HYUNDAI INFRACORE

950106-152002EN

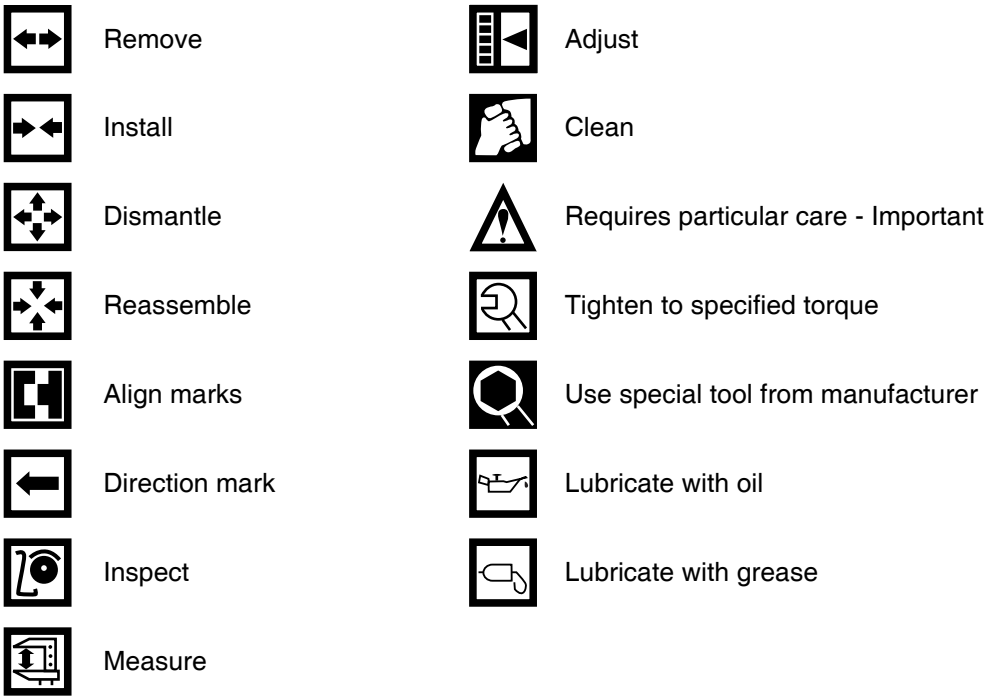
Operation & Maintenance Manual

GENERATOR ENGINE

DP126CE, DP126CD, DP126CB
DP126CA, DP126CCK, DP126CBK
DP126CAK

Preface

These maintenance guidelines were designed as a reference tool for HD Hyundai Infracore clients and distributors to gain basic product knowledge about the HD Hyundai Infracore generator diesel engine (DX12).
This economic, high-performance diesel engine (6-cylinder, 4-stroke, in-line direct injection) was designed and manufactured to be used as a generator. This diesel engine series satisfies all requirements for low noise, fuel efficiency, quick engine speed and durability.
In order to maintain this engine in its optimal state and maximum performance for an extended period of time, correct operation and proper maintenance are essential.
This manual uses the following symbols to represent the types of service to be performed.



While servicing the engine, be sure to comply with the following instructions in order to prevent environmental damage.

- Take used oil to a used oil recycling facility.
- Never allow oil or diesel fuel to enter the sea, streams, waterways or the ground.
- Dispose of undiluted anticorrosives, antifreeze, filter elements and cartridges as special waste.
- Used coolant and special waste must be disposed of in compliance with the regulations of local institutions.

If you have any questions or recommendations regarding this manual, please do not hesitate to contact our head office, dealership or nearby accredited service center.

Finally, the contents of this operation and maintenance manual may be subject to change without notice in order to improve quality. Thank you.

2024. 01.
950106-152002EN
HD Hyundai Infracore

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

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1. Safety Regulations

1.1. General Notes

There should be absolutely no problems with operating the diesel engine and necessary resources if this is done according to common sense by a technician who has completed relevant training and is performing the initial engine start-up, operation or maintenance.

This summary is a collection of information about important regulations divided into several main sections which include information necessary for preventing injury, property damage and contamination. In addition to these regulations, you must also comply with specific regulations which are applicable depending on the type of engine and engine location.

Important:
In the event that an accident (in particular, physical contact with dangerous acidic substances, penetration of oil through the skin, oil burns, antifreeze entering the eyes, etc.) occurs in spite of taking every precaution, please consult a doctor immediately.

Warning:
While running the engine, be careful not to touch the safety guard on the cooling fan. Otherwise, the spinning cooling fan may cause severe injury, such as severing fingers.

Warning:
While running the engine, be careful not to touch the safety guard on the V-belt. Otherwise, the spinning V-belt may cause severe injury, such as severing fingers.

Warning:
The V-belt safety guard is an optional item for customers. You must install the V-belt safety guard in order to prevent accidents. In the event that the V-belt safety guard is not installed, you must not approach the engine while it is running. HD Hyundai Infracore is not responsible for accidents or injuries which occur with the V-belt safety guard not installed.

Warning:
Be careful not to touch the components of the turbocharger immediately after stopping the engine or while the engine is running. Otherwise, the heated turbocharger may cause severe injury. In the event that you must touch the heated turbocharger for maintenance or repairs, wait a while for the turbocharger to cool off sufficiently before touching it.

Warning:
Be careful not to touch the components of the exhaust manifold or heat shield immediately after stopping the engine or while the engine is running. Otherwise, this may cause severe injury. The heat shield installed on the exhaust manifold is particularly hot so be careful not to touch it.

Warning:

In the event that you must perform emergency engine maintenance, use the mechanism installed on the generator first. It may be difficult to operate the 'manual emergency stop device' installed on the fuel pump, and touching the exhaust manifold may cause severe injury. Hence, you should use the 'manual emergency stop device' after installing a separate auxiliary cable. HD Hyundai Infracore is not responsible for accidents or injuries which occur without a separate auxiliary cable installed.

1.2. Regulations for Preventing Accidents

1.2.1. Initial Engine Start-Up, Starting and Operation

Before running the engine for the first time, be sure to read the operating guidelines carefully and familiarize yourself sufficiently with the "Main" items. Please contact a HD Hyundai Infracore dealership if you are unsure about anything.

- For the sake of safety, it is advisable to attach a notification decal to the door of the engine compartment in order to prevent access by unauthorized personnel as well as to notify the administrative personnel that they are responsible for the safety of workers entering the engine compartment.
- The engine must only be started and operated by qualified technicians. Please ensure that unauthorized personnel cannot start the engine.
- Do not get too close to rotating components while the engine is running. Wear properly fitting clothes.
- There is a risk of being burnt while the engine is running and hot so do not touch it with your bare hands.
- Exhaust gas is a toxic substance. Please comply with the installation guidelines for installing the HD Hyundai Infracore generator diesel engine when working in an enclosed space.
  Check that there is suitable ventilation and exhaust drainage.
- Always keep the areas around the engine, ladders and stairs free of oil and grease.
- Accidents caused by slipping can lead to severe consequences.

1.2.2. Maintenance and Operation

- Always perform maintenance with the engine turned off. In the event that you must perform maintenance on the engine while it is running (ex.: replacing the change-over filter element), remember that there is a risk of being burnt. Do not get too close to rotating components.
- Change the oil while the engine is running and warm.

Caution:
Risk of burns. Do not touch the oil discharge valve or oil filter with your bare hands.

- Consider the level of sump oil. Use a sufficiently large container to ensure that oil does not overflow.
- Only open the coolant circuit when the engine has cooled. In the event that the engine must unavoidably be opened while still warm, please comply with the guidelines in the chapter on "Cooling".
- Do not tighten or open pipes and hoses (lubricant circuit, coolant circuit and additional hydraulic oil circuits) while the engine is running. Oil leaks may cause injury.
- Fuel is a combustible substance. Do not smoke or use unshaded lamps near fuel. The tank must only be refilled while the engine is turned off.
- Only store service products (antifreeze) in containers which cannot be confused with containers for drinking water.
- When handling the battery, please comply with the manufacturer's guidelines.

Caution:
The acidic substance in the accumulator is dangerous and toxic. Battery gas is an explosive substance.

1.2.3. Performing Inspections, Adjustments and Repairs

- Only certified technicians may perform inspections, adjustments and repairs.
- Only use tools which are in a suitable condition. Slipping caused by wrenches with a worn-out opening can lead to injury.
- When the engine is hanging from a crane, there must be no one standing or passing beneath it. Keep the lifting gear in a suitable position.
- When inspecting the injector, do not place your hands beneath the fuel jet. Do not inhale fuel being sprayed.
- When working on the electrical system, disconnect the battery ground cable first. When connecting the cable, connect it last in order to prevent a short circuit.

Caution:
Do not spray highly pressurized water directly at the engine. The engine parts, electric parts, and wiring can be damaged.

1.3. Regulations for Preventing Engine Damage and Premature Wear

1) Do not use the engine for longer than its intended life.
   Please refer to the sales materials for more detailed information about this. Do not adjust the injection pump without prior consent from HD Hyundai Infracore.
2) In the event that a defect occurs, find the cause and resolve the issue immediately in order to prevent more severe damage.
3) Use only genuine spare parts from HD Hyundai Infracore. HD Hyundai Infracore is not responsible for damage caused by the installation of different parts considered to be of the "same grade".
4) Also, please bear in mind the following as well.
   - Never idle the engine without lubricant or coolant. Only use service products (engine oil, antifreeze and anticorrosive) approved by HD Hyundai Infracore.
   - Take particular care to maintain cleanliness. There must not be any water in the diesel fuel. Refer to "Maintenance and Operation".
   - Perform engine maintenance at the designated intervals.
   - Do not turn the engine off as soon as it has been preheated, and run it on idle for around 5 minutes in order to reach temperature equilibrium.
   - Never add cold coolant to a hot engine. Refer to "Maintenance and Operation".
   - Be sure not to add so much engine oil that the oil level exceeds the upper limit mark on the dip-stick. Do not exceed the maximum permissible engine inclination. The engine may be severely damaged if these guidelines are not followed.
   - Always check that testing and monitoring equipment (for monitoring battery charge, oil pressure and coolant temperature) functions satisfactorily.
   - Be sure to follow the guidelines related to operating the alternator. Refer to "Initial Start-Up and Operation".
   - Do not idle the water pump. If there is a risk of frost forming, discharge the coolant with the engine turned off.
5) Unloading should be minimized during operation. Under the unloaded condition, the temperature of the combustion chamber drops to the temperature that fuel cannot be fully combusted at, thereby resulting in the external leakage of uncombusted fuel and white smoke. When the generator is to be operated for long hours, a load should be connected to it at all times.

1.4. Regulations for Preventing Contamination

1.4.1. Engine Oil, Filter Element, Fuel Filter

- Be sure to deliver used oil to an oil collection facility. Take thorough precautions to ensure that used oil does not spill into the sewers or on the ground.
- This may contaminate the drinking water supply line.
- Oil and fuel filter elements are classified as hazardous wastes so they must be handled accordingly.

1.4.2. Coolant

- Undiluted anticorrosive and/or antifreeze must also be treated as hazardous wastes.
- When disposing of coolant which has reached the end of its life, follow the relevant regulations of local institutions.

1.4.3. Cold Start

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

Caution:
The engine is equipped with a preheating system for enhancing cold startability.

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

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

1.5. Safety Information for Handling Used Engine Oil

Skin is damaged in the event of prolonged or repeated contact between skin and engine oil.
This can cause skin dryness, agitation or inflammation. Results from animal experiments have also shown that engine oil contains hazardous substances which cause skin cancer. Handling used engine oil does not pose any threat to health if basic regulations regarding workplace hygiene, health and safety are followed.

Health Precautions

- Avoid prolonged or repeated contact between skin and used engine oil.
- Apply suitable protective agents (cream, etc.) or wear protective gloves to protect skin.
- Wash skin in the event that it comes into contact with engine oil.
  - Wash thoroughly with soapy water. Nail brushes may be useful for this.
  - You can wash your hands more easily by using certain products.
  - Do not use kerosene, diesel fuel, gas oil, thinner or solvents as cleaning products.
- After washing, apply an oily skin cream to the skin.
- In the event that clothing or shoes are soaked with oil, change into different clothing or shoes.
- Do not keep reclaimed oil in your pockets.

Check that used engine oil has been properly disposed of.
- The drinking water supply line may be harmed by engine oil -

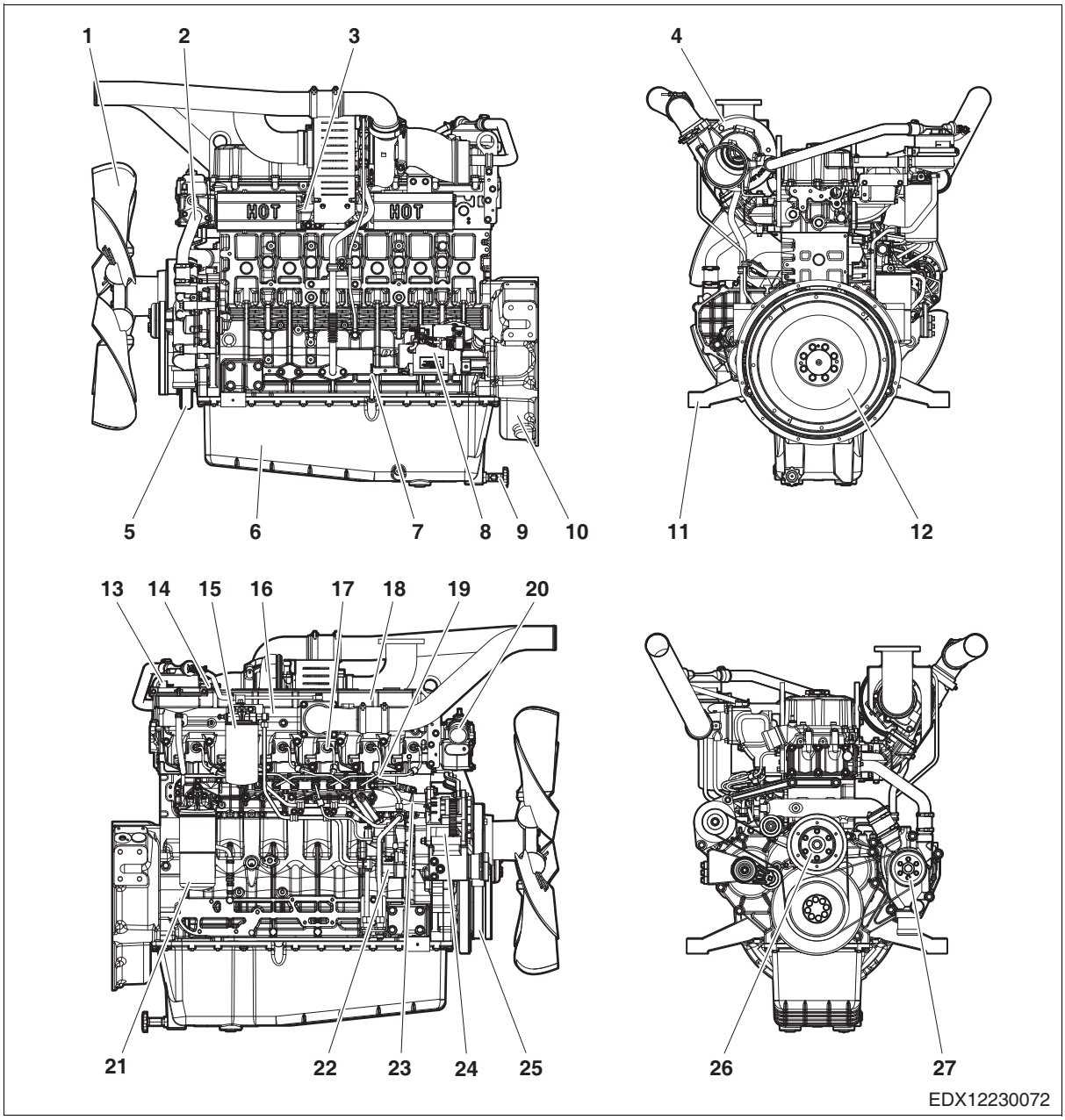
For this reason, do not spill engine oil on the ground, in waterways, sewers or drain pipes. A fine may be imposed in the event that this regulation is violated. Collect and dispose of used engine oil carefully.
For information about collection facilities, contact the dealer, supplier or local institutions.

2. General Information

2.1. Engine Assembly Diagram

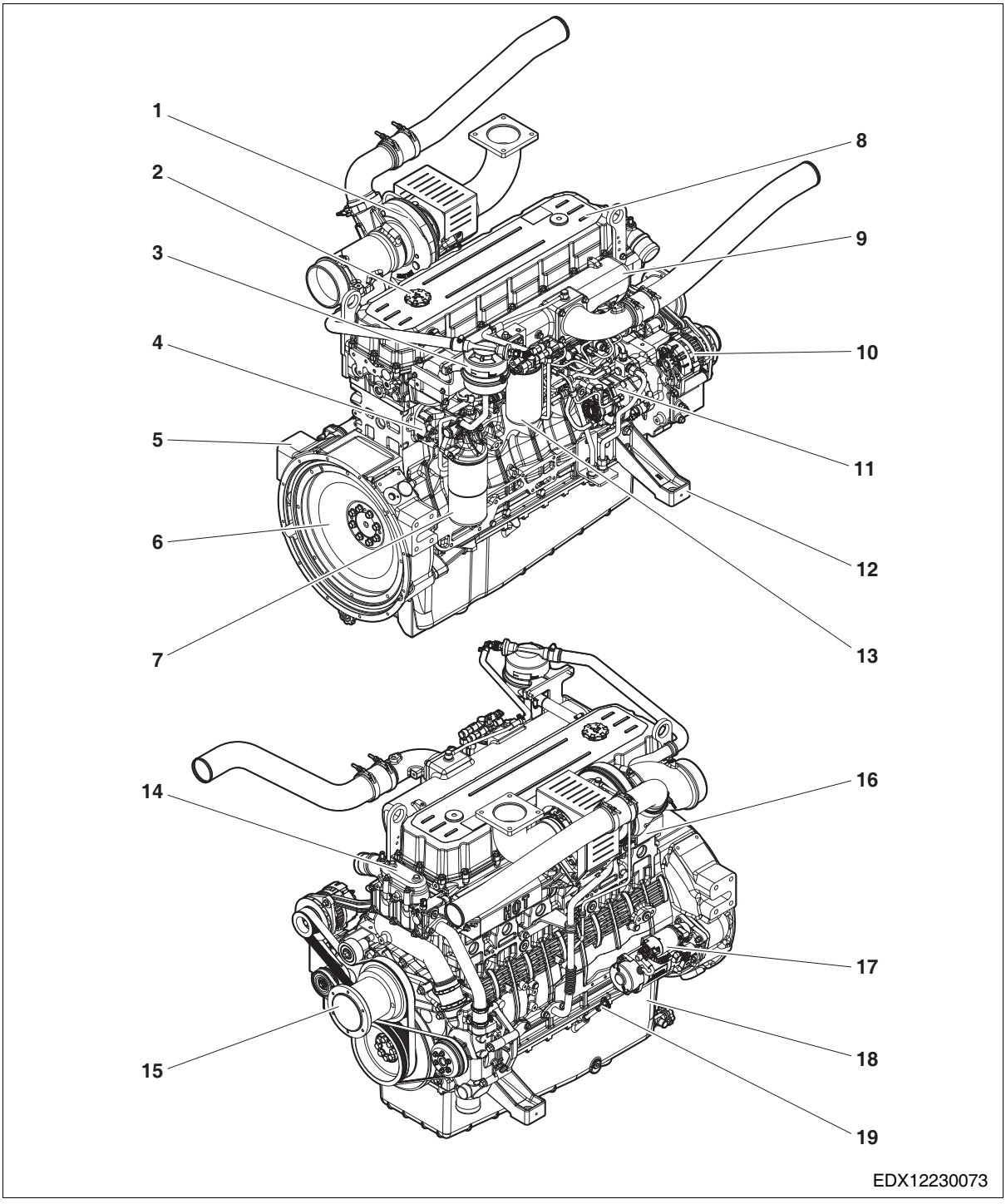
Caution: The images shown represent the standard model; they do not include all models.

1) Flatness



1. Cooling fan
2. Coolant pipe
3. Exhaust manifold
4. Turbocharger
5. Vibration Damper
6. Oil pan
7. Oil level gauge
8. Starter
9. Oil discharge valve
10. Flywheel housing
11. Mounting bracket
12. Flywheel
13. Breather
14. Oil filler cap
15. Fuel Filter
16. Intake manifold
17. Fuel pipe assembly
18. Cylinder head cover
19. Injection pipe
20. Thermostat
21. Oil filter
22. Injection pump
23. Oil cooler
24. Alternator
25. Crankshaft pulley
26. Fan actuator
27. Water Pump

2) Structural Diagram



1. Turbocharger
2. Oil filler cap
3. Breather filter
4. Oil cooler
5. Flywheel housing
6. Flywheel
7. Oil filter
8. Cylinder head cover
9. Intake manifold
10. Alternator
11. Injection pump
12. Mounting bracket
13. Fuel Filter
14. Thermostat
15. Cooling fan flange
16. Exhaust manifold
17. Starter
18. Oil pan
19. Oil level gauge

2.2. Engine Specifications

Item \ Engine Model		DX12 Generator						
		DP126CE	DP126CD	DP126CB	DP126CA	DP126CCK	DP126CBK	DP126CAK
Engine Type		Water-cooled, 4-cycle inline Turbocharger and intercooling						
Type of combustion chamber		Direct injection						
Type of cylinder liner		Replaceable dry liner						
Timing gear system		Gear-driven						
No. of piston rings		2 compression rings and 1 oil ring						
No. of cylinder bores x stroke (mm)		6 - 123 x 155						
Total piston displacement (cc)		11,051						
Compression ratio		16.5 : 1						
Engine dimensions (length x width x height) (mm)		1,404 x 1,089 x 1,314						
Engine weight (kg)		1,058						
Direction of rotation (based on flywheel)		Counterclockwise						
Fuel injection order		1 - 5 - 3 - 6 - 2 - 4						
Fuel injection timing (rests at B.T.D.C)		Controlled by ECU						
Type of injection pump		Common Rail System						
Engine control type		ECU (Bosch MD1CE100)						
Type of injection nozzle		Multi-hole type (8 holes)						
Fuel injection pressure (bar)		300						
Compression pressure (kg/cm^2)		25.0 (at 200 rpm)						
Intake and exhaust valve clearance (at low temp.) (mm)		Intake 0.4 ±0.05/Exhaust 0.7 ±0.05						
Intake valve	Opening	30°(B.T.D.C)						
	Closing	22°(A.B.D.C)						
Exhaust Valve	Opening	73°(B.B.D.C)						
	Closing	30°(A.T.D.C)						
Lubrication method		Forced pressure supply						
Type of oil pump		External spur gear type						
Oil filler cap		Full-flow, cartridge						
Lubricant oil capacity (max./min.) (lit)		44/20						
Oil cooler		Water-cooled						
Water Pump		Centrifugal (pulley type)						
Cooling method		Radiator						
Coolant capacity (engine only) (lit)		23						
Thermostat type		Wax-pellet type Start of Opening (71°C/85°C), Fully Open (95°C)						
Alternator volt. - capacity (V - A)		24 ~ 45						
Starter motor volt. - output (V - kW)		24 ~ 6.0						

2.2.1. Engine Power (ISO 3046)

Engine Model	Power (kWm)	Rated power (gross)		Rated power (net)		Remark
		Standby	Prime	Standby	Prime	
DP126CE	1,500 rpm (50 Hz)	441	401	426	386	Non-Tier
	1,800 rpm (60 Hz)	502	449	479	426	
DP126CD	1,500 rpm (50 Hz)	414	376	399	361	
	1,800 rpm (60 Hz)	458	416	435	393	
DP126CB	1,500 rpm (50 Hz)	362	329	347	314	
	1,800 rpm (60 Hz)	402	365	379	342	
DP126CA	1,500 rpm (50 Hz)	321	292	306	277	
	1,800 rpm (60 Hz)	375	341	352	318	
DP126CCK	1,800 rpm (60 Hz)	441		418		EPA-Tier3
DP126CBK	1,800 rpm (60 Hz)	402		379		
DP126CAK	1,800 rpm (60 Hz)	375		352		

Note:

Power definition

The standard power rating and prime power rating comply with ISO 8528.
They are equivalent to the fuel cell power rating defined by ISO 3046.
For the battery power (kWe), the cooling fan loss, alternator efficiency, deterioration by altitude difference, ambient temperature, etc. should be considered.

The Standby Power Rating is applied to the supply of standby power while the prime power is not being supplied.
Overloaded operation is not allowed at the standby power rating. The standby power generator should be sized for a maximum of an 80% average load factor and 200 hours per year. This includes less than 25 hours per year of running time at the standby power rating.

The prime power rating is accessible for an unlimited number of hours per year in a variable load setting. The variable load should not exceed a 70% average of the prime power rating during any operational period of 24 hours. If the generator is running at 100% prime power, the yearly hours should not exceed 500. A 10% overload capability is available for a 1 hour period within a 12 hour cycle of operation. However, the total number of hours at 10% overload power per year should not exceed 25.

The SESP (Special Emergency Standby Power) Rating is applied to the supply of standby power while the prime power is not being supplied.
Overloaded operation is not allowed at the SESP rating. The SESP generator should be sized for a maximum of a 70% average load factor and 100 hours per year. This includes less than 25 hours per year of running time at the SESP rating.

3. Technical Data

3.1. Engine Type

The DX12 engine is an in-line vertical water-cooled direct injection 6-cylinder 4-stroke diesel engine with a turbocharger and intercooler type.

3.1.1. Cylinder Block

This cylinder block is an assembled unit made of cast iron alloy. In order to increase strength, it has been extended to the level below the central line on the crankshaft. This engine is equipped with replaceable dry cylinder liner and individual cylinder heads (includes fixed valve seat rings and replaceable valve guide).

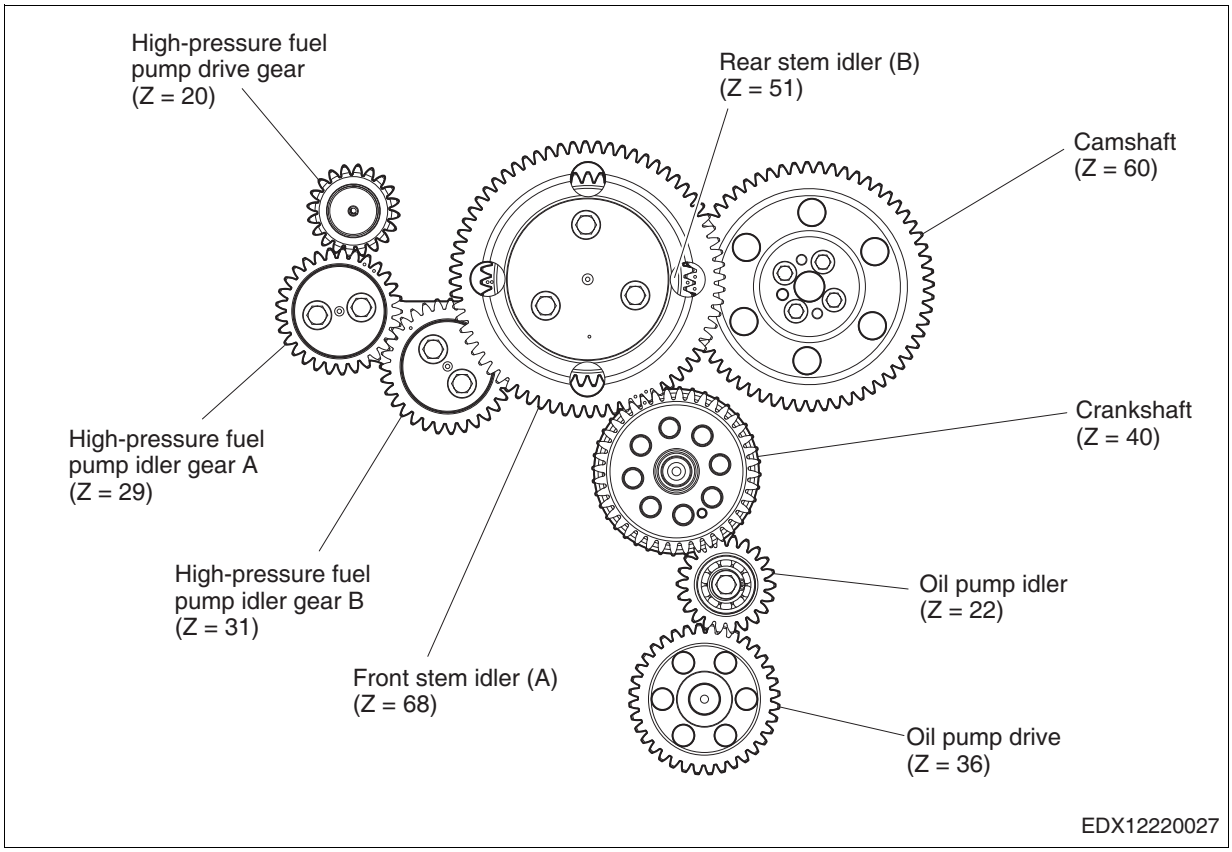
3.1.2. Piston Connecting Rod / Crankshaft

The forged crankshaft has an integrated structure in which the counterweight is made at the same time as the crankshaft during forging. The crankshaft and flywheel are provided with oil seals to seal them and prevent internal penetration of the flywheel housing. The connecting rod is a forged alloy steel unit whose big-end cap can be disassembled diagonally, allowing it to be removed along with the piston through the top of the cylinder.

The crankshaft and connecting rod are equipped with an alloy metal bearing made of Pb-free material which can be installed immediately.

3.2. Engine Timing

The camshaft, oil pump and injection pump are driven by the gear train aligned with the front end.



3.3. Valve

The overhead valve is driven by the camshaft's chilled cast iron tappet, pushrod and rocker arm.

3.4. Lubrication System

The engine is equipped with a forced supply-type lubrication mechanism.

Pressure is formed through direct engagement between the driving gear in the gear pump with the crankshaft gear on the front end of the cylinder block.

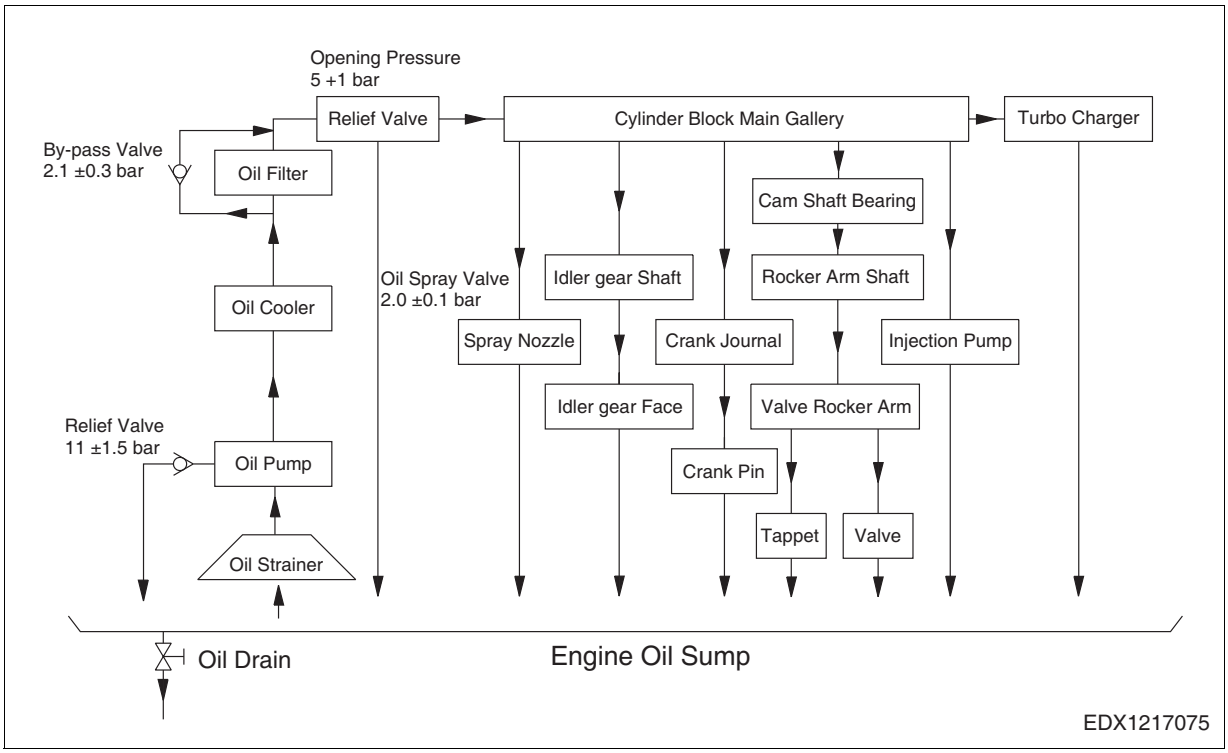
The oil pump draws oil from the oil sump which then passes through the oil cooler and oil filter to the main distributor gallery; from here, it is supplied to the main bearing, big-end bearing, camshaft bearing, small-end bearing and rocker arm.

The injection pump and turbocharger are also connected to the engine's lubrication system.

The cylinder wall and timing gears are lubricated with splash lubrication.

Each cylinder is provided with an oil jet to cool the bottom of the piston.

The lubricant is filtered in the full-flow oil filter.

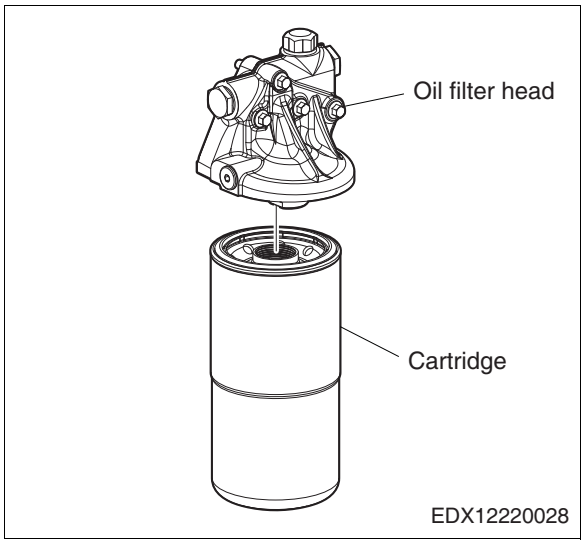


3.4.1. Oil cooler

There is an oil cooler between the oil filter and cylinder block. This flat tube-type cooler includes a turbulence insert and is cooled by the coolant.

3.4.2. Oil filter

Check the oil pressure and whether there are any oil leaks; if necessary, repair or replace the oil filter.
Be sure to also replace the oil filter cartridge whenever replacing the engine oil.



3.5. Air cleaner

Replace the air cleaner whenever the element is either deformed or damaged, or when the air cleaner is cracked.
The element must be cleaned and replaced regularly at the designated intervals.

- Cleaning the air cleaner element: Every 200 hours.
- Replacing the air cleaner element: Every 400 hours.

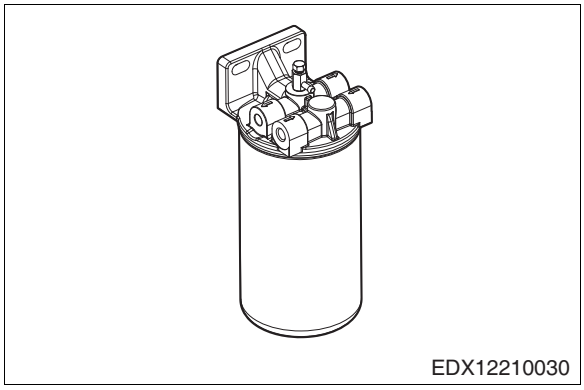
3.6. Fuel System

Fuel passes through the fuel filter to the injection pump by means of the fuel supply pump and is then conveyed from the injection pump to the injection nozzle.
Fuel is injected into the cylinder by means of the nozzle installed on the cylinder head.
Excess fuel conveyed to the nozzle or leaked fuel passes through the cylinder head return line and return pipe into the tank.
The strainer is positioned in front of the fuel supply pump.

3.6.1. Fuel Filter

This fuel filter performs the function of filtering fuel.
Before entering the injection pump, fuel is filtered by the strainer and fuel filter in the fuel supply pump.

The fuel filter must be replaced every 500 hours.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3.6.2. Fuel Requirements

The diesel fuel must be equivalent to EN590/ASTM D972 Grade 2 as follows:

3.6.3. Primary Fuel Filter

A primary fuel filter, two piping connecting adapters, and two fuel filter plugs are provided as separate accessories along with the engine.

Remove the plugs for preventing foreign matter from entering the fuel inlet/outlet of the primary fuel filter and tighten the connecting adapters provided to the specified torque.

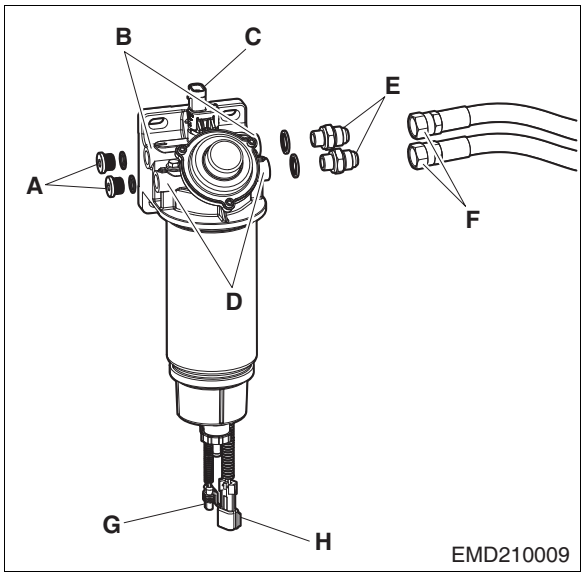
(Specified adapter tightening torque:
5.5 ±0.5 kg·m)

(Specified plug tightening torque:
2.25 ±0.25 kg·m)

According to the installation location of the primary fuel filter, one connecting adapter per port in the both inlet/outlet ports is used, and the fuel filter plugs are assembled in the remaining ports.

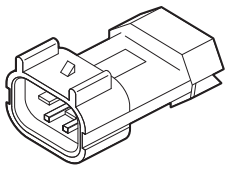
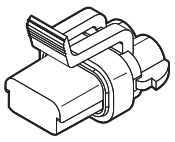
When tightening the hose, hold the adapter with a spanner so that it does not turn together.

(Specified hose tightening torque:
7.0 ±0.7 kg·m)

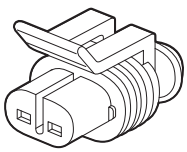
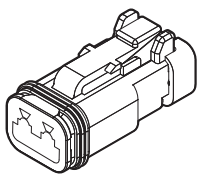


Number	Name
A	Fuel filter plug
B	Fuel inlet port
C	Fuel heater connector
D	Fuel outlet port
E	Fuel adapter SAE J516 37° CONE 7/8-14 UNF
F	Fuel hose
G	Water-in-fuel sensor connector
H	Fuel heater connector

- Fuel heater
  - Fuel heater specifications
    Operating voltage: DC24V
    Operating power: 200 W
    Operating temperature: turns on at 7 ±4°C or less, turns off at 24°C

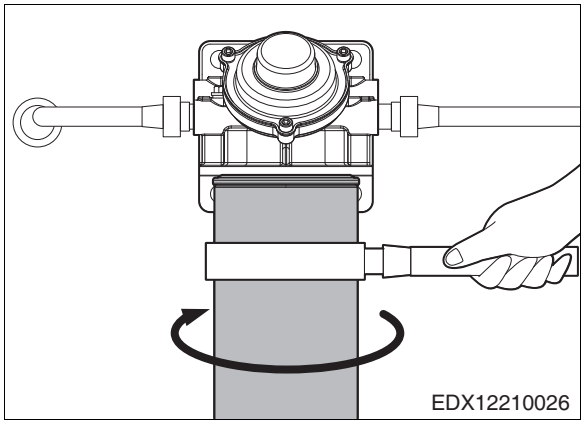
Primary Fuel Filter	Harness connecting part
	
15300002 (DELP HI)	15300027 (DELP HI)

- Water-in-fuel sensor
  - Water storage capacity of the primary fuel filter
    Start of electrical connection with water in fuel sensor switch: 90 ml
    Maximum water capacity: 200 ml
  - Water in fuel sensor switch specifications
    Operating voltage: 5 VDC
    Resistance: 82 kΩ ±2% @ 25°C

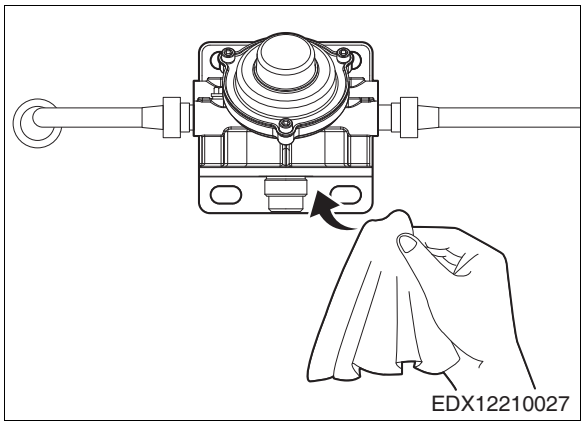
Primary Fuel Filter	Harness connecting part
	
DEUTSCH DT04-2P	DEUTSCH DT06-2S

3.6.4. Replacing the Primary Fuel Filter

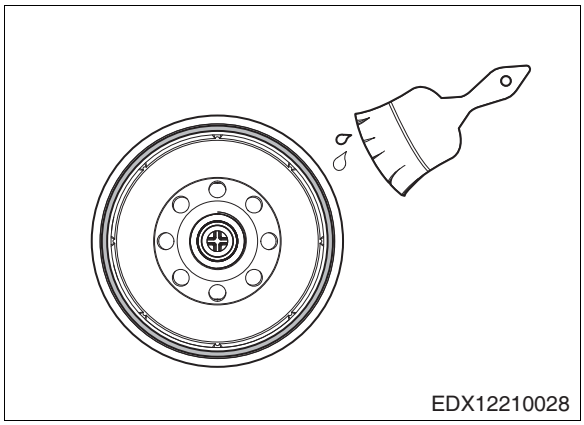
- Use a filter wrench to turn and unscrew the fuel filter cartridge in the counter-clockwise direction.
- Discard the used filter in the designated place.
- Clean the bowl with water, wipe it with a clean cloth, and let it dry.



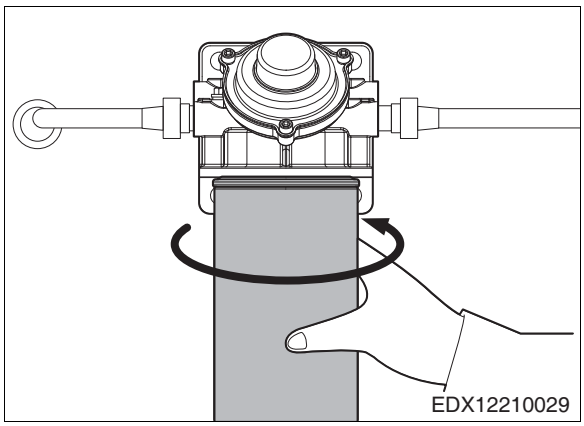
- Wipe the head with a clean cloth. Make sure to remove impurities from the filter contact surface of the head in particular.



- Use a brush to apply a thin layer of engine oil to the O-ring.



- Mount the cartridge perpendicularly to the head screw thread.
- Once the O-ring is touching the sealing surface, turn the cartridge 3/4 to one turn in the clockwise direction to assemble it.
- Mount the bowl perpendicularly to the filter screw thread.
- Once the O-ring of the bowl makes contact with the sealing surface, assemble it by turning the O-ring clockwise by 3/4.
- Once the O-ring of the bowl makes contact with the sealing surface, assemble it by turning the O-ring clockwise by 3/4.



