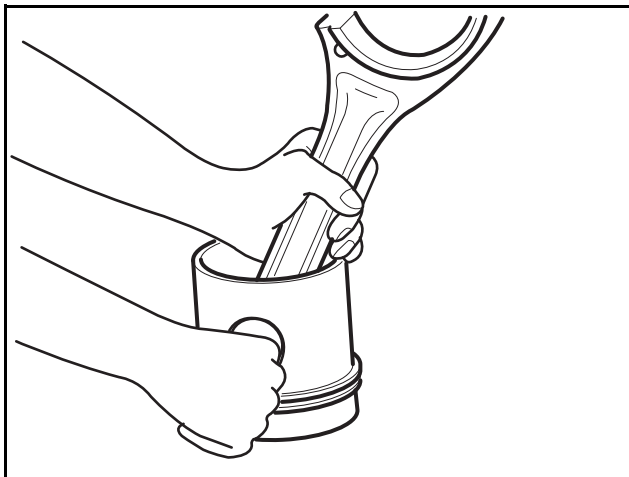
1. Attach the piston and connecting rod
- 1) Use a piston heater to heat the piston approximately 100°C for 5 minutes.



DV2213156A

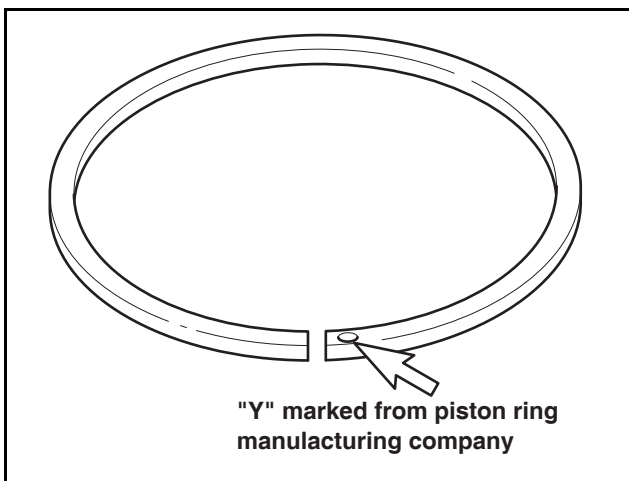
- 2) Align the piston pin hole with the oiled connecting rod small end and press the piston pin (by lightly tapping with a rubber hammer) to assemble the connecting rod with the piston.

12. Others/driving system



EAMD088I

- 3) Install the snap rings and check to see that it is securely assembled.
- 4) Install the piston ring in the piston using piston ring pliers.
- 5) 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" is upper surface.)

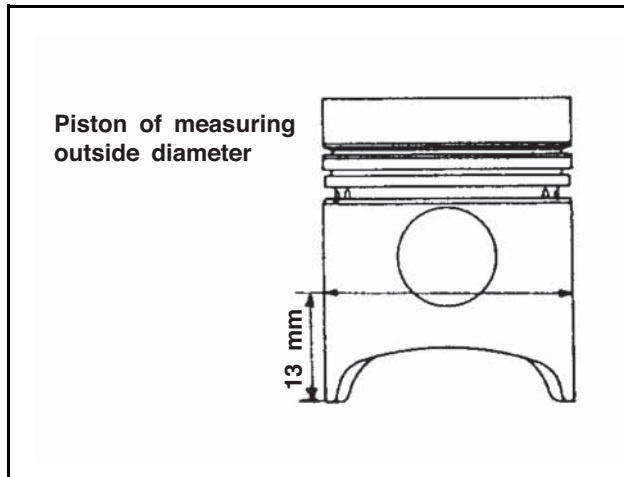


EAMD090I

Piston Inspection

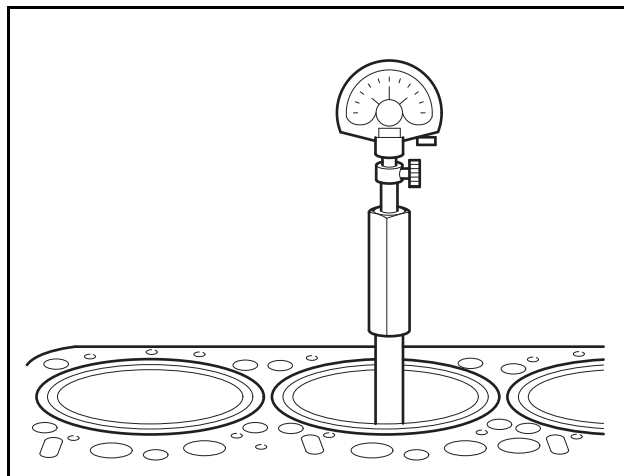
1. Visual check
 - 1) Visually check the pistons for cracks, scuff or wear, paying particular attention to the ring groove.
2. Clearance between the piston and cylinder liner
 - 1) With an outside micrometer, measure the piston outside diameter at a point 13mm away from the lower end of piston skirt in a direction at a right angle to the piston pin hole.

Piston of outside diameter	Ø110.883 ~ Ø110.897 mm
-----------------------------------	------------------------



EAMD066S

- 2) Assembly the cylinder liner at the cylinder block and measure inner diameter at upper, middle, lower that is, 3 step by 45° interval.



DV2213111A

- 3) Calculate the average values after eliminating the maximum and minimum values.
- 4) If the measured values are very close to the limit value or beyond, replace it.

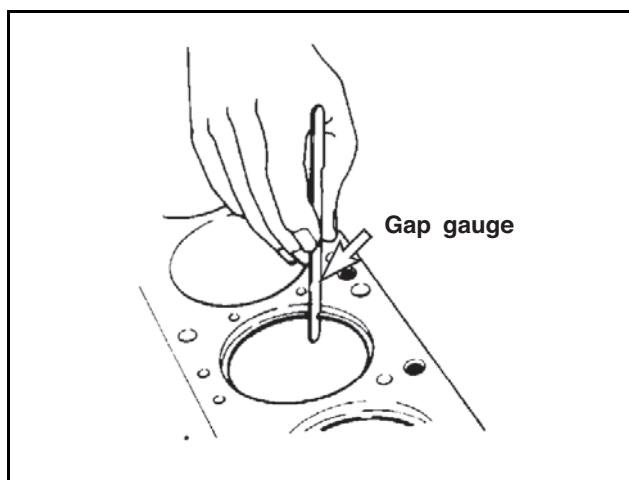
Standard	Limit
Ø111.000 ~ Ø111.022mm	Ø111.122mm

- 5) 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.

Clearance between piston and liner	0.103~0.139 mm
---	----------------

Piston Ring and Ring Groove

1. Visual check
 - 1) Replace the piston rings with new ones if detected worn or broken when the engine is overhauled.
2. Piston ring gap
 - 1) Insert the piston ring into the upper portion of the cylinder liner bore so that it is held at a right angle to the cylinder liner wall.



DV2213158A_E

- 2) Measure the piston ring gap with a feeler gauge.

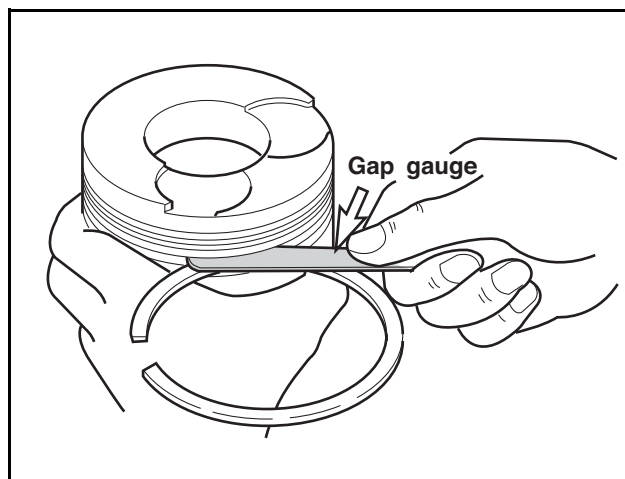
	Standard	Limit
Top ring	0.40 ~ 0.60 mm	1.5 mm
2nd ring	0.40 ~ 0.60 mm	1.5 mm
Oil ring	0.30 ~ 0.50 mm	1.5 mm

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

3. Piston ring side clearance

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

	Standard	Limit
Top ring	0.105 ~ 0.155 mm	0.2 mm
2nd ring	0.07 ~ 0.102 mm	0.15 mm
Oil ring	0.05 ~ 0.09 mm	0.15 mm



DV2213159A_E

4. Piston ring tension

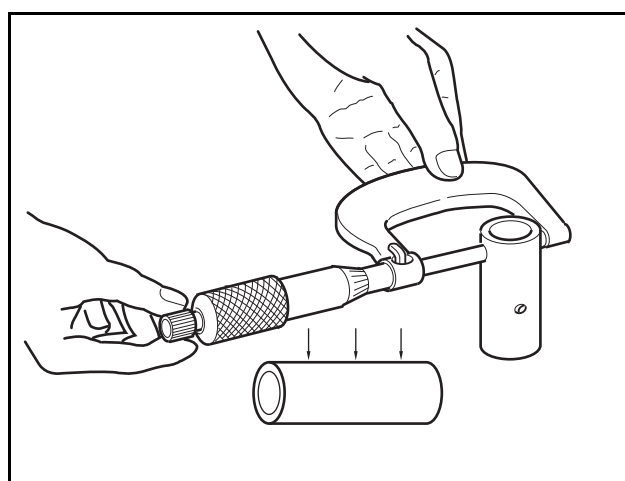
- 1) With a tension tester, measure piston ring tension.
Replace the piston ring if the measured value is beyond the limit.

	Standard
Top ring	2.58 ~ 3.88 kg
2nd ring	1.81 ~ 2.71 kg
Oil ring	3.57 ~ 5.03 kg

Piston pin

1. Wear

- 1) Measure the wear amount of the piston pin with a outside micrometer.
- 2) If the reading exceeds the tolerance limit, replace the pin.