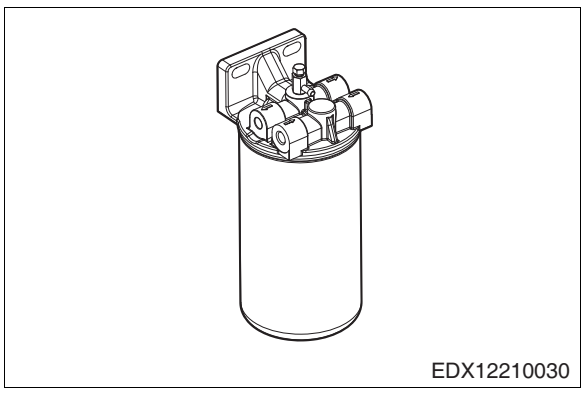
3.6.5. Fuel Filter

The fuel filter consists of a primary and secondary filter; the primary filter serves to filter out water and large particles of foreign matter, while the secondary filter is used to filter out smaller particles of foreign matter.
If you do not regularly inspect the fuel filter and discharge the water in the fuel filter, water enters the fuel system of the engine and can cause severe faults in the fuel injection pump, fuel injection pipe, common rail and injector. In addition, the fuel filter performance can be degraded or damaged.

- When draining the water in the fuel filter, fuel may also be drained as well. Fuel is a highly flammable substance. Hence, smoking or using an open flame near the engine may cause a fire.
- Only use clean fuel with the specified grade. Using imitation or unspecified fuel may increase the amount of water in the fuel filter.
- If you do not drain the water in the fuel filter when the fuel filter warning lamp is illuminated, water may enter the fuel system and cause the engine to turn off.
- New fuel filters must be assembled without any fuel in them. Do not use the fuel in replaced fuel filters or the fuel in the fuel tank in new fuel filters.

3.6.6. Replacing the fuel filter

- Turn the fuel filter cartridge counterclockwise with a filter wrench to loosen it. Discard the used filter in the designated place.
- Wipe the filter contact surface clean.
- Apply a thin layer of engine oil to the O-ring and add fuel to the new filter.
- Install the O-ring on the sealing surface and tighten the cartridge another 3/4 to one turn.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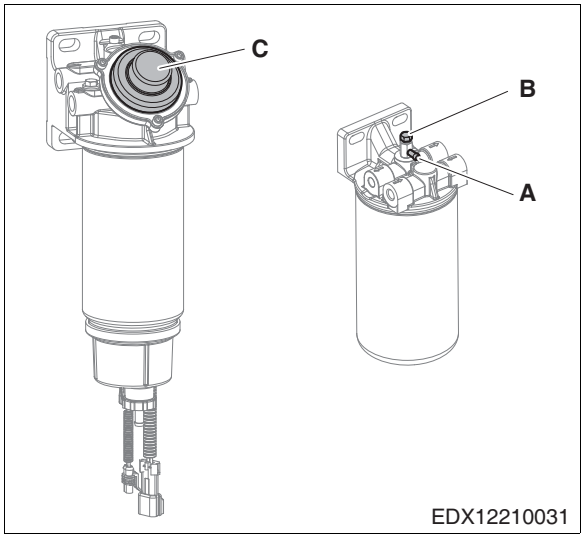
3.6.7. Bleeding the fuel system

Whenever the fuel filter is replaced or the engine stalls due to insufficient fuel, remove the air from the fuel line as follows.
Connect the hose to air bleeder port (A) of the secondary fuel filter; then, after unscrewing the fuel bleeder plug (B), operate the primary fuel filter's priming pump (C) to bleed the air.

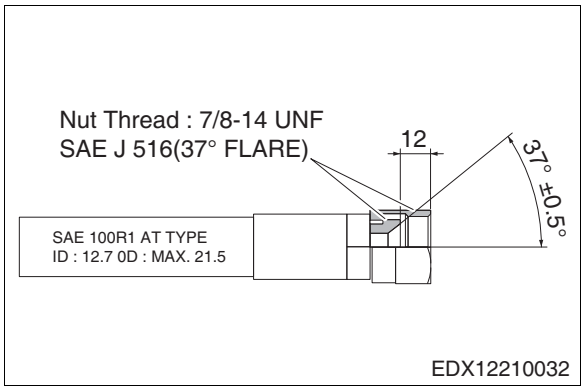
- Continue until bubble-free fuel flows out of the air bleeder port.
- After all air has been eliminated, reassemble the secondary fuel filter's air bleeder plug and remove the hose connected to the port.



3.6.8. Fuel Lines Connected to the Engine

Since the fuel lines connecting the engine and the fuel tank must be flexible enough to withstand vibrations while the engine is running, it is recommended to use hoses.
Install it where necessary depending on the location of the primary fuel filter and the fuel tank.
When additional fuel hoses of different lengths are required, use the fuel hose specifications provided to order hoses of the desired length from a hose supplier.

- Hose
  SAE 100R1 AT Type I.D. Ø12.7 mm
  max. O.D. Ø21.5 mm
- Hose coupling
  SAE J516 37° Flare, 7/8-14 UNF



3.6.9. Engine Low-Pressure Fuel Lines

All low-pressure fuel lines are made of metal and have couplings which are shaped to fit the lines in order to maintain an airtight seal. When reused after repeated removal and reinstallation, the lines lose their airtightness and may cause fuel leaks. Low-pressure fuel lines may be reused only up to three times; then, they must be replaced with new ones. In the event that running the engine with a reused part is unavoidable, check for leaks periodically until the part can be replaced with a new one and make sure to replace the part as soon as possible.

When installing parts, tighten the union nuts and hollow screws using the specified tightening method, and make sure to hold the opposing parts in place with a tool while tightening parts to ensure that the tightening torque is applied only to the coupling joint.

When the engine is running, all fuel lines must remain secured firmly in the positions where they were installed upon release from the factory. Running the engine with a missing or loose fastener produces vibrations which may damage the fuel lines, so always make sure that parts are secured in their proper positions.

3.7. Fuel system

- The common rail fuel injection system operates at high pressures (1,800 bar). Accordingly, the system must be handled and serviced with care, and the safety regulations must always be followed.
- The common rail fuel injection system should never be removed, installed or inspected while the engine is running or immediately after stopping the engine; inspections and service work should be performed at least 30 seconds to one minute after stopping the engine.
- During service work and inspections, make sure that the workspace is clean before performing any work to prevent foreign matter from entering the fuel system; keep any unnecessary removal and installation to a minimum; and in the case of parts which must be reused during removal and installation, take the necessary measures to prevent foreign matter from entering the parts after removing them and clean them before reusing them for installation.
- The normal performance of O-rings and sealing washers used on high-pressure fuel pipes and in the fuel system cannot be guaranteed if they are reused; make sure to use new parts.
- When assembling high-pressure fuel pump, common rails, injectors, and high-pressure fuel pipes, take care to prevent damage due to impacts, etc. resulting from carelessness and make sure to assemble them precisely.

3.7.1. Fuel Tank

The fuel tank must be able to store fuel cleanly and safely and must be structured to satisfy the following requirements so as not to affect the components of the engine injection system.

- Material

  Zinc (Zn), copper (Cu), lead (Pb), sodium (Na) and calcium (Ca) cause chemical reactions with water in fuel and biodiesel, thereby forming various corrosive acids, sludge and viscous substances. When this occurs, it causes premature clogging of the primary fuel filter, seizure of injectors, corrosion and wear of fuel system components, including the injection system, leading to excessive maintenance expenses resulting from engine failure. Hence, when the use of these materials cannot be avoided, make sure to apply a phosphate film or trivalent chromium plating to prevent the materials from coming into direct contact with fuel.
- Air Intake/Discharge System

  When fuel is delivered to the engine, a reduction in pressure equivalent to the volume occupied by the fuel in the tank occurs, leading to a fluctuation in the volume of fuel as a result of a change in the fuel temperature. Hence, if the fuel tank is an enclosed structure, excessive static/negative pressure is formed, causing abnormal engine operation. Accordingly, the fuel tank must be equipped with an air intake/discharge system to constantly maintain atmospheric pressure, while the ports through which air is drawn in or discharged must be connected by means of extension hoses or tubes to a clean environment with minimal dust, moisture, insects, etc. or a suitable air filter must be installed to prevent such foreign matter from entering the system. When air inlets and outlets are installed in extremely dusty or humid areas, the service life of the primary and secondary fuel filters is severely reduced, while wear and corrosion of injection system components are accelerated, resulting in a shortened service life and excessive maintenance expenses.
- Port for Draining Condensate and Cleaning Foreign Matter

  Inside the fuel tank, foreign matter entering through the air inlet and outlet ports as well as condensate on the inner wall of the tank resulting from the difference in temperature between fuel and ambient air form deposits continuously. The fuel tank must be equipped with a cleaning port for periodically removing and cleaning condensate and foreign matter to prevent foreign matter and condensate deposits in the tank from entering the engine fuel system.
- Cleaning and maintaining the fuel tank

  After filling the tank with the recommended fuel, draining any condensation accumulated on the bottom of the tank completely and keeping the fuel full help to enhance engine performance.

CAUTION

Check whether the fuel supply valve is open. (If used)

As the fuel tank cools after stopping the engine, condensation forms and can contaminate the fuel. In order to prevent this, add fuel to the tank after running the engine each day.

In maritime regions, most fuel contamination is caused by moisture and the reproduction of microorganisms. Generally, contamination arises from handling fuel improperly and not following common sense. If fuel contains moisture, it is easy for microorganisms to reproduce and coat the bottom of the tank in a black slime. Hence, it is important to keep the amount of moisture in the fuel storage tank to a minimum.

In order to remove contaminated fuel from the fuel tank, install a water separator to gather the moisture and foreign materials in the tank. Drain the contaminated, foreign matter accumulated here every day and change the engine fuel filter several times until the fuel system is clean.

3.7.2. Fuel Requirements

Allowable Fuel Under Warranty

1) Korea: Article 115 Schedule 33 "Ultra Low Sulfur Diesel" of the Clean Air Conservation Act
2) Europe: EN590:2013 AC:2014, EN16734:2016
3) North America: ASTM D975-15C Grade 1D or 2D
4) Japan: JIS K2204:2007 (lubricity $\leq$ 520 μm, FAME Max. 5%)
5) China: GB252:2015 and GB19147:2013
6) India: IS 1460 2005 Amm. 10 BS Ⅲ or BS Ⅳ
7) Brazil: ANP69/2014
8) Russia: GOST R32511-2013 (excluding Articles 3 and 4)

Fuel Selection Chart

Features	ASTM D975 GRADE NO.2		EN 590:2013	
Minimum ignition point	No 2D 52°C	D93	55°C	EN2719
Max. water & sediment	vol. 0.05%	D2709		
Max. water			200 mg/kg	EN ISO 12937
Max. contamination level in total			24 mg/kg	EN 12662
Distillation temperature (return vol%)	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	Max. vol. 5%	EN14078	FAME Max. vol. 7%	EN 14078
Max. ash content	0.01% wt	D482	0.01% wt	EN ISO 6245
Max. sulfur (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%			
Max. copper strip corrosion	No. 3	D130	Grade 1	EN ISO 2160
Min. cetane number	40	D613	51	EN ISO 5165
Min. cetane index			46	EN ISO 4264
- Cetane index	Min. 40	D976-80		
- Aromaticity	Max. vol. 35%	D1319		
Max. PAH			11% wet	EN 12916
Operability at:	Report	D2500 D4539 D6371		
- Cloud point				
- LTFT/CFPP				
Cloud Point			Varies depending on location and season	EN 23015
CFPP			Varies depending on location and season	EN 116
Carbon residue at 10% distillation residue (max.)		D524	0.30% wt	EN ISO 10370
	2D: 0.35% wt			
Max. oxidation stability			25 g/m^3	EN ISO 12205
Max. lubrication (at 60°C)	520 mm	D6079 D7688	460 mm	ISO 12156-1
Min. conductivity	25 pS/m	D2624 D4308		

* If the sulfur content of the fuel exceeds 0.5%, reduce the replacement and inspection intervals by half.

3.7.3. 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.

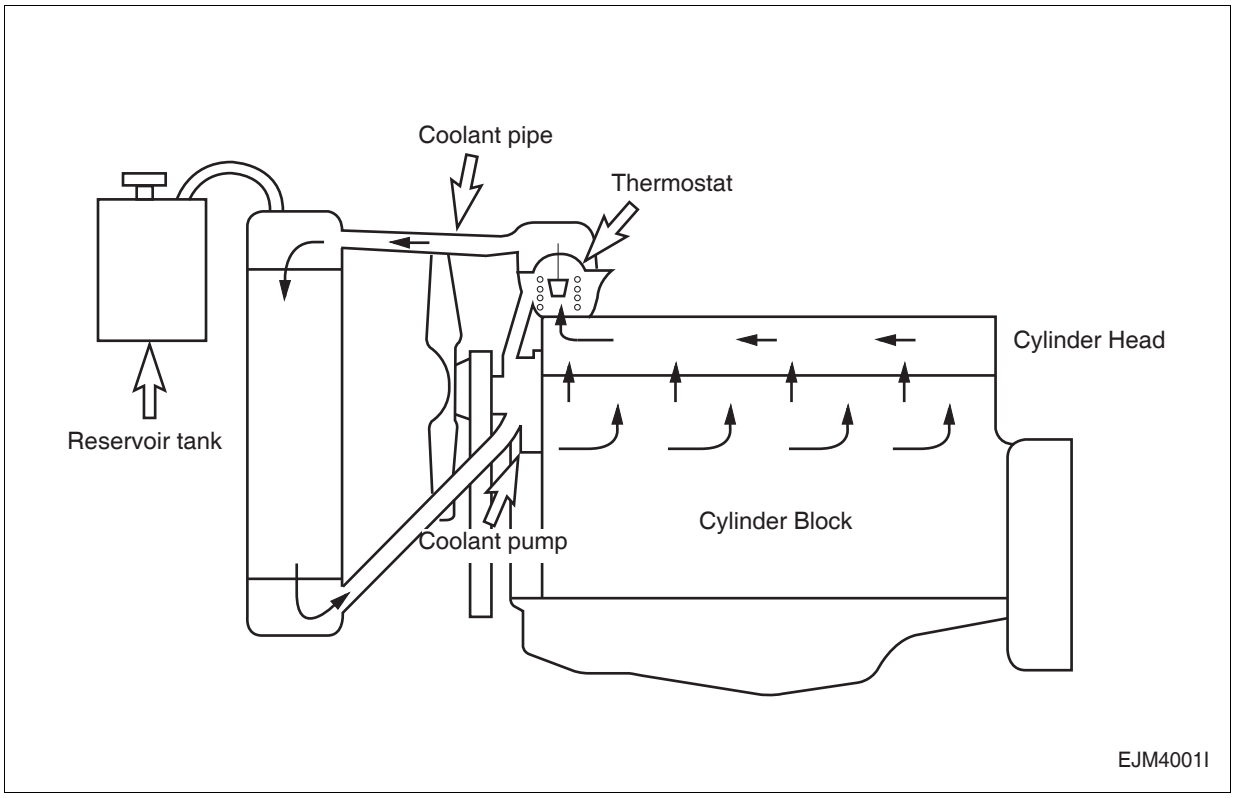
HD Hyundai Infracore approves the use of up to 100% HVO for engines in accordance with the EU standard EN15940.

3.8. Cooling System

This engine includes a liquid cooling system. The fresh water pump is a crankshaft gear-driven pump which does not require maintenance.

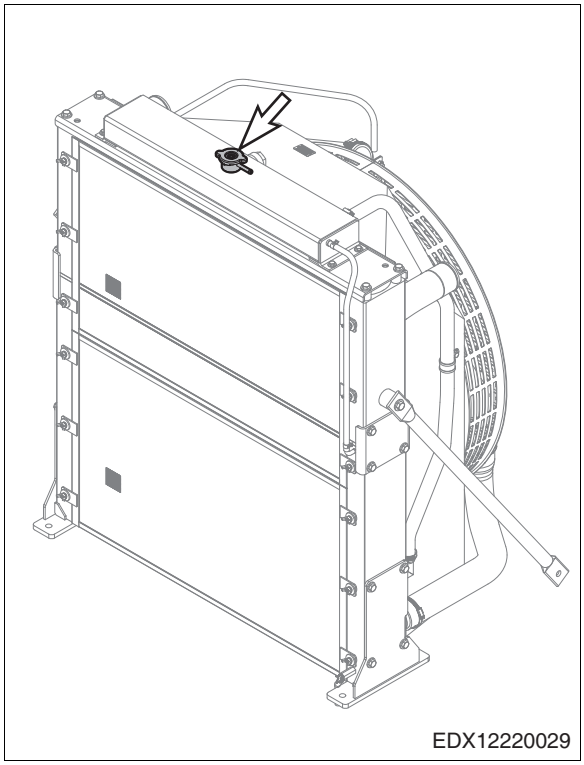
Depending on the scope of delivery and engine design agreed upon, the coolant circuit may be equipped with a temperature monitor which stops the engine when coolant is lost.

- Remove the expansion tank filler cap to check the level of coolant in the expansion tank and add coolant if necessary.
- When adding antifreeze, discharge the previous coolant from the cylinder block and radiator first, then clean these components with a cleaning solution.
- Antifreeze must be mixed with soft water.



3.8.1. Coolant Pressure Cap

Use the expansion tank cap tester to check the opening pressure of the pressure valve. If the valve measured does not reach the designated limit value, replace the filter cap assembly.
(Opening pressure of pressure valve: 0.9 kg/cm^2)



Note:
When the coolant is hot, it can be dangerous to open the pressure cap too soon so open it slowly first to lower the internal pressure in the tank, then open it completely.

3.8.2. Coolant

- The coolant used in the engine must be soft water, not hard water.
- You may dilute the engine coolant with 40% antifreeze and 3 to 5% anticorrosive (DCA4).
- Inspect the density of the solutions and additives above every 500 hours to maintain them at their proper levels.

Note:
If you maintain the density of the antifreeze and anticorrosive properly, you can effectively prevent corrosion and maintain stable engine quality.
Failing to maintain them may cause fatal damage to the water pump and cylinder liner so particular care is required.

- The DX12 has a dry type cylinder liner so coolant must be managed even more carefully.
- You can check the density of antifreeze and anticorrosive using a coolant test kit. (Fleetguard CC2602M)
- How to use the coolant test kit
  1) When the temperature of the engine coolant is 10 ~ 55°C, remove the coolant drain plug and fill the plastic cup around halfway.

Note:
When obtaining a coolant sample, it is difficult to measure the precise density if the coolant is obtained from the reservoir tank. If necessary, remove the coolant drain plug to obtain a coolant sample.

2) With the test strip soaked in the coolant sample, shake it around in water, then pull the strip out and shake the water to mix them.
3) Wait around 45 seconds until the colour of the test strip changes.

Note:
Do not wait for more than 75 seconds. The colour will change anyway if you wait for more than 75 seconds.

4) Compare the changed colour of the test strip with the colour list on the label of the storage container to obtain a numerical value.
5) Compare the changed yellowish green colour with the green colour index on the storage container for the test strip to check the density. (The density index must be between 33% and 50%.)
6) The brown and crimson indexes in the middle and bottom of the test strip, respectively, indicate the level of anticorrosive. If the numerical value where the brown (vertical) and crimson (horizontal) colours meet is within a 0.3 ~ 0.8 range of the ray colour list on the sample strip storage container, it is considered to be within a suitable range.
7) If it is less than 0.3, replenish the anticorrosive (DCA4); if higher than 0.8, drain around 50% of the coolant, then refill the clean fresh water to adjust the density again.

● Amount of antifreeze in winter

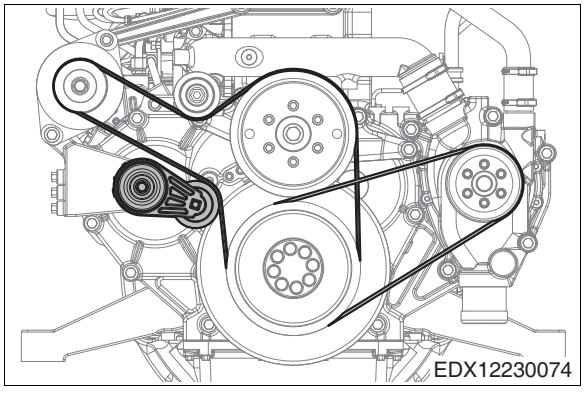
Outdoor air Temperature (°C)	Coolant (%)	Antifreeze (%)
-10 or more	85	15
-10	80	20
-15	73	27
-20	67	33
-25	60	40
-30	56	44
-40	50	50

3.9. Inspecting and Adjusting the Micro V-Belt Tension

The belt is equipped with an auto tensioner which automatically adjusts the belt tension so there is no need for extra adjustment of the tension.

During daily inspections, check whether the pointer shown on the auto tensioner indicates that it is time for replacement. If the pointer indicates that it is time for replacement, the belt must be replaced.

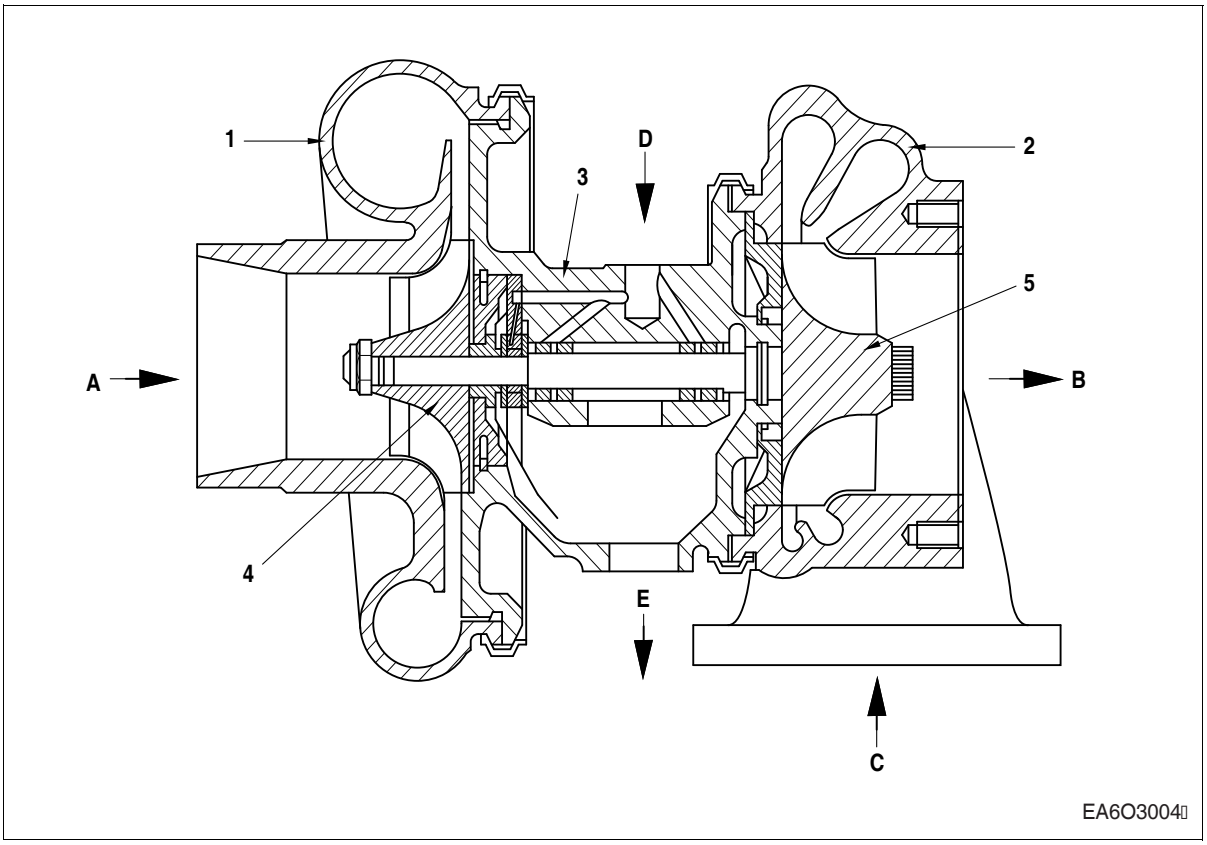
The belt shall also be replaced in case it is damaged or worn out due to other external causes.



3.10. Turbocharger

The engine's exhaust gas is conveyed through the turbine rotor of the turbocharger. The air compressor impeller installed on the same shaft draws in fresh air and delivers it to the cylinder with higher pressure.

The turbocharger is naturally air-cooled. Lubrication of the main bearing is performed by pressurized oil within the engine lubrication system.

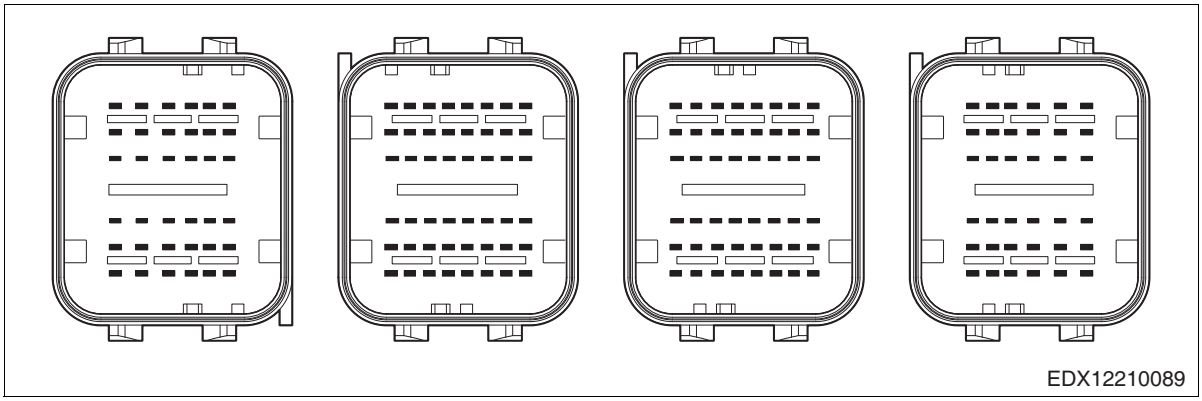


1.	Compressor casing	A.	Intake port
2.	Turbine casing	B.	Gas outlet
3.	Bearing casing	C.	Gas inlet
4.	Impeller	D.	Oil delivery
5.	Turbine	E.	Oil return

3.11. Electrical Equipment

3.11.1. General Information

- This section provides information on the engine wire harnesses and the circuit number of connectors.



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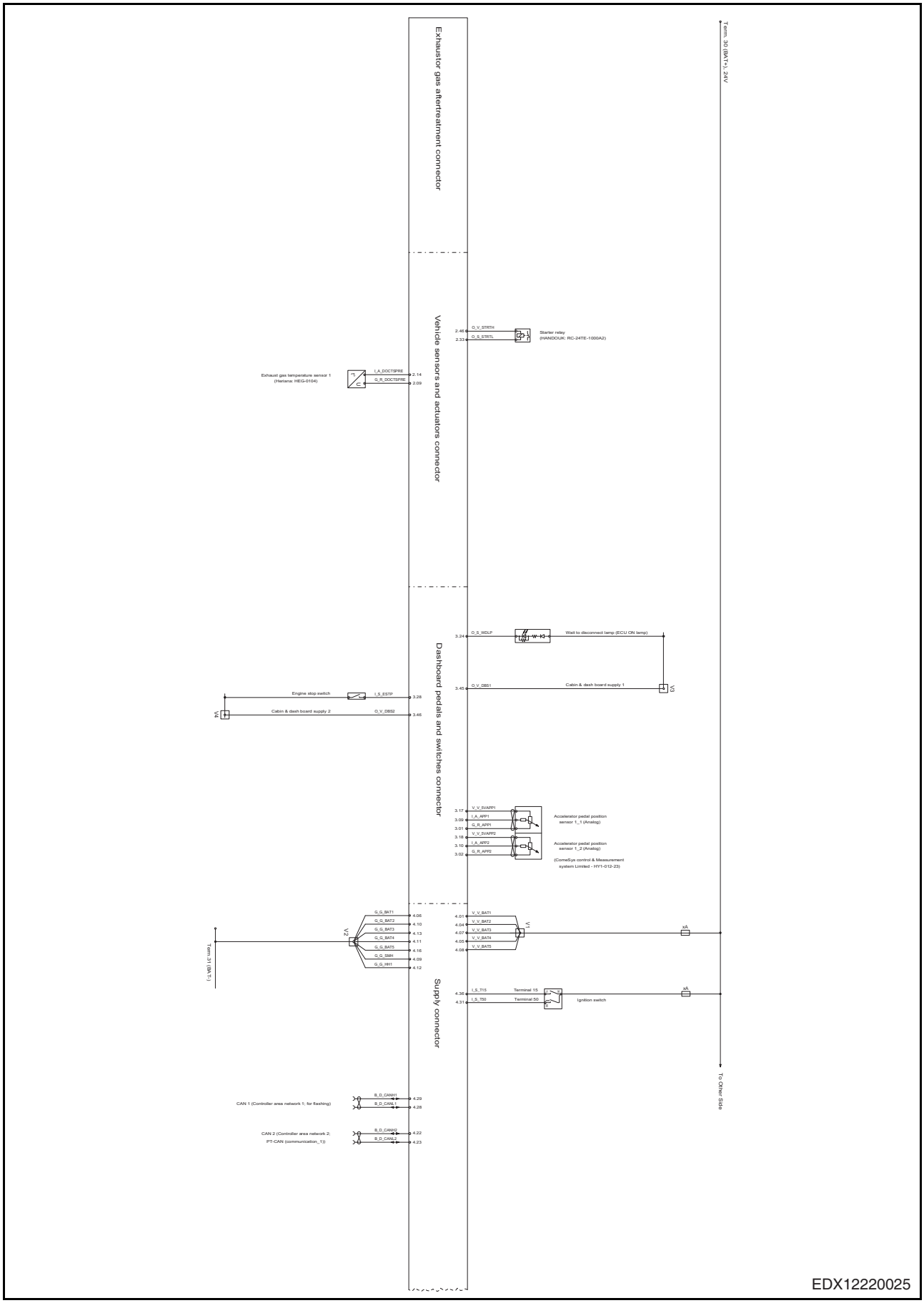
- The wire colors are as follows.
  1) B : Black
  2) Brn : Brown
  3) G : Green
  4) Gra : Gray
  5) L : Blue
  6) O : Orange
  7) W : White
  8) Y : Yellow
  9) R : Red
- The ECU pin no. refers to the pin number of each engine connector.
- The sensor pin no. refers to the pin number of each sensor connector.

3.11.2. Engine Connectors



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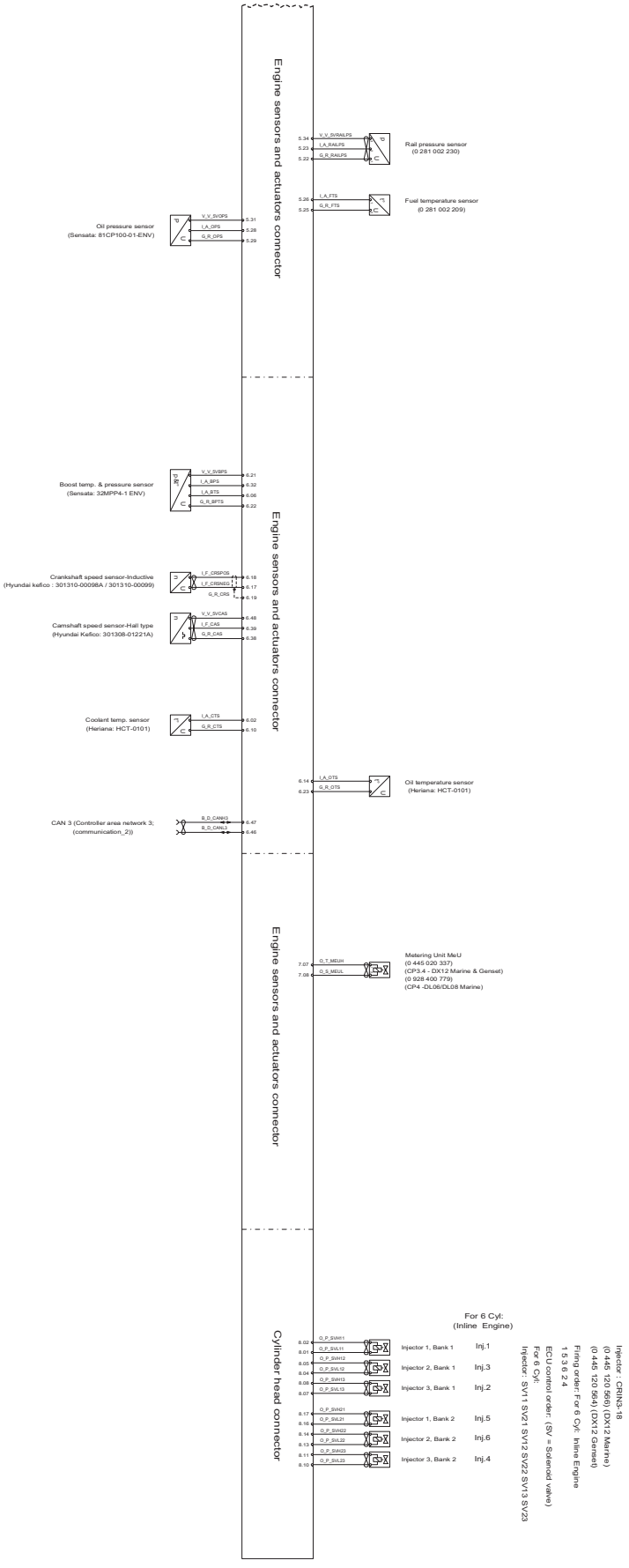

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3.11.3. Engine Control Unit (ECU) Engine Connectors

3.11.3.1 Non-Air Heater Specifications

No.	Wire Label	Size (mm^2)	Color	Circuit Description	From	No.	To	No.	Remark
1	2.26	0.75	Y	Ambient Temp Sensor Signal	ECU 2 (2)	26	Ambient Temp Sensor (ATS)	2	
2	2.34	0.75	B	Ambient Temp Sensor GND	ECU 2 (2)	34	Ambient Temp Sensor (ATS)	1	
3	4.22	0.75	W	CAN4 High	ECU 4 (4)	22	SP_01		Splice 01, Twisted Pair (4.22/4.23)
4	4.22A	0.75	W	CAN2 High	SP_01		Inter Conn (INT)	25	Splice 01, Twisted Pair (4.22A/4.23A)
5	4.23	0.75	Y	CAN2 Low	ECU 4 (4)	23	SP_02		Splice 02, Twisted Pair (4.22/4.23)
6	4.23A	0.75	Y	CAN2 Low	SP_02		Inter Conn (INT)	26	Splice 02, Twisted Pair (4.22A/4.23A)
7	4.29	0.75	O	CAN1 High	ECU 4 (4)	29	SP_03		Splice 03, Twisted Pair (4.28/4.29)
8	4.29A	0.75	O	CAN1 High	SP_03		Inter Conn (INT) SP 04	24	Splice 03, Twisted Pair (4.28a/4.29a)
9	4.28	0.75	Brn	CAN1 Low	ECU 4 (4)	28	SP_04		Splice 04, Twisted Pair (4.28/4.29)
10	4.28A	0.75	Brn	CAN1 Low	SP_04		Inter Conn (INT)	23	Splice 04, Twisted Pair (4.28A/4.29A)
11	5.22	0.75	B	Rail Press Sensor GND	ECU 5 (5)	22	Rail Press Sensor (RPS)	1	Twisted Pair (5.22/5.23/5.34)
12	5.23	0.75	W	Rail Press Sensor Signal	ECU 5 (5)	23	Rail Press Sensor (RPS)	2	Twisted Pair (5.22/5.23/5.34)
13	5.34	0.75	R	Rail Press Sensor PWR	ECU 5 (5)	23	Rail Press Sensor (RPS)	3	Twisted Pair (5.22/5.23/5.35)
14	5.26	0.75	Y	Fuel Temp Sensor Signal	ECU 5 (5)	26	Fuel Temp Sensor (FTS)	1	
15	5.25	0.75	B	Fuel Temp Sensor GND	ECU 5 (5)	25	Fuel Temp Sensor (FTS)	2	
16	5.31	0.75	R	Oil Press Sensor PWR	ECU 5 (5)	31	Oil Press Sensor (OPS)	3	
17	5.29	0.75	B	Oil Press Sensor GND	ECU 5 (5)	29	Oil Press Sensor (OPS)	2	
18	5.28	0.75	Y	Oil Press Sensor Signal	ECU 5 (5)	28	Oil Press Sensor (Ops)	1	
19	6.22	0.75	B	Boost Press/Temp Sensor GND	ECU 6 (6)	22	Boost P/T Sensor (BPTS)	1	
20	6.06	0.75	Y	Boost Temp Sensor Signal	ECU 6 (6)	6	Boost P/T Sensor (BPTS)	2	
21	6.21	0.75	R	Boost Press/Temp Sensor PWR	ECU 6 (6)	21	Boost P/T Sensor (BPTS)	3	
22	6.32	0.75	W	Boost Press Sensor Signal	ECU 6 (6)	32	Boost P/T Sensor (BPTS)	4	
23	6.10	0.75	B	Coolant Temp Sensor GND	ECU 6 (6)	10	Coolant Temp Sensor (CTS)		
24	6.02	0.75	W	Coolant Temp Sensor Signal	ECU 6 (6)	2	Coolant Temp Sensor (CTS)		

No.	Wire Label	Size (mm^2)	Color	Circuit Description	From	No.	To	No.	Remark
25	6.17	0.75	P	Crank Shaft Speed Sensor NEG	ECU 6 (6)	17	Crank Shaft Speed Sensor (CRS)	1	Shielded (6.17/6.18)/ Twisted Pair (6.17/6.18)
26	6.18	0.75	O	Crank Shaft Speed Sensor POS	ECU 6 (6)	18	Crank Shaft Speed Sensor (CRS)	2	Shielded (6.17/6.18)/ Twisted Pair (6.17/6.18)
27	6.19	0.75	B	Crank Shaft Speed Sensor GND	ECU 6 (6)	19	Crank Shaft Speed Sensor (CRS)	3	Shield Drain (6.17/6.18)
28	6.38	0.75	B	Cam Shaft Speed Sensor GND	ECU 6 (6)	38	Cam Shaft Speed Sensor (CAS)	1	Twisted Pair (6.38/6.39/6.49)
29	6.39	0.75	W	Cam Shaft Speed Sensor Output	ECU 6 (6)	39	Cam Shaft Speed Sensor (CAS)	2	Twisted Pair (6.38/6.39/6.48)
30	6.48	0.75	R	Cam Shaft Speed Sensor Supply	ECU 6 (6)	48	Cam Shaft Speed Sensor (CAS)	3	Twisted Pair (6.38/6.39/6.48)
31	7.07	0.75	O	Fuel Metering Unit H	ECU 7 (7)	7	Fuel Metering Unit (FMU)	1	Twisted Pair (7.07/7.08)
32	7.08	0.75	Brn	Fuel Metering Unit L	ECU 7 (7)	8	Fuel Metering Unit (FMU)	2	Twisted Pair (7.07/7.08)
33	8.02	1.50	L	Injector 1, Bank 1 High	ECU 8 (8)	2	Injector Conn (INJ)	1	Twisted Pair (8.01/8.02)
34	8.01	1.50	B	Injector 1, Bank 1 Low	ECU 8 (8)	1	Injector Conn (INJ)	2	Twisted Pair (8.01/8.02)
35	8.05	1.50	L	Injector 2, Bank 1 High	ECU 8 (8)	5	Injector Conn (INJ)	5	Twisted Pair (8.04/8.05)
36	8.04	1.50	B	Injector 2, Bank 1 Low	ECU 8 (8)	4	Injector Conn (INJ)	6	Twisted Pair (8.04/8.05)
37	8.08	1.50	L	Injector 3, Bank 1 High	ECU 8 (8)	8	Injector Conn (INJ)	3	Twisted Pair (8.07/8.08)
38	8.07	1.50	B	Injector 3, Bank 1 Low	ECU 8 (8)	7	Injector Conn (INJ)	4	Twisted Pair (8.07/8.08)
39	8.17	1.50	L	Injector 1, Bank 2 High	ECU 8 (8)	17	Injector Conn (INJ)	9	Twisted Pair (8.16/8.17)
40	8.16	1.50	B	Injector 3, Bank 2 Low	ECU 8 (8)	16	Injector Conn (INJ)	10	Twisted Pair (8.16/8.17)
41	8.14	1.50	L	Injector 3, Bank 2 High	ECU 8 (8)	14	Injector Conn (INJ)	11	Twisted Pair (8.13/8.14)
42	8.13	1.50	B	Injector 3, Bank 2 Low	ECU 8 (8)	13	Injector Conn (INJ)	12	Twisted Pair (8.13/8.14)
43	8.11	1.50	L	Injector 3, Bank 2 High	ECU 8 (8)	11	Injector Conn (INJ)	7	Twisted Pair (8.10/8.11)
44	8.10	1.50	B	Injector 3, Bank 2 Low	ECU 8 (8)	10	Injector Conn (INJ)	8	Twisted Pair (8.10/8.11)
45	2.33	0.75	Y	Starter Relay S	ECU 2 (2)	33	Inter Conn (INT)	22	
46	2.46	0.75	R	Starter Relay V	ECU 2 (2)	46	Inter Conn (INT)	21	
47	3.17	0.75	R	Accelerator Pedal1-1 PWR	ECU 3 (3)	17	Inter Conn (INT)	18	Twisted Pair (3.01/3.09/3.17)
48	3.09	0.75	W	Accelerator Pedal1-1 Signal	ECU 3 (3)	9	Inter Conn (INT)	17	Twisted Pair (3.01/3.09/3.17)
49	3.01	0.75	B	Accelerator Pedal1-1 GND	ECU 3 (3)	1	Inter Conn (INT)	16	Twisted Pair (3.01/3.09/3.17)

No.	Wire Label	Size (mm^2)	Color	Circuit Description	From	No.	To	No.	Remark
50	3.18	0.75	R	Accelerator Pedal1-2 PWR	ECU 3 (3)	18	Inter Conn (INT)	15	Twisted Pair (3.02/3.10/3.18)
51	3.10	0.75	G	Accelerator Pedal1-2 Signal	ECU 3 (3)	10	Inter Conn (INT)	14	Twisted Pair (3.02/3.10/3.18)
52	3.02	0.75	B	Accelerator Pedal1-2 GND	ECU 3 (3)	2	Inter Conn (INT)	13	Twisted Pair (3.02/3.10/3.18)
53	3.28	0.75	Y	E/G Emergency Stop Switch Signal	ECU 3 (3)	28	Inter Conn (INT)	30	
54	3.46	0.75	R	E/G Emergency Stop Switch Supply	ECU 3 (3)	46	Inter Conn (INT)	31	
55	4.36	0.75	Brn	Key-ON (T15)	ECU 4 (4)	36	SP 09		Splice 09
56	4.36A	0.75	Brn	Key-ON (T15)	SP_09		Inter Conn (INT)	12	Splice 09
57	4.31	0.75	O	Key Switch "Start" (T50)	ECU 4 (4)	31	Inter Conn (INT)	19	
58	4.01	1.50	R	ECU Power Supply	ECU 4 (4)	1	SP 05		Splice 05
59	4.01A	1.50	R	ECU Power Supply	SP_05		Inter Conn (INT)	7	Splice 05
60	4.04	1.50	R	ECU Power Supply	ECU 4 (4)	4	Inter Conn (INT)	8	
61	4.05	1.50	R	ECU Power Supply	ECU 4 (4)	5	Inter Conn (INT)	9	
62	4.07	1.50	R	ECU Power Supply	ECU 4 (4)	7	Inter Conn (INT)	10	
63	4.08	1.50	R	ECU Power Supply	ECU 4 (4)	8	Inter Conn (INT)	11	
64	4.06	1.50	B	ECU Ground	ECU 4 (4)	6	Inter Conn (INT)		Splice 06
65	4.06A	1.50	B	ECU Ground	SO_06		Inter Conn (INT)	1	Splice 06
66	4.09	1.50	B	ECU Ground	ECU 4 (4)	9	SP 07		Splice 07
67	4.10	1.50	B	ECU Ground	ECU 4 (4)	10	SP 07		Splice 07
68	4.09A	1.50	B	ECU Ground	SP_07		Inter Conn (INT)	2	Splice 07
69	4.11	1.50	B	ECU Ground	ECU 4 (4)	11	SP 08		Splice 08
70	4.12	1.50	B	ECU Ground	ECU 4 (4)	12	SP 08		Splice 08
71	4.12A	1.50	B	ECU Ground	SP_08		Inter Conn (INT)	3	Splice 08
72	4.13	1.50	B	ECU Ground	ECU 4 (4)	13	Inter Conn (INT)	4	
73	4.16	1.50	B	ECU Ground	ECU 4 (4)	16	Inter Conn (INT)	5	
74	4.36B	0.75	Brn	Key-ON (T15)	SP_09		Check Conn (Check)	6	Splice 09
75	4.29B	0.75	O	CAN1 High	SP_03		Check Conn (Check)	2	Splice 03, Twisted Pair (4.28B/4.29B)
76	4.28B	0.75	Brn	CAN1 Low	SP_04		Check Conn (Check)	1	Splice 04, Twisted Pair (4.28B/4.30B)
77	4.22B	0.75	W	CAN2 High	SP_01		Check Conn (Check)	8	Splice 01, Twisted Pair (4.22B/4.23B)
78	4.23B	0.75	Y	CAN2 Low	SP_02		Check Conn (Check)	7	Splice 02, Twisted Pair (4.22B/4.23B)
79	4.06B	0.75	B	Check Conn GND	SP_06		Check Conn (Check)	3	Splice 06
80	4.01B	0.75	R	Check Conn Supply	SP_05		Check Conn (Check)	4	Splice 05

3.11.3.2 Air Heater Specifications (optional)

No.	Wire Label	Size (mm^2)	Color	Circuit Description	From	No.	To	No.	Remark
1	2.26	0.75	Y	Ambient Temp Sensor Signal	ECU 2 (2)	26	Ambient Temp Sensor (ATS)	2	
2	2.34	0.75	B	Ambient Temp Sensor GND	ECU 2 (2)	34	Ambient Temp Sensor (ATS)	1	
3	4.22	0.75	W	CAN4 High	ECU 4 (4)	22	SP_01		Splice 01, Twisted Pair (4.22/4.23)
4	4.22A	0.75	W	CAN2 High	SP_01		Inter Conn (INT)	25	Splice 01, Twisted Pair (4.22A/4.23A)
5	4.23	0.75	Y	CAN2 Low	ECU 4 (4)	23	SP_02		Splice 02, Twisted Pair (4.22/4.23)
6	4.23A	0.75	Y	CAN2 Low	SP_02		Inter Conn (INT)	26	Splice 02, Twisted Pair (4.22A/4.23A)
7	4.29	0.75	O	CAN1 High	ECU 4 (4)	29	SP_03		Splice 03, Twisted Pair (4.28/4.29)
8	4.29A	0.75	O	CAN1 High	SP_03		Inter Conn (INT) SP 04	24	Splice 03, Twisted Pair (4.28a/4.29a)
9	4.28	0.75	Brn	CAN1 Low	ECU 4 (4)	28	SP_04		Splice 04, Twisted Pair (4.28/4.29)
10	4.28A	0.75	Brn	CAN1 Low	SP_04		Inter Conn (INT)	23	Splice 04, Twisted Pair (4.28A/4.29A)
11	5.22	0.75	B	Rail Press Sensor GND	ECU 5 (5)	22	Rail Press Sensor (RPS)	1	Twisted Pair (5.22/5.23/5.34)
12	5.23	0.75	W	Rail Press Sensor Signal	ECU 5 (5)	23	Rail Press Sensor (RPS)	2	Twisted Pair (5.22/5.23/5.34)
13	5.34	0.75	R	Rail Press Sensor PWR	ECU 5 (5)	23	Rail Press Sensor (RPS)	3	Twisted Pair (5.22/5.23/5.35)
14	5.26	0.75	Y	Fuel Temp Sensor Signal	ECU 5 (5)	26	Fuel Temp Sensor (FTS)	1	
15	5.25	0.75	B	Fuel Temp Sensor GND	ECU 5 (5)	25	Fuel Temp Sensor (FTS)	2	
16	5.31	0.75	R	Oil Press Sensor PWR	ECU 5 (5)	31	Oil Press Sensor (OPS)	3	
17	5.29	0.75	B	Oil Press Sensor GND	ECU 5 (5)	29	Oil Press Sensor (OPS)	2	
18	5.28	0.75	Y	Oil Press Sensor Signal	ECU 5 (5)	28	Oil Press Sensor (Ops)	1	
19	6.22	0.75	B	Boost Press/Temp Sensor GND	ECU 6 (6)	22	Boost P/T Sensor (BPTS)	1	
20	6.06	0.75	Y	Boost Temp Sensor Signal	ECU 6 (6)	6	Boost P/T Sensor (BPTS)	2	
21	6.21	0.75	R	Boost Press/Temp Sensor PWR	ECU 6 (6)	21	Boost P/T Sensor (BPTS)	3	
22	6.32	0.75	W	Boost Press Sensor Signal	ECU 6 (6)	32	Boost P/T Sensor (BPTS)	4	
23	6.10	0.75	B	Coolant Temp Sensor GND	ECU 6 (6)	10	Coolant Temp Sensor (CTS)		
24	6.02	0.75	W	Coolant Temp Sensor Signal	ECU 6 (6)	2	Coolant Temp Sensor (CTS)		
25	6.17	0.75	P	Crank Shaft Speed Sensor NEG	ECU 6 (6)	17	Crank Shaft Speed Sensor (CRS)	1	Shielded (6.17/6.18)/ Twisted Pair (6.17/6.18)

No.	Wire Label	Size (mm^2)	Color	Circuit Description	From	No.	To	No.	Remark
26	6.18	0.75	O	Crank Shaft Speed Sensor POS	ECU 6 (6)	18	Crank Shaft Speed Sensor (CRS)	2	Shielded (6.17/6.18)/ Twisted Pair (6.17/6.18)
27	6.19	0.75	B	Crank Shaft Speed Sensor GND	ECU 6 (6)	19	Crank Shaft Speed Sensor (CRS)	3	Shield Drain (6.17/6.18)
28	6.38	0.75	B	Cam Shaft Speed Sensor GND	ECU 6 (6)	38	Cam Shaft Speed Sensor (CAS)	1	Twisted Pair (6.38/6.39/6.49)
29	6.39	0.75	W	Cam Shaft Speed Sensor Output	ECU 6 (6)	39	Cam Shaft Speed Sensor (CAS)	2	Twisted Pair (6.38/6.39/6.48)
30	6.48	0.75	R	Cam Shaft Speed Sensor Supply	ECU 6 (6)	48	Cam Shaft Speed Sensor (CAS)	3	Twisted Pair (6.38/6.39/6.48)
31	7.07	0.75	O	Fuel Metering Unit H	ECU 7 (7)	7	Fuel Metering Unit (FMU)	1	Twisted Pair (7.07/7.08)
32	7.08	0.75	Brn	Fuel Metering Unit L	ECU 7 (7)	8	Fuel Metering Unit (FMU)	2	Twisted Pair (7.07/7.08)
33	8.02	1.50	L	Injector 1, Bank 1 High	ECU 8 (8)	2	Injector Conn (INJ)	1	Twisted Pair (8.01/8.02)
34	8.01	1.50	B	Injector 1, Bank 1 Low	ECU 8 (8)	1	Injector Conn (INJ)	2	Twisted Pair (8.01/8.02)
35	8.05	1.50	L	Injector 2, Bank 1 High	ECU 8 (8)	5	Injector Conn (INJ)	5	Twisted Pair (8.04/8.05)
36	8.04	1.50	B	Injector 2, Bank 1 Low	ECU 8 (8)	4	Injector Conn (INJ)	6	Twisted Pair (8.04/8.05)
37	8.08	1.50	L	Injector 3, Bank 1 High	ECU 8 (8)	8	Injector Conn (INJ)	3	Twisted Pair (8.07/8.08)
38	8.07	1.50	B	Injector 3, Bank 1 Low	ECU 8 (8)	7	Injector Conn (INJ)	4	Twisted Pair (8.07/8.08)
39	8.17	1.50	L	Injector 1, Bank 2 High	ECU 8 (8)	17	Injector Conn (INJ)	9	Twisted Pair (8.16/8.17)
40	8.16	1.50	B	Injector 3, Bank 2 Low	ECU 8 (8)	16	Injector Conn (INJ)	10	Twisted Pair (8.16/8.17)
41	8.14	1.50	L	Injector 3, Bank 2 High	ECU 8 (8)	14	Injector Conn (INJ)	11	Twisted Pair (8.13/8.14)
42	8.13	1.50	B	Injector 3, Bank 2 Low	ECU 8 (8)	13	Injector Conn (INJ)	12	Twisted Pair (8.13/8.14)
43	8.11	1.50	L	Injector 3, Bank 2 High	ECU 8 (8)	11	Injector Conn (INJ)	7	Twisted Pair (8.10/8.11)
44	8.10	1.50	B	Injector 3, Bank 2 Low	ECU 8 (8)	10	Injector Conn (INJ)	8	Twisted Pair (8.10/8.11)
45	2.33	0.75	Y	Starter Relay S	ECU 2 (2)	33	Inter Conn (INT)	22	
46	2.46	0.75	R	Starter Relay V	ECU 2 (2)	46	Inter Conn (INT)	21	
47	3.17	0.75	R	Accelerator Pedal1-1 PWR	ECU 3 (3)	17	Inter Conn (INT)	18	Twisted Pair (3.01/3.09/3.17)
48	3.09	0.75	W	Accelerator Pedal1-1 Signal	ECU 3 (3)	9	Inter Conn (INT)	17	Twisted Pair (3.01/3.09/3.17)
49	3.01	0.75	B	Accelerator Pedal1-1 GND	ECU 3 (3)	1	Inter Conn (INT)	16	Twisted Pair (3.01/3.09/3.17)
50	3.18	0.75	R	Accelerator Pedal1-2 PWR	ECU 3 (3)	18	Inter Conn (INT)	15	Twisted Pair (3.02/3.10/3.18)
51	3.10	0.75	G	Accelerator Pedal1-2 Signal	ECU 3 (3)	10	Inter Conn (INT)	14	Twisted Pair (3.02/3.10/3.18)
52	3.02	0.75	B	Accelerator Pedal1-2 GND	ECU 3 (3)	2	Inter Conn (INT)	13	Twisted Pair (3.02/3.10/3.18)

No.	Wire Label	Size (mm^2)	Color	Circuit Description	From	No.	To	No.	Remark
53	3.28	0.75	Y	E/G Emergency Stop Switch Signal	ECU 3 (3)	28	Inter Conn (INT)	30	
54	3.46	0.75	R	E/G Emergency Stop Switch Supply	ECU 3 (3)	46	Inter Conn (INT)	31	
55	4.36	0.75	Brn	Key-ON (T15)	ECU 4 (4)	36	SP 09		Splice 09
56	4.36A	0.75	Brn	Key-ON (T15)	SP_09		Inter Conn (INT)	12	Splice 09
57	4.31	0.75	O	Key Switch "Start" (T50)	ECU 4 (4)	31	Inter Conn (INT)	19	
58	4.01	1.50	R	ECU Power Supply	ECU 4 (4)	1	SP 05		Splice 05
59	4.01A	1.50	R	ECU Power Supply	SP_05		Inter Conn (INT)	7	Splice 05
60	4.04	1.50	R	ECU Power Supply	ECU 4 (4)	4	Inter Conn (INT)	8	
61	4.05	1.50	R	ECU Power Supply	ECU 4 (4)	5	Inter Conn (INT)	9	
62	4.07	1.50	R	ECU Power Supply	ECU 4 (4)	7	Inter Conn (INT)	10	
63	4.08	1.50	R	ECU Power Supply	ECU 4 (4)	8	Inter Conn (INT)	11	
64	4.06	1.50	B	ECU Ground	ECU 4 (4)	6	Inter Conn (INT)		Splice 06
65	4.06A	1.50	B	ECU Ground	SO_06		Inter Conn (INT)	1	Splice 06
66	4.09	1.50	B	ECU Ground	ECU 4 (4)	9	SP 07		Splice 07
67	4.10	1.50	B	ECU Ground	ECU 4 (4)	10	SP 07		Splice 07
68	4.09A	1.50	B	ECU Ground	SP_07		Inter Conn (INT)	2	Splice 07
69	4.11	1.50	B	ECU Ground	ECU 4 (4)	11	SP 08		Splice 08
70	4.12	1.50	B	ECU Ground	ECU 4 (4)	12	SP 08		Splice 08
71	4.12A	1.50	B	ECU Ground	SP_08		Inter Conn (INT)	3	Splice 08
72	4.13	1.50	B	ECU Ground	ECU 4 (4)	13	Inter Conn (INT)	4	
73	4.16	1.50	B	ECU Ground	ECU 4 (4)	16	Inter Conn (INT)	5	
74	4.36B	0.75	Brn	Key-ON (T15)	SP_09		Check Conn (Check)	6	Splice 09
75	4.29B	0.75	O	CAN1 High	SP_03		Check Conn (Check)	2	Splice 03, Twisted Pair (4.28B/4.29B)
76	4.28B	0.75	Brn	CAN1 Low	SP_04		Check Conn (Check)	1	Splice 04, Twisted Pair (4.28B/4.30B)
77	4.22B	0.75	W	CAN2 High	SP_01		Check Conn (Check)	8	Splice 01, Twisted Pair (4.22B/4.23B)
78	4.23B	0.75	Y	CAN2 Low	SP_02		Check Conn (Check)	7	Splice 02, Twisted Pair (4.22B/4.23B)
79	4.06B	0.75	B	Check Conn GND	SP_06		Check Conn (Check)	3	Splice 06
80	4.01B	0.75	R	Check Conn Supply	SP_05		Check Conn (Check)	4	Splice 05
81	6.42A	0.75	Brn	Preheat Relay C	SP_10		Air Heater RLY S (RLYS)	+	Splice 10
82	6.42	0.75	Brn	Preheat Relay C	SP_10		ECU 6 (6)	42	Splice 10
83	6.42B	0.75	Brn	Diode K	SP_10		Diode (DIO)	K	Splice 10
84	6.36A	0.75	W	Preheat Relay D	SP_11		Air Heater RLY S (RLYS)	-	Splice 11
85	6.36	0.75	W	Preheat Relay D	SP_11		ECU 6 (6)	36	Splice 11
86	6.36B	0.75	W	Diode A	SP_11		Diode (DIO)	A	Splice 11
87	6.09	1.50	W	Preheat Feedback	Heater Check (H_CK)	1	ECU 6 (6)	9	

3.11.4. Switches and Sensors

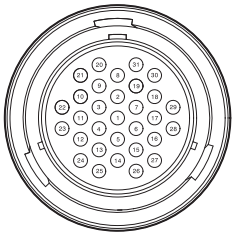
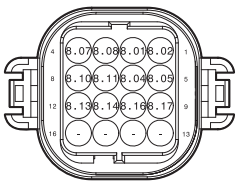
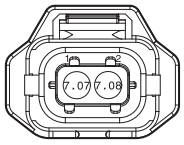
Figure	No.	Circuit	Color	Insulation	Circuit Description	From	Pin	Connec-tor Pin
Inter Conn (INT)  1 2 3 4 5 4.06A 4.09A 4.12A 4.16 6 7 8 9 10 - 4.01A 4.04 4.05 4.07 11 12 13 14 15 4.08 4.36A 3.02 3.10 3.18 16 17 18 19 20 3.01 3.09 3.17 4.31 - 21 22 23 24 25 2.46 2.33 4.28A 4.29A 4.22A 26 27 28 29 30 4.23A - - - 3.28 31 3.46	3	4.12A	B	FLR91X-A	ECU Ground	SP_08		3
	4	4.13	B	FLR91X-A	ECU Ground	ECU 4 (4)	13	4
	5	4.16	B	FLR91X-A	ECU Ground	ECU 4 (4)	16	5
	6	-						
	7	4.01A	R	FLR91X-A	ECU Power Supply	SP_05		7
	8	4.04	R	FLR91X-A	ECU Power Supply	ECU 4 (4)	4	8
	9	4.05	R	FLR91X-A	ECU Power Supply	ECU 4 (4)	5	9
	10	4.07	R	FLR91X-A	ECU Power Supply	ECU 4 (4)	7	10
	11	4.08	R	FLR91X-A FLR91X-A	ECU Power Supply	ECU 4 (4)	8	11
	12	4.36A	Brn	FLR91X-A	Key-ON (T15)	SP_09		12
	13	3.02	B	FLR91X-A_T15	Accelerator Pedal1-2 GND	ECU 3 (3)	2	13
	14	3.10	G	FLR91X-A_T15	Accelerator Pedal1-2 Signal	ECU 3 (3)	10	14
	15	3.18	R	FLR91X-A_T15	Accelerator Pedal1-2 PWR	ECU 3 (3)	18	15
	16	3.01	B	FLR91X-A_T14	Accelerator Pedal1-1 GND	ECU 3 (3)	1	16
	17	3.09	W	FLR91X-A_T14	Accelerator Pedal1-1 Signal	ECU 3 (3)	9	17
	18	3.17	R	FLR91X-A_T14	Accelerator Pedal1-1 PWR	ECU 3 (3)	17	18
	19	4.31	O	FLR91X-A	Key Switch "Start" (T50)	ECU 4 (4)	31	19
	20							
	21	2.46	R	FLR91X-A	Starter Relay V	ECU 2 (2)	46	21
	22	2.33	Y	FLR91X-A	Starter Relay S	ECU 2 (2)	33	22
	23	4.28A	Brn	FLR91X-A_T04	CAN1 Low	SP_04		23
	24	4.29A	O	FLR91X-A_T04	CAN1 High	SP_03		24
	25	4.22A	W	FLR91X-A_T02	CAN2 High	SP_01		25
	26	4.23A	Y	FLR91X-A_T02	CAN2 Low	SP_02		26
	27							
	28							
	29							
	30	3.28	Y	FLR91X-A	E/G Emergency Stop Switch Signal	ECU 3 (3)	28	30
	31	3.46	R	FLR91X-A	E/G Emergency Stop Switch Supply	ECU 3 (3)	46	31
Injector Conn 	1	8.02	L	FLR91X-A_T08	Injector 1, Bank 1 High	ECU 8 (8)	2	1
	2	8.01	B	FLR91X-A_T08	Injector 1, Bank 1 Low	ECU 8 (8)	1	2
	3	8.08	L	FLR91X-A_T10	Injector 3, Bank 1 High	ECU 8 (8)	8	3
	4	8.07	B	FLR91X-A_T10	Injector 3, Bank 1 Low	ECU 8 (8)	7	4
	5	8.05	L	FLR91X-A_T09	Injector 2, Bank 1 High	ECU 8 (8)	5	5
	6	8.04	B	FLR91X-A_T09	Injector 2, Bank 1 Low	ECU 8 (8)	4	6
	7	8.11	L	FLR91X-A_T13	Injector 3, Bank 2 High	ECU 8 (8)	11	7
	8	8.10	B	FLR91X-A_T13	Injector 3, Bank 2 Low	ECU 8 (8)	10	8
	9	8.17	L	FLR91X-A_T11	Injector 1, Bank 2 High	ECU 8 (8)	17	9
	10	8.16	B	FLR91X-A_T11	Injector 3, Bank 2 Low	ECU 8 (8)	16	10
	11	8.14	L	FLR91X-A_T12	Injector 3, Bank 2 High	ECU 8 (8)	14	11
	12	8.13	B	FLR91X-A_T12	Injector 3, Bank 2 Low	ECU 8 (8)	13	12
Fuel Metering Unit (FMU) 	1	7.07	O	FLR91X-A_T07	Fuel Metering Unit H	ECU 7 (7)	7	1
	2	7.08	Brn	FLR91X-A_T07	Fuel Metering Unit L	ECU 7 (7)	8	2

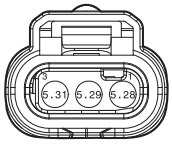
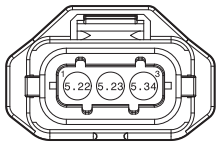
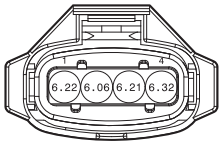
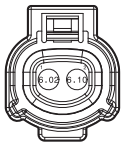
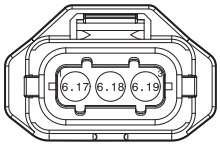
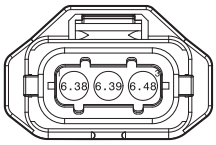
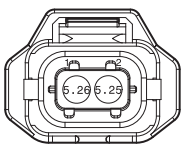
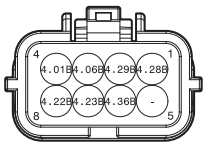
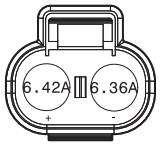
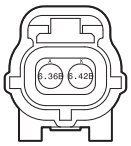
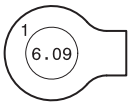
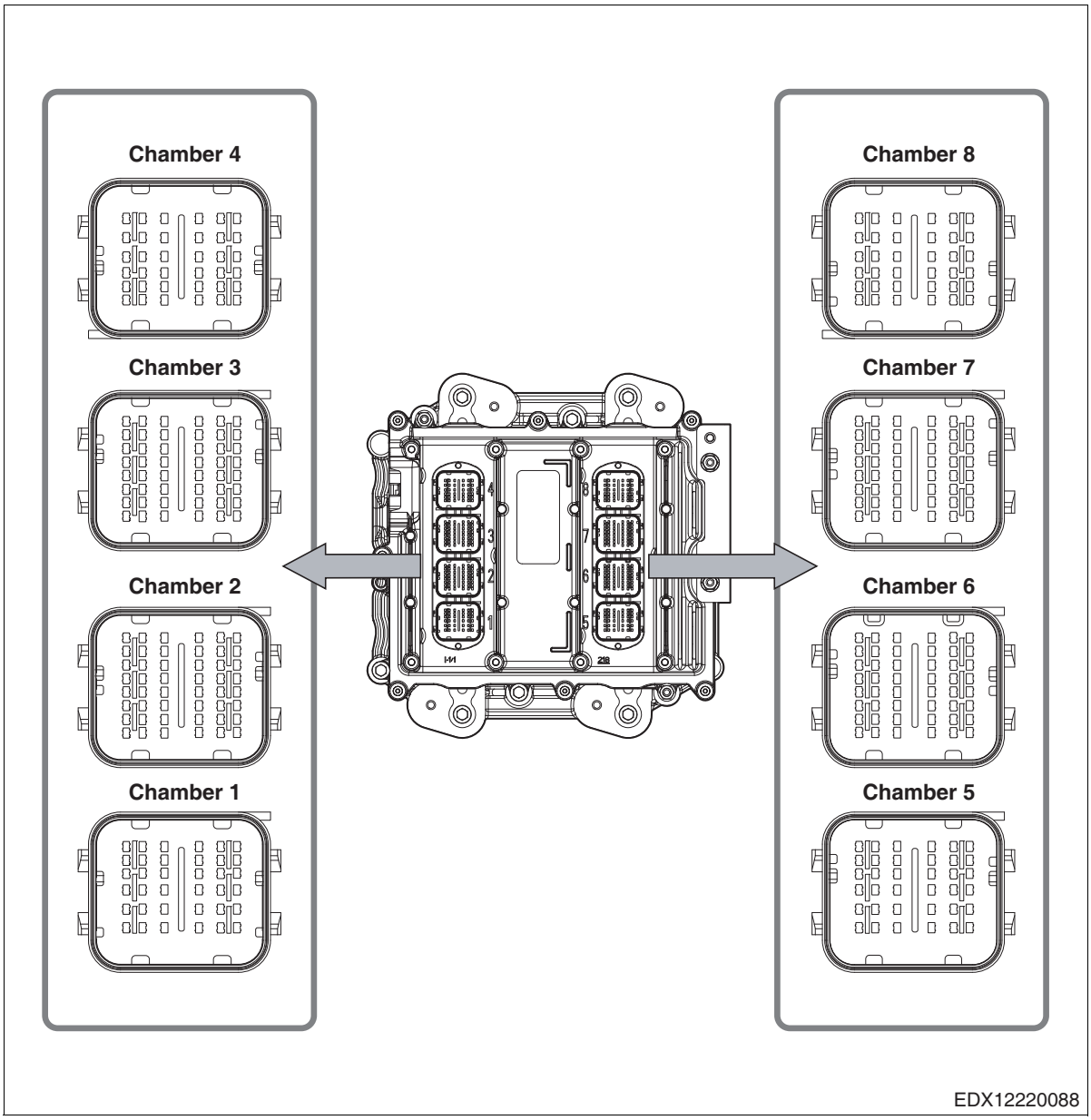
Figure	No.	Circuit	Color	Insulation	Circuit Description	From	Pin	Connec-tor Pin
Oil Press Sensor (OPS) 	1	5.28	Y	FLR91X-A	Oil Press Sensor Signal	ECU 5 (5)	28	1
	2	5.29	B	FLR91X-A	Oil Press Sensor GND	ECU 5 (5)	29	2
	3	5.31	R	FLR91X-A	Oil Press Sensor PWR	ECU 5 (5)	31	3
Rail Press Sensor (RPS) 	1	5.22	B	FLR91X-A_T05	Rail Press Sensor GND	ECU 5 (5)	22	1
	2	5.23	W	FLR91X-A_T05	Rail Press Sensor Signal	ECU 5 (5)	23	2
	3	5.34	R	FLR91X-A_T05	Rail Press Sensor PWR	ECU 5 (5)	23	3
Boost P/T Sensor (BPTS) 	1	6.22	B	FLR91X-A	Boost Press/Temp Sensor GND	ECU 6 (6)	22	1
	2	6.06	Y	FLR91X-A	Boost Temp Sensor Signal	ECU 6 (6)	6	2
	3	6.21	R	FLR91X-A	Boost Press/Temp Sensor PWR	ECU 6 (6)	21	3
	4	6.32	W	FLR91X-A	Boost Press Sensor Signal	ECU 6 (6)	32	4
Coolant Temp Sensor (CTS) 	1	6.02	W	FLR90X-A	Coolant Temp Sensor Signal	ECU 6 (6)	2	
	2	6.10	B	FLR91X-A FLR91X-A FLR91X-A	Coolant Temp Sensor GND	ECU 6 (6)	10	
Crank Shaft Speed Sensor (CRS) 	1	6.17	P	FLR91X-A_BS01	Crank Shaft Speed Sensor NEG	ECU 6 (6)	17	1
	2	6.18	O	FLR91X-A_BS01	Crank Shaft Speed Sensor POS	ECU 6 (6)	18	2
	3	6.19	B	FLR91X-A	Crank Shaft Speed Sensor GND	ECU 6 (6)	19	3
Cam Shaft Speed Sensor (CAS) 	1	6.38	B	FLR91X-A_T06	Cam Shaft Speed Sensor GND	ECU 6 (6)	38	1
	2	6.39	W	FLR91X-A_T06	Cam Shaft Speed Sensor Output	ECU 6 (6)	39	2
	3	6.48	R	FLR91X-A_T06	Cam Shaft Speed Sensor Supply	ECU 6 (6)	48	3
Fuel Temp Sensor 	1	5.26	Y	FLR91X-A	Fuel Temp Sensor Signal	ECU 5 (5)	26	1
	2	5.25	B	FLR91X-A	Fuel Temp Sensor GND	ECU 5 (5)	25	2

Figure	No.	Circuit	Color	Insulation	Circuit Description	From	Pin	Connec-tor Pin
Check Conn (Check) (Non Air Heater) 	1	4.28B	Brn	FLR91X-A_T16	CAN1 Low	SP_04		1
	2	4.29B	O	FLR91X-A_T16	CAN1 High	SP_03		2
	3	4.06B	B	FLR91X-A	Check Conn GND	SP_06		3
	4	4.01B	R	FLR91X-A	Check Conn Supply	SP_05		4
	5	-						
	6	4.36B	Brn	FLR91X-A	Key-ON (T15)	SP_09		7
	7	4.23B	Y	FLR91X-A_T17	CAN2 Low	SP_02		5
	8	4.22B	W	FLR91X-A_T17	CAN2 High	SP_01		6
Ambient Temp Sensor (ATS) 	1	2.34	B	FLR91X-A	Ambient Temp Sensor GND	ECU 2 (2)	34	1
	2	2.26	Y	FLR91X-A	Ambient Temp Sensor Signal	ECU 2 (2)	26	2
Air Heater RLY S (RLYS) 	1	6.36A	W	FLR91X-A	Preheat Relay D	SP_11		-
	2	6.42A	Brn	FLR91X-A	Preheat Relay C	SP_10		+
Diode (DIO) 	1	6.42B	Brn	FLR91X-A	Diode K	SP_10		K
	2	6.36B	W	FLR91X-A	Diode A	SP_11		A
Heater Check (H_CK) 	1	6.09	W	FLR91X-A	Preheat Feedback	Heater Check (H_CK)	1	9

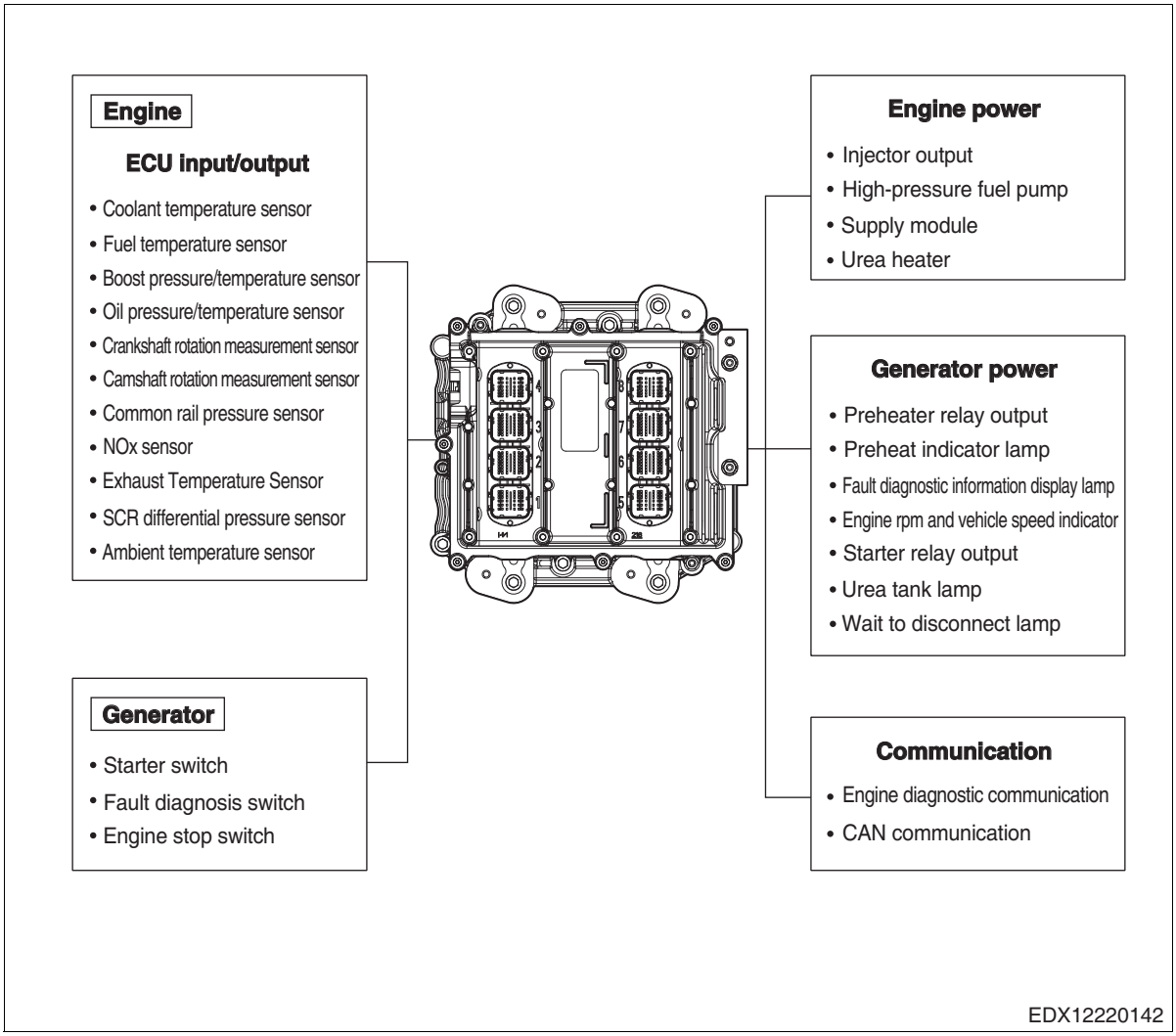
3.11.5.1 Engine Control Unit (ECU) Connectors

Engine control unit (ECU) connectors consist of connectors for connecting to the ship and connectors for connecting to the engine.

- ECU assembly
  1) Secure the ECU mounting plate.
  2) Install the ECU.



3.11.5.2 Engine Control Unit (ECU) Input/Output



3.11.5.3 Engine Control Unit (ECU) Operating Conditions

1) Starting the engine
   a) To set the reference temperature for determining whether or not to perform preheating, the ECU sets the lowest temperature among the coolant temperature, fuel temperature, intake air temperature, and oil temperature as the reference temperature.
   b) To set the reference temperature for determining the amount of fuel, the ECU sets the engine coolant temperature as the reference temperature.
   c) After determining a suitable amount of fuel for starting the engine, the ECU supplies the fuel to the engine and uses the crankshaft speed sensor to measure the engine rpm signal.
2) Sailing
   a) It calculates essential data required for sailing, such as CAN data received from the ship control unit and the engine rpm, etc..
3) Adjusting the engine rpm to the needs of the driver
   a) The ECU controls the engine rpm according to the needs of the driver and controls the engine according to the engine rpm required by the ship's control unit.
4) Failure Diagnosis
   a) The fault diagnosis information lamp on the gauge panel activates in the event of a fault.
   b) The fault diagnosis information lamp can be used to check the fault code.

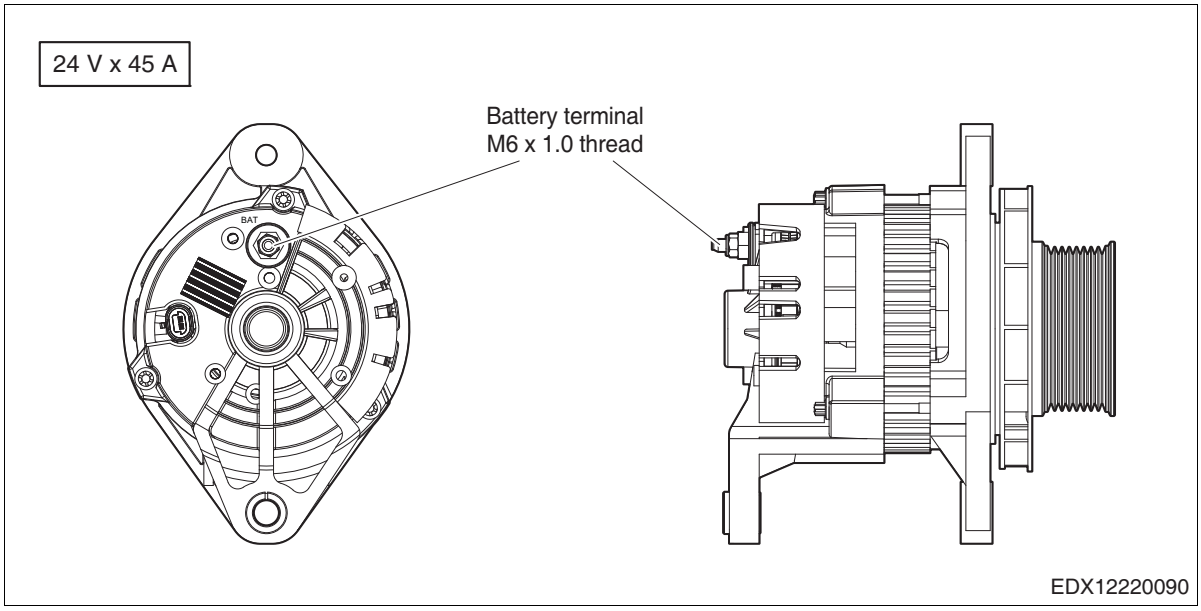
CAUTION

It can also be checked using the fault diagnosis information on the gauge panel.

   c) The type of fault can be diagnosed by connecting a diagnostic tool to the check connector on the back of the driver's seat.
5) Sailing record
   a) Sailing-related information is recorded in the engine control unit.
   b) Information such as the fuel consumption rate, engine operating time, and engine control unit operating time is recorded in the engine control unit.
   c) Information can be monitored using the ECU diagnostic system.

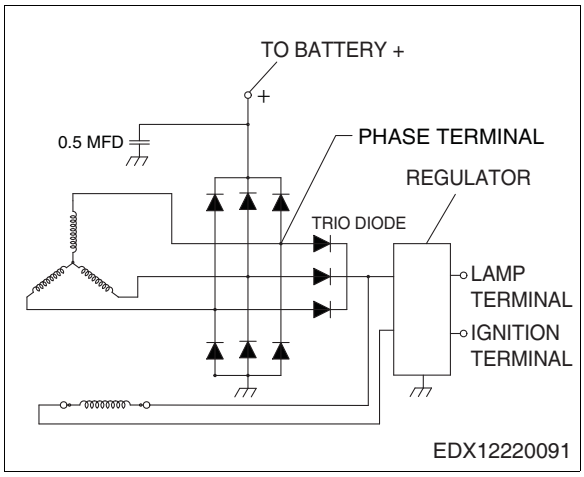
3.11.6. Alternator

The alternator is equipped with a silicon rectifier. The transistor-type regulator installed in the body of the alternator restricts the voltage of the alternator. In order to prevent damage to the rectifier and regulator, do not run the alternator unless the regulator and battery are connected to the circuit.



The alternator does not require maintenance, but it must be protected from dust, moisture and water.

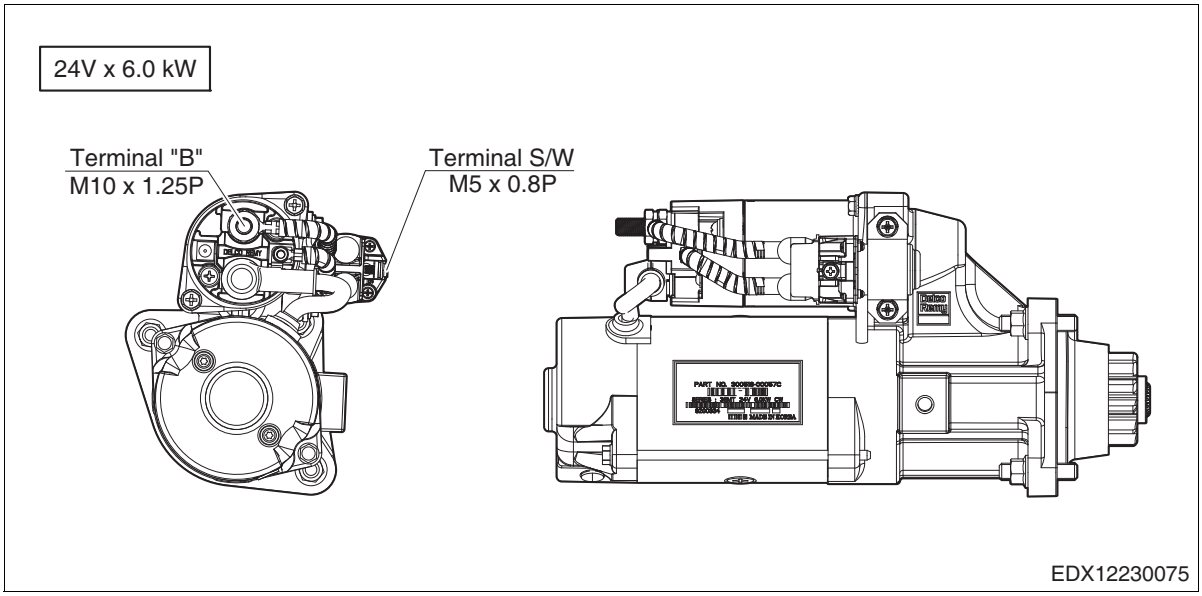
Run the alternator in accordance with the guidelines provided in this chapter.



3.11.7. Starter Motor

The sliding gear starter motor is installed on the flange at the back of the flywheel housing on the left. When you turn on the ignition key switch, the starter motor pinion moves to engage with the ring gear on the flywheel. Then the engine starts once the main contact closes and current is flowing. If you release the ignition key switch after the engine is running, the pinion automatically returns to its initial position. Once the engine is running, the ignition key switch must be released immediately. Otherwise, the starter motor may be damaged or burn out.

When repairing the engine, submerge the starter's pinion and ring gear in fuel and remove any corrosion with a brush. Then apply grease to protect them from corrosion. Whenever you clean the starter, always be careful that electrical short circuits do not occur due to contact with water.



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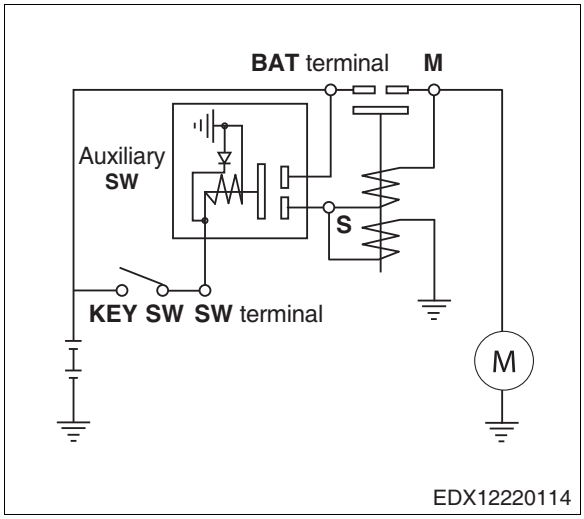
Always protect the starter motor from water.

Warning:
Before beginning any work related to the electrical system, always unplug the battery ground cable. When connected, there is a risk of a short circuit occurring so connect the grounding cable last.