DV2213160A

Item	Standard	Limit
Outside diameter	Ø41.994 ~ Ø42.000mm	Ø41.940mm

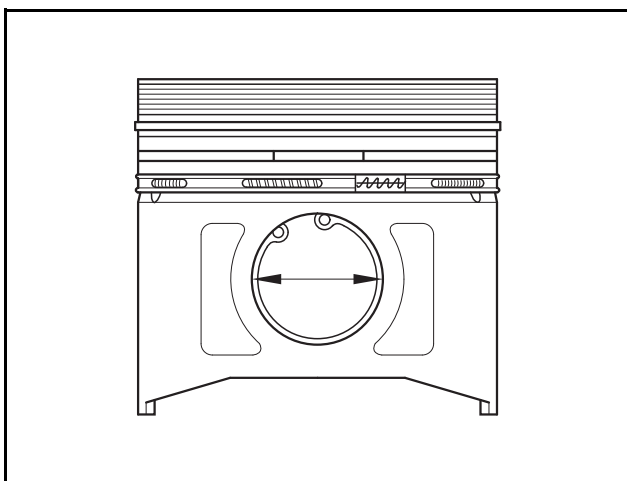
12. Others/driving system

2. Clearance

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

	Standard	Limit
Piston Pin (Piston)	0.003 ~ 0.015 mm	0.08 mm
Piston Pin (Connecting rod)	0.050 ~ 0.081 mm	0.15 mm

3. Condition check



DV2213161A

- 1) Check the engaged condition of the piston and piston pin.
If it is possible to force the pin into the piston heated with piston heater, the piston is normal.
- 2) When replacing the piston, be sure to replace the piston pin together.

Connecting rod

Inspecting the connecting rod

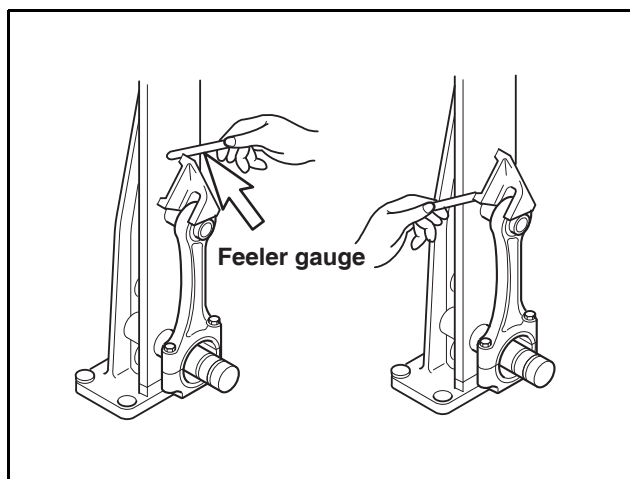
1. Distorsion

- 1) 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.
- 2) If the connecting rod is found distorted, never re-use it but replace with a new one.

2. Holes alignment (parallelism)

- 1) 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
0.05 mm	0.1 mm or less



EA0M4034

3. Wear

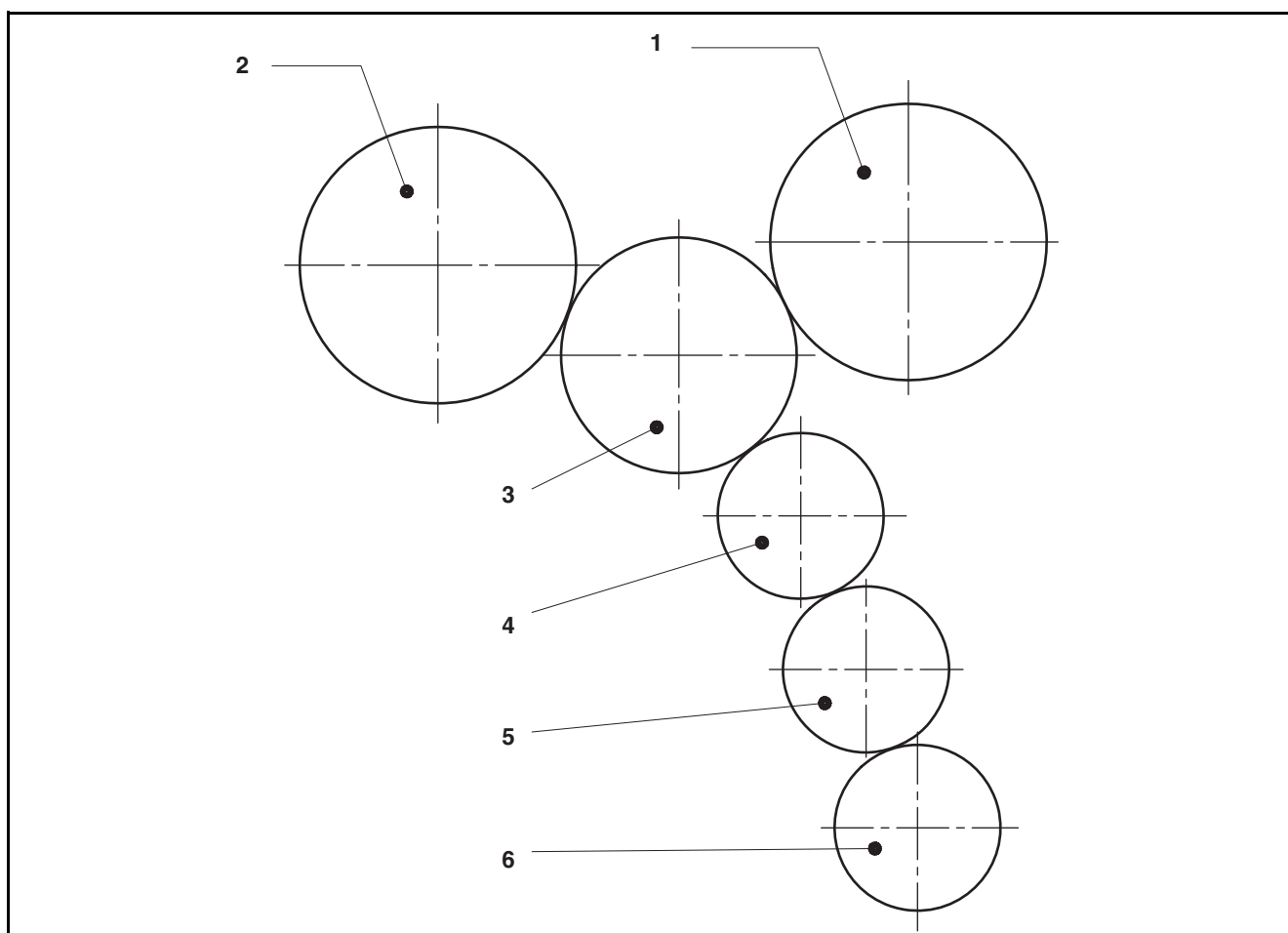
- 1) Assemble the connecting rod to the crankshaft and measure connecting rod big end side clearance using a feeler gauge.
- 2) Assemble the connecting rod to the piston and measure connecting rod small end side clearance.
- 3) If the measured values are beyond the limit, replace the connecting rod.

Limit	0.5 mm
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12. Others/driving system

Others

Engine timing



EA9O2004

1. Camshaft gear (Z= 54)

2. Injection pump gear (Z= 54)

3. Idle gear (Z= 42)

4. Crankshaft gear (Z= 27)

5. Oil pump idle gear (Z= 23)

6. Oil pump drive gear (Z= 36)

Appendix

Engine assembly tolerance 197

Engine assembly tolerance

(unit: mm)

Item	Component	Inspection Item		Specifications	Limit for Use	Action	Remarks
Engine body	Cylinder block and liner	Cylinder liner I.D. wear		Ø111 ~ Ø111.022	Ø111.222	Replace the liner	Measure the bottom of intact edge on the top
		Liner projection		0.03 ~ 0.08	-		At top of cylinder block
		Flatness of top of cylinder block		0.05	-	Correct it with surface grinder	For length 200 mm
		Water pressure test (for 1 min.) (kg/cm ²)		4	-	Replace in case of water leak	
	Cylinder head and valve	Valve seat press	Intake	0 ~ 0.3	0.55	Replace the valve seat	
			Exhaust	0 ~ 0.3	0.55		
		Cylinder head height		109.9 ~ 110.1	108.4	Replace the cylinder head	
Major drive components	Piston	Maximum piston O.D.		Ø110.883 ~ Ø110.897	-	Replace the piston	Measure at the point 13 mm up from the bottom of the piston
		Clearance between the piston and liner		0.041 ~ 0.221	0.3	Replace if worn over the limit	
		Piston ring groove width	Top ring	-	-	If the groove is over the limit, replace the piston	
			2nd ring	3.06 ~ 3.08	-		
			Oil ring	4.04 ~ 4.06	-		
		Piston projection at top of cylinder block		0.357 ~ 0.533	-		Measure the bottom of intact edge on the top
		Allowable weight difference among pistons		±15 g	-	Replace the piston	
	Piston ring	Piston ring gap	Top ring	0.40 ~ 0.60	1.5	Replace the ring	Standard gauge I.D.: Ø108
			2nd ring	0.40 ~ 0.60	1.9		
			Oil ring	0.30 ~ 0.50	1.5		
		Piston ring side clearance	Top ring	-	-	Replace the ring or piston	The allowable limit is based on the standard clearance
			2nd ring	0.07 ~ 0.102	0.15		
			Oil ring	0.05 ~ 0.09	0.15		
		Direction of ring opening		-	-	Install rings only with their openings 120° apart	
	Piston pin	Piston pin O.D.		Ø41.994 ~ Ø42	Ø41.94	Replace the piston pin	
		Clearance between piston pin and piston groove		0.003 ~ 0.015	0.08	Replace if wear amount is over the specification	

Appendix

(unit: mm)