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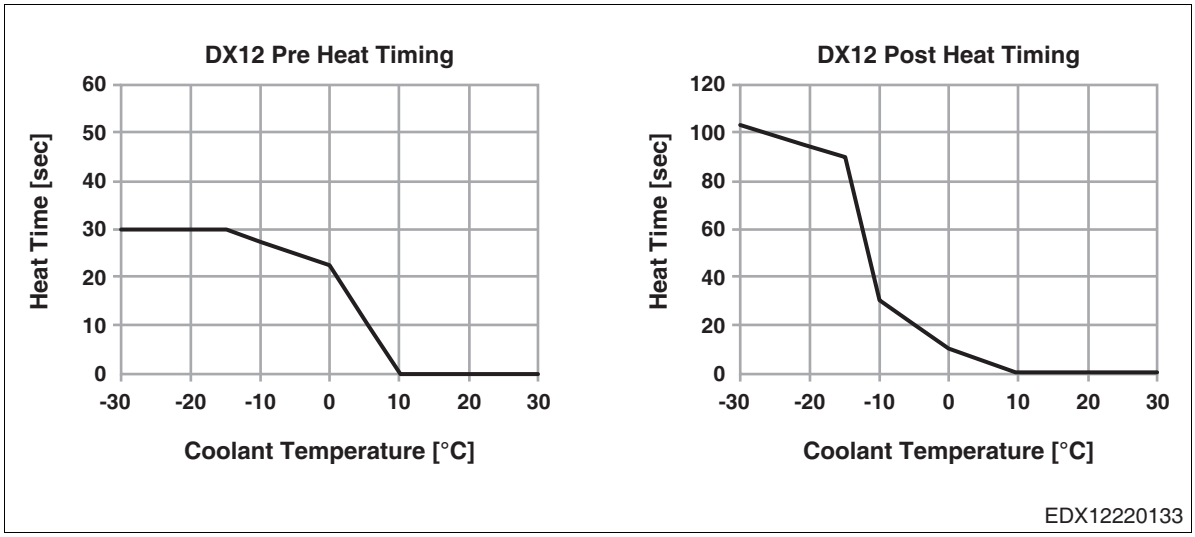
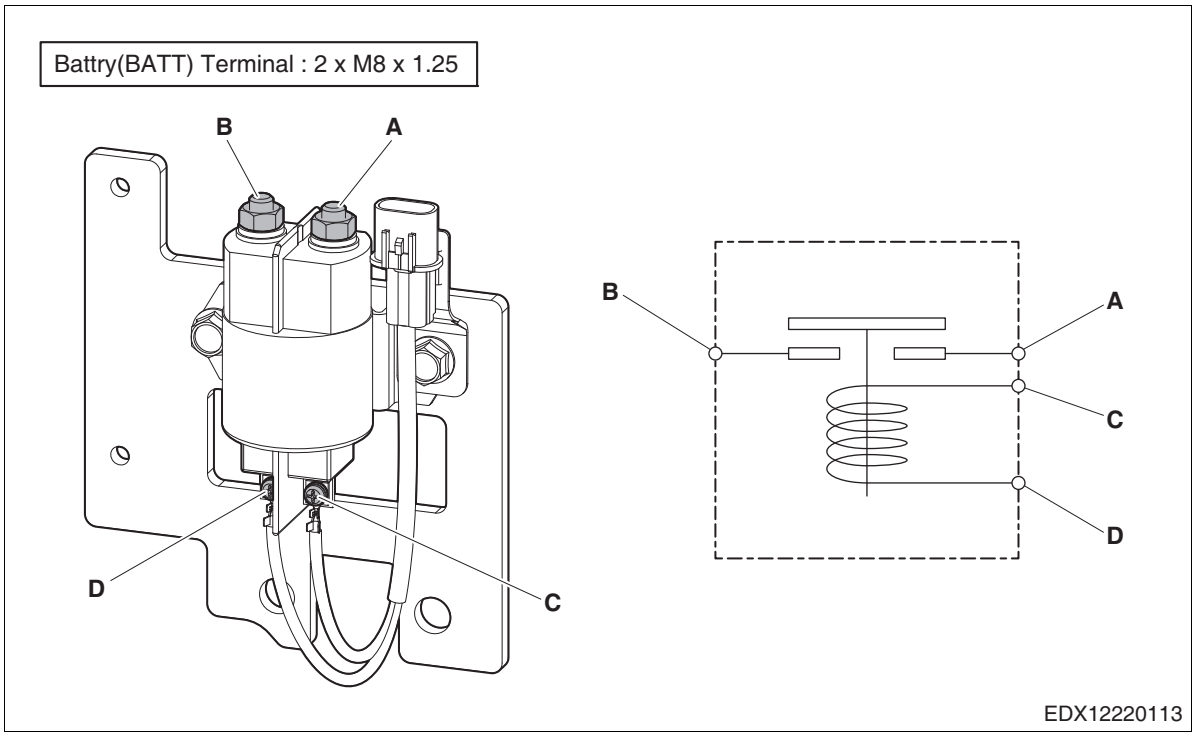
3.11.8. Air Heater (Optional)

- Operating Conditions



- Circuit Diagram



4. Initial Start-Up and Operation

4.1. Preparation

When first starting the engine after the break-in and overhaul inspection, you must comply with the "Technical Information for Installing the HD Hyundai Infracore Generator Engine".

- Oil filler neck on the cylinder head cover
  Before starting the engine each day, check the levels of fuel, coolant and oil, and replenish if necessary.
  The marks on the dipstick indicate the maximum and minimum permissible oil levels.
  The oil required for the sump is stipulated in the "Engine Specifications".

Note:
The amount of oil required to fill the oil filler and pipe differs depending on the type of engine and use; this must be determined individually when first starting the engine. (Indicate the minimum and maximum values of the amount measured by the oil level gauge.)

- Cleanliness
  Maintain the utmost cleanliness when handling fuel, lubricant and coolant.

4.2. Engine Break-In

4.2.1. Running a New Engine (Break-In)

The sliding surface of a new engine has not been sufficiently broken in, which may cause the oil film to break easily due to overload or overspeeding, thereby reducing the engine life.
Therefore, the following rules should be followed:

For the first 50 hours

- Avoid work which involves overloading or continuous overspeeding.
- Avoid overspeeding in an unloaded state.
- Avoid starting or stopping the engine suddenly.
- Maintain the engine speed at less than 70% of the maximum speed.
- Perform thorough maintenance and inspections.

4.2.2. Break-In Inspection Items

During the break-in (initial engine operation) period, comply with the following items in particular.

1) Check the engine oil level frequently. Maintain the oil level within a safe range (between the "minimum" and "maximum" marks on the dipstick).

Note:
In the event that there is an issue with obtaining a suitable oil level readout from the dipstick, turn the dipstick 180°, reinsert it and then perform the inspection again.

2) Pay careful attention to the oil warning lamp. In the event that the lamp is flashing, there may not be oil covering the oil pickup screen. Check the oil level. Add oil to the oil pan if necessary. Do not overfill oil. If an issue persists even though the level is correct, contact the dealership to check for a problem with the function of the switch, oil pump or line.

Note:
As the RPM increases, the oil pressure also rises; when the RPM decreases, the oil pressure also drops. In addition, a low oil temperature generally indicates higher oil pressure at a certain RPM than a high oil temperature. This state indicates that the engine is running normally.

3) Pay attention to the engine coolant temperature gauge and check whether coolant is circulating properly. If the coolant level in the expansion tank is too low, the needle on the water temperature gauge will drop.
When the break-in period ends, remove the break-in oil and replace the oil filter. Refill the oil pan with the recommended engine oil. Refer to the following chart.

<Engine oil capacity>

Model	Max.	Min.
DX12	44 L	20 L

4.2.3. Operation After Break-In Period

When starting the engine in low temperatures, always warm the engine up gradually. Never run the engine at full throttle until the engine is completely warmed up. The oil consumption is high until the piston rings are properly seated so check the oil level frequently for the first 50 hours of operation.

4.3. Inspections After Starting the Engine

While running the engine, monitor the oil pressure in the engine lubrication system. Turn the engine off immediately in the event that the monitoring device registers a decrease in the lubricant pressure. While the engine is running, the alternator's charge warning lamp must be turned off.

- Do not remove the battery, pole terminal or cable.
- If the battery charge warning lamp suddenly flashes during operation, turn the engine off immediately and check for a defect in the electrical system!
- The engine must be turned off if the colour, sound or smell of exhaust gas is abnormal.
- Check the following items with the warning lamps and gauge panel.

4.3.1. Lubricant Pressure

Normal pressure is a maximum of 1 kg/cm² (1.0 bar) during idling and 3 ~ 5 kg/cm² (3.0 ~ 4.9 bar) at maximum speed. If the pressure changes during idling or fails to reach the expected level at high speeds, turn the engine off immediately and inspect the oil level and oil line for leaks.

4.3.2. Coolant Temperature

The coolant temperature should be 82 ~ 95°C in normal operating mode. An abnormally high coolant temperature (100°C or higher) may lead to engine overheating and seizure of cylinder components. In addition, an excessively low coolant temperature increases fuel consumption, accelerates the wear of the cylinder liner and shortens engine life.

4.4. Running the Engine During Winter

Pay particular attention to the viscosity of the lubricant and coolant freezing.

4.4.1. Preventing Coolant Freezing

In the event that antifreeze is not used, drain the coolant completely after running the engine. Coolant freezing may cause fatal damage to the engine. Antifreeze is used in order to prevent coolant from freezing so be sure to check the "Amount of Antifreeze".

4.4.2. Preventing Excessive Cooling

Excessive cooling of the engine is prevented because decreased thermal efficiency caused by excessive cooling increases fuel consumption.

If the coolant temperature fails to reach a normal state (82 ~ 95°C) after continuously running the engine, inspect the thermostat and various coolant lines.

4.4.3. Lubricant

Oil viscosity increases in cold weather, causing the engine speed to be unsteady after starting the engine. Hence, lubricant for the winter season must be used in order to prevent instability. Refer to the "Lubricant" section.

4.5. Engine Tuning

The purpose of engine tuning is to restore the output or performance of one or more parts or components which has been lost due to wear, corrosion or degradation. As the engine runs normally, these changes may gradually occur in several places so it is not advisable to attempt to enhance performance by modifying only one or two parts. By following the proven, thorough procedures for analysis and modification of all parts which affect output and performance, you can save time and obtain results which last longer.
If you perform a complete tune-up every year (preferably in the spring), you can maintain economic, fault-free performance with even greater certainty. The following components affect output and performance and require inspection.

- Components which affect fuel injection:
  Nozzle, delivery valve, fuel filter, water separator, etc.
- Components which affect intake and exhaust:
  Air filter, intercooler, turbocharger, silencer, etc.
- Components which affect lubrication and cooling:
  Air filter and oil filter, antifreeze, etc.

5. Maintenance and Handling

5.1. Regular Inspection and Maintenance

In order to always maximize fault-free engine performance, regular inspections, adjustments and maintenance must be performed.

- Perform the daily inspections in the chart below every day.
- Regular maintenance must be performed thoroughly.
  ("7.1. Regular Inspection Intervals")

5.2. Lubrication System

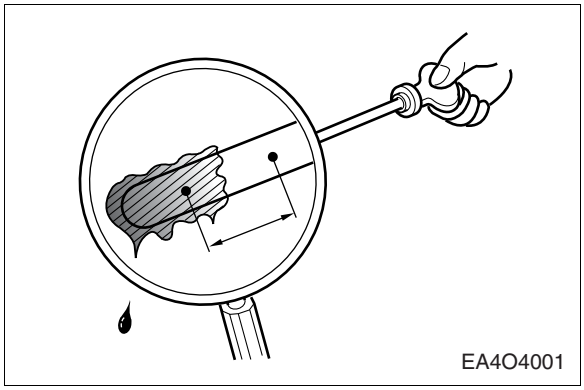
5.2.1. Change the lubricant

The engine oil and oil filter are important factors which affect the engine life. The oil and oil filter affect the ease of ignition, fuel consumption, deposits in the combustion chamber and engine wear. Drain and change the oil in the oil pan every 500 hours of operation or 1 year whichever occurs first (whichever of the two occurs first).

5.2.2. Oil Level

Use the dipstick to check the oil level in the engine sump daily.

- The oil level indicated by the mark on the dipstick must be between the maximum and minimum permissible levels.
- The oil level must be checked with the engine in a horizontal position within 5 minutes after the engine stops.
- Inspect the viscosity and state of the oil on the dipstick and change the engine oil if necessary.

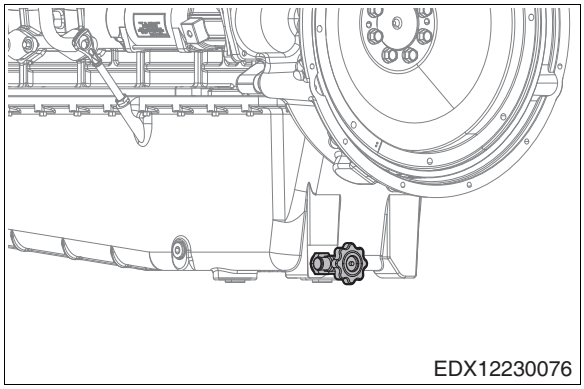


Caution:
Be sure not to add so much engine oil that the oil level exceeds the upper limit mark on the dipstick. The engine can be damaged by overfilling oil.

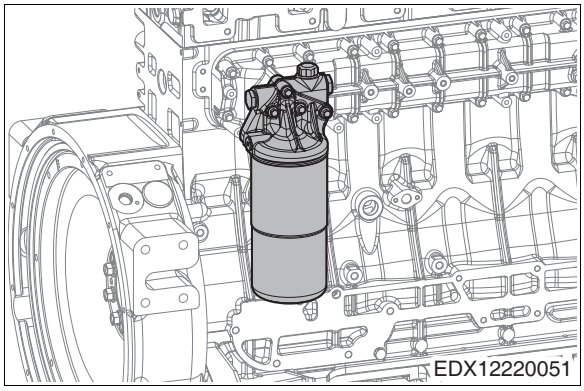
5.2.3. Procedure for Changing Oil

If the oil is still hot, change the oil as follows.

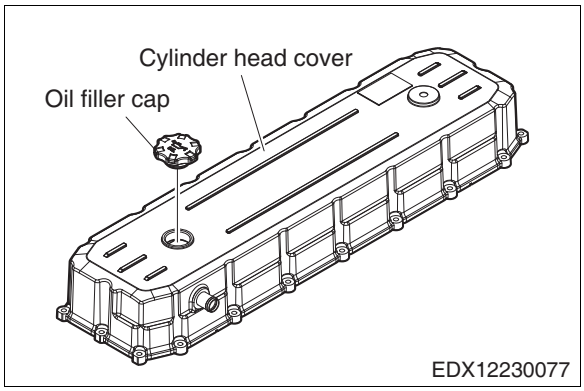
- Remove the oil dipstick.
- Open the oil discharge valve on the oil pan and drain the engine oil into a container.



- When replacing the filter, remove the plug on the oil filter head to drain the engine oil, and then close the oil pan discharge valve.

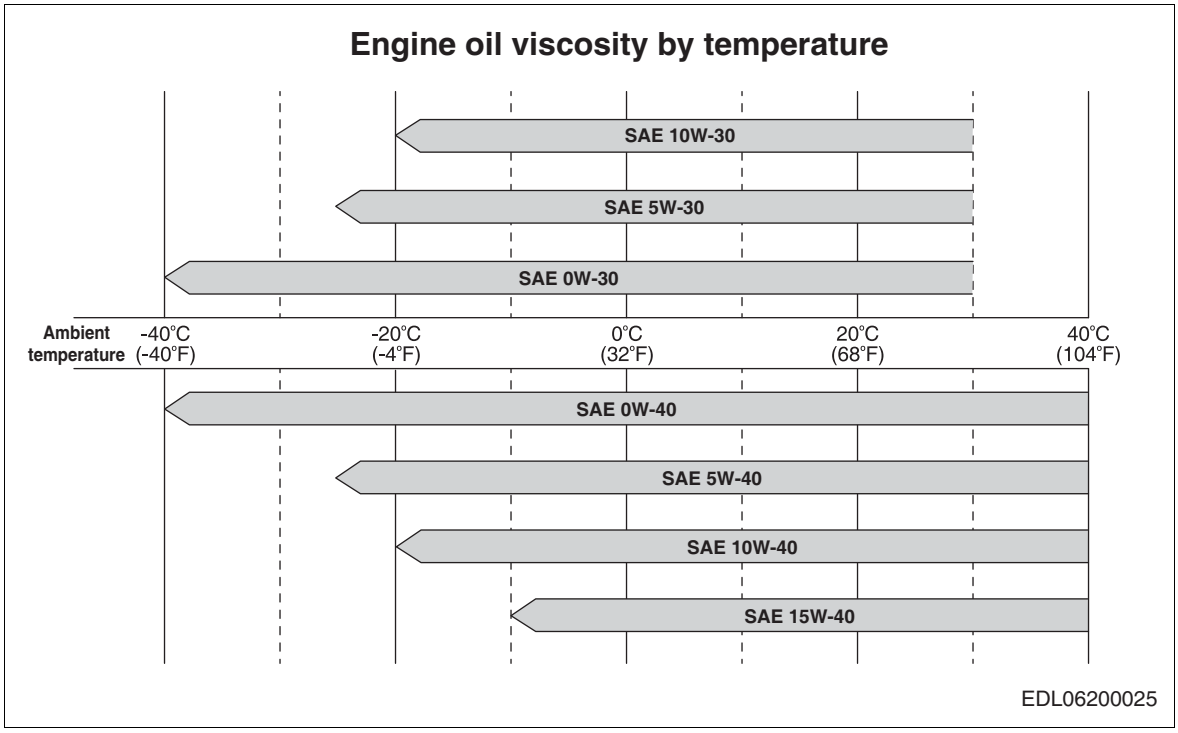


- Using the oil filler, add new engine oil to the oil filler neck on the head cover depending on the engine's oil capacity, and refill the lubricant. Ensure that dust or other contaminants are not mixed in while refilling oil. Next, check whether the oil level gauge is near the maximum level.
- Run the engine on idling speed for several minutes to circulate the oil in the lubrication system.
- Then stop the engine. After waiting for around 10 minutes, measure the oil level and add oil if necessary.



● Recommended Lubricant

When first shipped from the factory, the engine is filled with high-quality break-in oil (API Service grade CI-4). During the break-in period (50 hours), inspect the oil level frequently. It is normal that the oil consumption rate is slightly higher than usual until the piston rings are properly seated. Maintain the oil level within a safe range (between the "minimum" and "maximum" marks on the dipstick). In order to maximize the engine performance and engine life, the API Service has designated engine oils with acronyms and SAE viscosity indexes. If you cannot use the designated engine oil, use API Service CI-4 and SAE viscosity 15W-40 or a well-known brand of engine oil with the 10W-40 label. Refer to the oil identification code on the container.



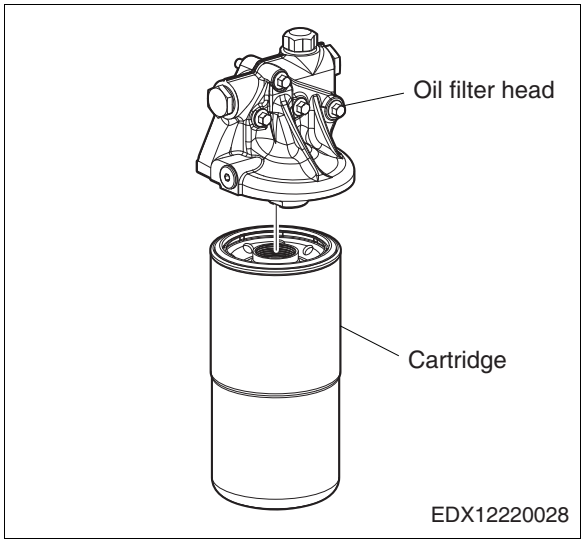
5.2.4. Replace the oil filter cartridge

Be sure to also replace the oil filter cartridge when changing the oil.

- Loosen the drain plug on the filter head to discharge the engine oil.

Caution:
Do not forget to tighten the drain plug after draining the engine oil.

- Use a filter wrench to turn and loosen the oil filter in the counterclockwise direction.
- Use a rag wipe to clean the filter body and mounting surface of the oil filter body and ensure that the new oil filter cartridge is seated properly.
- Lubricate the O-ring lightly with oil and turn the oil filter until the sealing surface aligns with the O-ring. Use a filter wrench to turn it an additional 1 - 1/4 turns.



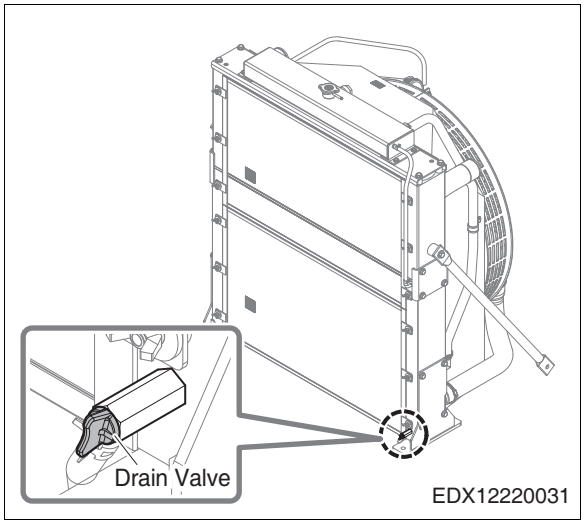
Note:
We strongly recommend using genuine HD Hyundai Infracore oil filter cartridges for replacements.

5.3. Cooling System

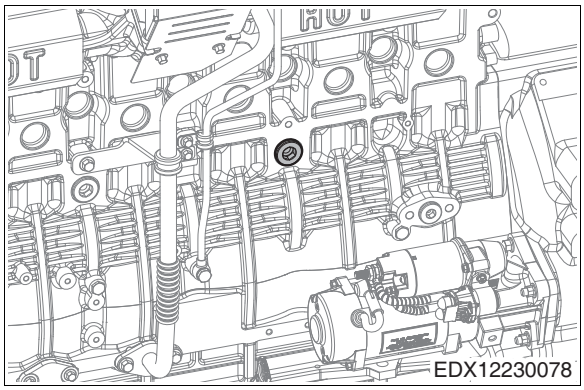
Coolant must be replaced every 1,200 hours of operation or every 6 months (whichever of the two occurs first). If the coolant becomes excessively dirty, either the engine will overheat or coolant will leak from the expansion tank.

5.3.1. Draining Coolant

1) Remove the pressure cap.
2) Open the drain valve on the lower part of the radiator to drain the coolant as shown in the picture on the right.



3) Loosen the coolant drain plug. Remove the coolant drain plug from the cylinder block.



Caution:
When removing the pressure filler cap while the engine is still hot, wrap the cap with a rag and turn it slowly to release the steam pressure inside. In doing so, the worker will not be burnt even if hot steam is released from the filler port.

5.3.2. Cleaning the Internal Circuit of the Cooling System (to be performed by a certified technician)

Cooling efficiency drops when the cooling system circuit becomes dirty with slime or residue particles. Research indicates that in most cases, defects in the coolant and/or cooling system cause damage to the mechanical seal on the water pump, and generally, defects in the coolant system are not caused by premature replacement of the rubber neck cover and operating valve, but rather by use of or defects in unsuitable or insufficient antifreeze/ anticorrosive.

In the event that a leak occurs twice within a short period of time or the coolant is severely contaminated in the engine's water pump (cloudy, brown, mechanically contaminated, gray or black traces of leakage on the water pump case), clean the cooling system as follows before removing the water pump.

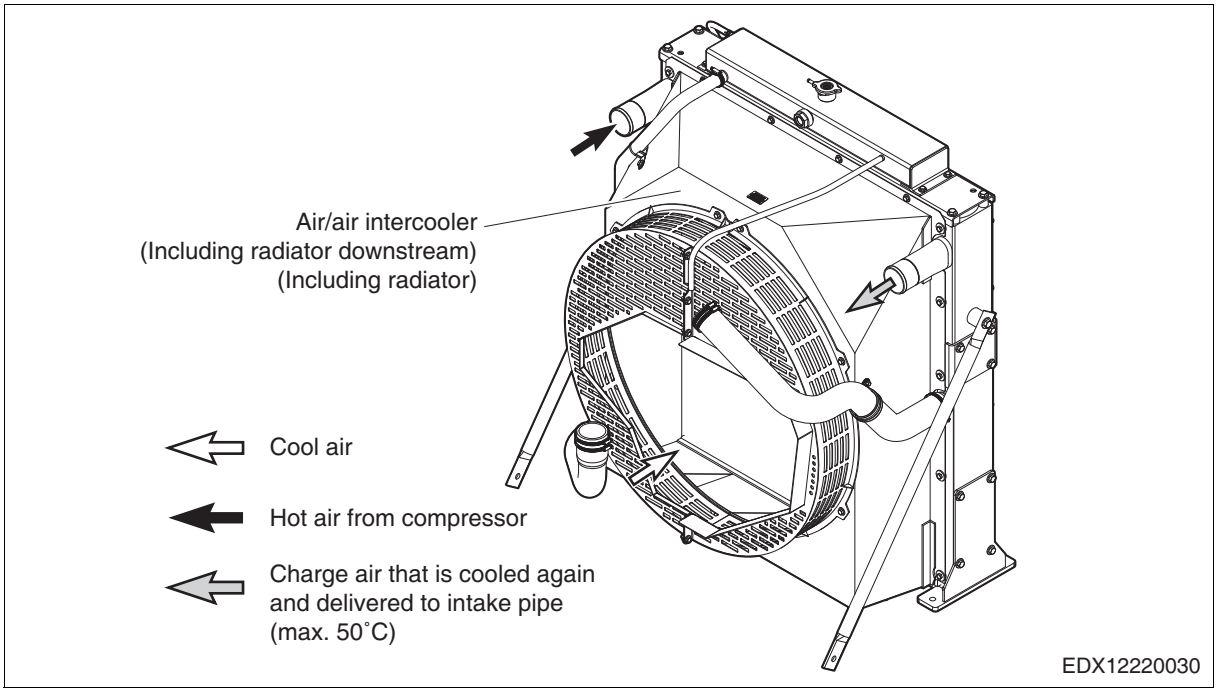
1) Drain the coolant.
2) During cleaning, remove the thermostat so that the coolant is drained immediately from the entire cooling system.

3) Fill the cooling system with a mix of drinking water and a cleaning agent (1.5%). (Henkel P3T5175)
4) Warm up the engine in a loaded state. Once the temperature reaches 60°C, run the engine for an additional 15 minutes.
5) Discharge the cleaning agent.
6) Repeat steps 3) and 4) above.
7) Rinse out the cooling system.
8) Replace the drain plug with a drain plug which has a hole diameter of 8 mm.
9) Fill the cooling system with hot water.
10) Run the engine at idling speed for 30 minutes. Add fresh water to continuously refill the water as it pours out of the hole in the drain plug.

Clean the inside of the circuit regularly with a cleaning agent.
- Cooling system cleaning intervals: Every 1,200 hours.

5.3.3. Intercooler

The intercooler is an air to air type with a very large cooling fan capacity. The life and performance of the intercooler vary greatly depending on the state of intake air. The intercooler air fin can be contaminated and clogged due to contaminated air. This leads to decreased engine output and defects in the functioning of the engine. Hence, be sure to always check whether parts of the intake system such as the air filter element are worn out or contaminated.

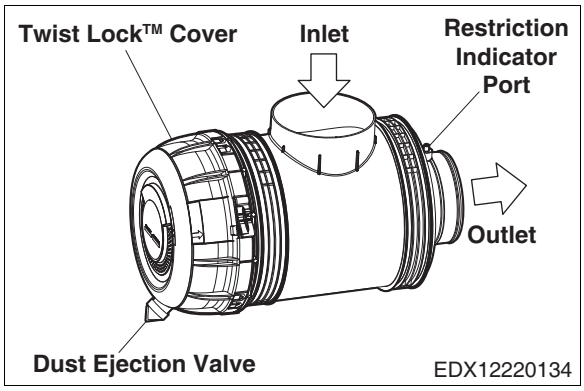


5.4. Intake system

5.4.1. Maintenance (with the engine stopped)

Empty the dust ejection valve regularly.
Never let the valve fill more than halfway with dust.

Caution:
When removing the cover to replace the element, the valve can be detached during the disassembly and assembly. Make sure that the valve is in position after its reassembly.

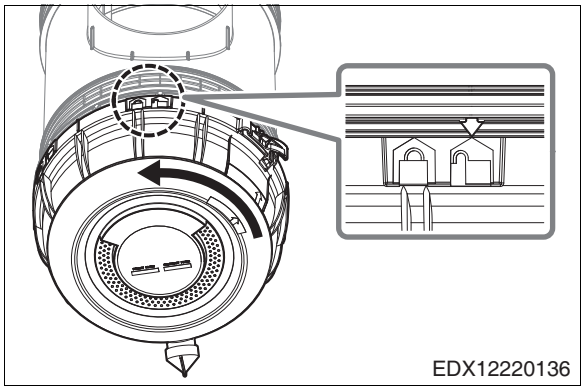


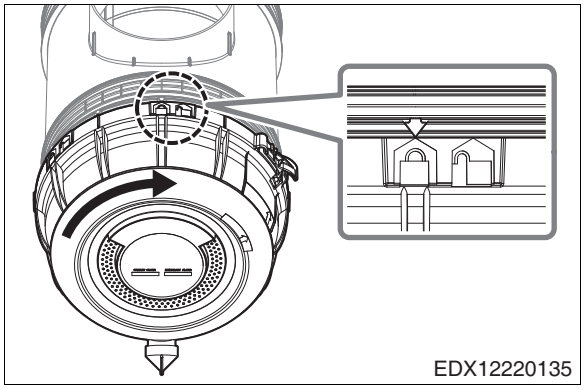
Note:
Replace it at every 500 hours.

5.4.2. Replacing the Filter Element

Caution:
Make sure that dust does not enter the inside of the case.

To remove the twist lock cover, raise the lift and place the cover in the open position as shown in the figure.
When removing the element, twist and pull it out to avoid damage to the gasket.
Clean the sealing surface and housing inner surface.
Insert a new element into the housing and reinstall the twist lock cover.
Place the twist lock cover in the lock position as shown in the figure, and then lower the lift to seal the air cleaner.





5.4.3. Cleaning the Filter Element

Cleaning the filter element is not recommended.

The element's dust capture capability can be deteriorated by approx. 25% compared to a new one after its cleaning. Every subsequent cleaning can further decrease such capability.

Deterioration of the dust capture capability shortens the service life of the element, leading to more frequent maintenance service and a risk of incorrect maintenance, which is an additional danger.

The filter media can be weakened and ruptured by cleaning. Even a small rupture can reduce the filter efficiency and let dust enter the engine/equipment, thereby leading to severe damage, shutdown, and repairs.

A new element features approx. 99.9% efficiency during its service life.

A cleaned element with approx. 95% efficiency passes dust into the engine 50 times more than an intact element. Nevertheless, if still decide to clean the air filter, a few risks will come along with that action.

As DIY cleaning techniques and instant cleaning tools can bring considerable risks to the integrity of the element, they should be avoided.

A commercial element cleaning service is equipped with fine tools for cleaning air filters as well as the use of reliable techniques.

When using a commercial cleaning fluid, use one with high performance and an effective cleaning method.

5.5. Fuel System

5.5.1. Fuel Injection System

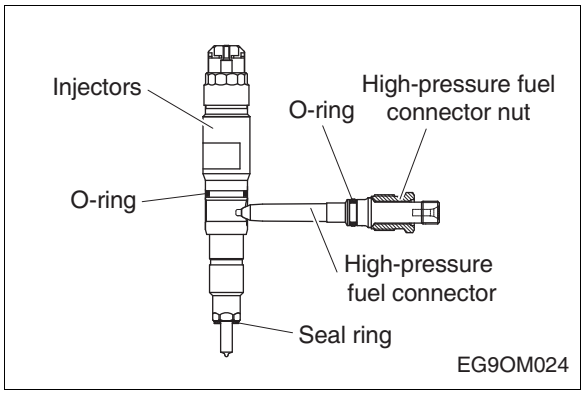
High-pressure fuel generated by the high-pressure pump is stored in the common rail. The injection timing and amount of fuel are calculated based on the data programmed in the electronic control unit (ECU) by the operator. During injection, the electronic control unit activates the solenoid valve on the injector installed in each engine cylinder and causes it to inject fuel.

3.5.2. Bleeding the Fuel Line

In order to bleed air from the fuel line, slightly loosen the fuel supply pipe between the secondary fuel filter and the high-pressure fuel pump and bleed the air by manually operating the priming pump in the primary fuel filter until no more bubbles are visible.

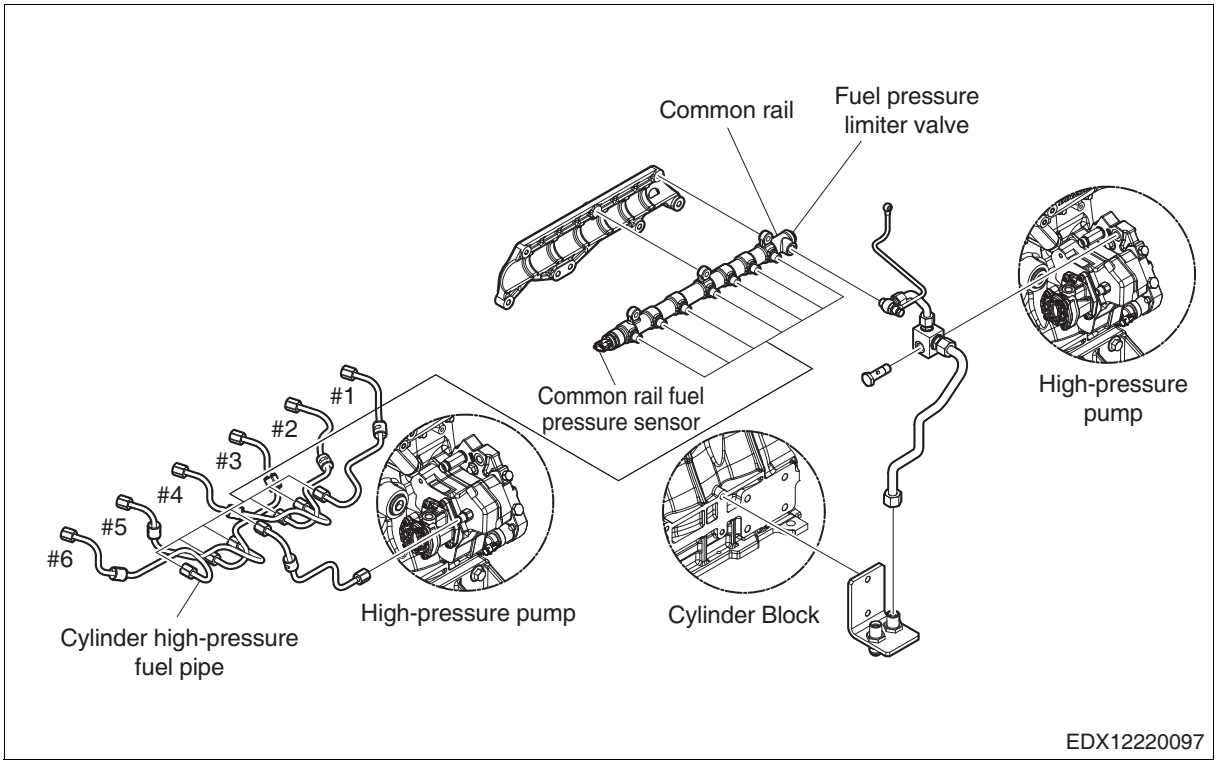
5.5.3. Injector and High-Pressure Connector

- During disassembly and inspection, be careful not to let any foreign matter enter the injector and high-pressure connector.
- During reassembly, make sure to replace O-rings and copper washers with new parts.
- Apply oil to O-rings before assembling them.
- During assembly, check the product number before assembling them.
- When disassembling and assembling injectors, make sure to follow the correct order in the chapters on disassembly and assembly.



5.5.4. Common Rail System

HD Hyundai Infracore's common rail fuel injection system is divided into a high-pressure generation system and a fuel injection system. After determining the amount of fuel, injection timing, and injection pressure which will enable the engine to deliver optimal performance based on the engine operating conditions, the ECU injects fuel into the cylinders.



6. Inspection and Setting

6.1. Adjusting the Valve Clearance

6.1.1. General Information

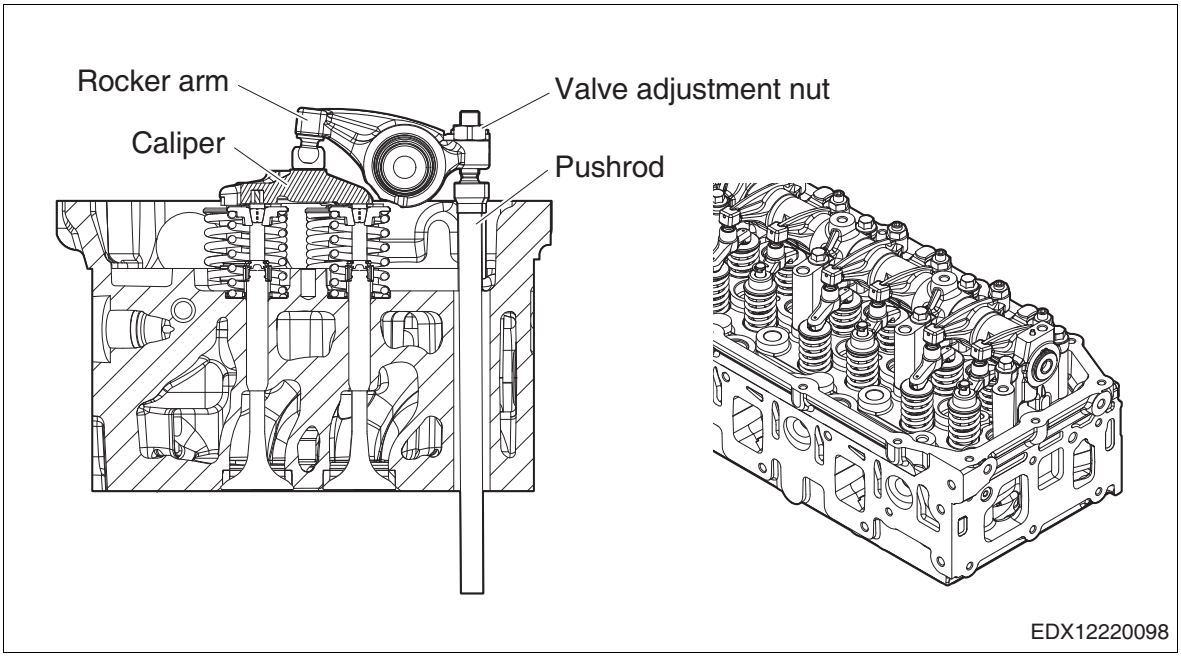
The valve clearance must be adjusted in the following circumstances.

- After the first 50 hours of operation
- When performing an engine overhaul and disconnecting the cylinder head
- Cases where severe noise is heard coming from the valve train
- Cases where the engine is not running properly in spite of there being no issue with the fuel system

6.1.2. Adjusting Sequence of Valve Clearance

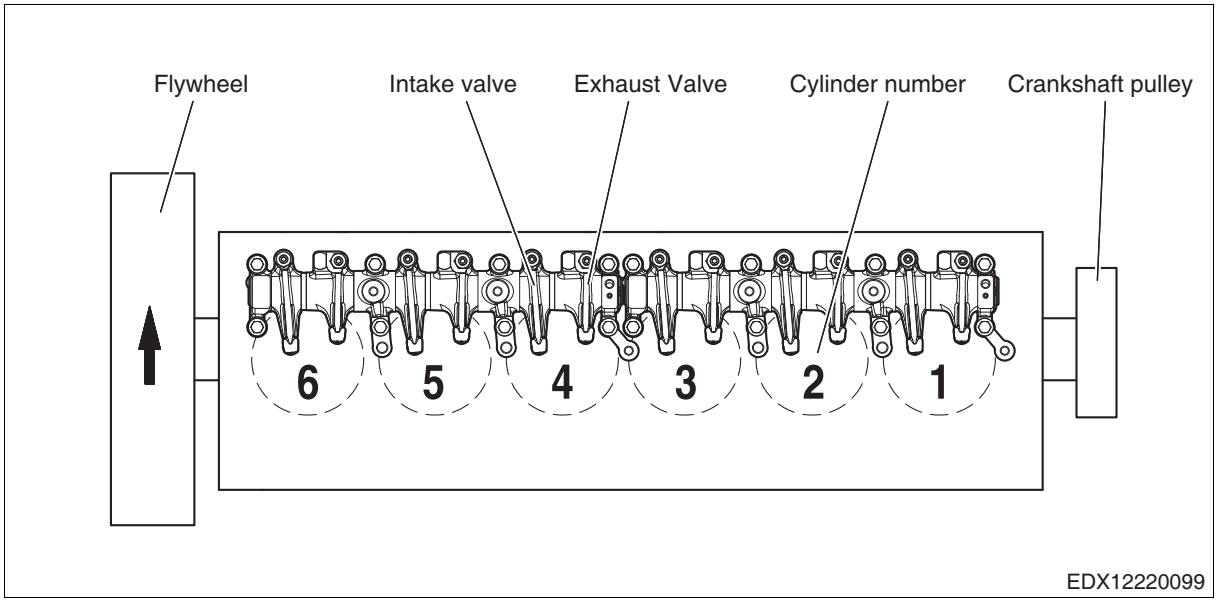
- Turn the crankshaft to set the piston of cylinder no. 1 at TDC of the compression stroke; then, adjust the valve clearance.
  (Cylinder no. 1 starts at the front of the engine while cylinder no. 6 starts at the rear where the fly-wheel is mounted.)
- Unscrew the rocker arm mounting nut and fit the feeler gauge between the rocker arm and valve. Adjust each clearance with the adjusting screw, then tighten the mounting nut.
- Adjust the valve clearance as follows while the engine is cold:

Reference value		Allowable measuring tolerance	
Intake valve	**Exhaust Valve**	**Intake valve**	**Exhaust Valve**
0.4 mm	0.7 mm	±0.05 mm	



< How to Adjust Valve Clearance 1 >

- After turning the crankshaft to have cylinder no.1 align with the TDC position, adjust the valve in position "O" in the following image. At this time, cylinder no.1 must be in the TDC position of the ignition stroke (O.T.).



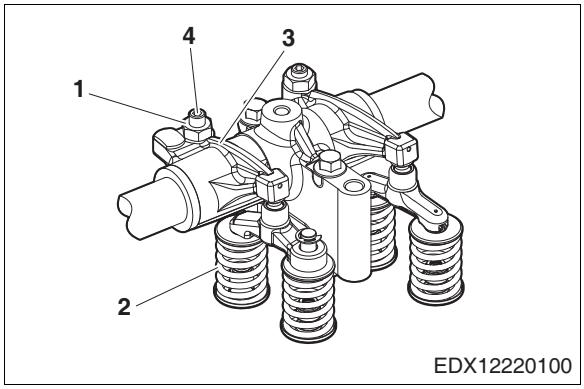
< How to Adjust Valve Clearance 2 >

- Valve adjustments for the valve overlap of each cylinder are to be performed as follows.

Valve overlap of each cylinder (Cylinder firing order)	1	5	3	6	2	4
Valve adjustment cylinder number	6	2	4	1	5	3

6.1.3. How to Adjust Valve Clearance

1) Use a ring spanner to loosen the locknut (1).
2) Insert an intake 0.4 mm, exhaust 0.7 mm feeler gauge between the valve stem (2) and rocker arm (3).
3) Use a screwdriver to turn the adjustment bolt (4) until the gauge can be pulled out with a slight feeling of tightness.
4) Fasten the adjustment bolt in place so that the locknut does not tighten while rotating after the adjustment.
5) Measure the clearance once more and adjust again if necessary.

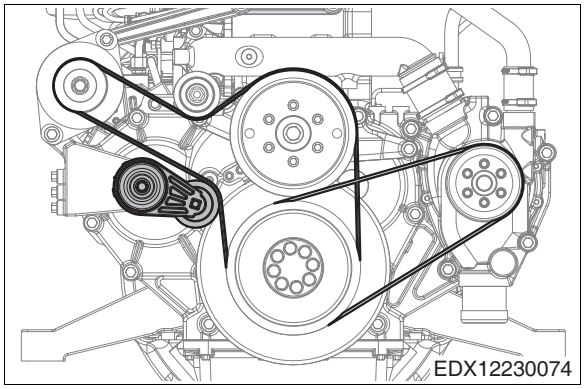


6.2. Micro V-Belt

The belt is equipped with an auto tensioner which automatically adjusts the belt tension so there is no need for extra adjustment of the tension.
During daily inspections, be sure to inspect whether the pointer on the auto tensioner is indicating that it is time for a replacement, as well as whether there is any damage to the belt due to external factors.

1) Replacing the Micro-V Belt if necessary

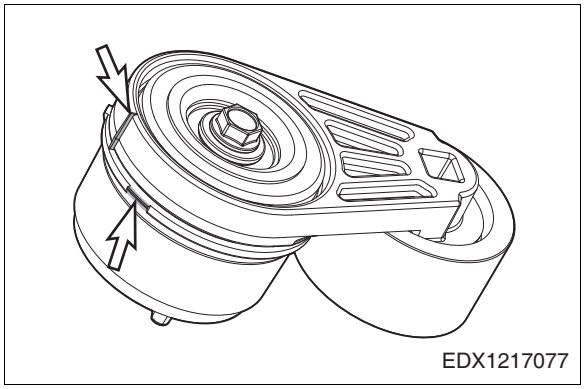
Replace the belt set in the event that the pointer on the auto tensioner indicates that it is time for a replacement, or in cases where damage to the belt from external factors has been confirmed and there are concerns of severe damage occurring.



2) Inspecting the Condition

Inspect the Micro V-belt for cracks, oil, overheating and wear.

The vertical rod shown by the arrow is the "pointer," and the belt replacement period is indicated when this "pointer" enters the horizontal range shown in orange.



3) Measuring Tension

The belt is equipped with an auto tensioner which automatically adjusts the belt tension so there is no need for extra measurement of the tension. However, in the event that measuring tension is deemed necessary, measure the tension as follows.

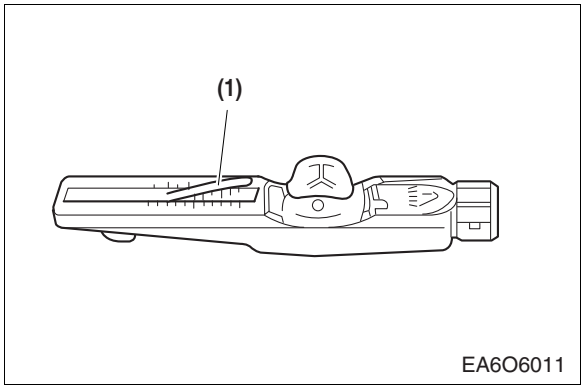
(1) Lower the indicator arm (1) to within the scale.

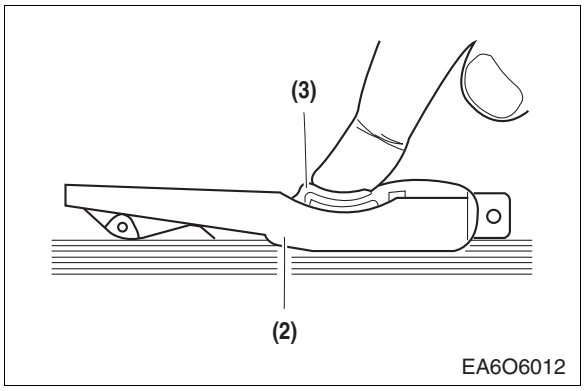
- Mount the tester on the belt between the two pulleys so that the edge of the contact surface (2) is at the same height as the V-belt.
- Press down on the pad (3) slowly until the sound of the spring being released is heard. Then, the indicator moves upwards.

  In the event that pressure is maintained even after the spring separates, you will not obtain an accurate reading!

(2) Reading the Tension Value

- Read the tension of the belt at the point where the top surface of the indicator arm (1) intersects with the scale.
- Before reading the value, check whether the indicator arm is remaining in place.

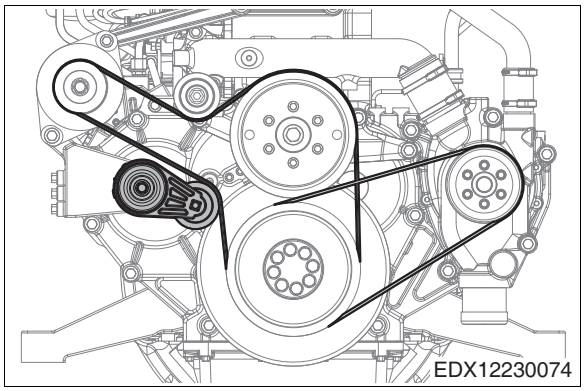




Type	Drive belt width	Tension on the tester		
		Newly installed		During service after prolonged operation (replacement interval)
		Installation	10 minutes after operation	
8PK Micro V	27.61 mm	450 ~ 650 N	450 ~ 650 N	300 N

4) Adjusting tension and replacing the Micro-V Belt

- Use the square groove located at the top of the pulley on the auto tensioner to rotate the auto tensioner clockwise.
- Remove the existing belt.
- After fitting all of the pulleys (except the auto tensioner) with a new belt, rotate the auto tensioner clockwise one last time to wind the belt onto the auto tensioner pulley, then release the auto tensioner which was being pulled in the clockwise direction.



7. Operating Tips

7.1. Regular Inspection Intervals

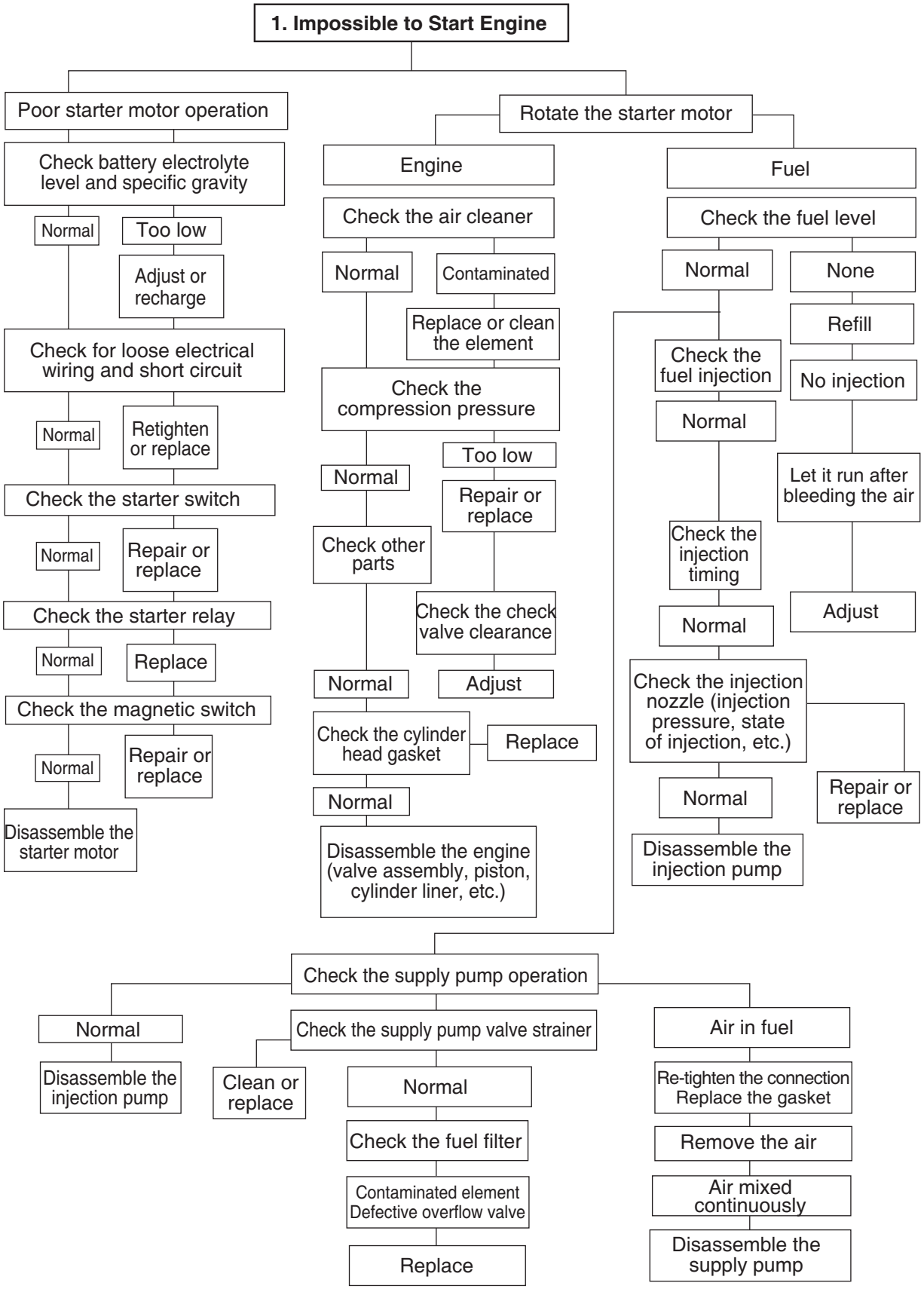
○ : Inspect and adjust ● : Replace

Finished		Daily	Every 50 hours	Every 100 hours	Every 200 hours	Every 250 hours	Every 400 hours	Every 500 hours	Every 800 hours	Every 1,200 hours	Remarks
Cooling System	Check for leaks (hoses, clamps)	○									
	Check the coolant level	○									
	Replacing Coolant										1 year/ 1,000 hours whichever occurs first
	Adjust tension of Micro V-belt (Position of pointer on auto tensioner)						○				Every 2,000 hours
	Cleaning the radiator									○	
Lubrica-tion System	Check for leaks	○									
	Check the oil level gauge	○									
	Change the lubricant		● Initial					●			1 year/ 500 hours whichever occurs first
	Replace the oil filter cartridge							●			
Intake and Exhaust System	Check for leaks in the following Intercooler (hose, clamp)	○									
	Air cleaner element							●			
Fuel System	Inspect for leaks in fuel line	○									
	Remove residue from fuel tank (Clean the fuel tank)										Whenever necessary
	Drain water from oil-water separator			○							
	Replacing the fuel filter							●			
	Inspect fuel injection nozzle										Whenever necessary
	Inspect fuel injection nozzle										Whenever necessary
Engine Adjust	Check emission condition	○									
	Check the battery charge level	○									
	Check the compression pressure									○	Whenever necessary
	Adjust the intake/exhaust valve clearance		○ 1st					○			

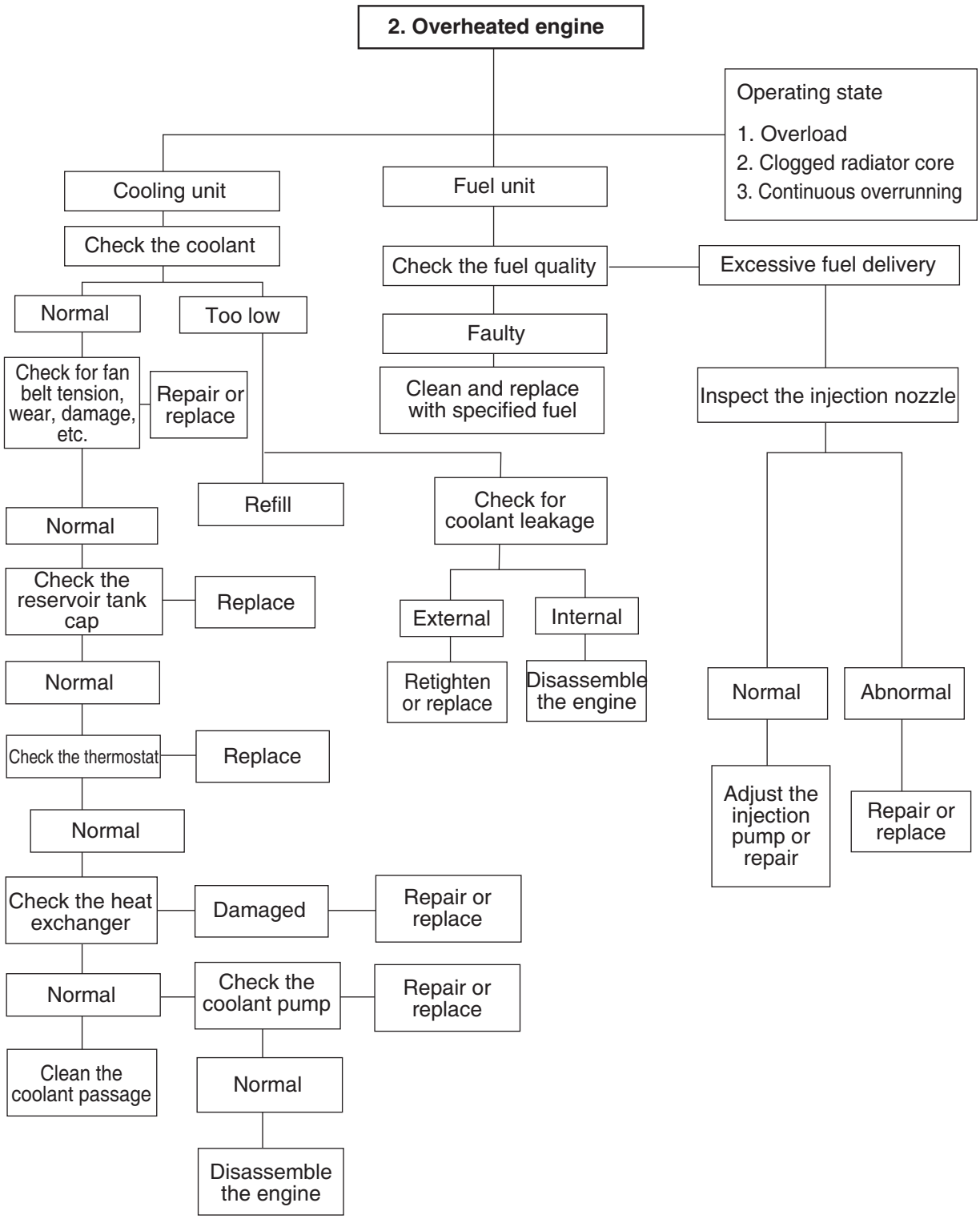
* If the sulfur content of the fuel exceeds 0.5%, reduce the replacement and inspection intervals by half.

7.2. Troubleshooting

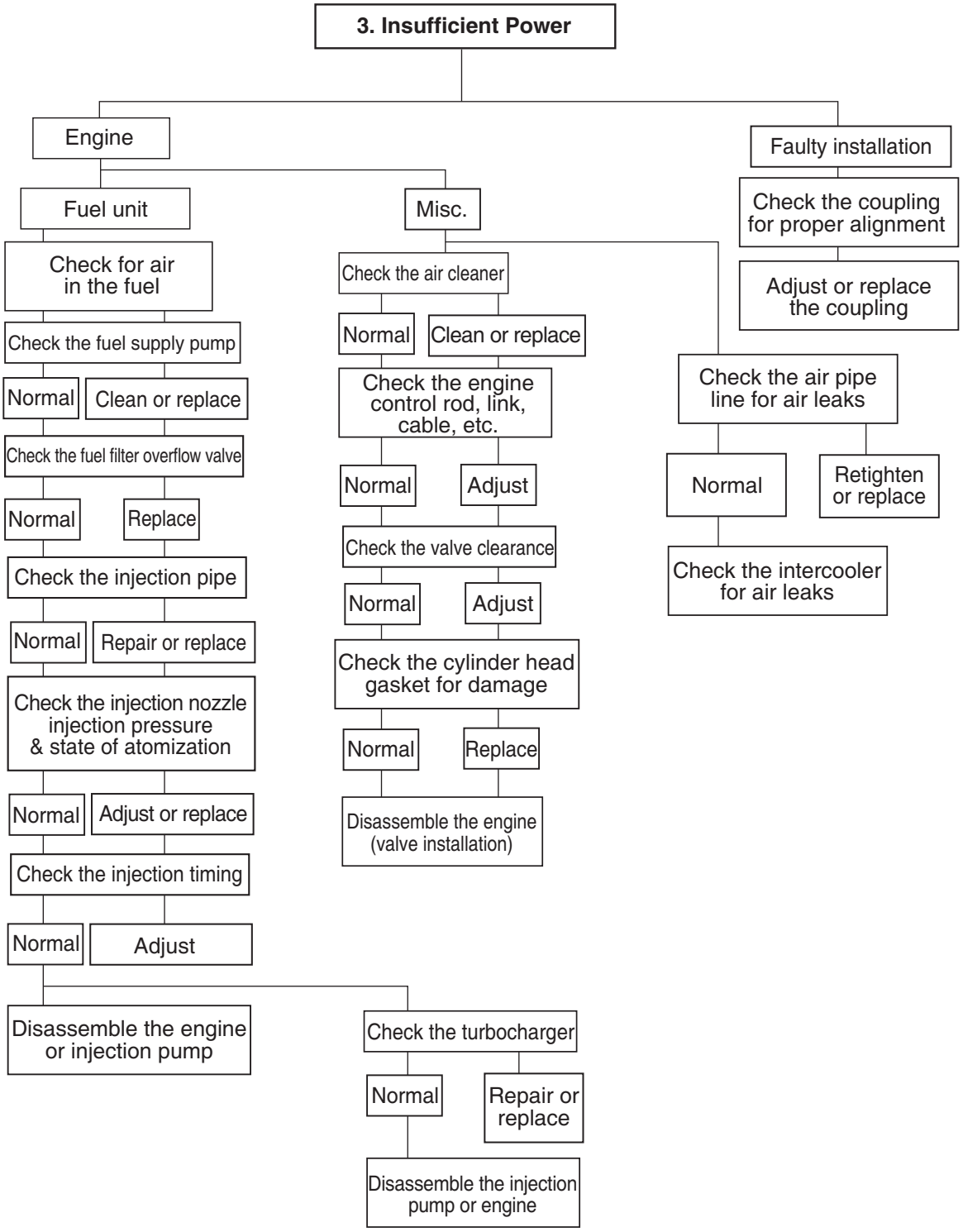
7.2.1. Impossible to Start Engine



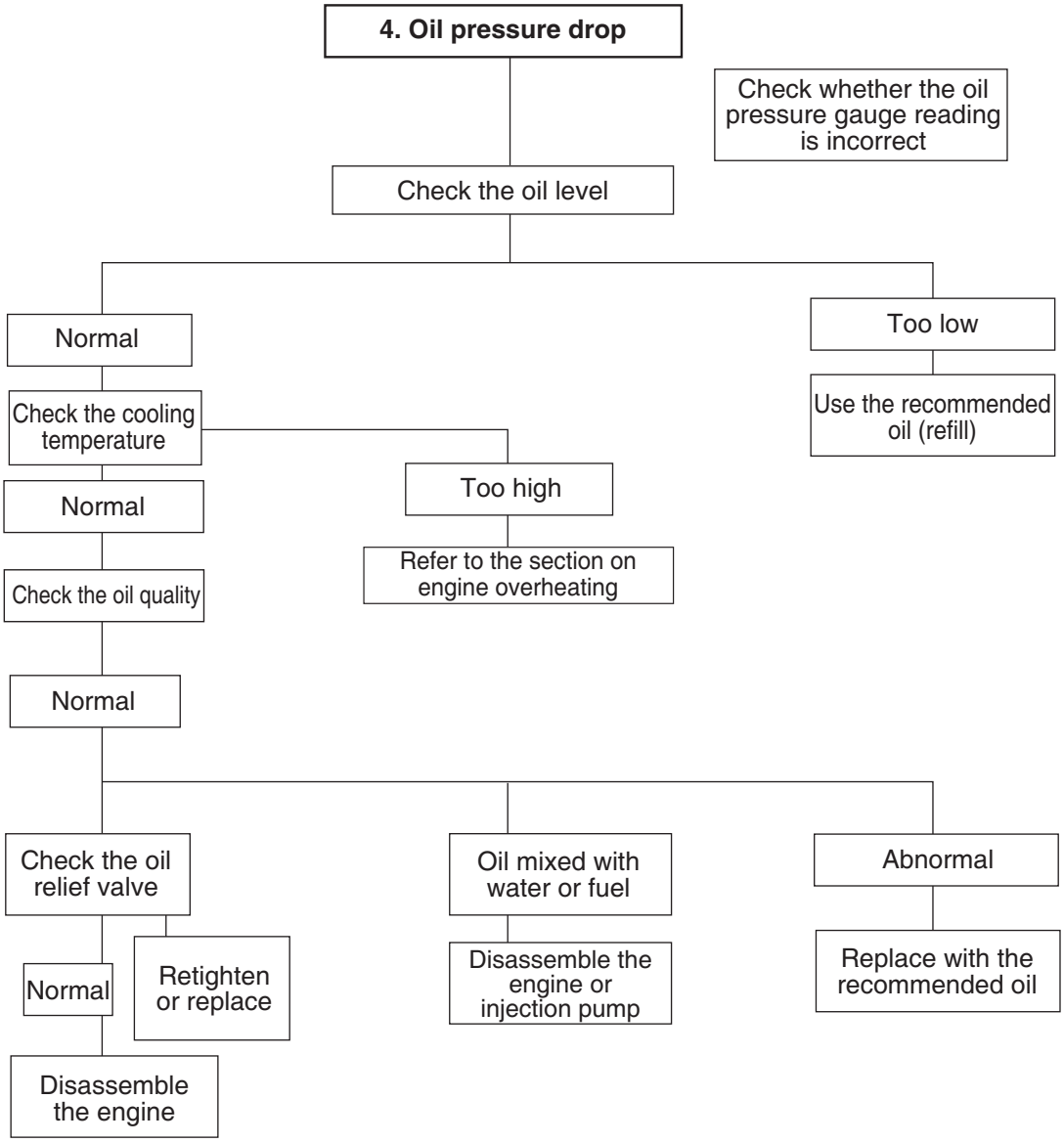
7.2.2. Overheated engine



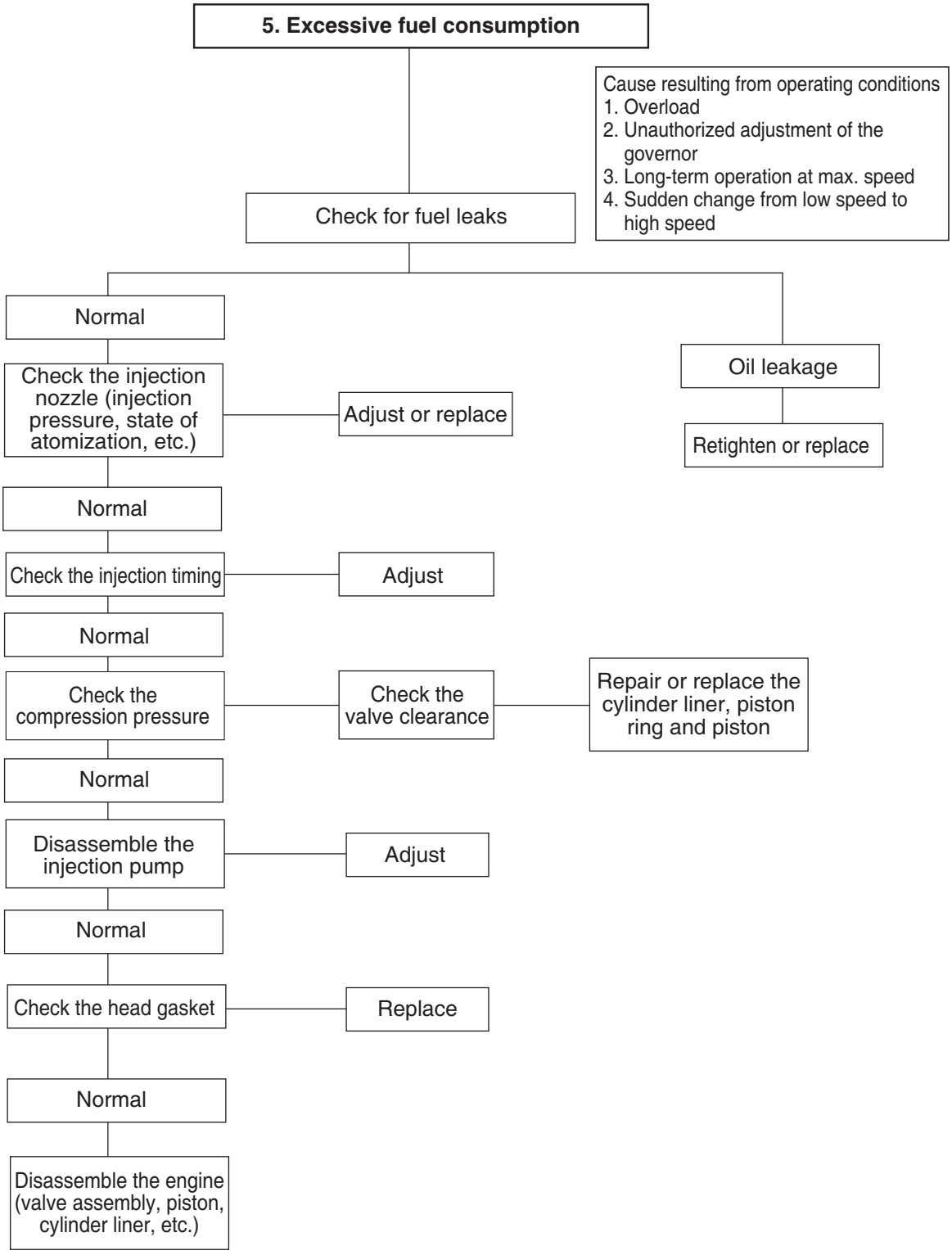
7.2.3. Insufficient Power



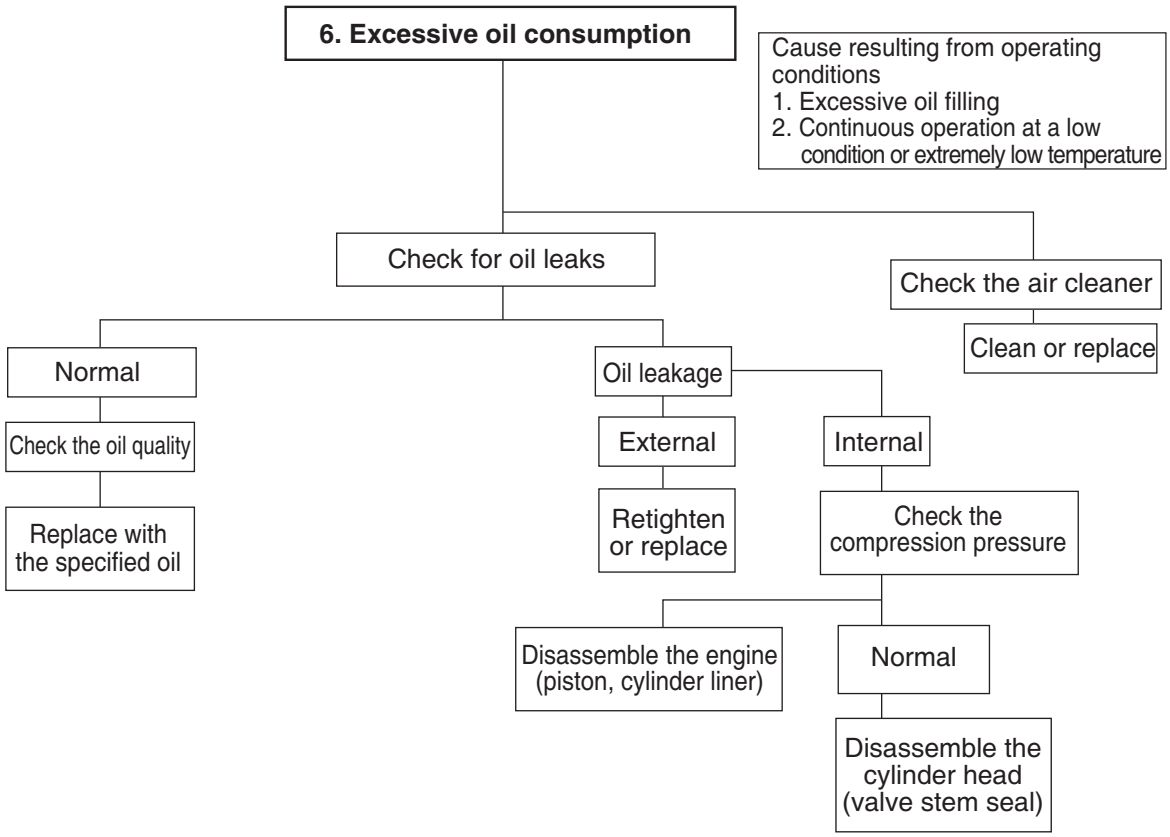
7.2.4. Decreased Oil Pressure



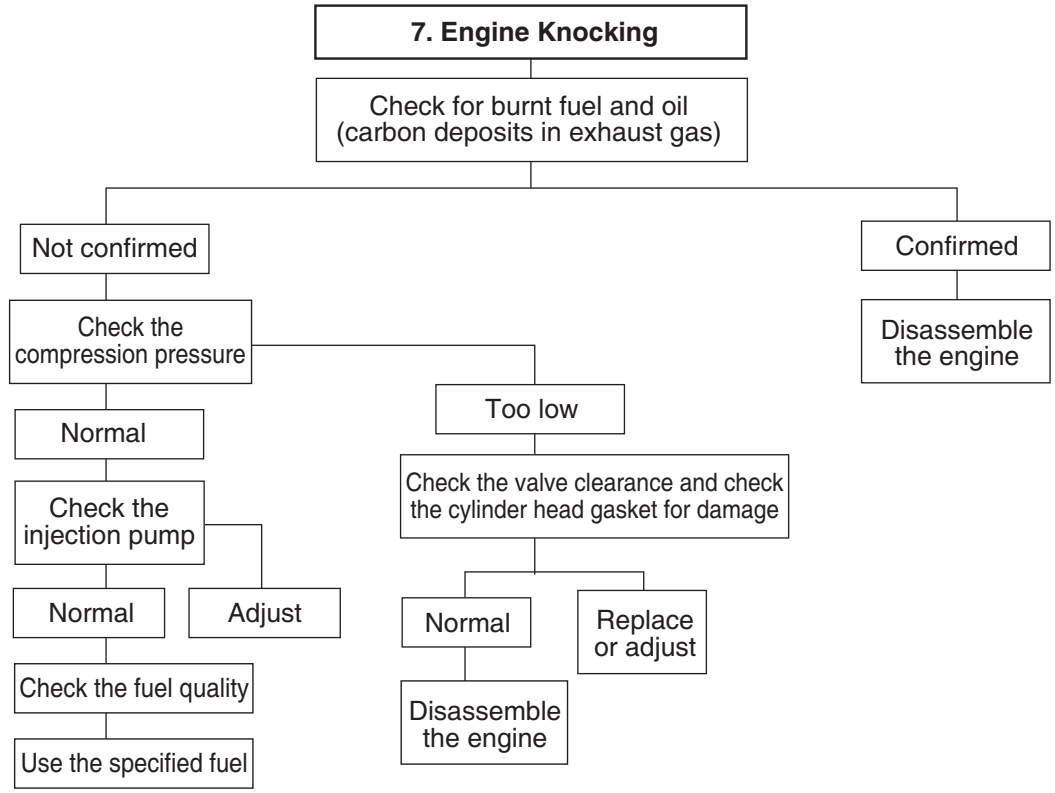
7.2.5. Fuel Consumption



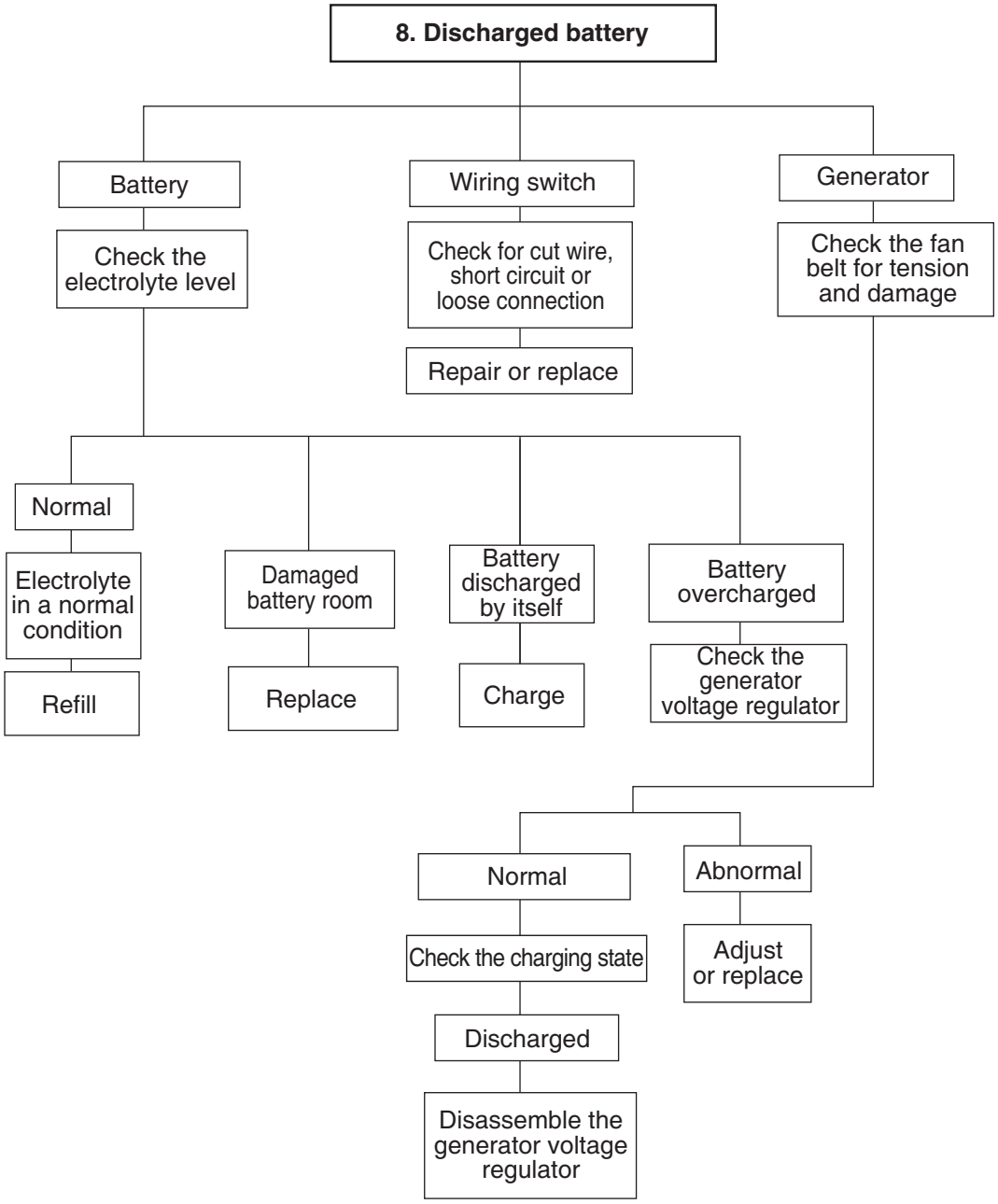
7.2.6. Excessive oil consumption



7.2.7. Engine Knocking



7.2.8. Discharged Battery



7.3. Causes and Solutions

Issue	Cause	Solution
1) Ignition problems (1) Compression pressure	● Poor valve blocking, deformed stem ● Damaged valve spring ● Leaking cylinder head gasket ● Worn piston, piston ring or liner	Repair or replace Replace the valve spring Replace the gasket Adjust
2) Abnormal idling	● Incorrect injection timing ● Air mixture in injection pump	Adjust Remove the air
3) Insufficient engine power (1) Continuously insufficient power	● Incorrect valve clearance ● Faulty valve tightening ● Leaking cylinder head gasket ● Worn, seized or damaged piston ring ● Incorrect injection timing ● Insufficient fuel injection amount ● Nozzle injection pressure incorrect or seized ● Degraded transfer pump performance ● Clogged fuel pipe system ● Insufficient intake volume ● Defective supercharger	Adjust Repair Replace the gasket Replace the piston ring Adjust Adjust the injection pump Adjust or replace Repair or replace Repair Clean or replace the air cleaner Replace Repair or replace
(2) Insufficient power during acceleration	● Insufficient compression pressure ● Incorrect injection timing ● Insufficient fuel injection amount ● Faulty injection pump timer function ● Incorrect nozzle injection pressure or injection angle ● Degraded transfer pump performance ● Insufficient cleaner intake volume	Engine Disassembly Adjust Adjust the injection pump Repair or replace Repair, replace Repair or replace Clean or replace air
4) Overheating	● Insufficient or improper engine oil ● Insufficient coolant ● Loose, worn or damaged fan belt ● Degraded water pump performance ● Malfunctioning water temperature regulator ● Incorrect valve clearance ● Increased resistance in exhaust system	Add or change Add or change Adjust or replace Repair or replace Replace Adjust Clean or replace
(5) Engine noise	In the event that noise occurs from a combination of rotating and lapped parts, be sure to find the correct cause of the noise.	
(1) Crankshaft	● Increase of the oil clearance due to a worn bearing or crankshaft ● Unevenly worn crankshaft ● Insufficient oil transfer due to clogged oil gallery ● Seized bearing	Replace bearing and Polish crankshaft Polish or replace Clean the oil gallery Replace and polish bearing

Issue	Cause	Solution
(2) Connecting rod and connecting rod bearing	● Unevenly worn connecting rod bearing	Replace the bearing
	● Unevenly worn crank pin	Polish crankshaft
	● Bent connecting rod	Repair or replace
	● Seized bearing	Replace and polish crankshaft
	● Insufficient oil transfer due to clogged oil gallery	Clean the oil gallery
(3) Piston, piston pin & Piston ring	● Increase of the piston clearance due to worn piston or piston ring	Replace the piston and piston ring
	● Worn piston or piston pin	Replace
	● Seized piston	Replace piston
	● Faulty piston fitting condition	Replace piston
	● Damaged piston ring	Replace piston
(4) Misc.	● Worn crankshaft or thrust bearing	Replace the thrust
	● Increased crankshaft end play	Replace the thrust plate
	● Increased end play of idler gear	Replace the thrust washer
	● Excessive timing gear backlash	Repair or replace
	● Excessive valve clearance	Adjusting the Valve Clearance
	● Abnormally worn tappet or cam	Replace tappet or cam
	● Damaged component inside supercharger	Repair or replace
6) Excessive fuel consumption	● Incorrect injection timing	Adjust
	● Excessive fuel injection amount	Adjust the injection pump
7) Excessive oil consumption		
(1) Increased oil level	● Clearance between cylinder liner and piston	Replace
	● Worn piston ring or ring groove	Replace the piston or piston ring
	● Damaged, seized or worn piston ring	Replace the piston ring
	● Incorrect alignment of piston ring opening	Adjust position
	● Damaged or abnormally worn piston skirt component	Replace piston
	● Clogged oil return hole in oil ring	Replace the piston ring
	● Poor oil ring contact	Replace the piston ring
(2) Decreased oil level	● Loose valve stem and guide	Replace as a set
	● Worn valve stem seal	Replace the seal
	● Leaking cylinder head gasket	Replace the gasket
(3) Oil leak	● Loose connecting parts	Replace or repair the gasket
	● Faulty packing of various parts	Replace the packing
	● Faulty oil seal	Replace the oil seal

8. General Information

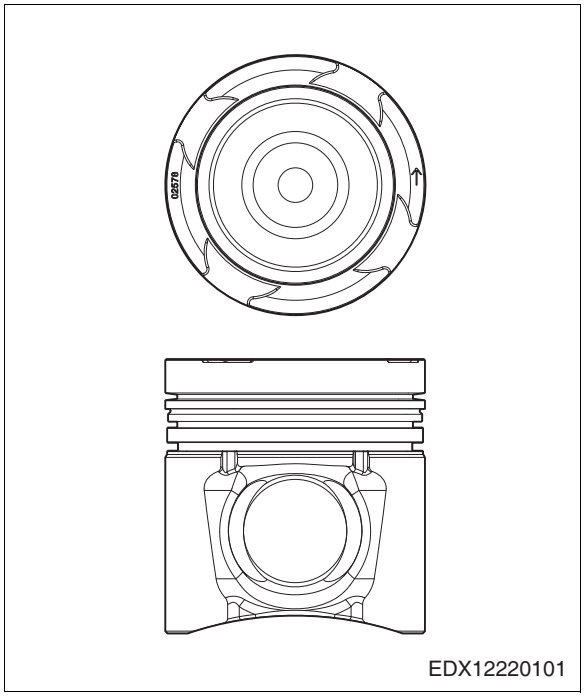
8.1. General Repair Instructions

1) Before performing maintenance, unplug the grounding cable from the battery in order to reduce the possibility of cable damage and burning due to short circuits.
2) Use the cover to protect components from damage or contamination.
3) Engine oil and antifreeze may damage painted surfaces so take particular care when handling them.
4) For the sake of efficient and stable maintenance, it is important to use the proper tools and special tools (in specified cases).
5) Make sure to use genuine HD Hyundai Infracore parts.
6) When reused, parts such as cotter pins, gaskets, O-rings, oil seals, lock washers and self-locking nuts cannot maintain their normal performance so be sure to dispose of used parts and prepare new ones for replacement.
7) In order to perform reassembly properly and smoothly, store disassembled parts neatly in groups. The designed hardness of fastening bolts and nuts varies depending on the installation location so it is very important to store these parts separately.
8) Clean parts before inspecting or reassembling them. Also, clean oil components with compressed air to ensure that there are no restricted parts.
9) Before installation, lubricate the rotating and sliding surfaces of parts with oil or grease.
10) If necessary, use a sealer on gaskets to prevent leakage.
11) Be sure to comply with all standards regarding the torque of bolts and nuts.
12) When maintenance is complete, perform a final inspection to check whether the maintenance was completed properly.

8.2. Engine Characteristics

8.2.1. OMEGA Combustion Bowl

The OMEGA Combustion Bowl is a mechanism designed to perform high-efficiency, low-emission combustion. The rim around the combustion bowl at the top of the piston is made smaller than the inside of the combustion bowl, thereby producing a continuous vortex in the bowl while mixing fuel and air sufficiently with a powerful pressurized flow. Because of the optimal utilization rate and OMEGA combustion system applied to the structure of the intake and exhaust ports in the cylinder head, the engine lowers the amount of harmful emissions produced, such as exhaust smoke, nitric oxide, hydrocarbons and carbon monoxide, while maintaining high performance and low fuel consumption.



EDX12220101

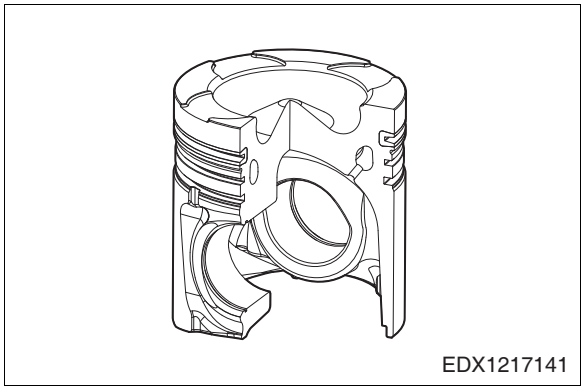
8.2.2. Oil Gallery Cooling Type Pistons

High-performance/ high-output engines have high specific output so there is a high thermal load on the piston combustion chamber.

In order to prevent premature ignition and ring seizure in the piston combustion chamber, the oil gallery needs to provide cooling for the pistons.

The design and location of the oil gallery and oil injection nozzle, as well as the oil flow rate within the gallery are important elements in lowering the temperature to the desired level.

In order to maximize cooling efficiency, the cross section of the gallery must be designed to allow enough delivery of oil.


EDX1217141

9. Removing and Installing Main Components

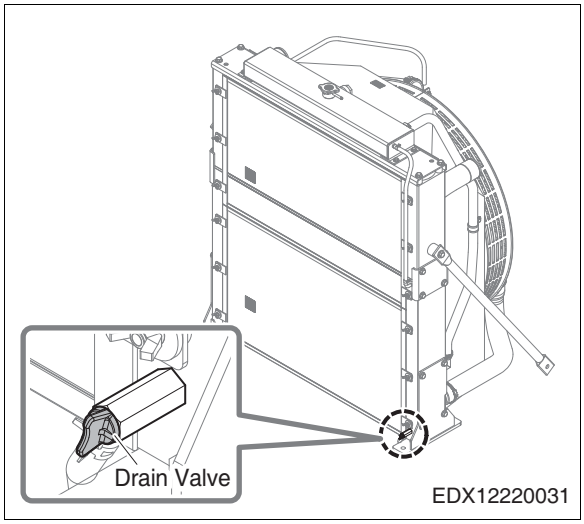
9.1. Disassembly

9.1.1. General Precautions

- Maintenance must be performed in a bright and clean place.
- Before beginning disassembly, prepare a parts rack for storing various tools and disassembled parts.
- Arrange disassembled parts in the order in which they were disassembled, and take particular care to ensure that parts are not damaged.