Item	Component	Inspection Item	Specifications	Limit for Use	Action	Remarks
Major drive components	Crankshaft	Uneven wear on journal and pin	-	0.01	Repair it with a grinder	Lateral/longitudinal
		Journal O.D.	Ø83.966 ~ Ø83.988	Ø83	Use the under-size bearing (0.25, 0.5, 0.75, 1.0)	
		Pin O.D.	Ø70.971 ~ Ø70.990	Ø70		
		Ovalness of journal and pin	0.008	0.025		
		Allowable concentricity of journal and pin	0.01	0.03		
		Allowable inclination of journal and pin	0.02	0.03		
		Clearance between crankshaft and main bearing	0.052 ~ 0.122	0.25	Replace the bearing	Measure at the crown section
		Axial play of crankshaft	0.1 ~ 0.289	0.5	Replace the thrust bearing	
		Crankshaft deflection	0.06↓	0.1	Repair it with a press	Bearing No. 4 (Supporting No. 1 and 7)
		Crankshaft levelness (g·cm)	60↓	60 or below	Check the dynamic balancing	Measure at 400 rpm
		Journal bearing cap bolt tightening torque (kg·m)	30	-	Apply oil to the bolt	There should be no foreign material on the bearing cap mounting surface
		Journal bearing crush	0.08 ~ 0.110	-		Tighten the bearing cap and unscrew one bolt for measurement
		Oil seal wear (Back side of crankshaft)	-	-	Replace the oil seal if oil leak is found	
	Connecting rod	Connecting rod play	0.170 ~ 0.248	0.50	Replace the connecting rod	
		Clearance between connecting rod bearing and crank pin	0.034 ~ 0.098	0.25	Replace the bearing	
		Clearance between small end bushing and piston pin	0.050 ~ 0.081	0.12		
		Connecting rod bearing crush height	0.04 ~ 0.07	-		Tighten the bearing cap and unscrew one bolt for measurement
		Big end and small end side clearance	-	0.50	Replace the connecting rod	
		Allowable weight difference among connecting rods	30 g↓	-		
		Connecting rod bearing cap bolt tightening torque (kg·m)	1st: 4 kg·m ±0.2 2nd: 60° ±3°	-	Remove oil from bolt	Remove foreign materials from the connection surface

(unit: mm)

Item	Component	Inspection Item	Specifications	Limit for Use	Action	Remarks
Major drive components	Camshaft	Camshaft journal O.D.	Ø57.86 ~ Ø57.88	Ø57.52		
		Clearance between camshaft and bushing	0.12 ~ 0.17	0.24	Replace the cam bushing	
		Axial play of camshaft	0.28 ~ 0.43	0.6	Replace the thrust plate	
		Camshaft deflection	0.05	0.2	Repair or replace the camshaft	
	Timing gear	Clearance between idle shaft bushing and idle shaft	0.025 ~ 0.091	0.15		
		Axial play of idle gear	0.043 ~ 0.167	0.3	Repair or replace the gear	
		Gear backlash (cam, idle, crank and injection pump)	0.16 ~ 0.28	0.35	Replace the gear	

Appendix

(unit: mm)

Item	Component	Inspection Item		Specifications	Limit for Use	Action	Remarks	
Exhaust valve	Valve	Intake valve stem O.D.		Ø8.950 ~ Ø8.970	Ø8.93	Replace the valve and valve guide	When replacing the valve, replace the guide as well	
		Exhaust valve stem O.D.		Ø8.935 ~ Ø8.955	Ø8.91			
		Clearance between valve stem and valve guide	Intake	0.030 ~ 0.065	0.1	Replace the valve and valve guide	Replace either one of them with more wear	
			Exhaust	0.045 ~ 0.080	0.15			
		Valve head thickness	Intake	2.7	2.2	Replace the valve		
			Exhaust	2.2	1.7			
		Clearance between valve guide and valve spring seat	Intake	2.0	-			
			Exhaust	2.0	-			
		Clearance between valve guide and cylinder head mounting hole		-0.039 ~ -0.010	-		Press fit after applying oil to the valve guide	
		Concentricity of valve seat and guide		0.05	-		Excluding spring seat	
		Intake valve spring	Free length	Approx. 64	-	Replace the valve spring		
				Tension (kg) (Measuring length: 41 mm)	67 ~ 73			66.5
				Squareness (free)	1.5°			-
		Exhaust valve spring	Inner	free length	73.8	-	Replace the valve spring	
				Tension (kg) (Measuring length: 38 mm)	36 ~ 40	-		
				Squareness (free)	1.5°	-		
			Outer	free length	77.7	-	Replace the valve spring	
				Tension (kg) (Measuring length: 41 mm)	71 ~ 79	-		
				Squareness (free)	1.5°	-		
				Contact surface of valve stem and rocker arm		-		
		Clearance between rocker arm shaft and rocker arm bushing		0.040 ~ 0.113	0.2	Replace the bushing or shaft		
		Rocker arm shaft wear		Ø23.939 ~ Ø23.96	Ø23.75	Replace		
		Push rod deflection		-	0.3	Replace		

(unit: mm)

Item	Component	Inspection Item	Specifications	Limit for Use	Action	Remarks
Valves	Tappet	Clearance between tappet and cylinder block	0.035 ~ 0.077	0.15	Replace the tappet	
		Tappet O.D.	Ø19.944 ~ Ø19.965	-	Replace the tappet	
		Contact of tappet and cam	-	-	Replace if excessive wear or deformation is found	
Lubrication system	Oil pressure	Oil pressure (kg/cm ²) (at rated speed)	4.8 or below	3.5	Check for oil leakage and clearance at each section	
		Oil pressure (kg/cm ²) (idling without load)	0.8 ~ 1.4	0.6	Use the recommended oil	
	Oil temperature	Max. allowable oil temp. (°C)	-	105		Temperature above this limit is not allowed
		Instant allowable oil temperature (°C)	-	120		
	Oil pump	Axial clearance of oil pump gear	0.055 ~ 0.105	-	Replace the gear or cover	
		Clearance between gear shaft and oil pump cover hole	0.032 ~ 0.077	-		
		Clearance between drive gear shaft and cover hole	0.040 ~ 0.094	-	Replace the bushing or cover	
		Gear shaft O.D.	Ø16.950 ~ Ø16.968	-	Replace the gear shaft	Ø17e7
		Drive gear bushing O.D.	Ø28.000 ~ Ø28.033	-	Replace the bushing	Ø28e7
		Backlash	Crank gear and idle gear	0.15 ~ 0.25	Adjust the backlash	
			Pump drive gear and idle gear	0.15 ~ 0.25		
	Valve opening pressure	Oil pressure adjusting valve (kg/cm ²)	4.0 ~ 5.0	-	Replace the valve	
		Bypass valve for oil filter element (kg/cm ²)	1.8 ~ 2.3	-		
		By-pass valve for oil cooler (kg/cm ²)	5.0 ~ 6.0	-		
		Relief valve for oil pump (kg/cm ²)	8.5 ~ 11.5	-		
		Adjusting valve for injection nozzle (kg/cm ²)	1.5 ~ 1.8	-		
	Oil filter	Damaged oil filter cartridge	-	-	Clean or replace	

Appendix

(unit: mm)

Item	Component	Inspection Item	Specifications	Limit for Use	Action	Remarks
Cooling system	Radiator	Corrosion, damage or poor contact of radiator or pump	-	-	Repair or replace	
		Air leak test (air pressure) (kg/cm ²)	1.0	-	Place the part into water. Replace it if air bubbles are seen	
		Pressure valve's opening pressure (kg/cm ²)	0.5	-		
		Negative pressure valve's opening pressure (kg/cm ²)	20	-		
	Coolant pump	displacement (l/min) - Engine speed: 1,800 rpm - Coolant temperature: 80°C - Negative pressure: 0.5 (kg/cm ²)	190 or higher	-	Check the coolant passage	Clogged
		Clearance between pump impeller and housing body	0.35	-	Replace if the impeller and housing touch each other	
		Squareness of pulley	0.3	-	Repair it with a bench press	
		Fan belt deflection (with thumb)	Approx. 15	-	Adjust	
	Coolant temperature	Operating temperature (ideal temp.) (°C)	79 ~ 95	-	Temperature above this limit is not allowed	
		Instant allowable temp. (°C)	-	105		
	Thermostat	Thermostat's opening temperature (under atmospheric pressure) (°C)	79	-	Replace	Type 2) Opening temperature: 83°C Fully open temperature: 95°C
		Thermostat's fully open temperature (°C)	94	-	Replace if a defect is found. Lift: 8 mm or higher	
Fuel system	Pipe and others	Damaged, cracked poor packing of fuel pipe, injection pipe or nozzle holder	-	-	Repair or replace	
		Damaged fuel filter cartridge	-	-	Replace the cartridge	
		Injection pressure of injection nozzle (kg/cm ²)	220	-	Adjust with shims	1st: 160 2nd: 220
		Injection pump's overflow valve opening pressure (kg/cm ²)	1.0 ~ 1.5	-	Replace the valve	
		Protrusion height of cylinder head surface (mm)	3.6 ~ 4.1	-	Replace the cylinder head and nozzle	
Completion test	Engine test operation		-	-	Refer to the information for test operation in Appendix.	
	Cylinder compression pressure	Cylinder compression pressure (kg/cm ²)	24 ~ 28	24 or higher	Repair	
		Compression pressure difference among cylinders	Below ±10% from average value	-	Repair	At 200 rpm or higher (20°C)

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

Ver_1.07

300611-01127A(Land)

300611-01440(Marine)



HYUNDAI

HD Construction Equipment

Contents

1. Product Overview and General Specification

1.1 Product Information	4
1.2 Product Appearance	4
1.3 Product Specification	5
1.4 Product System Diagram	6
1.5 Product I/O Signals	7
1.6 Product Dimension	8

2. Installation

2.1 Connecting to the Engine	9
2.1.1 Battery, Pick-up, Actuator Connection Diagram	9
2.1.2 Connecting to Batteries	10
2.1.3 Connecting to Actuators	10
2.1.4 Connecting to Pick-up Sensors	10
2.1.5 Operating Sequence for Digital Speed Controller	10
2.2 Connecting to Speed Trim, Droop, Idle and Other Inputs	11
2.2.1 Speed Trim, Droop, Idle and Other Inputs Diagram	11
2.2.2 Connecting to Speed Trim	12
2.2.3 Connecting to Droop	12
2.2.4 Connecting to Idle	12
2.2.5 Connecting to AUX	12
2.2.6 Connecting Power to External Devices	12
2.3 Connecting to Crank, Run, Over Speed and Communication	13
2.3.1 Crank, Run, Over Speed and Communication Connection Diagram	13
2.3.2 Connecting to Crank Terminals	13
2.3.3 Connecting to Run Terminals	14
2.3.4 Connecting to Over Speed Terminals	14
2.3.5 Connecting to CAN Communication	14
2.3.6 Connecting to RS232 Communication	14

3. Configuration and Operation

3.1 Input Keys	15
3.2 LCD Display Menu	16
3.2.1 LCD Displays After Powered On	17
3.2.2 LCD Main Menu Display	18
3.2.3 Engine Type Setup Menu	19

3.2.4 System Setup Menu	19
3.2.5 PID Gain Setup Menu	20
3.2.6 PID Auto Setup Menu	21
3.2.7 DateTime Setup Menu	21
3.2.8 Alarm List Menu	21
3.2.9 Default Setup Menu	22
3.2.10 System Info Menu	22
3.3 Engine Configuration	22
3.3.1 Engine Type Configuration	22
3.3.2 System Setup Configuration	24
3.3.3 PID Gain Setup Configuration	29
3.3.4 PID Auto Setup Configuration	30
3.3.5 DateTime Setup Configuration	31
3.3.6 Alarm List	31
3.3.7 Actuator Test	32
3.3.8 Default Setup Functions	32
3.3.9 System Info Functions	33
3.3.10 LCD Setup Function Configuration	33
3.3.11 System Monitor Function Configuration	33
 4. How to Operate	
4.1 Operating Sequence for Digital Speed Controller	34
4.2 Detailed Operating Sequence	34
 5. Troubleshooting	
5.1 Alarm List Check	35
5.2 System Checks and Measures	36
 6. Warranty and A/S Service	37
6.1 Warranty	37
6.2 A/S Service Information	37

1. Product Overview and General Specification

1.1 Product Information

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

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

[Product Features]

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

1.2 Product Appearance

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

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

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

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

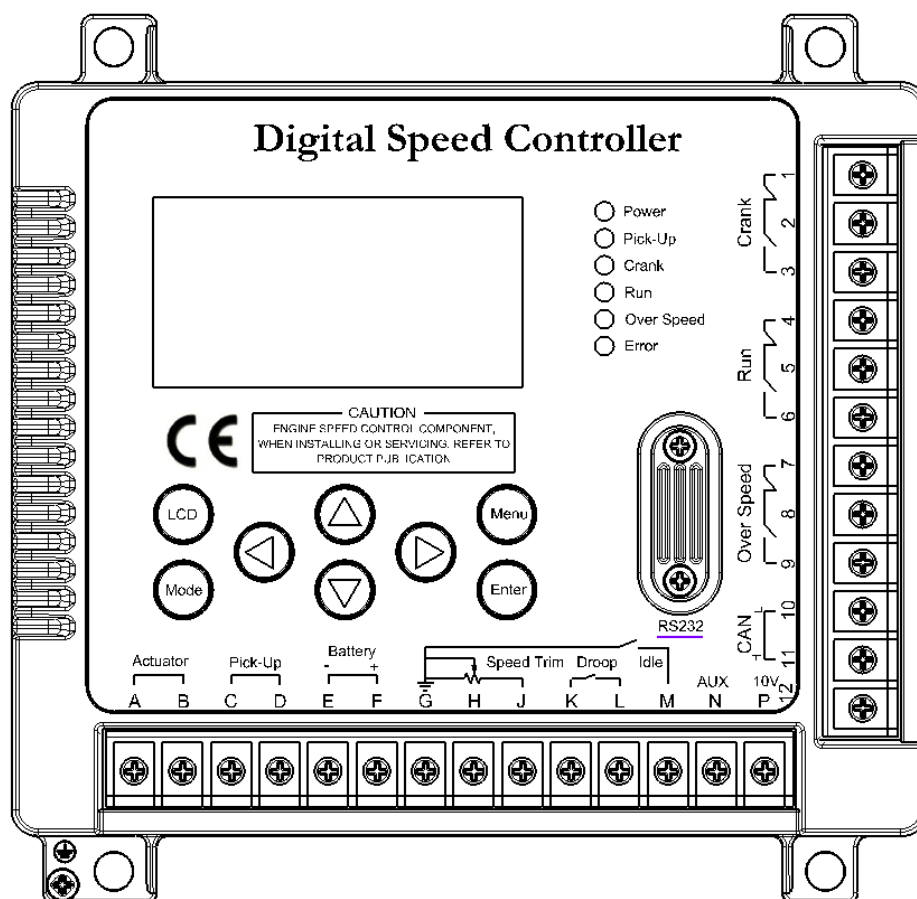


Figure 1: Product Front View

1.3 Product Specification

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

1.4 Product System Diagram

Cautions on wiring

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

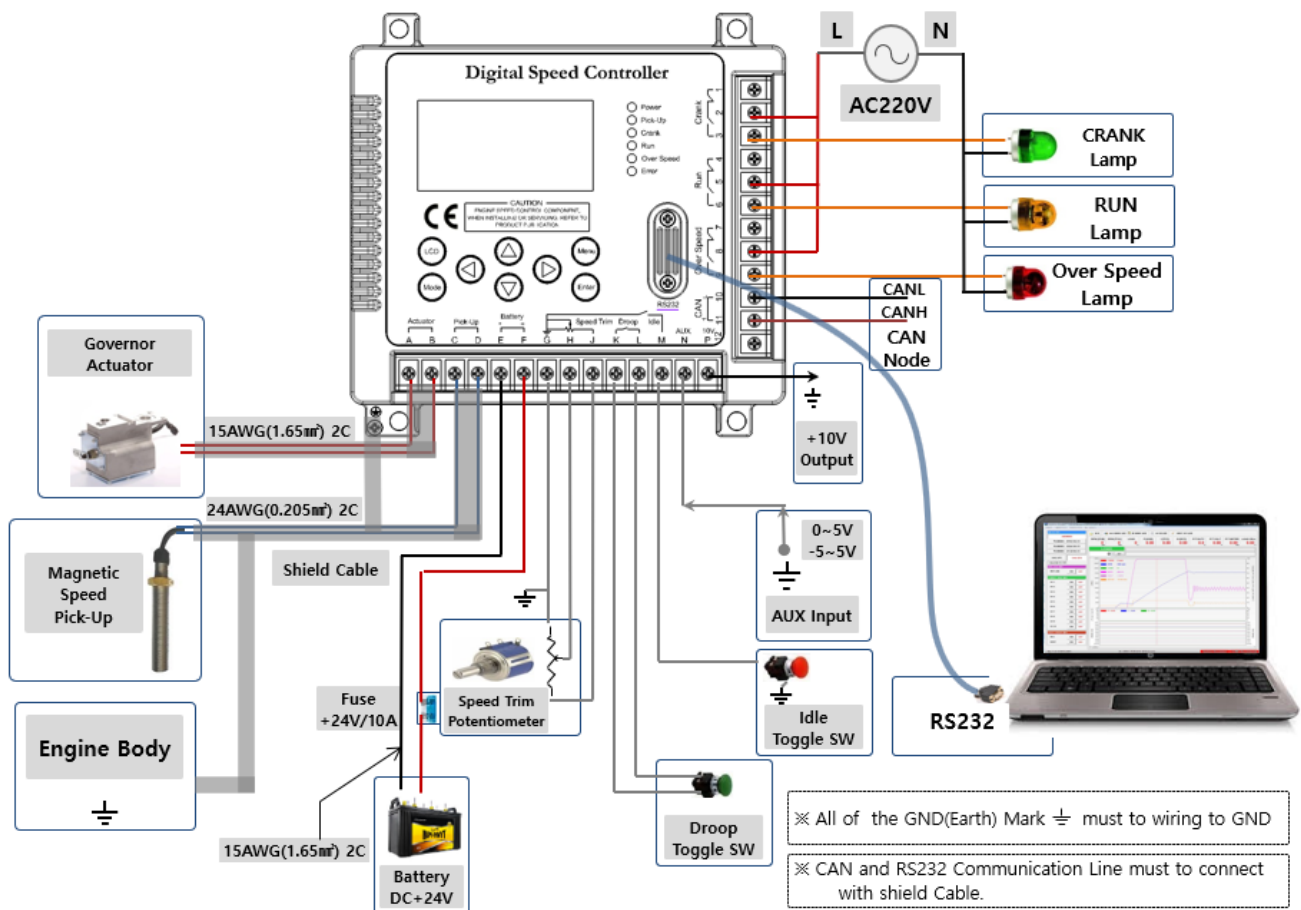


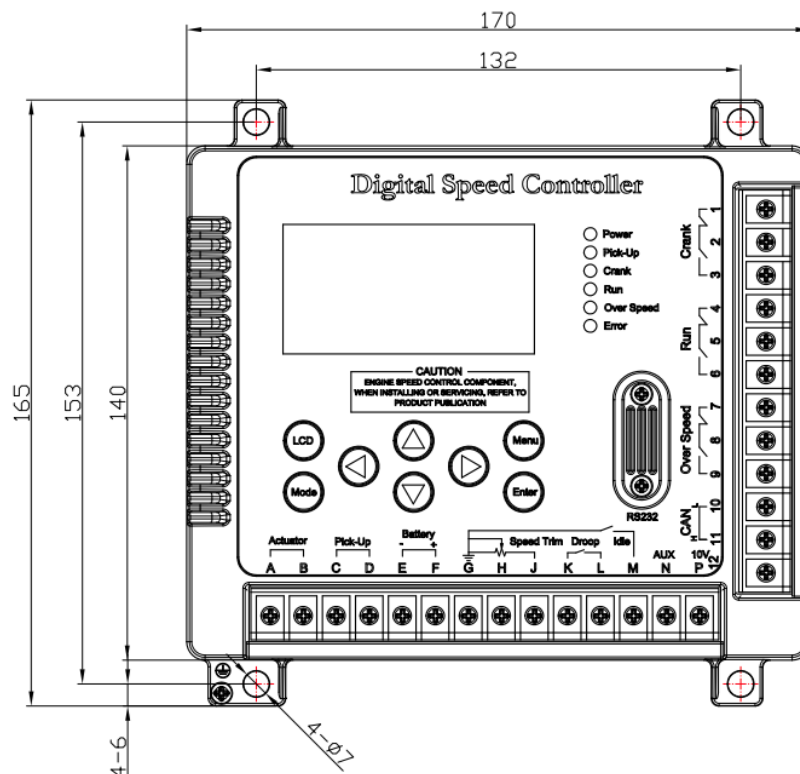
Figure 2: System Diagram for Digital Speed Controller