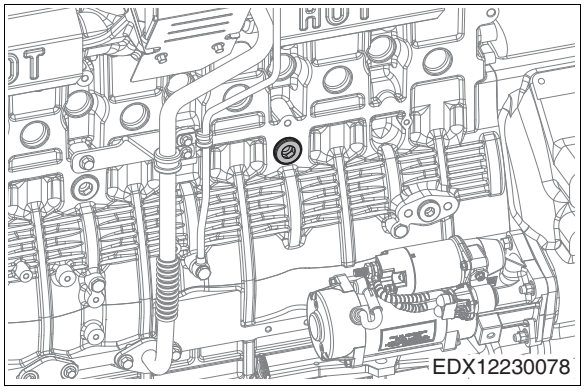
9.1.2. Coolant

- Remove the radiator cap. Open the drain plug on the lower part of the radiator to drain the coolant as shown in the picture on the right.



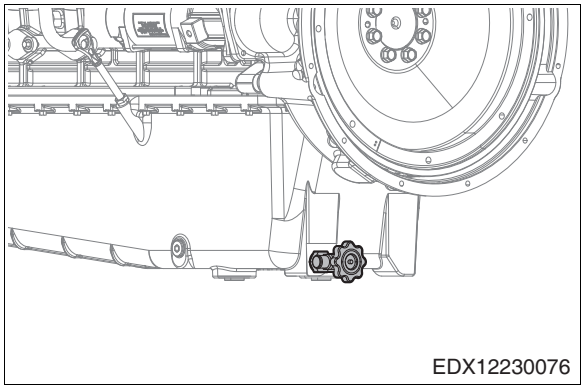
Caution:
When removing the radiator filler cap while the engine is still hot, wrap the cap with a rag and turn it slowly to release the steam pressure inside. In doing so, you can prevent burns caused by the hot steam released from the filler port.

- Remove the drain plug from the cylinder block and drain the coolant into a container.



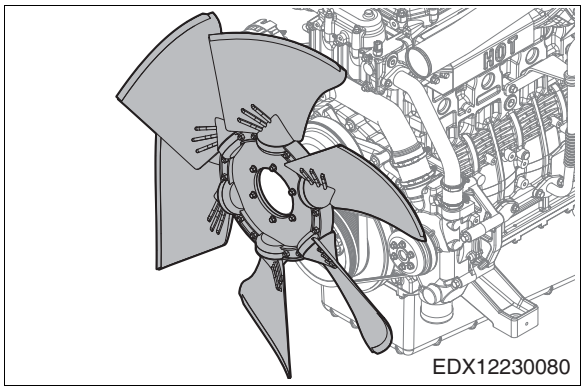
9.1.3. Engine oil

- Pull out the oil dipstick.
- Remove the oil drain valve on the oil pan and drain the engine oil into a prepared container.


EDX12230076

9.1.4. Cooling fan

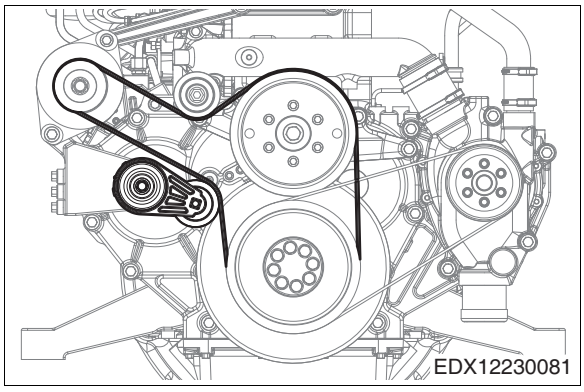
- After removing the flange mounting bolt, remove the flange and cooling fan.



EDX12230080

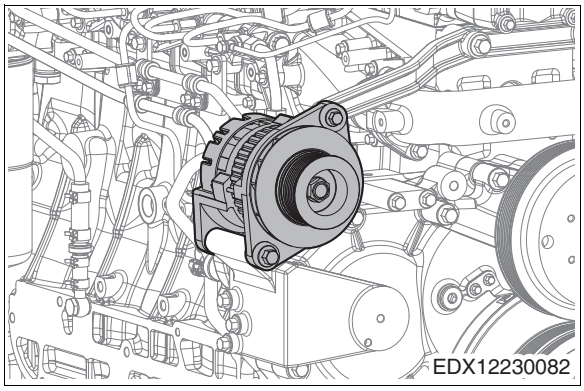
9.1.5. Alternator Belt

- The alternator belt is equipped with an auto tensioner and runs both the cooling fan and alternator with a single belt.
- Turn the auto tensioner clockwise to remove the belt.


EDX12230081

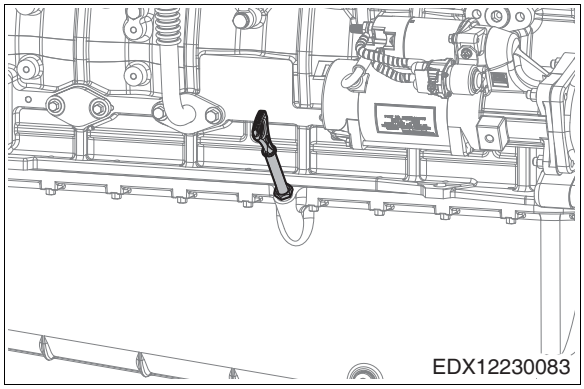
9.1.6. Alternator

- Remove the alternator mounting bolt and remove the alternator.


EDX12230082

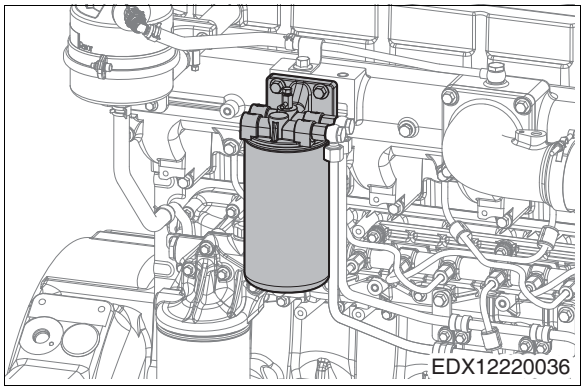
9.1.7. Oil Level Gauge Guide Tube

- Loosen the flange nut installed on the oil pan and remove the guide tube.



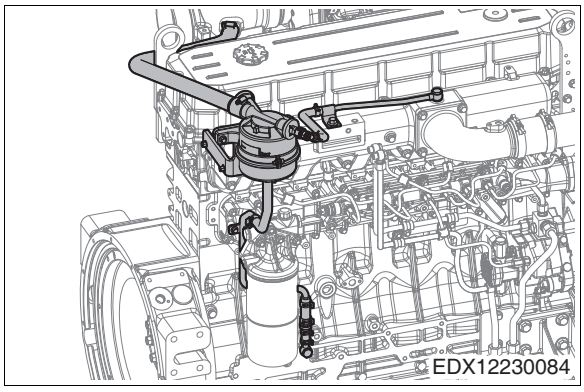
9.1.8. Fuel Filter

- Remove the fuel pipe connected to the fuel injection pump and remove the bracket fastener bolt, then remove the fuel filter.



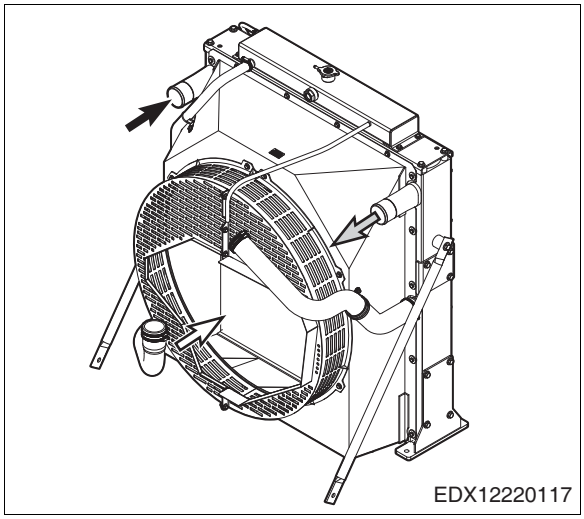
9.1.9. Breather

- Loosen the clamp screw to remove the rubber hose.



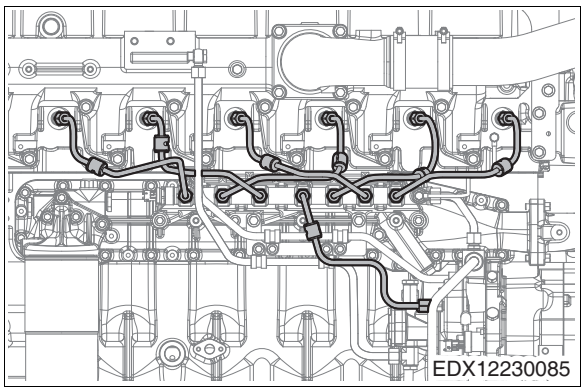
9.1.10. Intercooler

- Disconnect the various hoses and air pipes from the intercooler.
- Remove the intercooler mounting bolt to remove the intercooler.



9.1.11. Fuel injection pipes

- Disconnect the injection pipes on cylinders 1 to 6 between the high-pressure fuel connectors and the common rail.
- Disconnect the injection pipe between the fuel pump and the common rail.



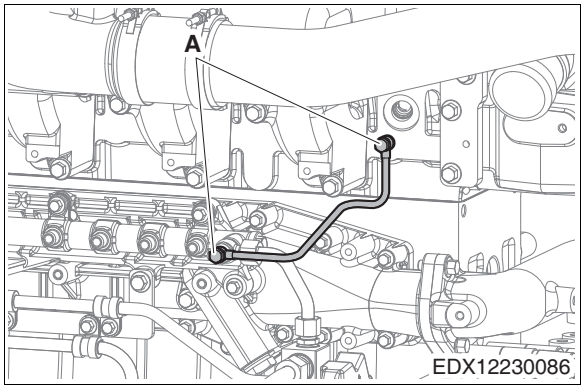
CAUTION:
There may be fuel remaining in the injection pipes, so be careful not to spill fuel when removing nuts.

CAUTION:
Injection pipes are designed to maintain an airtight seal; if they are reused, the metal may be deformed, causing the pipes to lose their airtightness and resulting in leaks. Make sure to replace them with new ones during removal and reassembly.

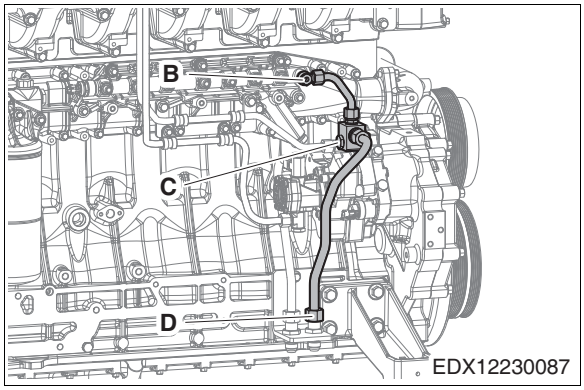
CAUTION:
Injection pipes act as seals for high-pressure fuel lines; never reuse them.

9.1.12. Common rail and mounting bracket

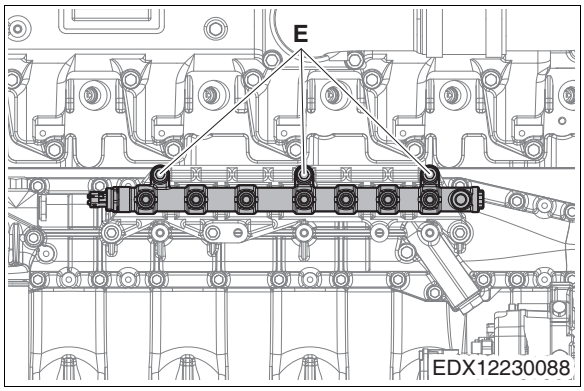
- Unscrew hollow screws (A) on the cylinder head and common rail, and disconnect the fuel return pipe.



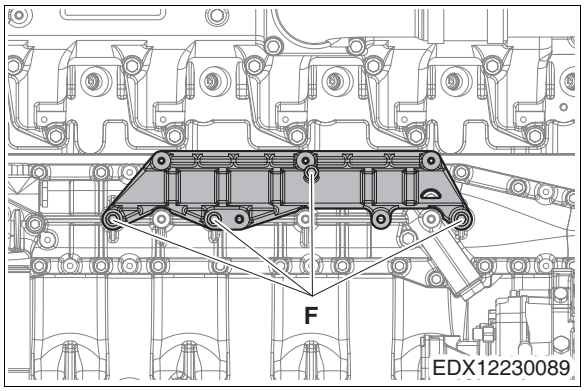
- Unscrew common rail hollow screw (B) and fuel pump hollow screw (C); then, unscrew pipe union nut (D) and disconnect the return pipe.



- Unscrew common rail mounting bolts (E) and remove the common rail.

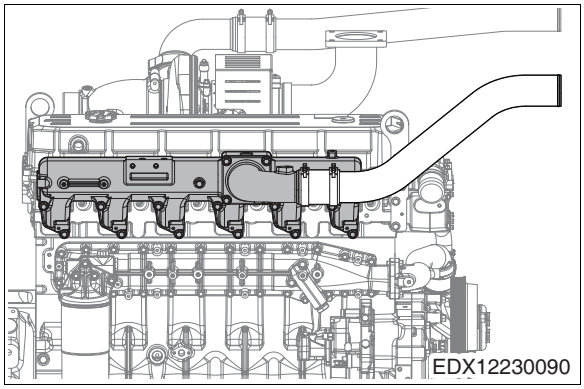


- Unscrew common rail bracket mounting bolts (F) and remove the bracket.



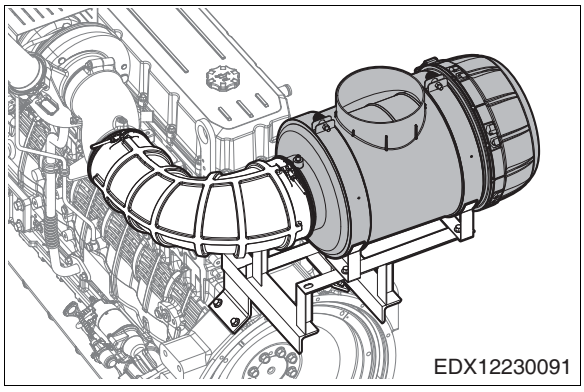
9.1.13. Intake manifold

- Remove the parts attached to the intake manifold.
- Loosen the intake manifold mounting bolts; then, remove the intake manifold.



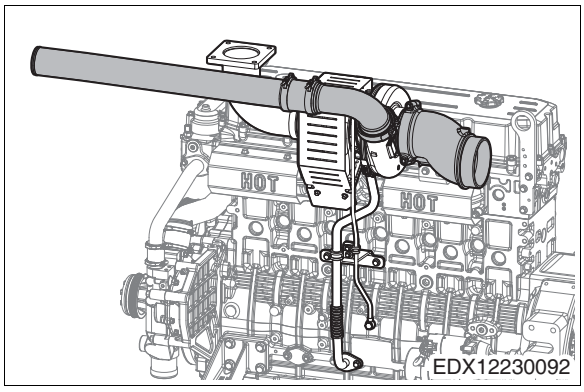
9.1.14. Air cleaner (optional)

- Loosen and remove the hose clamp from the air cleaner.
- Loosen and remove the bracket bolts from the air cleaner.
- Remove it by loosening the bolts of the bracket.



9.1.15. Air pipe

- Remove the rubber hose clamps from the pipe by loosening their screws.
- Disconnect the pipe from the turbo-charger.

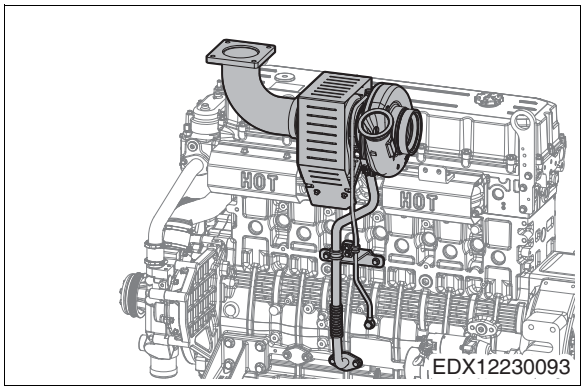


9.1.16. Turbocharger

- Disconnect the pipe from the turbo-charger.
- Remove the heat shield.

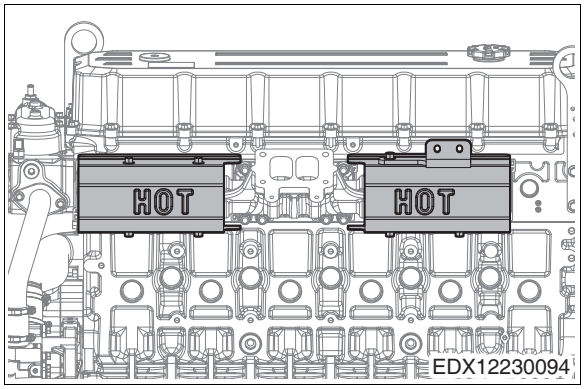
CAUTION:
Be careful of burns from hot parts and do not touch them right after the engine is turned off.

- Remove the oil delivery pipe and return pipe, then loosen the turbocharger nut and remove the turbocharger.

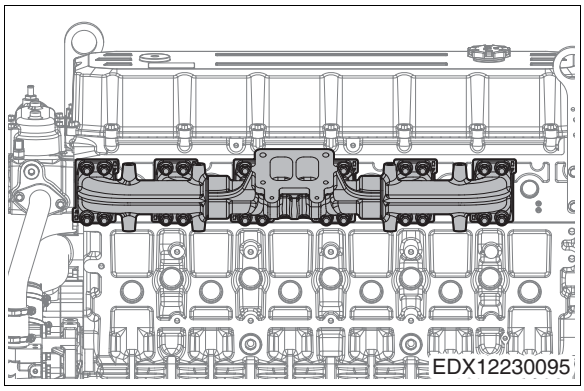


9.1.17. Exhaust manifold

- Loosen the heat shield mounting bolts to remove the heat shield.
- Loosen the exhaust manifold mounting bolt and remove the exhaust manifold, then remove the gasket.

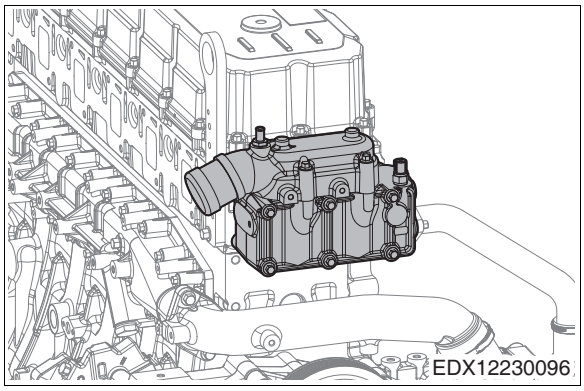


Note:
The exhaust manifold comes loose if both nuts are loosened simultaneously, so loosen them one at a time.



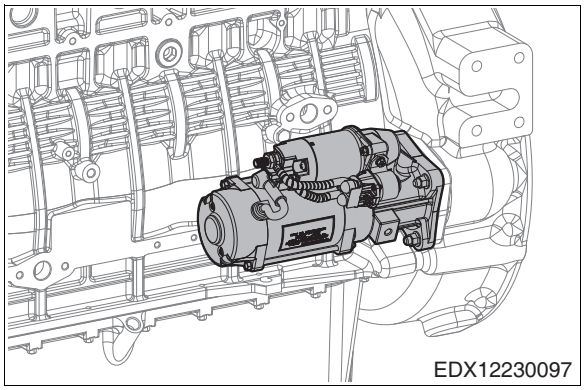
9.1.18. Thermostat

- Remove the bypass pipe connected to the water pump and loosen the thermostat mounting bolt, then remove the thermostat housing.
- Remove the thermostat housing and remove the thermostat.
- Loosen the bolt and nut installed on the cylinder head and disconnect the coolant pipe.



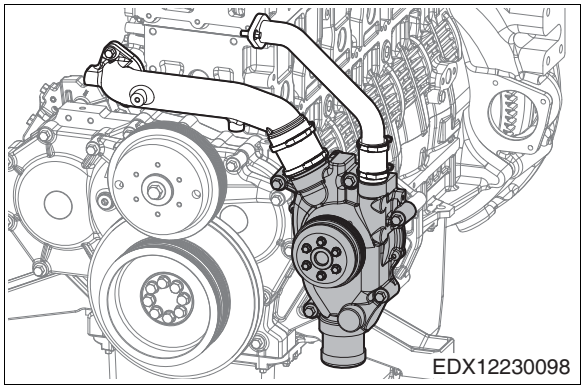
9.1.19. Starter

- Loosen the starter mounting bolt and then remove the starter.



9.1.20. Water Pump

- Remove the coolant pipe connected to the expansion tank.
- Remove the coolant pipe and hose connected to the water pump.
- Loosen the water pump mounting bolt and remove the water pump.



9.1.21. Fuel pump

- Unscrew hollow screws (A) and union nuts (B, C) connected to the fuel pump, and disconnect the fuel pipes.

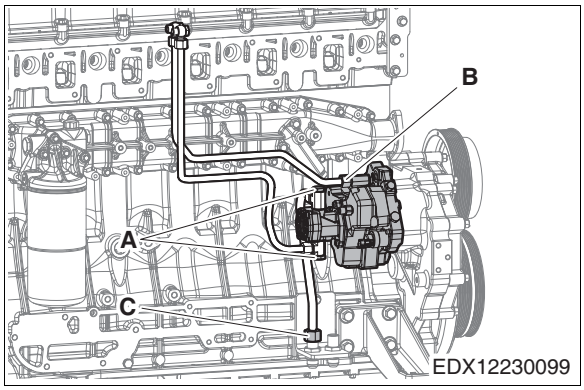
CAUTION

There may be fuel remaining in the fuel pipes, so be careful not to spill fuel when removing nuts.

- Unscrew the fuel pump mounting bolts and remove the fuel pump.

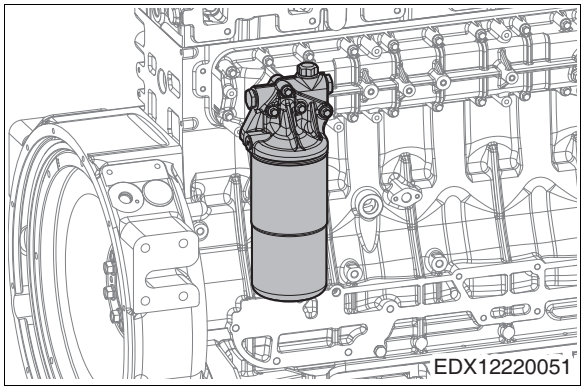
CAUTION

After disassembling the fuel pump, seal it to prevent foreign matter from entering.



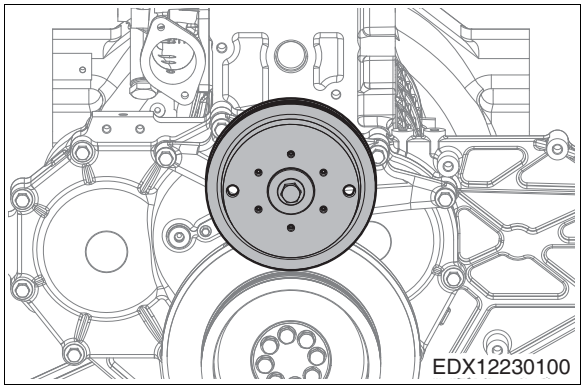
9.1.22. Oil filter

- Use a filter remover wrench to remove the oil filter cartridge.
- Remove the pipe connected to the oil cooler.
- Loosen the oil filler mounting bolt and remove the oil filter head from the oil cooler.



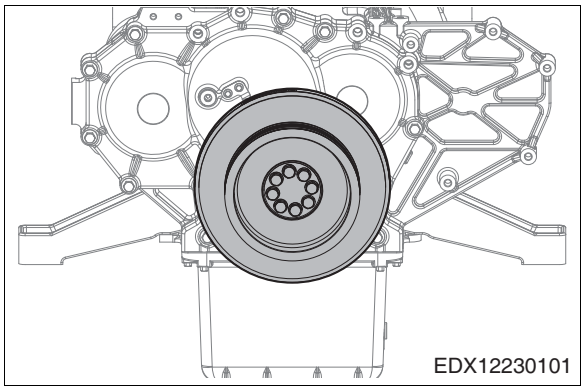
9.1.23. Fan Drive Pulley

- After fixing the belt with an auto tensioner or fitting a long bolt into the mounting hole on the pulley, unscrew the pulley mounting bolts and remove the pulley.



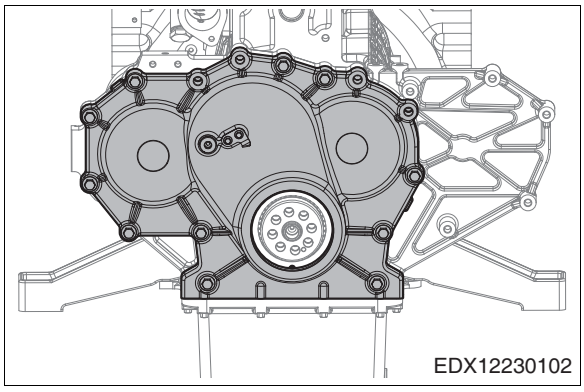
9.1.24. Vibration Damper

- Loosen the pulley mounting bolt and remove the pulley-vibration damper assembly.
- Loosen the vibration damper mounting bolt and disconnect the damper from the pulley.



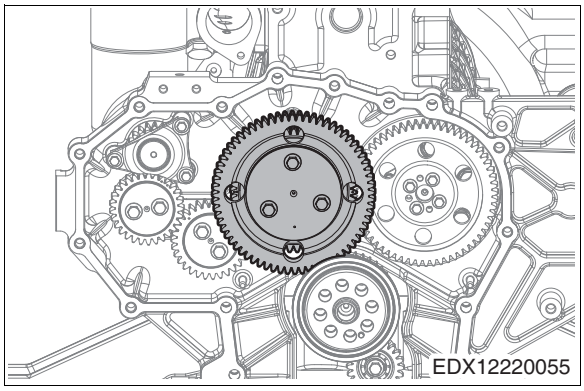
9.1.25. Timing Gear Case Cover

- Use an oil seal removal jig to disconnect the oil seal.
- Remove the cover mounting bolt and disconnect the cover from the timing gear case.



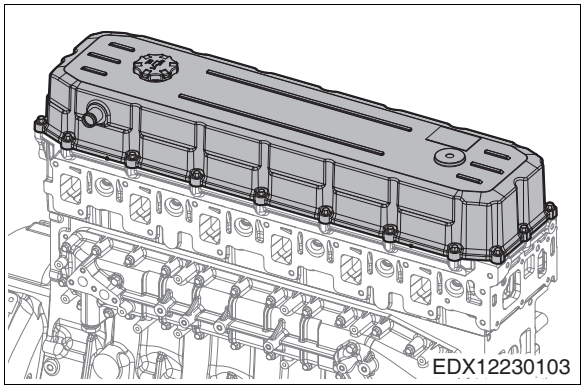
9.1.26. Idler gear

- Loosen the idler gear mounting bolts and remove the idler gear pin and gear.
- Use a rubber hammer to remove the idle pin without damaging it.



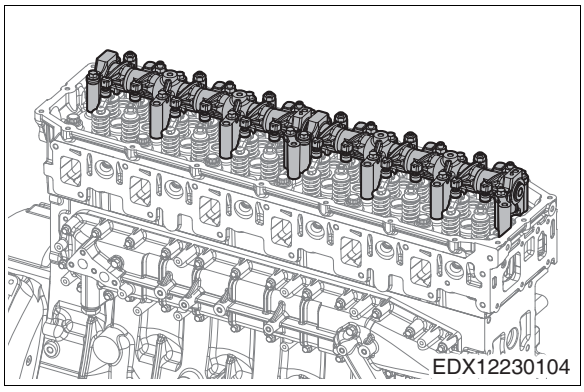
9.1.27. Cylinder head cover

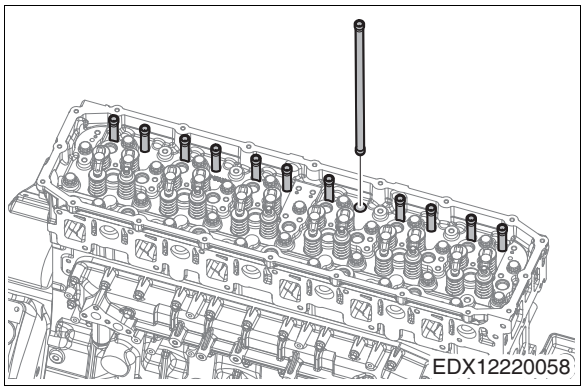
- Loosen the cover mounting bolt and disconnect the cover.
- Keep the bolt in its assembled state so as not to damage the packing and washer, and keep the cover packing assembled to the cover.



9.1.28. Rocker arm assembly

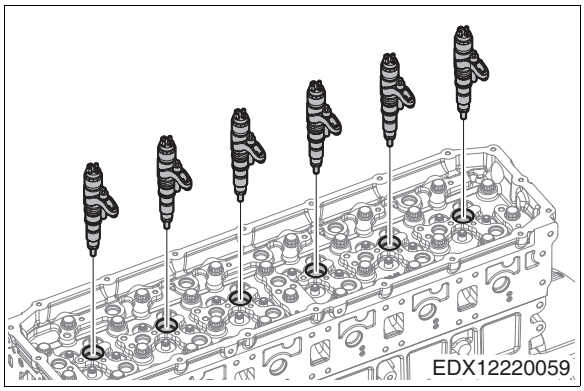
- Loosen the rocker arm bracket bolt and remove the rocker arm assembly.
- Remove the calipers after disconnecting the rocker arm assembly.
- Remove the pushrod.





9.1.29. Injectors

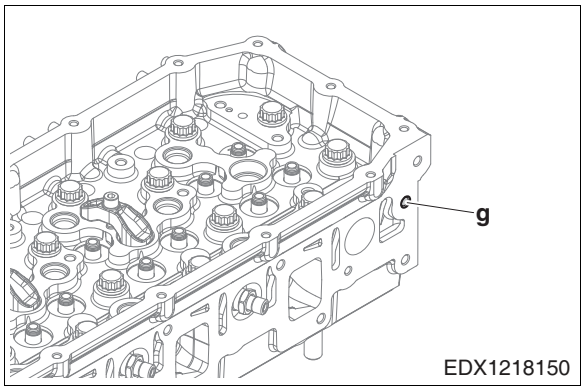
- The O-rings on the injectors and high-pressure fuel connectors are always installed; they do not require separate assembly.



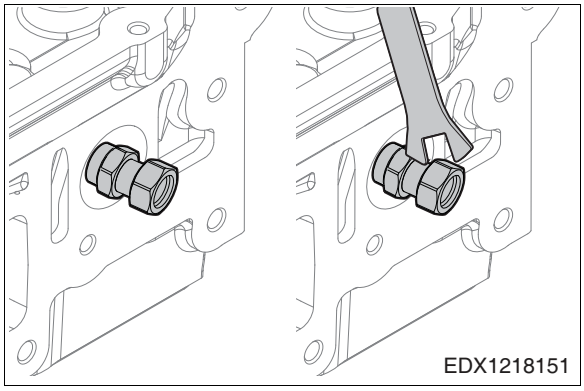
- Remove the fuel in/out hoses from the fuel tank and drain the return fuel (g) in the cylinder head.

CAUTION:
If the injectors and high-pressure fuel connectors (HPC) are removed without draining the return fuel in the cylinder head, the return fuel may enter the combustion chamber and cause white smoke or piston damage.

Loosen the high-pressure fuel connector mounting nuts and remove the high-pressure fuel connector.



- The high-pressure fuel connector cannot be reused after being removed.
- Remove the harness connected to the injector, unscrew the injector mounting caliper bolt, and remove the injector.
- Be careful not to damage the nozzle while removing the injector.
- Pull out the seal ring from the nozzle hole on the cylinder head and discard it.



CAUTION:
1 **When removing the injector, unscrew the high-pressure fuel connector mounting nut and completely disconnect the high-pressure fuel connector. Then, unscrew the mounting bolt on the injector mounting bracket and remove the injector.**
2 **Seal the injector and high-pressure fuel connector after removing them to prevent foreign matter from entering.**

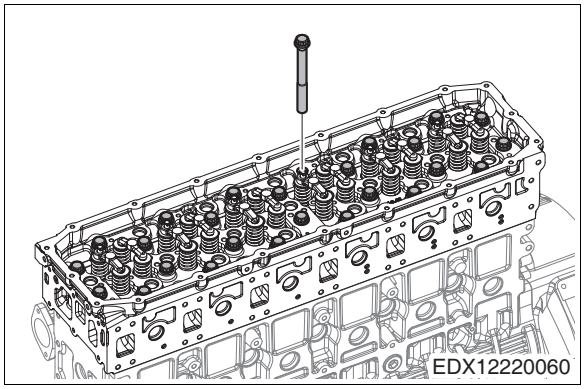
CAUTION:
Use the special injector assembly/ removal tool (refer to the list of special tools) to remove the injector from the cylinder head.

- Check whether any injector sealing washers remain in the grooves on the cylinder head; if any are found, remove them using pincers or a suitable tool.

CAUTION:
Remove injectors after high-pressure fuel connectors (HPC) have been completely removed.

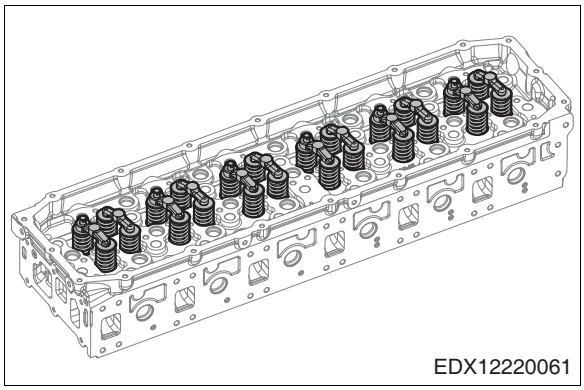
9.1.30. Cylinder Head

- Loosen the cylinder head mounting bolt and remove the cylinder head.
- Remove the cylinder head gasket.



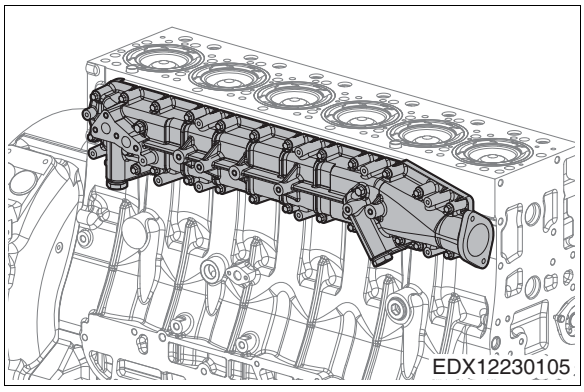
9.1.31. Valve and Valve Stem Seal

- Apply pressure to the valve spring retainer with a jig and remove the valve cotter pin.
- Disconnect the valve spring and retainer.
- Remove the valves.
- Use regular tools to remove it and dispose of the valve stem seal so that it cannot be reused.



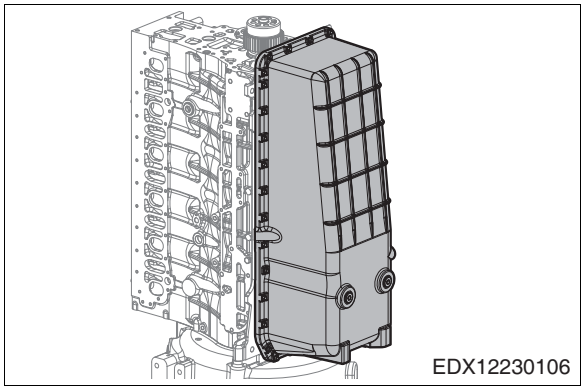
9.1.32. Oil cooler

- Remove the coolant pipe connected to the water pump.
- Remove the oil pipe connected to the cylinder block.
- Loosen the oil cooler cover mounting bolt and disconnect the oil cooler assembly from the cylinder block.
- Loosen the oil cooler mounting bolt and disconnect the oil cooler from the oil cooler cover.



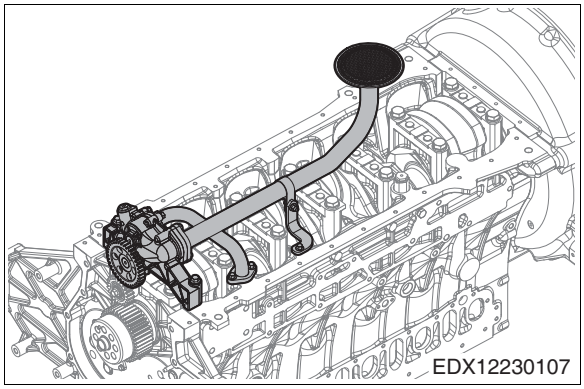
9.1.33. Oil pan

- Set the engine up so that the flywheel housing faces downwards.
- Loosen the oil pan mounting bolts and remove the oil pan.



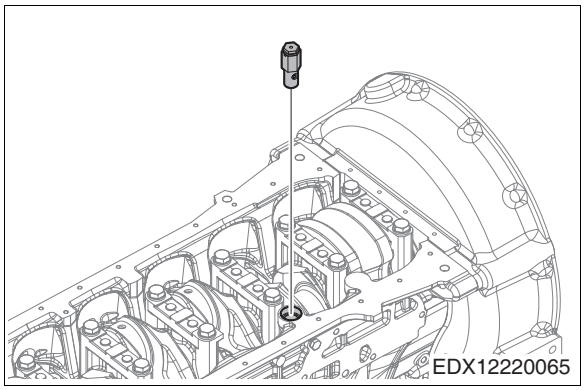
9.1.34. Oil Pump and Oil Pipe

- Loosen the pipe mounting bolt while loosening the bolt on the oil suction pipe bracket, then disconnect the oil suction pipe assembly.
- Disconnect the oil pipe which delivers oil from the oil pump to the cylinder block.
- Loosen the oil pump mounting bolt and remove the oil pump.


EDX12230107

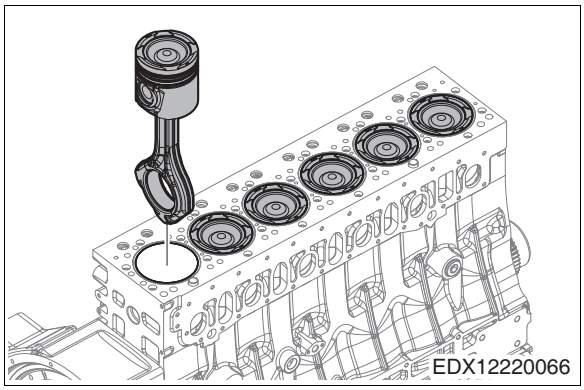
9.1.35. Relief valve

- Disconnect the relief valve.

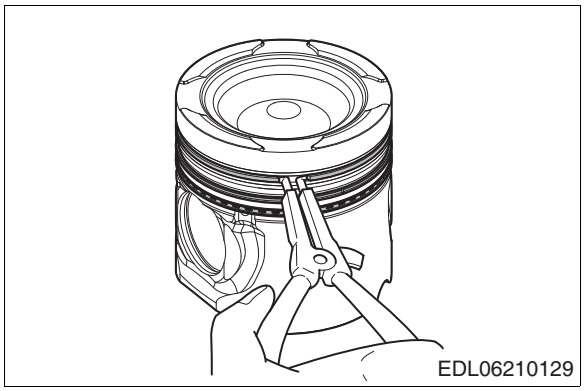

EDX12220065

9.1.36. Piston and Connecting Rod

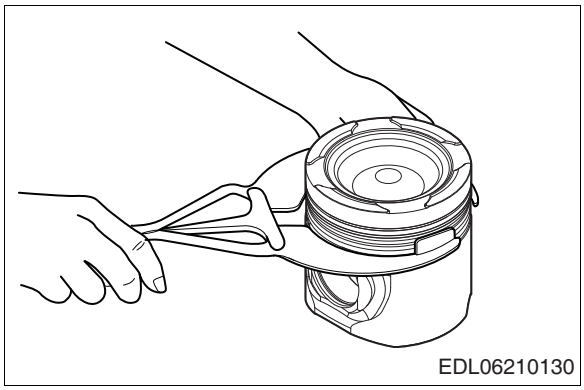
- Turn the crankshaft to disconnect the piston from the two cylinders.
- Loosen the connecting rod mounting bolt and remove the connecting rod and piston in the direction of the piston.


EDX12220066

- Remove the piston pin snap ring and the piston pin, then remove the connecting rod from the piston.

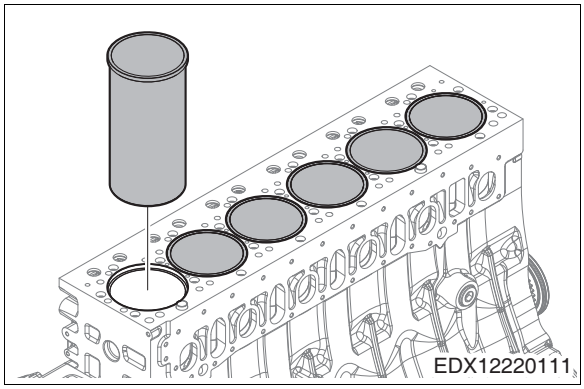

EDL06210129

- Use ring pliers to disconnect the piston ring.
- Be careful not to mix up the order of removed parts; keep them in the order of the cylinder numbers.


EDL06210130

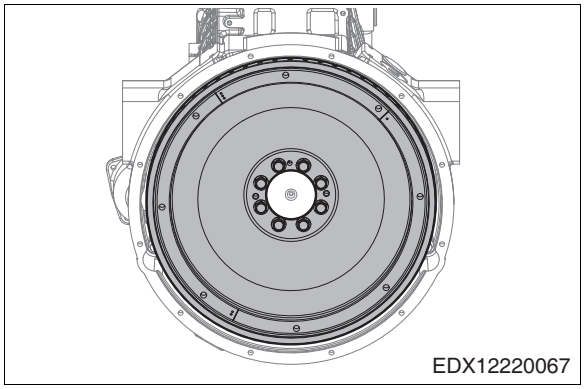
9.1.37. Cylinder liner

- Use a liner puller to remove the cylinder liner.


EDX12220111

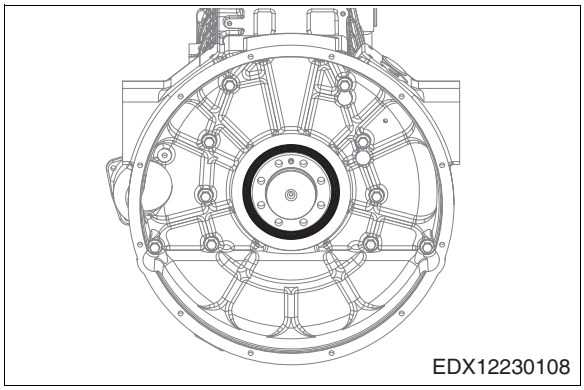
9.1.38. Flywheel

- Place the engine so that the head mounting surface of the cylinder block is facing downwards.
- Loosen the flywheel mounting bolt and install the dowel pin.
- Install the flywheel removal bolt in the bolt hole on the flywheel, then disconnect the flywheel.