1.5 Product I/O Signals

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

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

1.6 Product Dimension



2. Installation

Cautions for installing the digital speed controller

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

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

2.1 Connecting to the Engine

2.1.1 Battery, Pick-Up and Actuator Connection Diagram

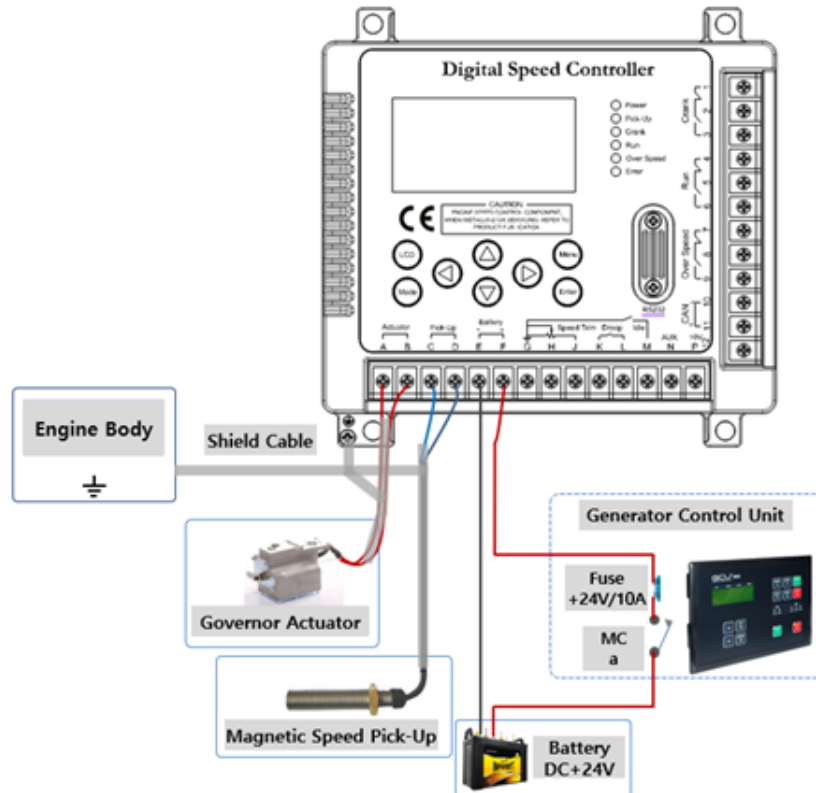


Figure 3: Battery, Pick-Up and Actuator Connection Diagram

2.1.2 Connecting to Batteries

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

2.1.3 Connecting to Actuators

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

2.1.4 Connecting to Pick-Up Sensors

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

2.1.5 Operating Sequence for Digital Speed Controller

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

[Operating Sequence for the Controller]

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

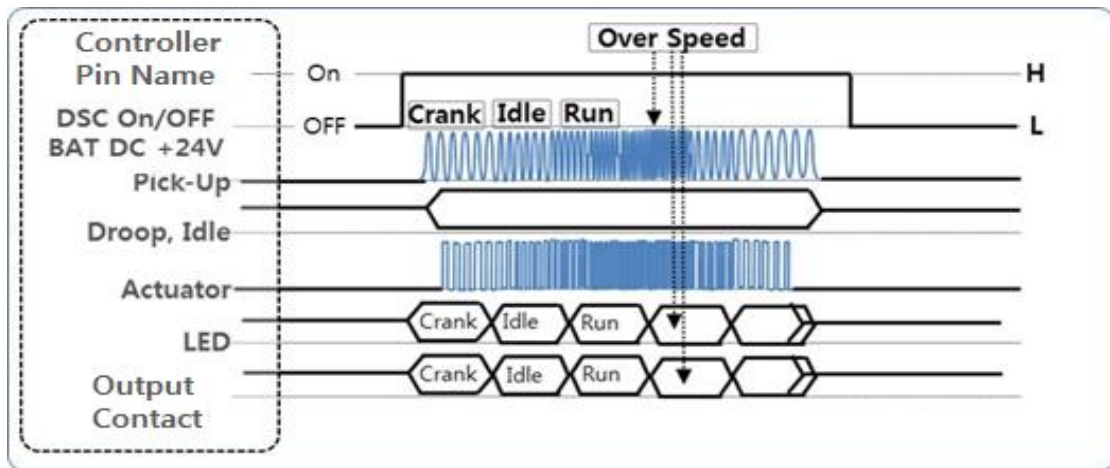


Figure 4: Time Chart for Operation of the Controller

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

2.2.1 Speed Trim, Droop, Idle and Other Inputs Diagram

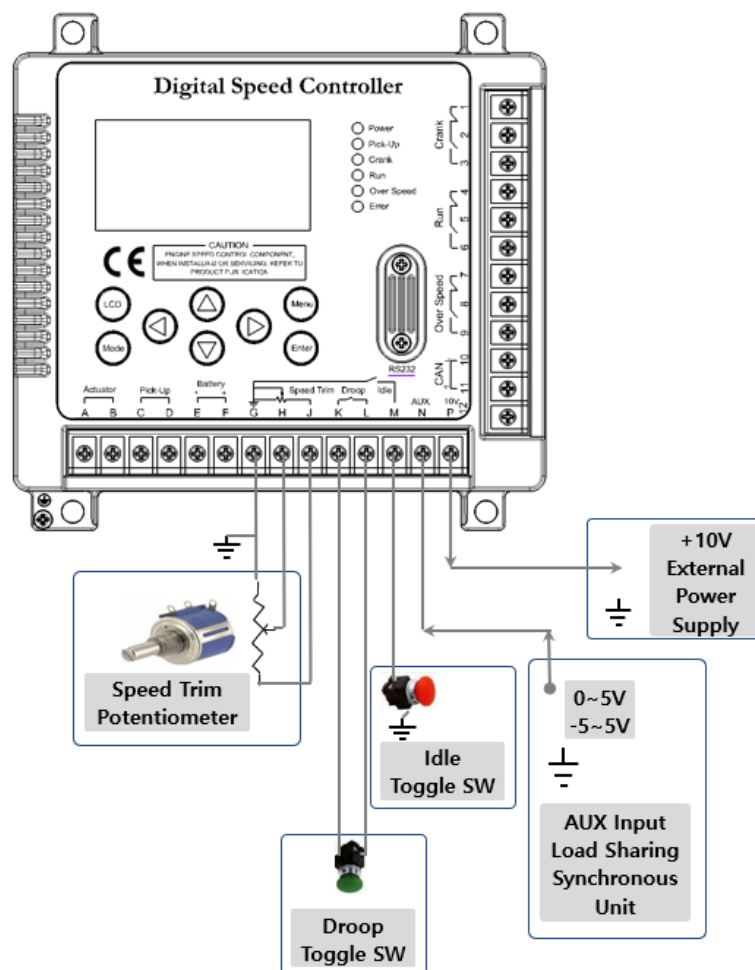


Figure 5: Speed Trim, Droop, Idle and Other Inputs Diagram

2.2.2 Connecting to Speed Trim

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

2.2.3 Connecting to Droop

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

2.2.4 Connecting to Idle

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

2.2.5 Connecting to AUX

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

2.2.6 Connecting Power to External Devices

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

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

2.3.3 Connecting to Run Terminals

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

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

2.3.4 Connecting to Over Speed

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

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

2.3.5 Connecting to CAN Communication

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

2.3.6 Connecting to RS232 Communication

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

3. Configuration and Operation

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

3.1 Input Keys

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

Each key as respective functions as follows:

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

3.2 LCD Display Menu

The overall menu tree of the controller is as follows:

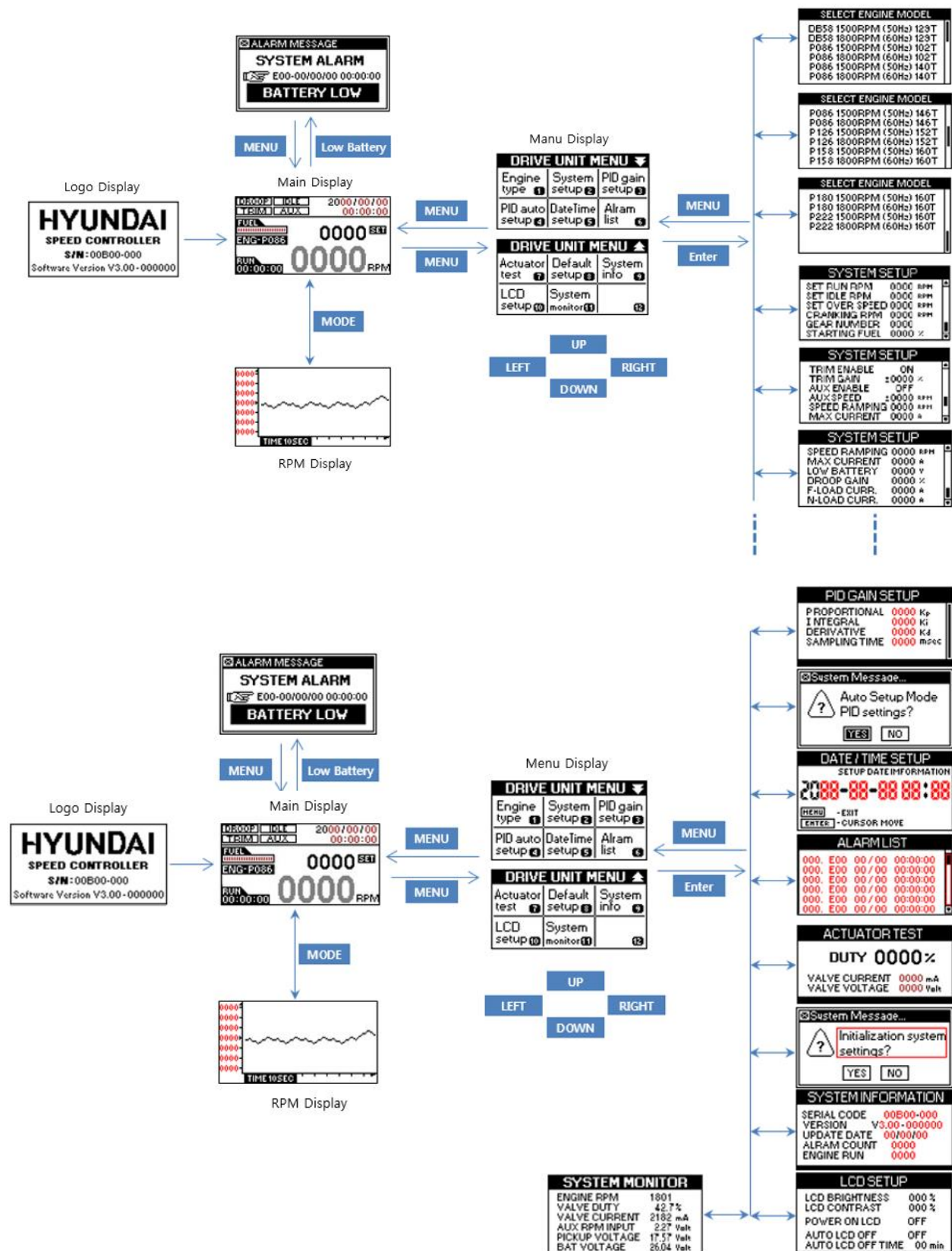


Figure 7: Overall LCD Menu Tree Diagram

3.2.1 LCD Displays After Powered On

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

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

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

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



Figure 8: **HYUNDAI** Logo

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

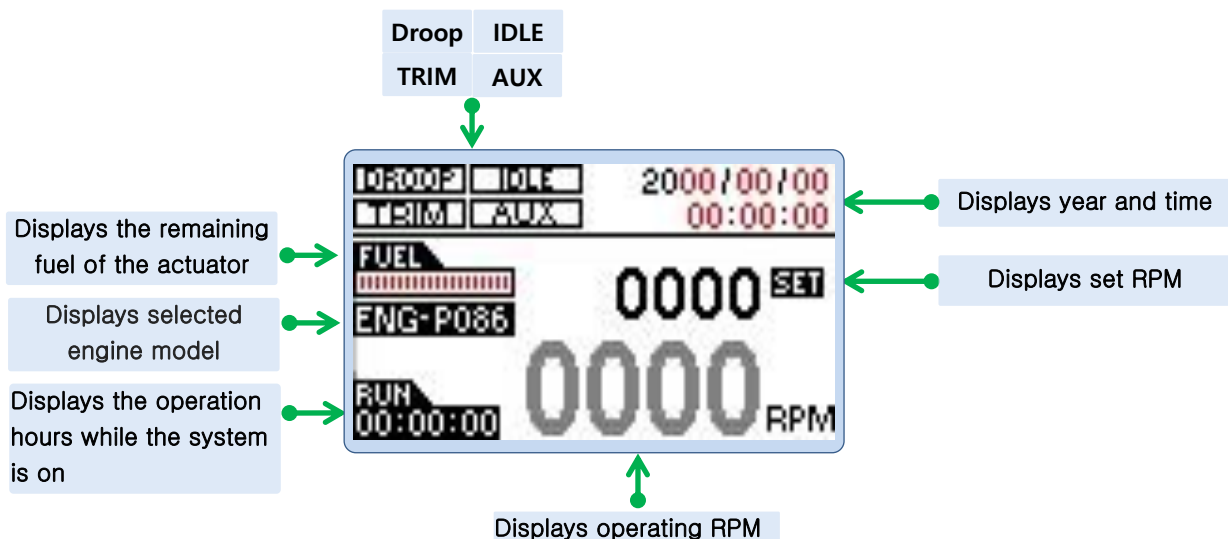
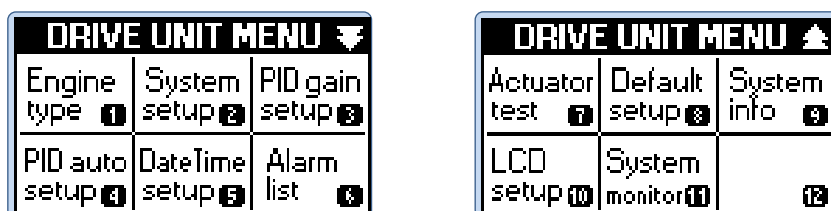


Figure 9: Operation Display

3.2.2 LCD Main Menu Display

Displays main menu screen of the controller

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



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

1) Engine type

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

2) System setup

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

3) PID gain setup

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

4) PID auto setup

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

5) DateTime setup

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

6) Alarm list

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

7) Actuator Test

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

8) Default setup

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

9) System info

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

10) LCD setup

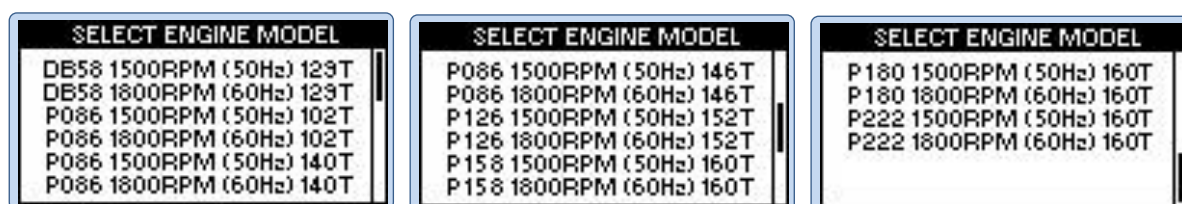
It offers menu to configure LCD operating conditions including brightness, auto on/off and off hours.

11) System monitor

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

3.2.3 Engine Type Setup Menu

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

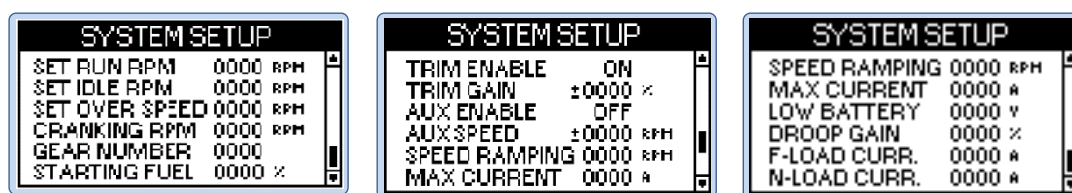


Menu 2: Engine Type Selection Menu

3.2.4 System Setup Menu

System Setup Menu Display of the Controller

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



Menu 3: System Setup Menu - 1 to 3

1) SET RUN RPM

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

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

2) SET IDLE RPM

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

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

3) SET OVER SPEED

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

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

4) CRANKING RPM

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

5) GEAR NUMBER

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

6) STARTING FUEL

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

7) AUX SPEED

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

8) SPEED RAMPING

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

9) MAX CURRENT

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

10) LOW BATTERY

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

11) DROOP GAIN

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

12) F-LOAD CURR

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

13) N-LOAD CURR

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

3.2.5 PID Gain Setup Menu

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



Menu 4: PID Gain Setup Menu

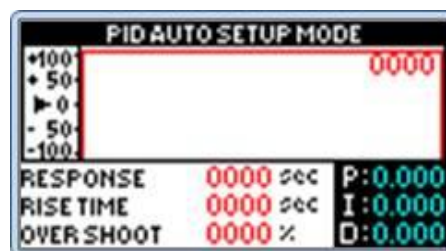
3.2.6 PID Auto Setup Menu

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

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

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

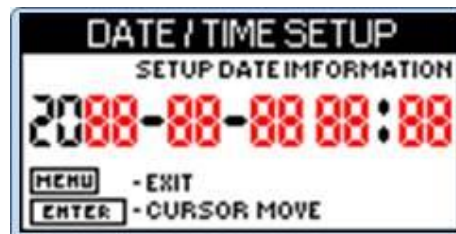
If the controller fails to identify the optimized P, I and D values within 30 cycles, it will display "PID No Successful, OK". When you press Enter, it will apply the final P, I and D values and close the menu.



Menu 5: PID auto setup menu

3.2.7 Date/Time Setup Menu

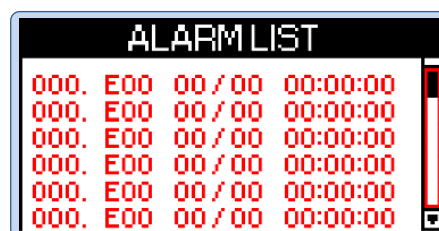
Users can designate year, month, day, hour and minute for the controller and the designated time will be used to monitor the system and manage fault messages.



Menu 6: DATE/TIME SETUP Menu

3.2.8 Alarm List Menu

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



Menu 7: ALARM LIST Menu

3.2.9 Default Setup Menu

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

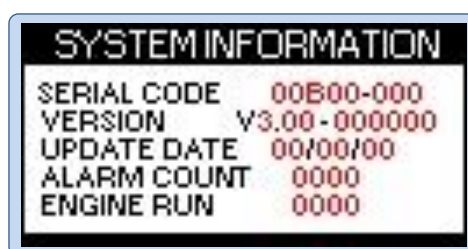
If you press YES, all the configuration values will be changed to the default ones of the engine.