EDX12220067

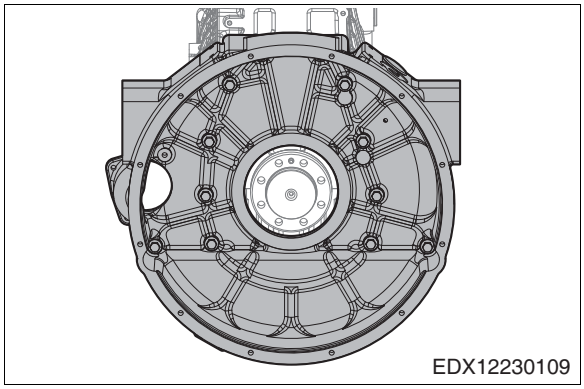
9.1.39. Oil Seal

- Use an oil seal removal jig to remove the rear oil seal.
- In the event that only the inner guide ring is being removed, use a special tool to remove the outer seal.


EDX12230108

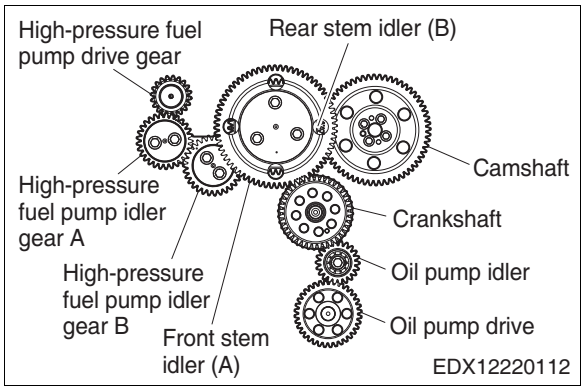
9.1.40. Flywheel housing

- Loosen the housing mounting bolt and disconnect the flywheel housing.



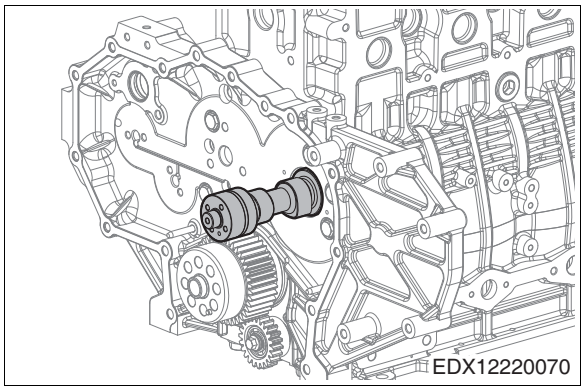
9.1.41. Camshaft idler gear and Cam Gear

- Unscrew the idler gear mounting bolts to remove the idler gear pin.
- Unscrew the camshaft gear mounting bolts to remove the camshaft gear.



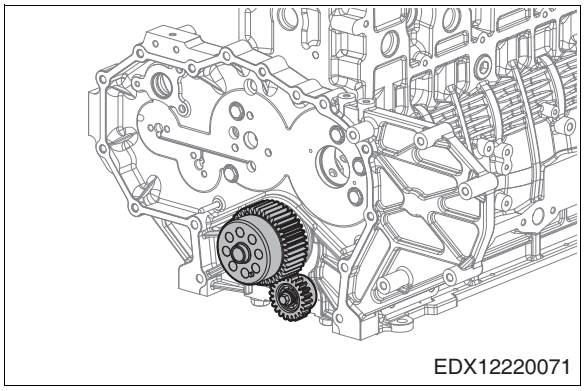
9.1.42. Camshaft and Tappet

- Remove the camshaft gear.
- Remove the camshaft gear thrust washer.
- Be careful not to damage the camshaft during removal.
- Push the tappet out by hand.



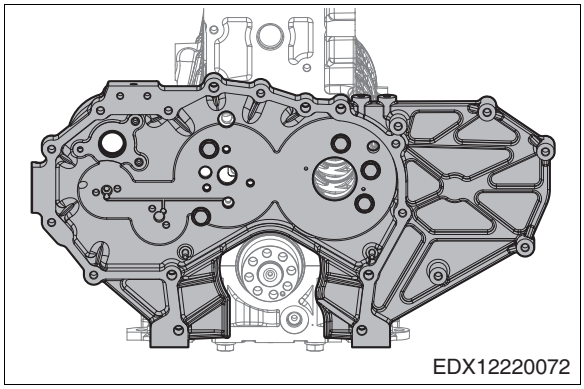
9.1.43. Crankshaft Gear and Oil Pump idler gear

- Loosen the bolt and remove the oil pump idler gear.
- Use pullers to remove the crankshaft gear.



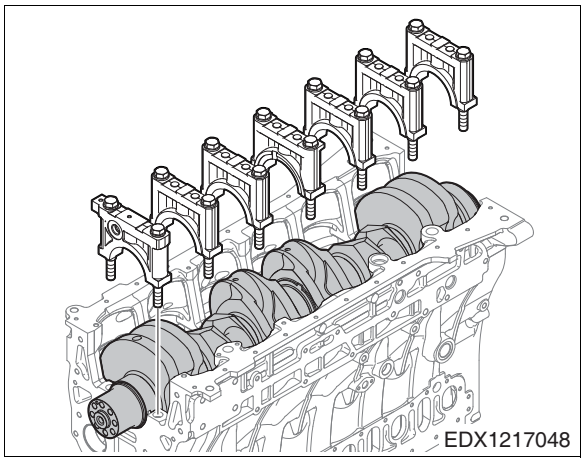
9.1.44. Timing gear case

- Remove the case mounting bolt and disconnect the timing gear case.
- Tap the back of the left and right sides on the contact surface of the timing gear case with a urethane hammer gently to remove the timing gear case.


EDX12220072

9.1.45. Crankshaft

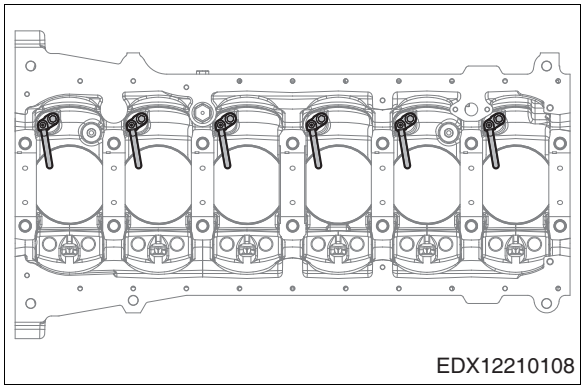
- Remove the bolts from the bearing caps.
- Remove the main bearing cap mounting bolts in the order of assembly.
- (Follow the same instructions for removal of the cylinder head bolts.)
- Keep the removed bearing caps in the order of the cylinders.
- After temporarily installing bolts on either side of the crankshaft, lift the shaft with a rope.


EDX1217048

Note:
Do not mix up the metal bearings and bearing caps. In order to avoid mixing them up, assemble the metal bearings temporarily in order with the matching bearing caps.

9.1.46. Oil injection nozzle

- Loosen the mounting bolts to remove the oil injection nozzle.


EDX12210108

9.2. Finished

9.2.1. Cylinder Block

1) **Clean the cylinder block thoroughly and perform a visual inspection for cracks or damage.**
2) **Replace the cylinder block in the event that there are cracks or severe damage; repair any minor damage.**
3) **Check for clogging or corrosion in the oil and coolant flow lines.**
4) **Perform a hydraulic pressure test to check for cracks or air leaks. (Hydraulic pressure test) :**
5) **Block each of the outlet ports of the coolant/ oil passages in the cylinder block and apply 4 kg/cm^2 of air pressure to the inlet port, then submerge the cylinder block in water for around one minute and check for leaks. (Water temperature: 70°C)**

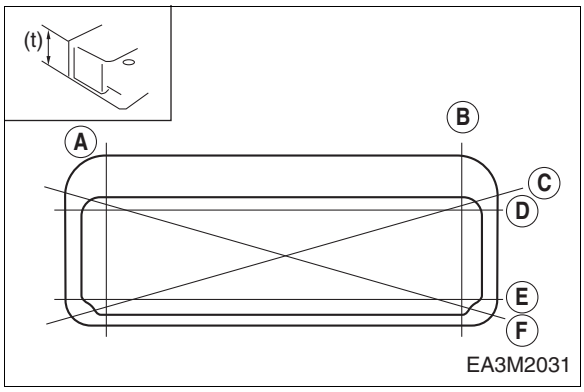
9.2.2. Cylinder Head

1) Finished

- In order to avoid scratching the valve seat surface, use a non-metallic material to carefully remove carbon from the lower surface of the cylinder head.
- Use a hydraulic pressure tester or magnetic fault detector to check the entire engine head for minor cracks or damage which are not usually visible.

2) Deformation of the lower surface

- As shown in the picture on the right, use a straightedge and feeler gauge to measure the level of deformity at six locations (A to F).
- If the measured value exceeds the standard value, use a polishing tool with fine particles to polish the course that the head follows and fix the defect.
- If the measured value exceeds the maximum allowable limit, replace the cylinder head.

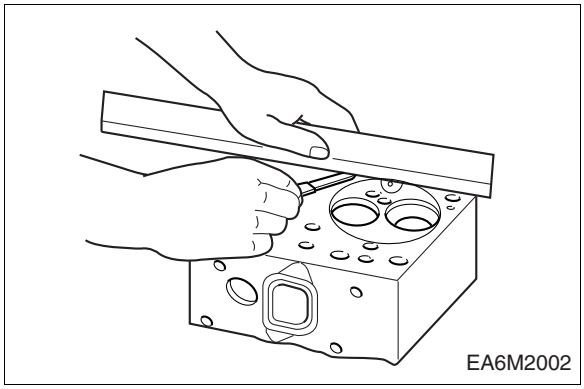


EA3M2031

<Distortion and Height of Lower Surface>

(mm)

	Standard	Limit
Distortion	0.2 or less	0.3
Thickness: t (standard)	154.7 ~ 155.3	153.9


EA6M2002

3) Flatness

Use a straightedge and feeler gauge to measure the flatness of the intake/ exhaust manifold mounting surface of the cylinder head.

(mm)

Standard	Limit
0.05	0.2

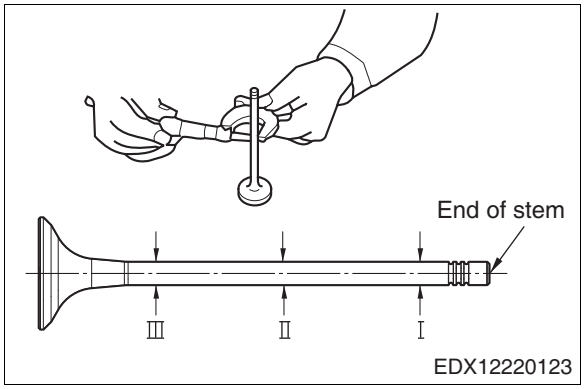
4) Hydraulic Pressure Test

The hydraulic pressure test method for the cylinder head is the same as for the cylinder block.

9.2.3. Valve and Valve Guide

1) Replace the valve

After cleaning the valve with diesel fuel, measure the outside diameter of the valve stem at the top, middle and bottom as shown in the figure to check for wear. Repair slightly damaged parts. Replace valves whose wear exceeds the limit.



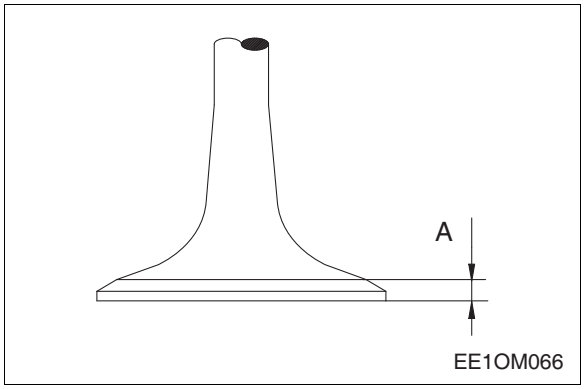
<Valve stem O.D.>

(mm)

Dimensions / Description	Standard	Limit
Intake valve stem	Ø7.963 ~ Ø7.977	Ø7.943
Exhaust valve stem	Ø7.950 ~ Ø7.964	Ø7.920

- Valve seat contact surface
  Check for scratches or wear on the valve seat contact surface and polish the contact surface with sandpaper if necessary. Replace if severely damaged.

- Valve head thickness
  Measure the thickness of the valve head and replace the valve if the measured value exceeds the limit.

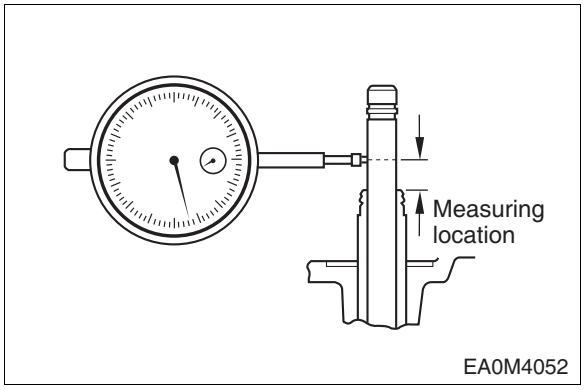


(mm)

Dimensions / Description	Standard	Limit
Intake valve	3.3 ~ 3.7	2.8
Exhaust Valve	4.0 ~ 4.4	3.5

2) Valve Guide

- Install the valve and valve guide, and measure the clearance between the valve and valve guide resulting from valve movement. If the clearance is too great, measure the valve and replace either the valve or valve guide (whichever part is more severely worn).



<Valve stem end play>

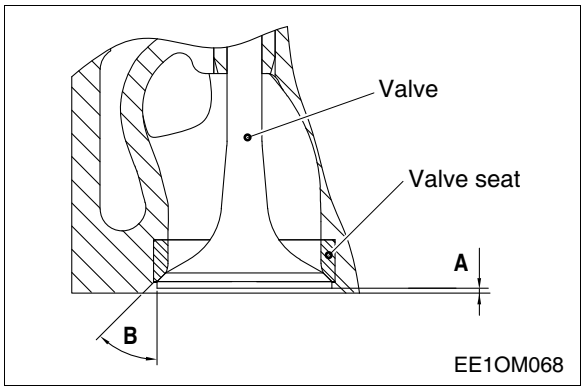
(mm)

	Standard	Limit
Intake valve	0.023 ~ 0.052	0.10
Exhaust Valve	0.036 ~ 0.065	0.15

- Assemble the valve with the cylinder head valve guide and use a special tool to measure whether the central line of the valve guide and valve seat is aligned.

3) Valve seat

- Check the valve seat for wear or damage and replace if necessary.
- Assemble the valve with the cylinder head valve seat and use a measuring instrument on the bottom surface of the cylinder head to measure the projection of the valve.
  Replace the valve seat if the measured value exceeds the limit.



<Valve Projection>

(mm)

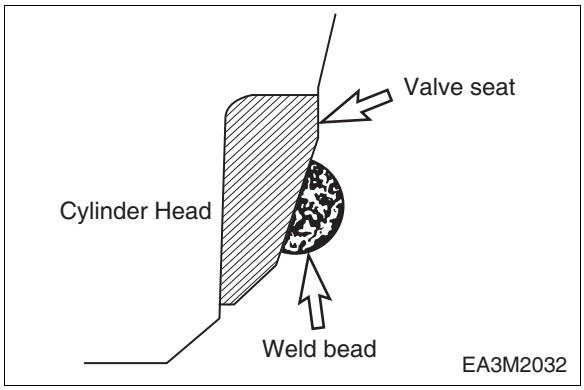
	Standard
Intake valve (A)	0.66 ~ 0.96
Exhaust valve (A)	0.60 ~ 0.90

<Valve Angle>

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

- When removing the valve seat, weld beads onto the seat inserted into the head and use a special tool to remove it.

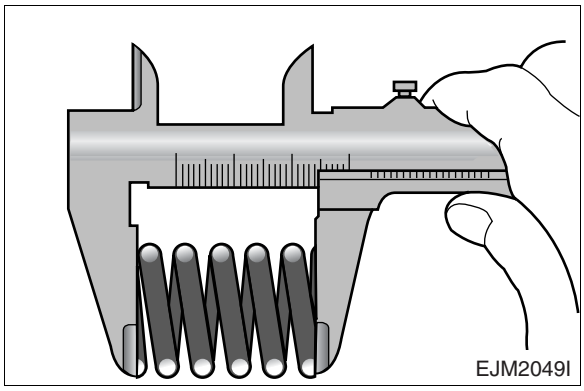
- Cool and contract the valve seat in dry ice for around one hour. Then, use a special tool to insert it into the cylinder head.
  (The bore of the inner diameter requires drilling when replacing the valve seat)
- Spread an abrasive on the valve head contact surface of the valve seat and rotate the valve to polish it until it fits in place, then wipe any abrasive remaining on the valve and head surface clean with oil.



Note:
When the valve seat has been prepared, use diesel fuel or an equivalent product to clean the valve and cylinder head and check whether there is any abrasive remaining.

4) Valve spring

- Check the exterior for any scratches on the valve spring and replace the spring if necessary.
- Measure the free length and tension of the valve spring.



(mm)

		Free length of spring
Intake valve	Inside	-
	Out-side	62.5
Exhaust Valve	Inside	-
	Out-side	62.5

- Measure the squareness of the valve spring.
- Compare the measured value with the standard value.

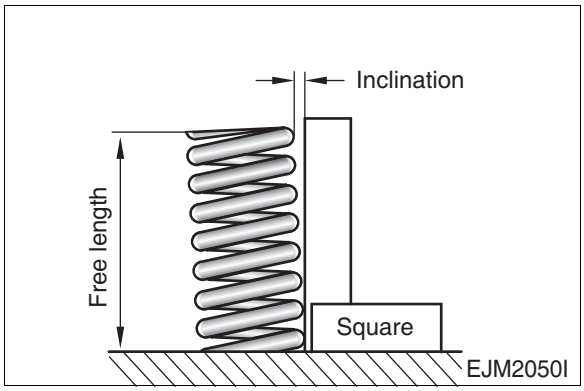
● Valve spring squareness

Use a surface plate and straightedge to measure the squareness of the valve spring.

If the measurement exceeds the allowable limit, replace the valve spring.

(mm)

		Standard	Limit
Intake valve	Internal	-	-
	External	1.6	2.0
Exhaust Valve	Internal	-	-
	External	1.6	2.0

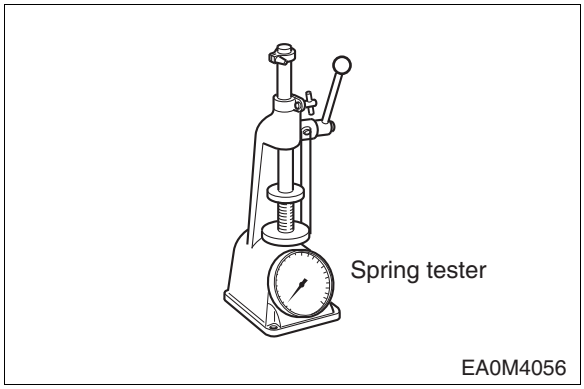


● Measure the squareness of the valve spring.

● Compare the measured value with the standard value.

<Valve spring tension>

		Set length (P1/P2) (mm)	Spring force (P1/P2) (kg)	Allowable limit (P1/P2) (kg)
Intake valve	Internal	-	-	-
	External	44.0/31.6	39.4/65.8	±2.0/±2.5
Exhaust Valve	Internal	-	-	-
	External	44.0/31.6	39.4/65.8	±2.0/±2.5



9.2.4. Rocker Arm Shaft Assembly

1) Rocker arm shaft

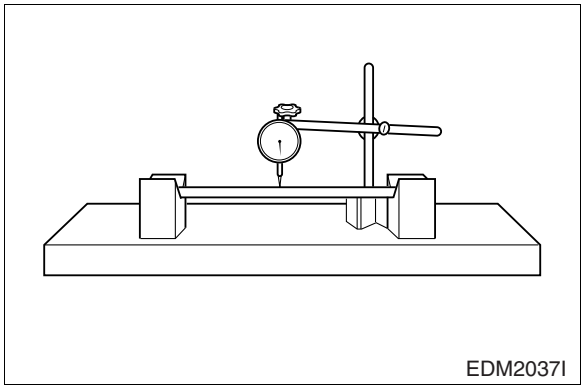
● Rocker Arm Shaft Runout

Place the rocker arm shaft on two V-blocks and use a dial gauge to check whether the shaft is bent.

If the runout value is small, apply pressure to the shaft with a bench press to correct the runout. Replace the shaft if the measured value exceeds the limit.

(mm)

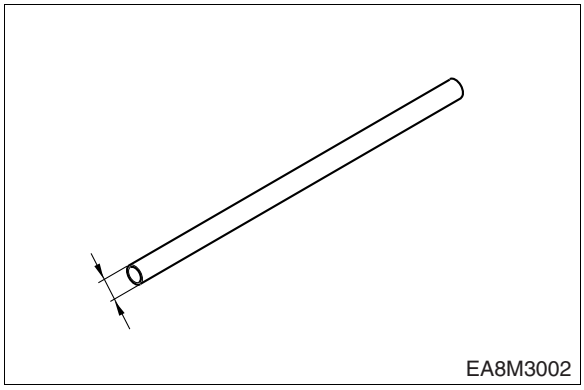
Limit	0.2



● Diameter of rocker arm shaft

Use an outside micrometer to measure the diameter of the rocker arm shaft at the place where the rocker arm is installed.

Replace the rocker arm if the amount of wear exceeds the specified limit.



(mm)

Standard	Limit
Ø24.953 ~ Ø24.976	Ø24.916

2) Rocker arm

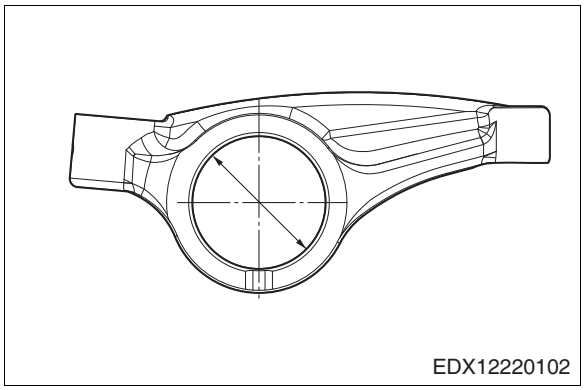
● Visual inspection

Perform a visual inspection for wear such as scratches or bumps on the surface of the rocker arm where it makes contact with the front end of the valve stem. If the wear is minimal, use fine sandpaper or an oil stone to correct it. Rocker arms with severe bumps must be replaced.

● Rocker arm bushing diameter

Use an inside micrometer or vernier caliper to measure the internal diameter of the rocker arm bushing and compare the measured value with the diameter of the rocker arm shaft.

If the clearance exceeds the limit, replace either the bushing or the shaft (whichever part is more severely worn).



<Clearance>

(mm)

Standard	Limit
0.015 ~ 0.059	0.12

3) Tappet and pushrod

● clearance

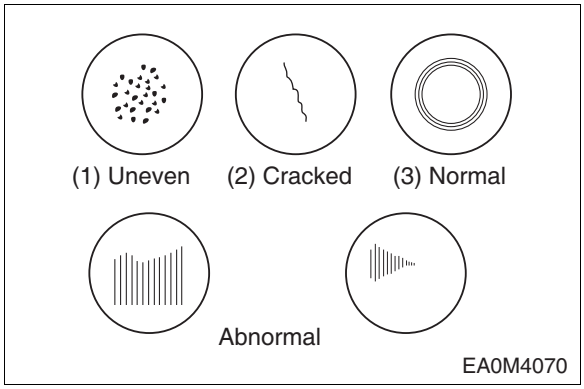
Measure the clearance between the tappet and tappet hole on the cylinder block. Replace the tappet if the value exceeds the specified limit.

(mm)

Standard	Limit
0.035 ~ 0.077	0.15

● Inspecting the tappet visually

Inspect the tappet surface in contact with the cam visually for pitting, scratches or cracks and replace if severely damaged. If the cracks or pitting are minor, use an oil stone or sandpaper to fix them.

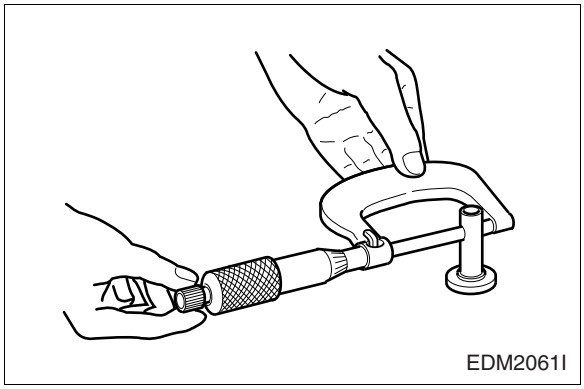


● Tappet O.D.

Use an outside micrometer to measure the outside diameter of the tappet. Replace the tappet if the measured value exceeds the limit.

(mm)

Tappet diameter	Ø19.944 ~ Ø19.965



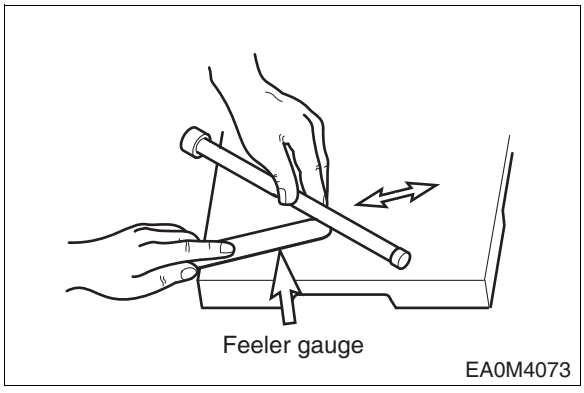
● Pushrod runout

(mm)

Limit	0.3 or less

Use a feeler gauge to measure the pushrod runout.

Roll the pushrod over a smooth surface as shown in the picture.



9.2.5. Camshaft

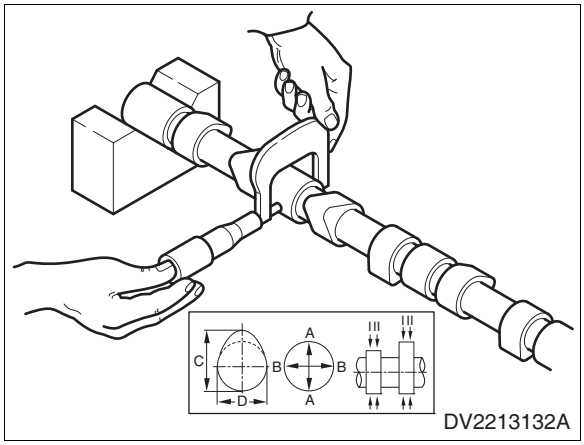
1) Cam

● Cam journal diameter and lobe height

(mm)

		Standard	Limit
Cam journal diameter (A,B)		Ø59.86 ~ Ø59.88	Ø59.56
Cam lobe height (C)	Intake	50.27	49.97
	Exhaust	50.30	50.00

Use a micrometer to measure the cam journal diameter. The camshaft must be replaced if the measured value is greater than the designated limit.



● Cam surface

Use a micrometer to measure the cam journal diameter. The camshaft must be replaced if the measured value is greater than the designated limit. For minor layered wear or damage, use an oily grindstone or fine sandpaper to polish the surface. For severe damage, replace the cam.

2) Camshaft

● Clearance between the camshaft journal and camshaft bushing

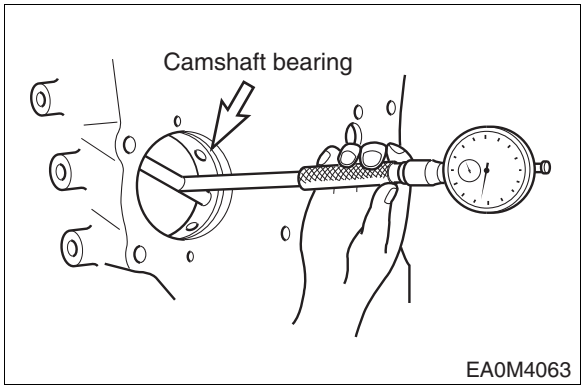
- Use an outside micrometer to measure the camshaft journal diameter.
- Use a cylinder bore indicator to measure the inside diameter of the cylinder block camshaft bushing, then compare the measured value with the camshaft O.D. to check the clearance.

<Clearance>

(mm)

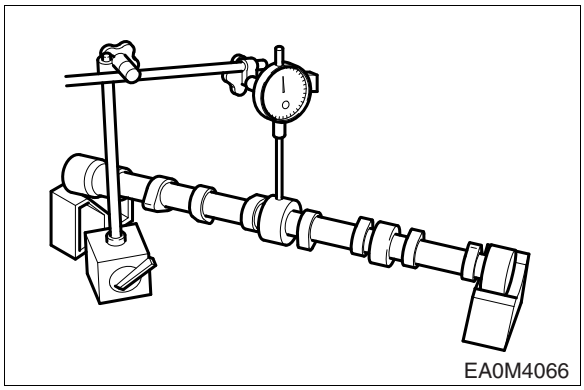
Standard	Limit
0.045 ~ 0.100	0.2

Replace the bushing if the measured value exceeds the specified limit.



● Runout

Support the camshaft on two V-blocks and use a dial indicator to check the runout. If the measured value indicates that the runout exceeds the limit and requires maintenance, fix or replace the camshaft.


EA0M4066

(mm)

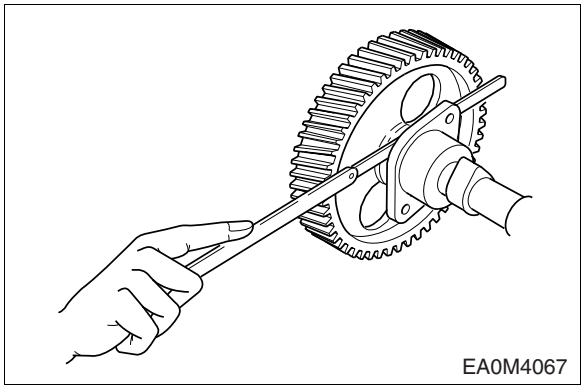
Standard	Limit
0.05	0.15

3) Camshaft and Free Play

● Push the thrust plate toward the cam gear.

● Use a feeler gauge to measure the clearance between the thrust plate and camshaft journal.

● If there is excessive end play, replace the thrust plate.


EA0M4067

(mm)

Standard	Limit
0.14 ~ 0.25	0.3

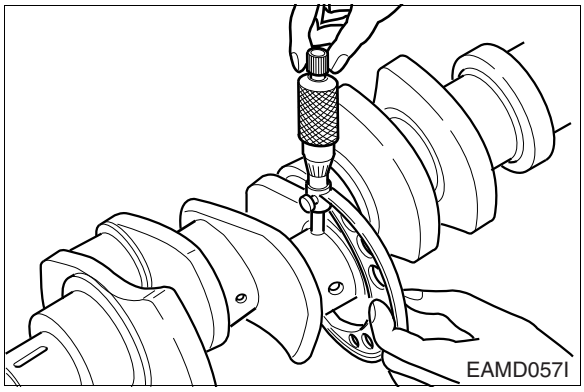
9.2.6. Crankshaft

1) Inspecting for Defects

- Inspect the crankshaft journal and crank pin visually for scratches or cracks.
- Perform a magnetic particle test and colour check to inspect for any cracks in the crankshaft and replace the crankshaft if it is cracked.

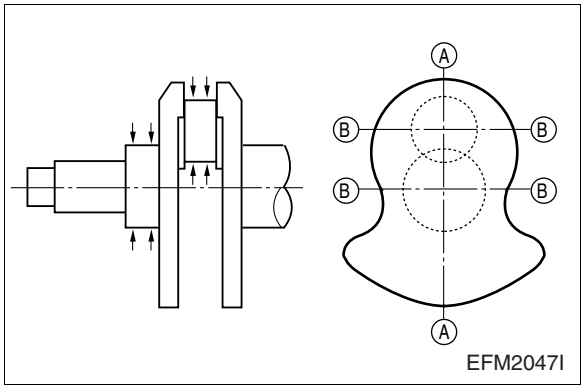
2) Wear

- Use an outside micrometer to measure the diameter of the crankshaft journal and pin in the direction shown in the picture and compare the measured values to check the amount of wear.
- If the amount of wear exceeds the limit, polish the crankshaft and install a small bearing. However, if the amount of wear is within the limit, use an oil stone or fine sandpaper soaked in oil to fix the wear. (You must use sandpaper completely soaked in oil.)



(mm)

	Standard	Limit
Journal diameter	Ø95.966 ~ Ø95.988	Ø95.916
Pin diameter	Ø85.966 ~ Ø85.988	Ø85.916



*** A small bearing may be used**

◆ Standard

◆ 0.25 (I.D. is 0.25 mm smaller than the standard size)

◆ 0.50 (I.D. is 0.50 mm smaller than the standard size)

Small bearings are provided in the two sizes indicated above, and you may polish the crankshaft to the sizes above.

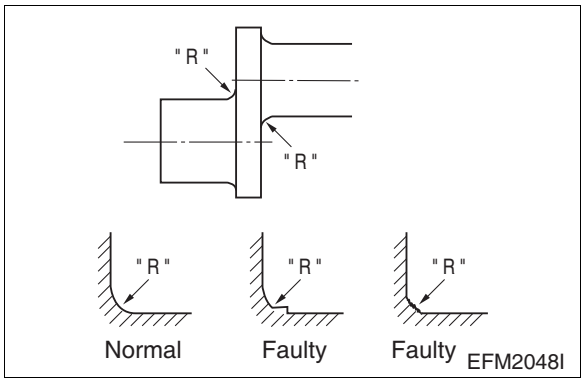
Note:

When repolishing the crankshaft as explained below, fillet 'R' must be finished properly. Avoid parts with sharp corners or no fillet.

* Standard "R" value

① Crankshaft pin "R" : 5.5 $^{0}_{-0.2}$

② Crankshaft journal "R": 5 $^{0}_{-0.2}$

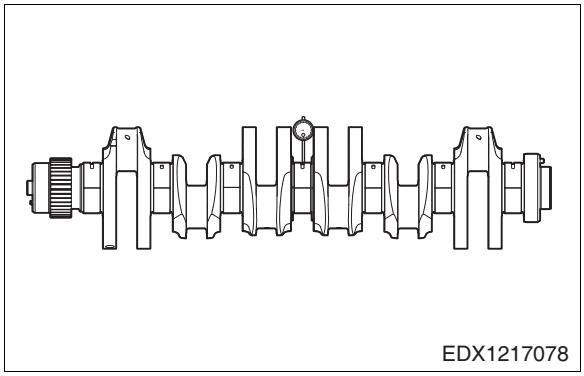


3) Crankshaft Runout

- Support the crankshaft on a V-block.
- Use a dial indicator placed on the surface plate to find the amount of crankshaft runout while rotating the crankshaft.

(mm)

No.	Standard	Limit
4	0.1	0.15
3, 5	0.08	0.12
2, 6	0.05	0.07



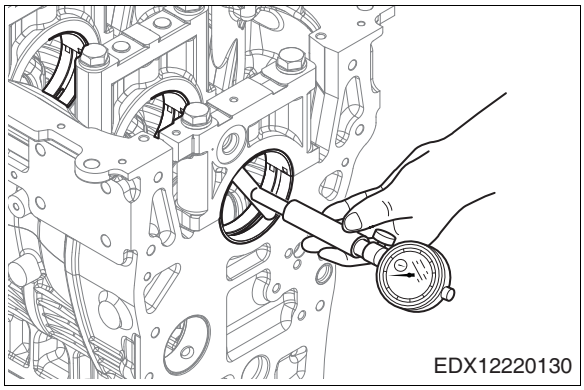
9.2.7. Crankshaft Bearings and Connecting Rod Bearings

1) Visual inspection

Inspect the crankshaft bearings and connecting rod bearings visually for scratches, uneven wear or damage.

2) Crankshaft and bearing oil clearance

● Main bearing clearance (method 1)
Install the main bearing on the cylinder block, tighten the bearing cap to the specified torque, and measure the inside diameter.


EDX12220130

Torque	30 kg·m

(mm)

Standard diameter	Ø96.06 ~ Ø96.108

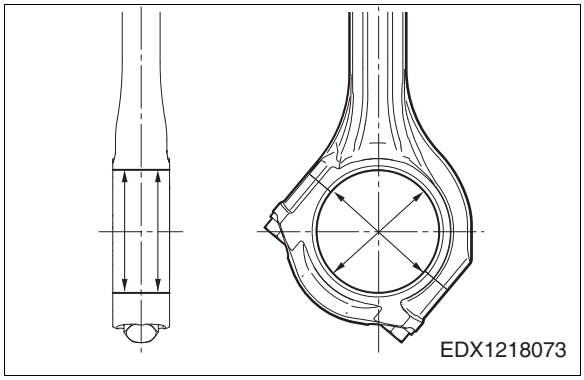
Measure the inside diameter of the main bearing and compare the two values obtained with the outside diameter of the crankshaft journal to check the oil clearance.

< Main bearing oil clearance >

(mm)

Standard	Limit
0.072 ~ 0.142	0.2

● Connecting rod bearing clearance
Install the connecting rod bearing on the connecting rod bearing cap, tighten the connecting rod cap bolt to the specified torque, then measure the inside diameter.


EDX1218073

Torque	8 kg·m +60° (0 ~ 10°)

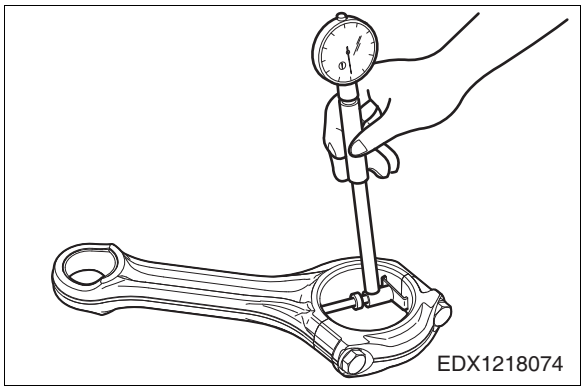
(mm)

Standard diameter	Ø86.036 ~ Ø86.084

Measure the inside diameter of the connecting rod bearing and compare the two values obtained with the outside diameter of the crankshaft pin to check the oil clearance.

(mm)

Standard	Limit
0.048 ~ 0.118	0.18

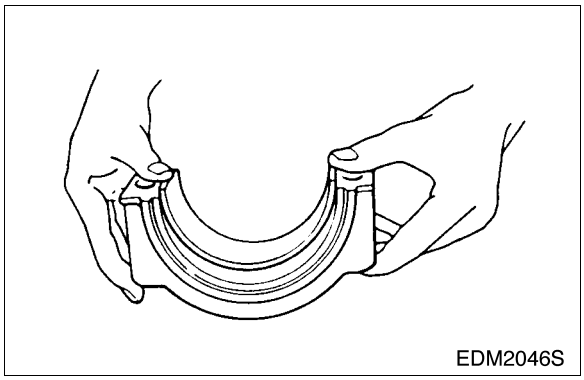

EDX1218074

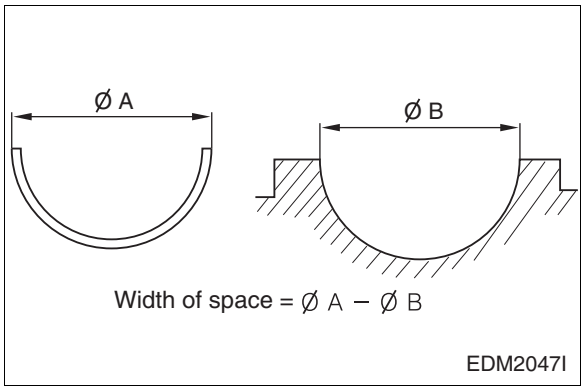
- If the clearance exceeds the specified range, polish the crankshaft journal and pin, and install a small bearing.

- Connecting rod bearing clearance (method 2: using a plastic gauge)
  Assemble the crankshaft to the cylinder block, stick a plastic gauge between the crankshaft journal and pin, then assemble the bearing cap and tighten the bolt to the specified torque. Remove the bolt again to remove the bearing cap, then pull out the flattened plastic gauge and use a plastic gauge measurement scale to measure the ratio of the plastic gauge. This value is the oil clearance.

3) Bearing Spread and Crush

- Finished
  Check how much finger strength is required when reassembling bearings.


EDM2046S

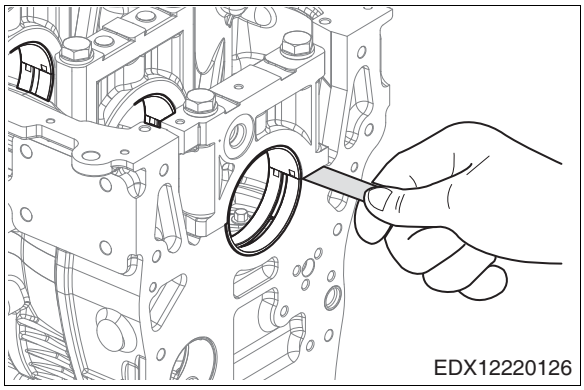


EDM2047I

● Crankshaft Bearing Crush
Install the bearings and caps on the cylinder block and tighten the bolts to the specified torque, then loosen one bolt completely and use a feeler gauge to measure the clearance between the bearing cap and cylinder block.

(mm)

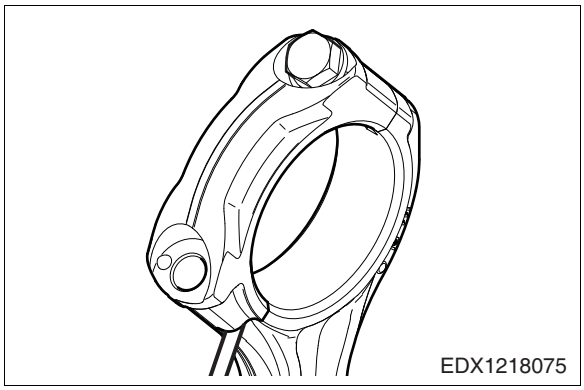
Standard diameter	0.15 ~ 0.23


EDX12220126

● Connecting rod bearing crush
Install the bearings and caps on the big end of the connecting rod and tighten the bolts to the specified torque, then loosen one bolt completely and use a feeler gauge to measure the clearance between the bearing cap and the big end of the connecting rod.

(mm)

Standard	0.13 ~ 0.21


EDX1218075

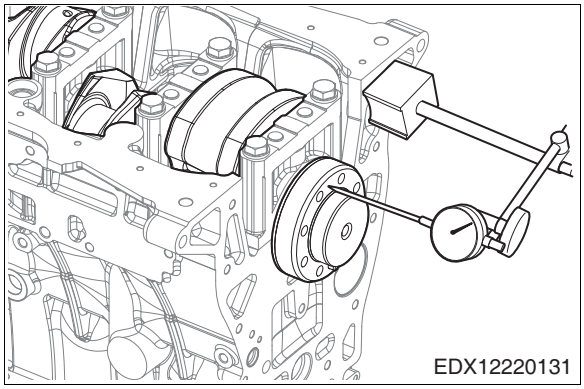
4) Crankshaft End Play

● Assemble the crankshaft to the cylinder block.

● Use a dial gauge to measure the crankshaft end play.

(mm)

Standard	Limit
0.1 ~ 0.3	0.5


EDX12220131

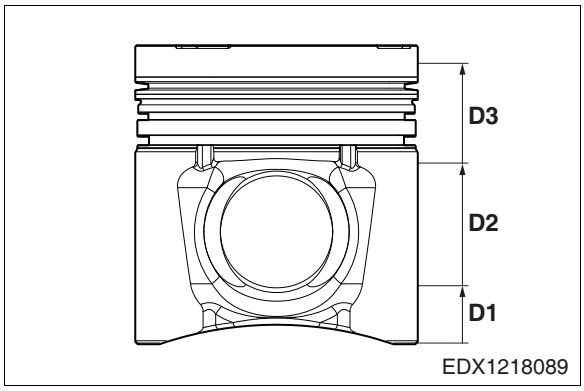
9.2.8. Pistons

1) Visual inspection

Pay particular attention to the ring groove while performing a visual inspection of the pistons for cracks, grooves and wear.