Menu 8: Default Setup Menu

3.2.10 System Info Menu

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



Menu 9: System Info Menu

3.3 Engine Configuration

3.3.1 Engine Type Configuration

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

Designated Parameters by Engine Type (Land use)

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

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

Designated Parameters by Engine Type (marine use)

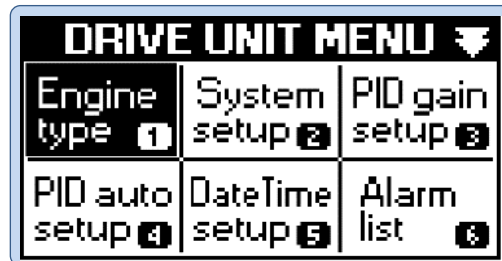
No	Menu Name	Run RPM	Over Speed	Gear Teeth	Starting Fuel	PID Value
1	AD066TI 1500RPM (50Hz) 129T	1500 RPM	1725RPM	129	60%	Optimized Value
2	AD066TI 1800RPM (60Hz) 129T	1800 RPM	2070RPM	129	60%	Optimized Value
3	AD086TI 1500RPM (50Hz) 140T	1500 RPM	1725RPM	140	60%	Optimized Value
4	AD086TI 1800RPM (60Hz)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

Table 1: Configuration Values by Engine Type

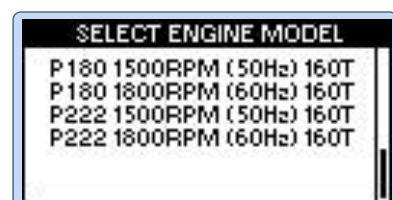
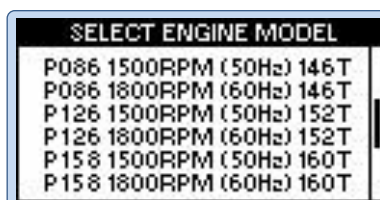
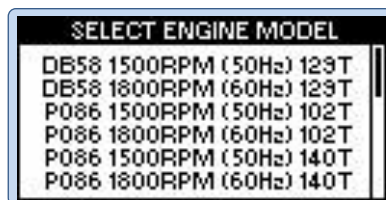
- **Engine Configuration Procedure**

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

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



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



Menu 10: Selection List by Engine Type

3.3.2 System Setup Configuration

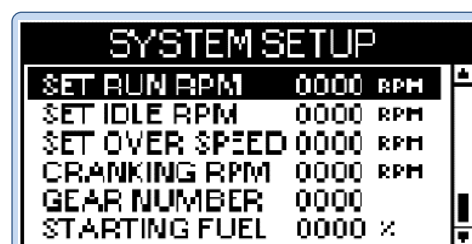
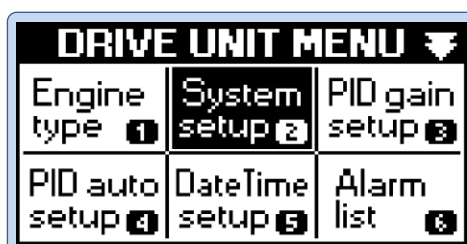
Main setting items of the controller includes **GEAR NUMBER**, **CRANKING RPM** and **SET RUN RPM**. You need to designate setting values to these items. Other system setup items are optional and therefore you can designate values for those items as necessary.

- **Configuring SET RUN RPM**

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

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

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

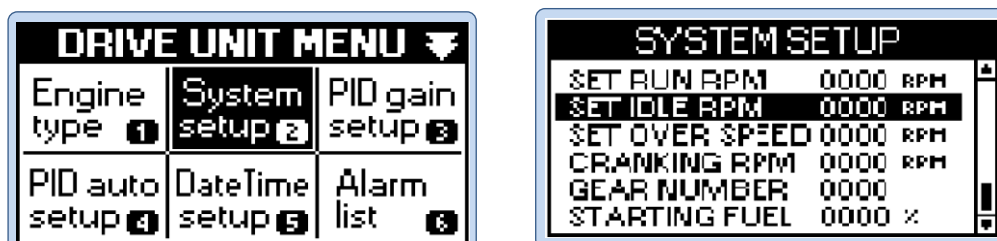


- **Configuring SET IDLE RPM**

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

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

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

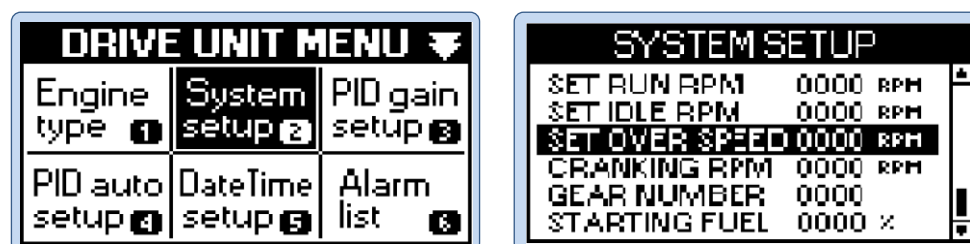


- **Configuring SET OVER SPEED**

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

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

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

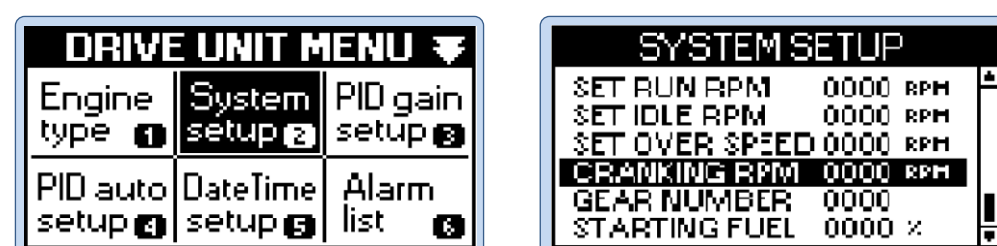


- **Configuring CRANKING RPM**

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

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

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

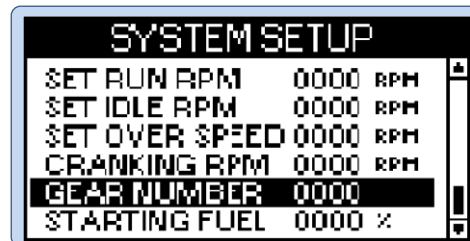
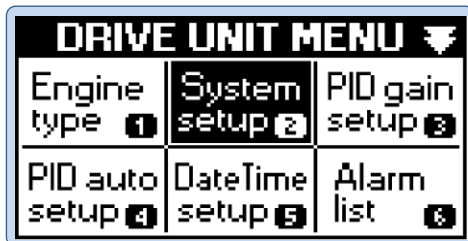


- Configuring **GEAR NUMBER**

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

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

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

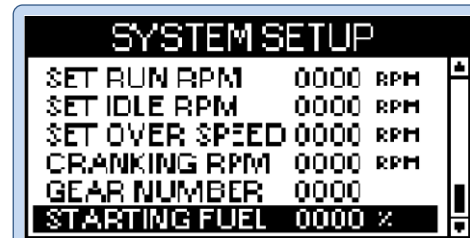
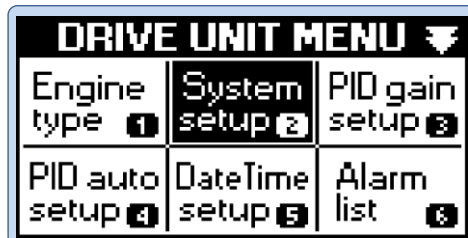


- Configuring **STARTING FUEL**

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

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

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

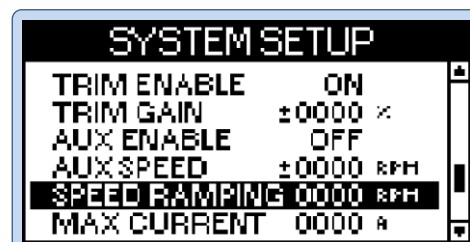
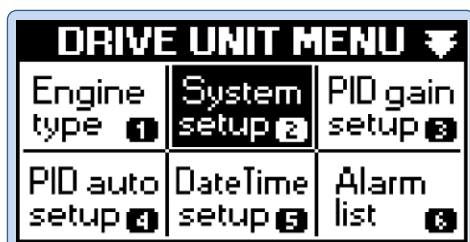


- Configuring **SPEED RAMPING**

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

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

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

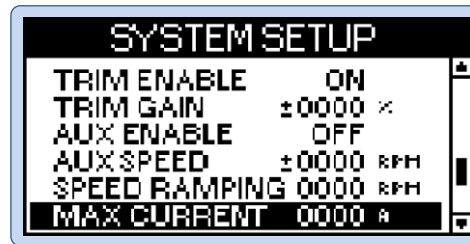
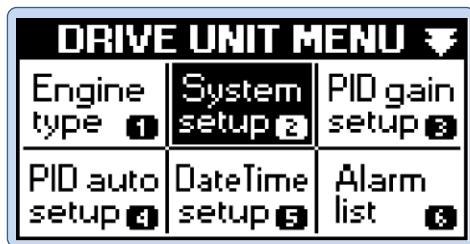


- Configuring **MAX CURRENT**

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

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

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

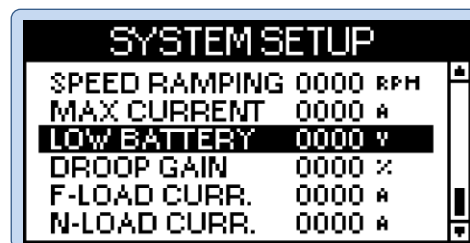
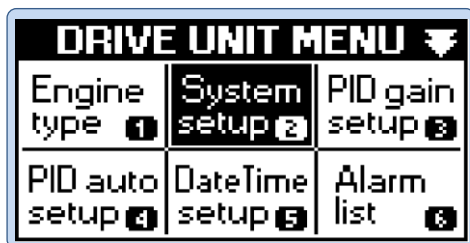


- Configuring **LOW BATTERY**

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

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

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

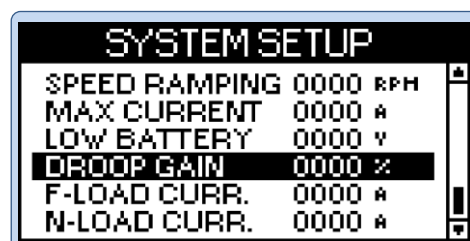
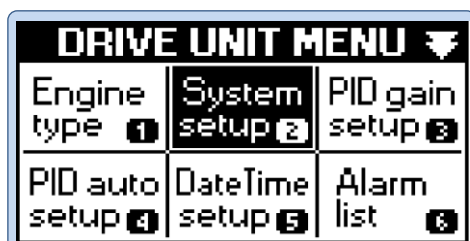


- Configuring **DROOP GAIN**

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

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

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



DROOP Function

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

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

(Example for 3% Droop)

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

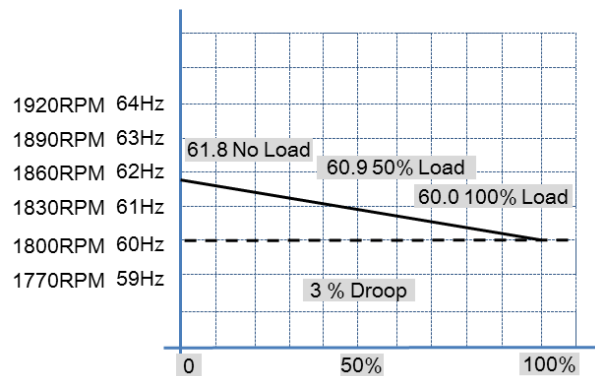


Figure 10: 3% Droop

(Example for 7% Droop)

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

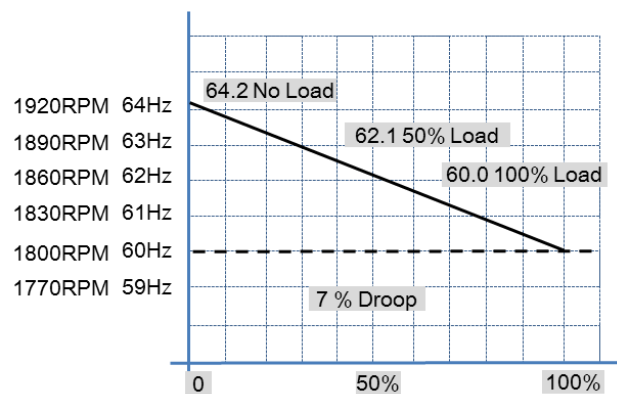


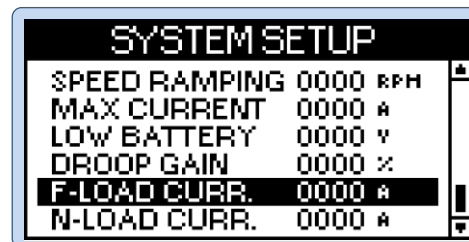
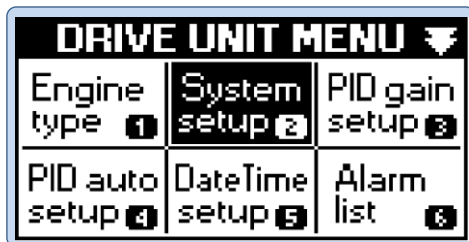
Figure 11: 7% Droop

- **F-LOAD CURR.**

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

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

Step3) Select **F-LOAD CURR.** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to input the maximum current values of the **actuator** for the generator with full load and then press **Enter** button.

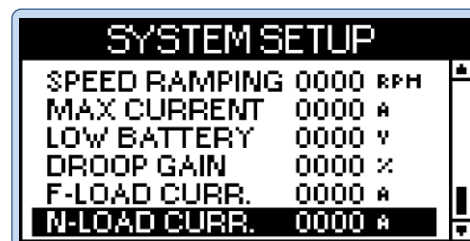
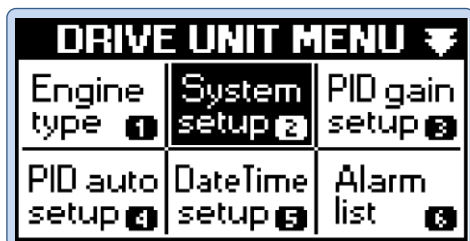


- **N-LOAD CURR.**

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

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

Step3) Select **N-LOAD CURR.** in **SYSTEM SETUP** menu and then press **Enter** button. Use **Up** and **Down** buttons to input the operating current values of the **actuator** for the generator with no load and then press **Enter** button.



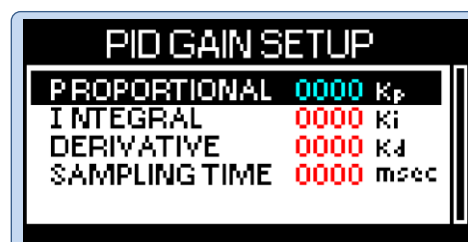
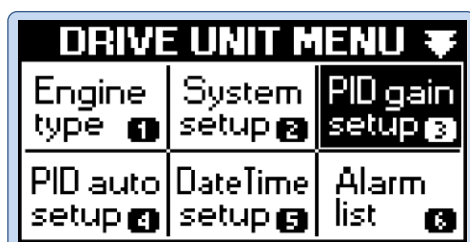
3.3.3 PID Gain Setup Configuration

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

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

Step2) Use **Up** and **Down** buttons in **PID GAIN SETUP** to select **PROPORTIONAL, INTEGRAL** or **DERIVATIVE** and then press **Enter** button.

In **PID GAIN SETUP**, if a user sets the value over than 100 about each **P, I, D**, we could not the warrant of the product quality.



- Configuring **PID SAMPLING TIME**

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

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

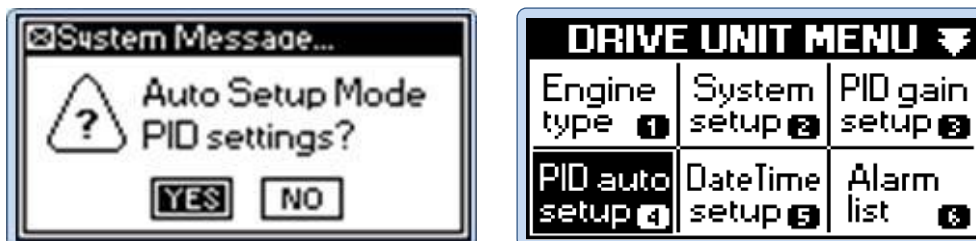


3.3.4 PID Auto Setup Value Configuration

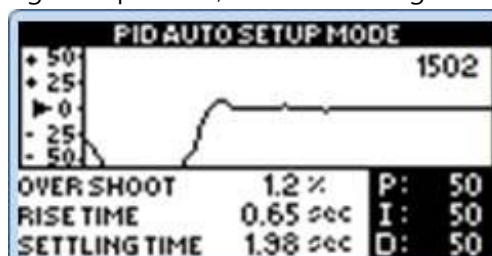
Step1) Select your type in Engine Type menu and then start the engine with the preset configuration values maintaining it with no load.

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

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



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



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

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



3.3.5 DATE/TIME Value Configuration

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

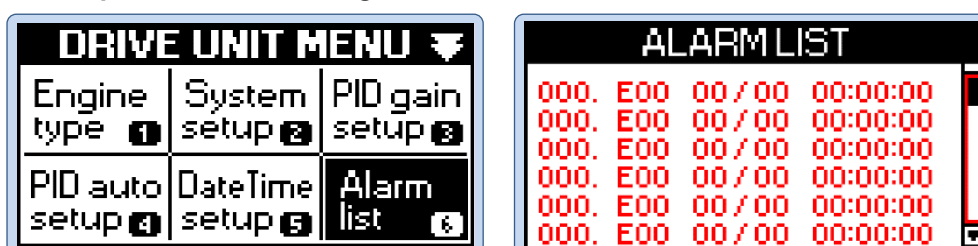
Step2) Use **Up**, **Down**, **Left** and **Right** buttons to input year, month, day and hour and then press **Enter** button.



3.3.6 ALARM LIST

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

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



[Alarm Code Table]

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

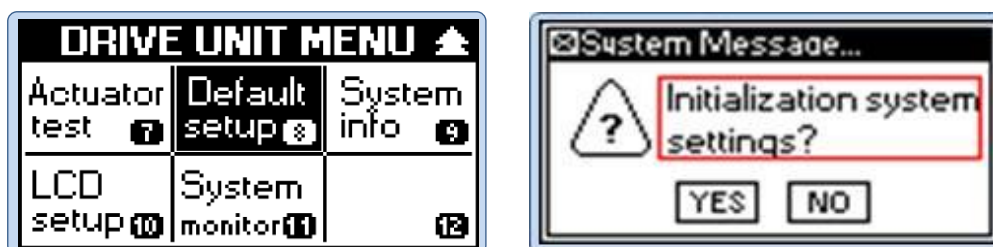
3.3.7 Actuator test

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

3.3.8 Default setup Functions

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

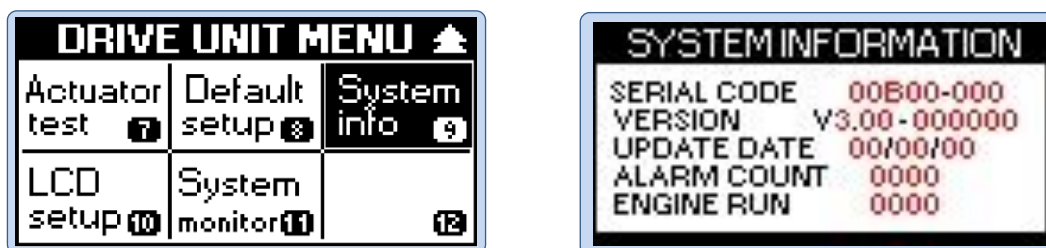
Step2) Use **Left** and **Right** buttons to select either **YES** or **NO** in **System Message** and then press **Enter** button.



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

3.3.9 System info Functions

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

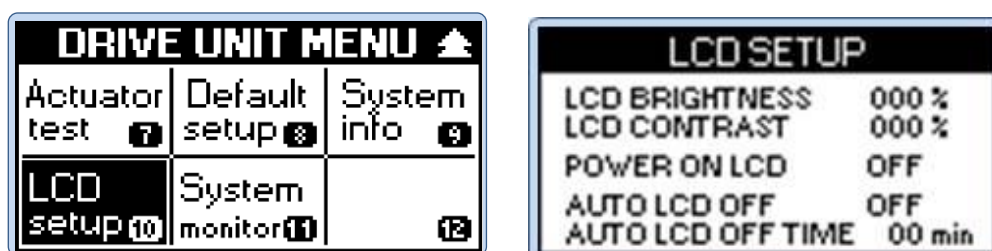


The menu displays information of the controller and the information includes the serial number, software version, last update date, alarm count and engine runs.

3.3.10 LCD setup Functions

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

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



3.3.11 System monitor Functions

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

4. How to Operate

4.1 Operating Sequence for Digital Speed Controller

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

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

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

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

4.2 Detailed Operating Sequence

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

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

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

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

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

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

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

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

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

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

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

5. Troubleshooting

5.1 Alarm List Check

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

Land/marine

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

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

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

5.2 System Checks and Measures

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

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

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

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

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

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

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

6. Warranty and A/S Service

6.1 Warranty

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

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

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

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

6.2 A/S Service Information

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