2) Clearance between the piston and cylinder liner

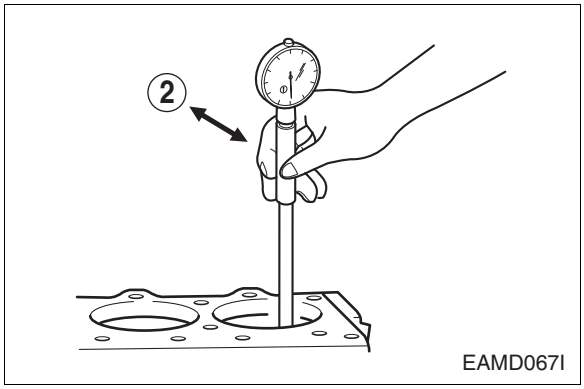
- Use an outside micrometer at a right angle to the piston pin hole to measure the piston outside diameter in the places where the distance from the bottom part of the piston skirt is D1, D2 and D3.



(mm)

Position	Standard diameter
D1 (25 mm)	∅122.870 ± 0.007
D2 (78.5 mm)	∅122.696 ± 0.009
D3 (122 mm)	∅121.490 ± 0.010

- Use a cylinder bore gauge at a 45° angle to measure the inside diameter of the cylinder liner in three places (ring contact surface at the top of the cylinder, middle, and oil ring contact surface at BDC). Find the average value, excluding the maximum and minimum values.



(mm)

Standard	Limit
∅123 ~ ∅123.025	∅123.223

- The clearance is the value of the piston O.D. subtracted from the cylinder liner I.D. In the event that the clearance exceeds the specified limit, replace the piston or cylinder liner (whichever part is more severely worn).

< Clearance between the piston and cylinder >

(mm)

Standard	0.123 ~ 0.162

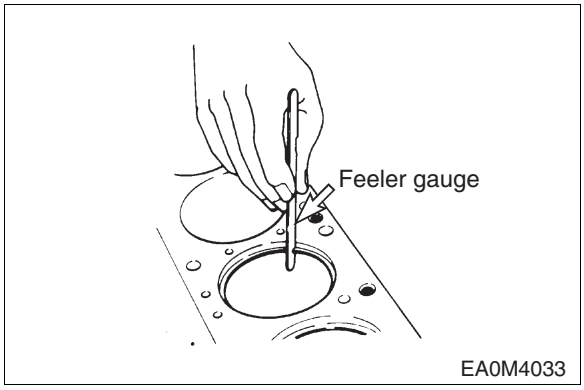
9.2.9. Piston ring

1) Visual inspection

If any parts are found to be worn or damaged when overhauling the engine, replace the piston ring with a new one.

2) Piston ring gap

- Insert the piston ring into the top hole of the cylinder liner so that it maintains a right angle with the wall of the cylinder liner.
- Use a feeler gauge to measure the piston ring gap.



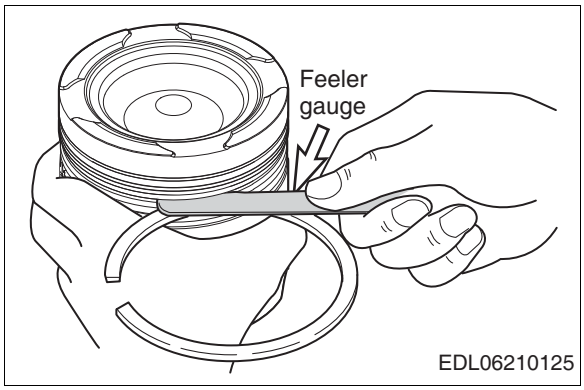
(mm)

	Standard	Limit
Top ring	0.30 ~ 0.45	0.70
Second ring	1.00 ~ 1.20	1.45
Oil ring	0.30 ~ 0.45	0.70

If the gap exceeds the limit, replace the piston ring with a new one.

3) Piston ring side gap

- Install the compression ring and oil ring into the piston ring groove.
- Use a feeler gauge to measure the side clearance of each ring. If the measured value exceeds the specified limit, replace the ring or piston.



(mm)

	Standard	Limit
Top ring	0.105 ~ 0.155	
Second ring	0.070 ~ 0.105	0.125
Oil ring	0.050 ~ 0.090	0.110

4) Piston ring tension

Use a tension tester to measure the piston ring tension. If the measured value exceeds the limit, replace the piston ring.

	Standard
Top ring	23.2 ~ 34.8 N
Second ring	19.3 ~ 28.9 N
Oil ring	57.4 ~ 77.6 N

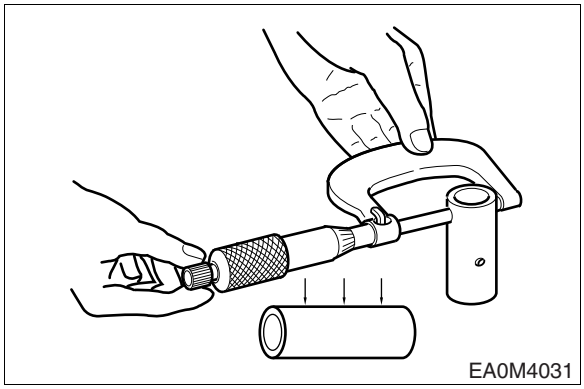
9.2.10. Piston pins

1) Wear

Measure the wear of the piston pin at the designated spot. If the measured value exceeds the limit (0.005 mm or higher), replace the pin.

(mm)

Standard	Limit
∅48.995 ~ 49.000	∅48.990 or less

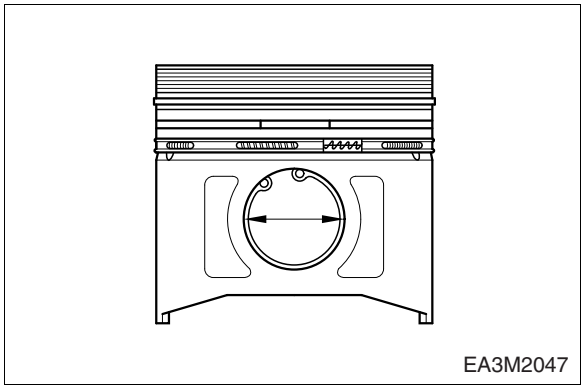

EA0M4031

2) clearance

Measure the clearance between the piston pin and connecting rod bushing. If the measured value exceeds the limit, replace one of the two (whichever part is more severely damaged).

(mm)

Standard	Limit
0.05 ~ 0.08	0.1


EA3M2047

3) Inspecting the Condition

Check the fitting of the piston and piston pin. The piston is normal if you are able to force the pin into the piston heated by the piston heater.

When replacing the piston, you must also replace the piston pin.

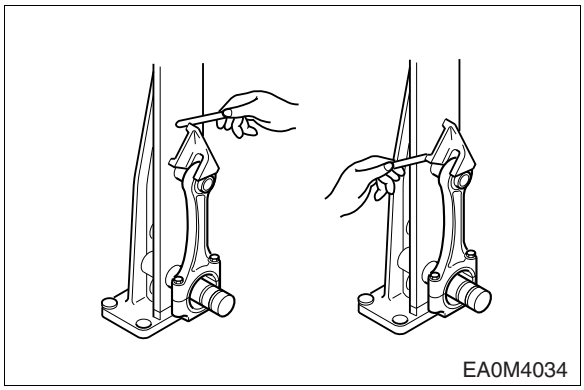
9.2.11. Connecting Rod

1) Deformation

Check whether the connecting rod is deformed. Install the connecting rod on the connecting rod tester as shown in the image below, then use a feeler gauge to check for deformation. If it is confirmed that the connecting rod is deformed, it should never be reused and must be replaced with a new one.

2) Hole Alignment (Parallelism)

Measure the alignment between the hole in the connecting rod piston pin bushing and the hole in the big end of the connecting rod. When doing so, use both a connecting rod tester and a feeler gauge.


EA0M4034

(mm)

Standard	Limit
0.05	0.1 or less

3) Wear

- Assemble the connecting rod with the crankshaft and use a feeler gauge to measure the side clearance of the big end of the connecting rod.
- Install the connecting rod on the piston and measure the side clearance of the small end of the connecting rod.
- If the measured value exceeds the limit, replace the connecting rod.

(mm)

Limit	0.5

9.3. Reassembly

9.3.1. General Precautions

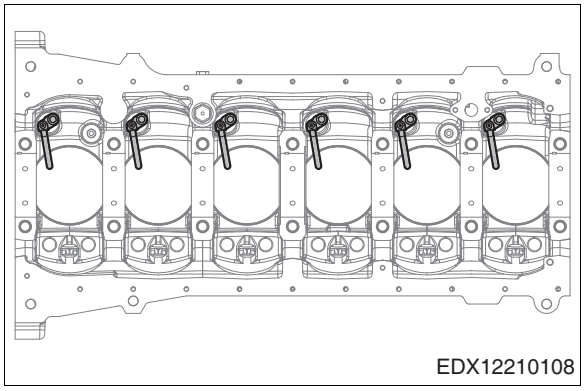
- Use compressed air to thoroughly clean all of the removed parts (especially oil and coolant ports), then check for any restricted parts.
- Keep regular and special tools nearby for engine assembly.
- Prepare clean engine oil to spread on the various sliding components.
- Prepare materials for repair, such as sealant and gaskets.
- Dispose of all used gaskets, seal rings and consumables, and replace them with new ones.
- Tighten bolts only until the specified torque in the specified tightening sequence and do not over-tighten them.
- After reassembly, check whether all engine parts are operating smoothly.
- After the preliminary reassembly, check whether bolts are loose.
- After completing the engine reassembly, check whether any parts are missing or insufficient.
- Keep your hands clean while working.

9.3.2. Cylinder Block

Lay a wooden plate or thick strip on the floor of the maintenance center to prevent damage to the cylinder head, and place the cylinder block with the head mounting surface facing downwards.

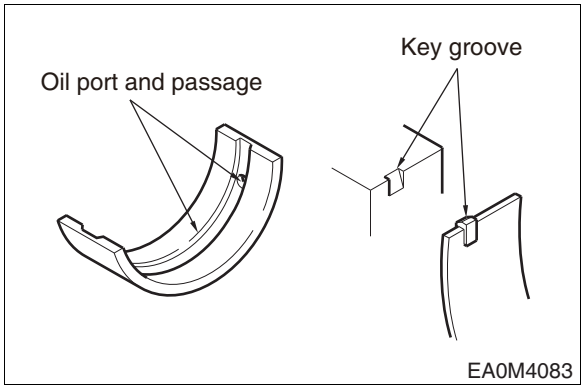
9.3.3. Oil injection nozzle

- Use an injection nozzle jig to tighten and assemble the oil injection nozzle flange with mounting bolts.


EDX12210108

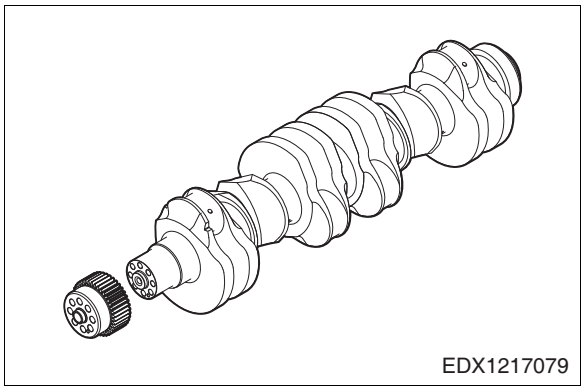
9.3.4. Crankshaft

- Install the main bearing, with two holes made to align the key with the key seat, in the cylinder block, then apply oil to the bearing surface.

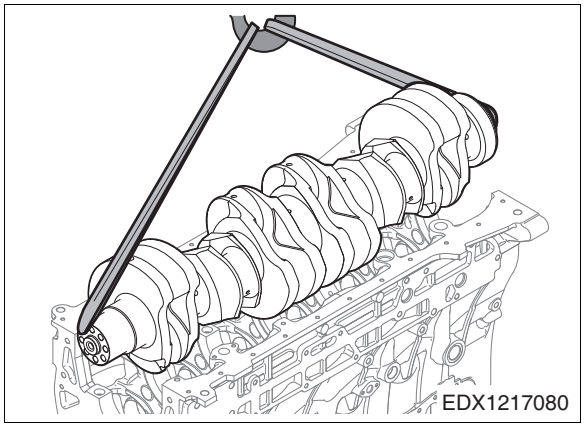


EA0M4083

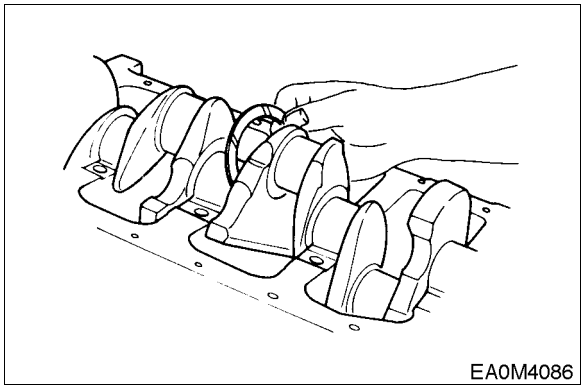
- After heating the crankshaft gear to 120˚C for 10 minutes or more, apply sealant (Loctite 641) evenly to the inner wall of the heated crankshaft gear before inserting it into the end of the crankshaft.


EDX1217079

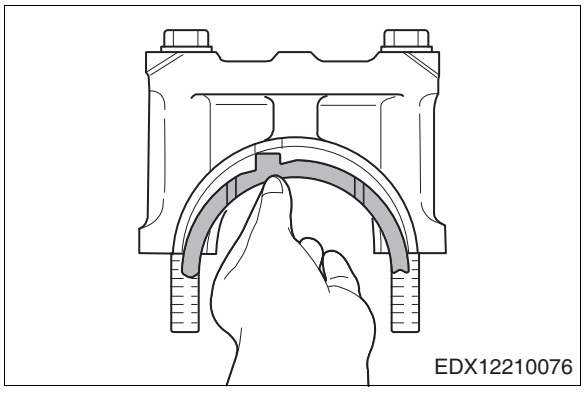
- Tighten the bolts around halfway on both sides of the crankshaft and apply engine oil to the journal and pin, then tighten the mounting bolts to assemble the crankshaft with the cylinder block.


EDX1217080

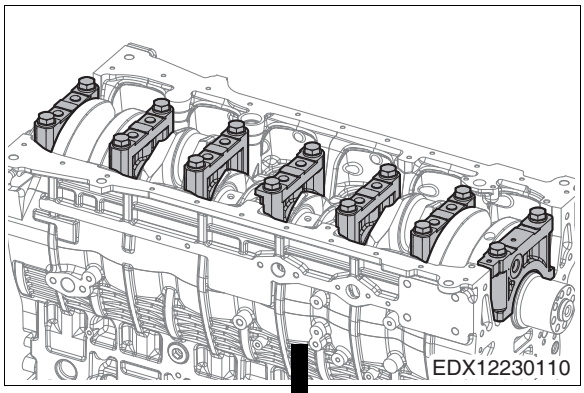
- Install the thrust washers soaked in oil with the oil groove facing outwards.

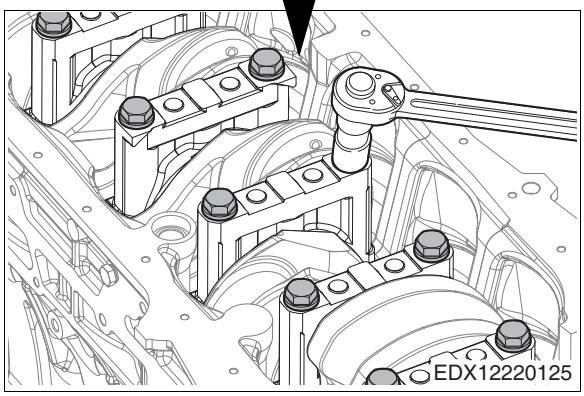

EA0M4086

- Mount the bearings and thrust washers on the bearing caps; then, apply oil to the bearings and thrust washers.


EDX12210076

- Install the bearing caps while aligning the cylinder block numbers with the bearing cap numbers.





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

Torque	30 kg·m

- After evenly tightening two bolts around halfway, use a torque wrench to tighten the bolts diagonally to the specified torque as follows.

< Tightening sequence >

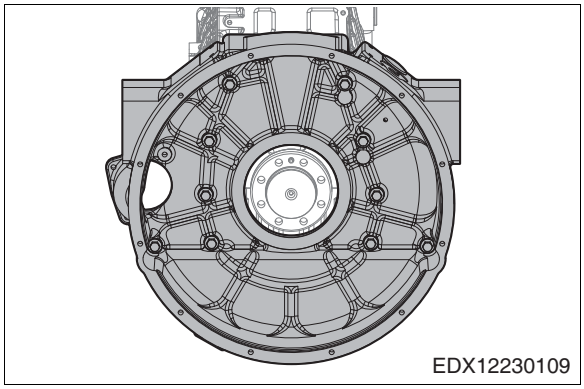
(1) Step 1: Apply engine oil to the top of the bolts.
(2) Step 2: Temporarily install the bolts so that only one or two threads are engaged.
(3) Step 3: Use an impact wrench to tighten them to around 15 kg.m.
(4) Step 4: Use a torque wrench to tighten them to around 25 kg.m.
(5) Step 5: Finally, use a torque wrench to tighten them to the specified torque. (30 kg·m).

- Tighten the bearing caps in the sequence 4-3-5-2-6-1-7.
- Check whether the assembled crankshaft rotates smoothly.

9.3.5. Flywheel housing

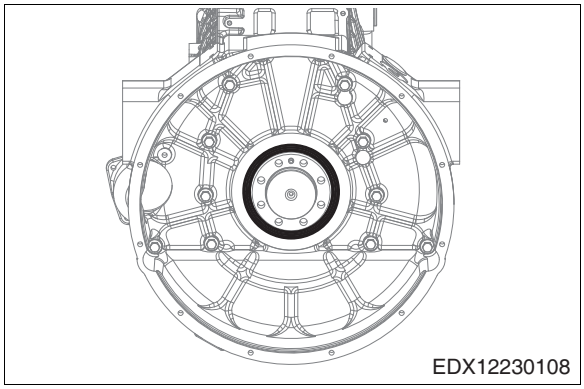
- Temporarily install a guide bar on the cylinder block.
- Fit gaskets onto the cylinder block.
- Use a dowel pin and guide bar to install the flywheel housing and tighten the mounting bolts to the specified torque in a diagonal sequence.

Torque	12 kg·m



9.3.6. Rear Oil Seal

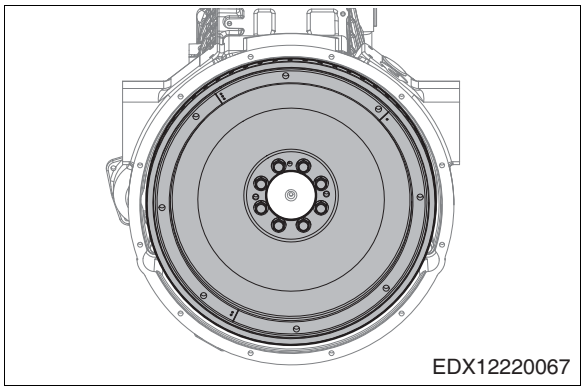
- After applying lubricating oil to the oil seal and inside diameter of the flywheel housing, install them on the top of the crankshaft, then use an oil seal mounting jig to assemble the oil seal.

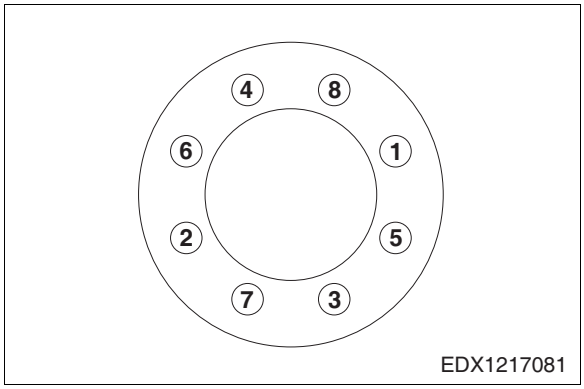

EDX12230108

9.3.7. Flywheel

- Install the guide bar in the bolt hole of the crankshaft, then lift the flywheel to align the holes for the dowel pin and flywheel pin for temporary assembly.
- Insert bolts in the remaining holes and remove the guide bar, then insert a bolt into the hole in which the guide bar was inserted.
- Use a torque wrench to tighten the mounting bolts diagonally to the specified torque.

Torque	20 kg·m

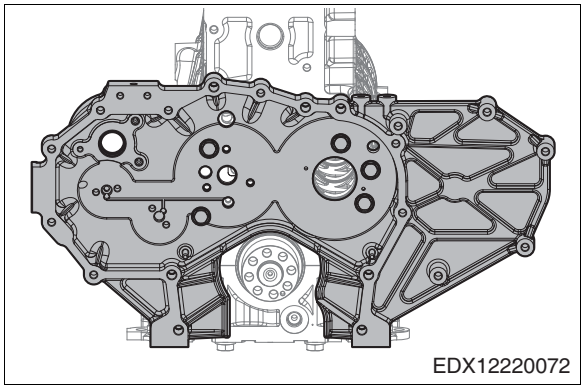

EDX12220067



EDX1217081

9.3.8. Timing gear case

- Use parallel pins to mount the gaskets on the cylinder block.
- Align the dowel pins with the dowel pin holes in the timing gear case and install the timing gear case.
- Tighten the bolts to the specified torque.

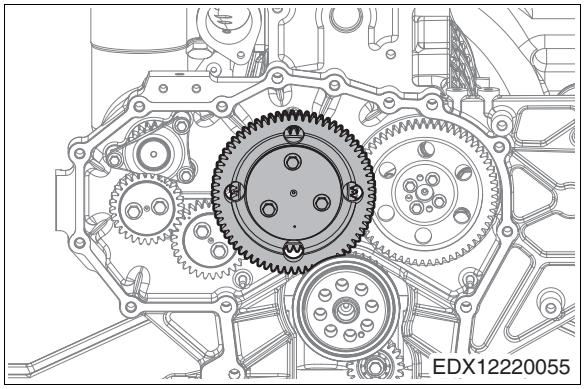

EDX12220072

9.3.9. Timing gear

- Insert the oil pump idler gear into bearing cap no.1.

- Install thrust washers on the camshaft, then assemble the cam gears in line with the camshaft key seat.

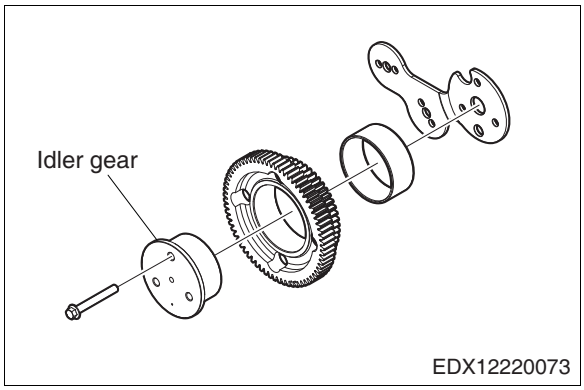
Camshaft thrust washers	0.9 kg·m
Camshaft gear mounting bolts	3.1 kg·m



- Install the idler gear pin so that the oil port on the idle pin faces the cylinder block.

- Assemble the idler gear while aligning the marks on the crank gear, cam gear, fuel injection pump driving gear and idler gear.

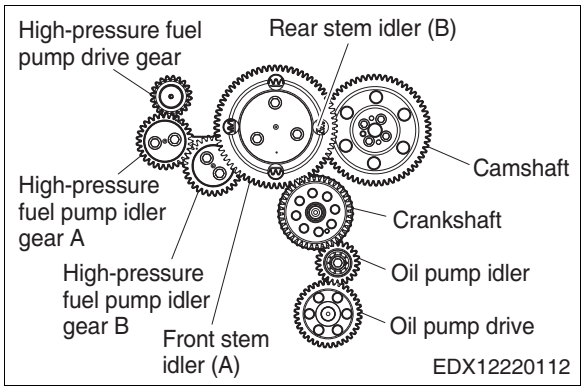
idler gear Pin Mounting Bolts	6.2 kg·m



- Use a feeler gauge to inspect and adjust the amount of backlash between gears.

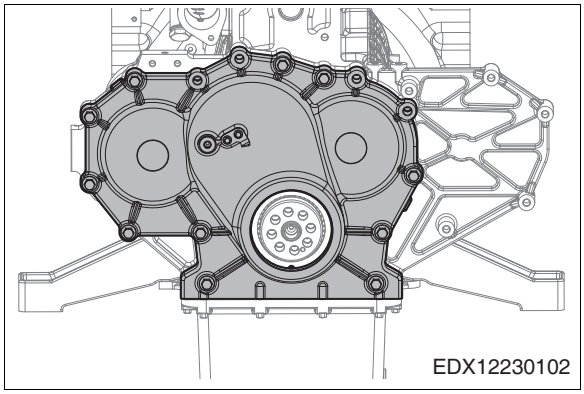
(mm)

Measuring location (between)	**Backlash**
Crank gear and oil pump idler gear	0.060 ~ 0.184
Oil pump idler gear and oil pump drive gear	0.020 ~ 0.292
Crank gear and stem idler (A) front gear	0.062 ~ 0.194
Rear stem idler (B) and cam gear	0.090 ~ 0.236
Rear stem idler (B) and high-pressure fuel pump idler gear B	0.072 ~ 0.189
High-pressure fuel pump idler gear B and high-pressure fuel pump idler gear A	0.071 ~ 0.191



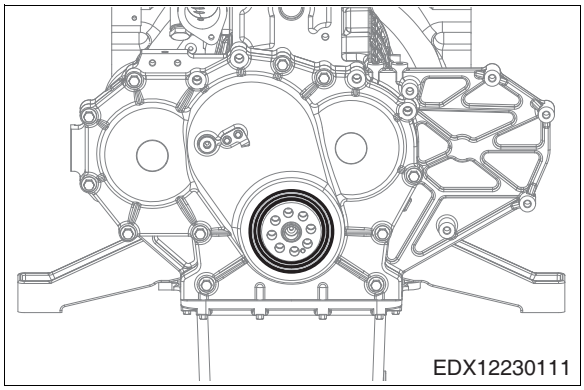
9.3.10. Timing Gear Case Cover

- Install parallel pins on top of the timing gear case.
- Mount the gaskets while aligning the mounting bolt holes and gasket holes.
- After aligning the cover pin holes with the parallel pins, tap the cover lightly while installing it.
- Tighten the mounting bolts starting from the mounting surface of the oil pan.



9.3.11. Front Oil Seal

- After applying lubricating oil to the oil seal and inside diameter of the timing gear case, install them on top of the crankshaft, then use an oil seal mounting jig to assemble the oil seal.

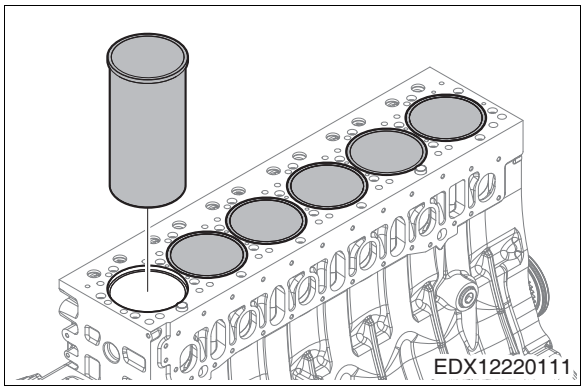


9.3.12. Cylinder liner

- Set up the cylinder block with the flywheel facing downwards.

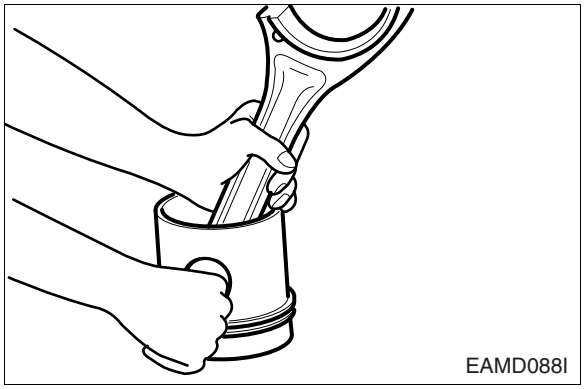
- Use compressed air to thoroughly clean the liner flange contact surface and inside the holes while ensuring that foreign matter does not enter them.
- After cleaning, dry the cylinder liner completely and then push it into the cylinder block manually.

- Apply engine oil to the inside diameter of the liner.

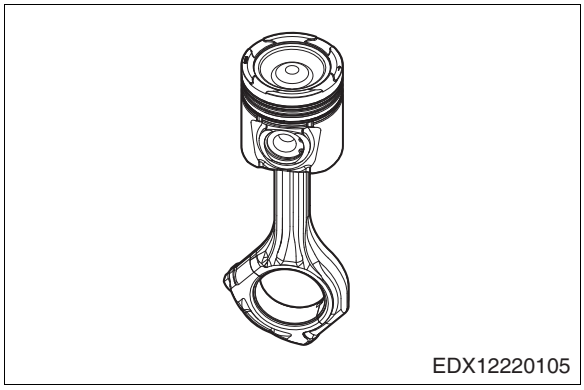


9.3.13. Piston and Connecting Rod

- Align the piston pin hole with the small end of the connecting rod soaked in oil, then push on the piston pin (tap it gently with a rubber hammer) to assemble the connecting rod with the piston.

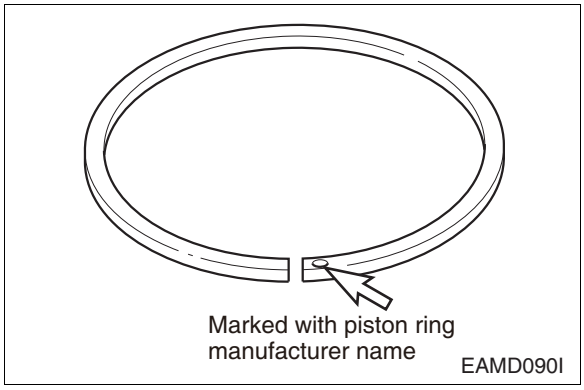

EAMD088I

- Pay attention to the direction of the piston and ensure that the shorter part of the big end of the connecting rod and the "serial number" mark engraved on the piston head are in the same position. The piston combustion chamber is located in the center and can be difficult to check from the direction of the valve pocket, so be sure to assemble it according to the instructions above.


EDX12220105

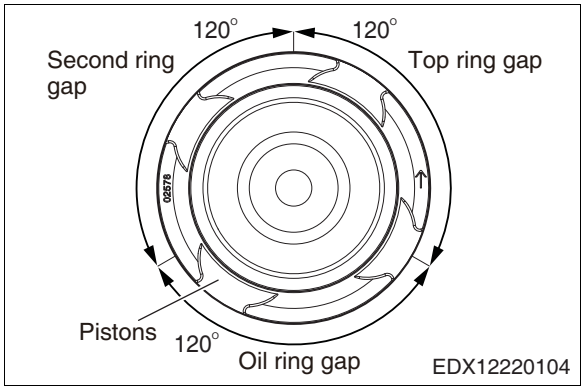
- Install the snap ring and check that it is securely assembled.
- Use piston ring pliers to install the piston ring in the piston.
- In order to ensure that the top and bottom end of the piston ring are not reversed, identify the "Y" or "TOP" mark displayed on the top of the ring and ensure that the top end is facing upwards.

Note:
The surface with the top of the piston ring marked ("Y" or "TOP") must be facing upwards.



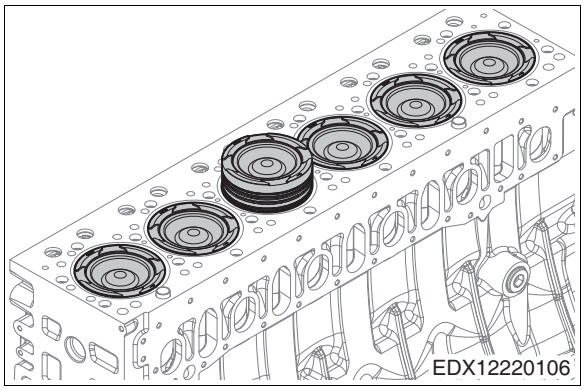
EAMD090I

- Adjust the angle between each piston ring gap to 90° and fit the piston assembly jig into the piston. Take particular care to ensure that the direction of the pin and the ring gap are not the same.
- Align the bearing with the key seat of the connecting rod to install it, then apply oil to the bearing and piston.



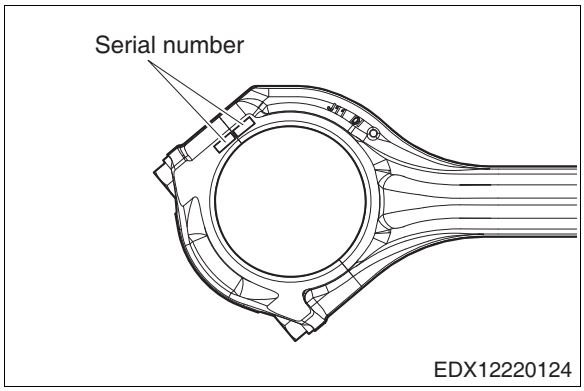
EDX12220104

- Place the valve mounting surface facing the tappet hole and insert the piston manually.
  Take particular care to ensure that the cylinder liner and piston are not damaged, and lift the piston slightly inside the cylinder when inserting it to ensure that the ring is not damaged by the fillet on the liner.



- Fit the bearing into the connecting rod cap and apply oil to it.

- Check whether the manufacturing serial numbers printed on the connecting rod cap and big end of the connecting rod match and install the connecting rod cap while keeping it aligned with the dowel pin.

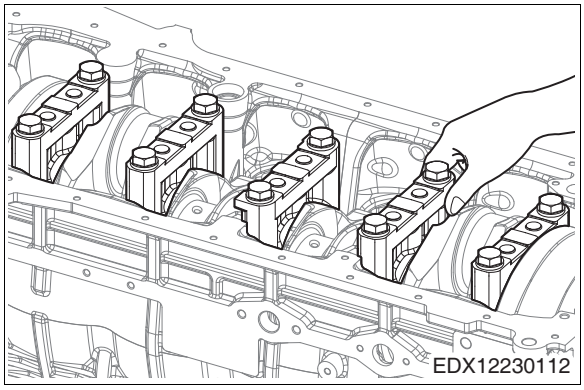


- After applying oil to the mounting bolts, tighten the mounting bolts manually around halfway as follows, then use a torque wrench to tighten them to the specified torque.

  < Tightening sequence >
  (1) Step 1: Apply engine oil to the top of the bolts.
  (2) Step 2: Temporarily install the bolts so that only one or two threads are engaged.
  (3) Step 3: Use a torque wrench to tighten them to around 8 kg·m.
  (4) Step 4: Use a torque wrench to tighten them to around 60°.

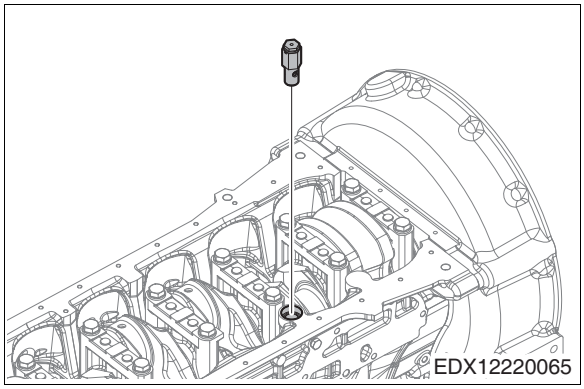
Torque	8 kg·m +60° (0 ~ 10°)

- Try moving the bearing cap by hand. If it does not move, loosen and then retighten it.



9.3.14. Relief valve

- Assemble the relief valve.

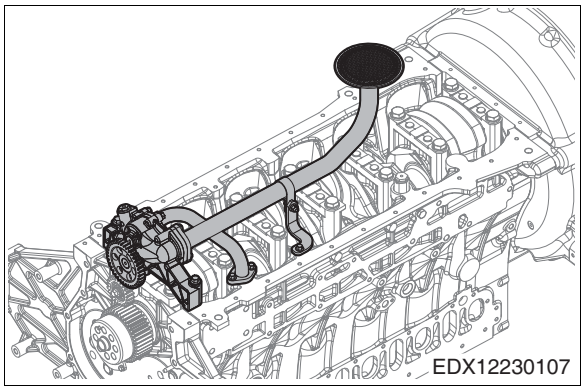


9.3.15. Oil Pump and Oil Pipe

- Insert a dowel pin into bearing cap no.7, then tighten the oil pump to the specified torque.

Torque	4.4 kg·m

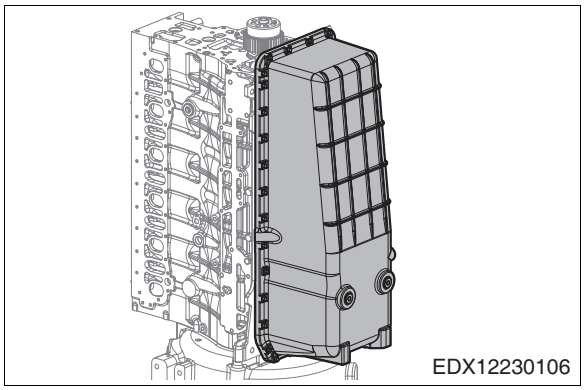
- After assembling the oil suction pipe and delivery pipe, install the brackets on the bearing caps.



9.3.16. Oil pan

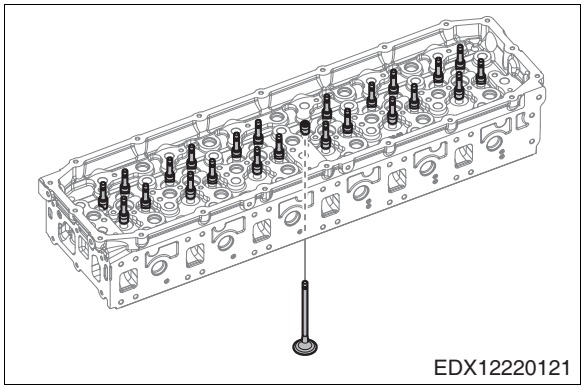
- Mount the gaskets, then place the oil pan on top of them.
- Tighten the bolts.
- In order to prevent gasket damage, align the bolt holes with the gasket holes, then tighten them to the specified torque.

Torque	3.1 kg·m

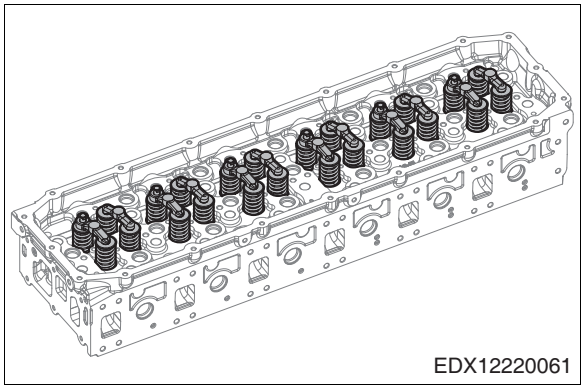


9.3.17. Intake/Exhaust Valves

- Before assembling the valves and valve heads, find the "N (IN)" and "X (EX)" marks on the valve heads.
- Use a valve stem seal mounting jig to assemble the valve stem seals and valve guides.

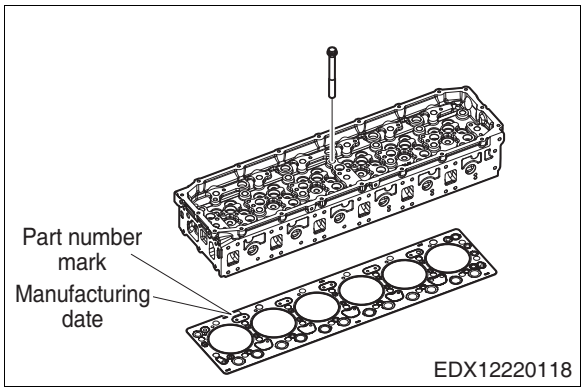

EDX12220121

- After installing the valve springs and spring retainers, use the jig to press down on the retainers; then, install the cotter pins.
- Tap on the valve stems gently with a rubber hammer to check whether the valves have been assembled correctly.


EDX12220061

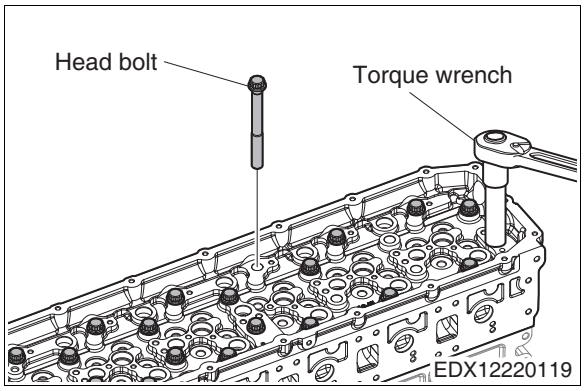
9.3.18. Cylinder Head

- Clean the bolt holes in the cylinder head with compressed air.
- Clean the cylinder head gasket contact surface thoroughly.
- Make sure that no foreign matter enters the combustion chamber during this step.
- Align the bolt hole on the new gasket with the offset pin on the cylinder block and install it with the mark on the right facing up.



EDX12220118

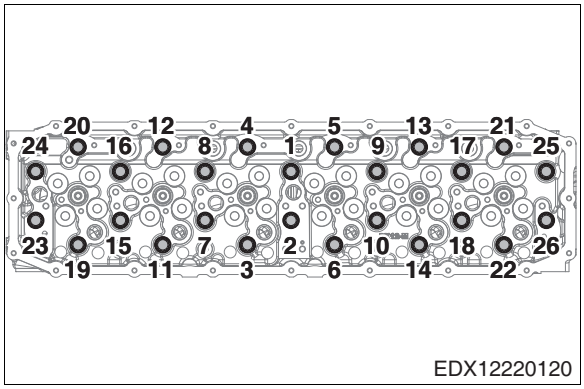
- Check for any foreign matter in the combustion chamber. Then, mount the cylinder head by aligning it with the offset pin.
- Be careful not to damage the gasket. If the pin hole is not aligned, lift the cylinder head and put it down again.
- When removing the cylinder head bolts after installation, replace the gasket with a new one.



- Assemble at the specified tightening torque in the correct order of assembly.

<Cylinder head bolts>

	Type 5 (10.9T)
Specifications	 M16×1.5×161
Torque	1st tightening: 6 kg·m 2nd tightening: 90° + 90° Final tightening: 30°

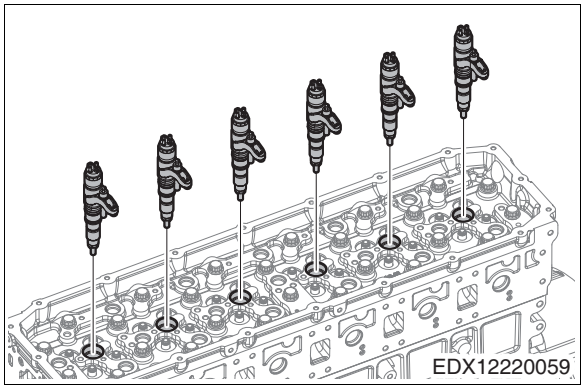


<Cylinder head bolt tightening sequence>

Step 1 : Tighten the bolts manually one or two threads.
Step 2 : Tighten the bolt to 6 kg·m with a torque wrench.
Step 3: Tighten the bolts 90° with a torque wrench
Step 4: Tighten the bolts 90° with a torque wrench
Step 5: Finally, use a torque wrench to rotate the bolts 30°.

- Follow the tightening sequence specified above for all bolts.
- Apply engine oil to the pushrod and insert it into the pushrod hole in the cylinder head.

9.3.19. Injector



- Clean all parts thoroughly, taking care not to contaminate them with foreign matter.
- Fuel lines connecting the common rail to the injectors require particular cleanliness as they lack a filtration function.
- Clean and remove all foreign matter from the holes drilled in the cylinder head for inserting high-pressure fuel connectors and holes for injectors.
- When the injector is disassembled, the high-pressure fuel connector must be replaced with a new one.
- In the event that fuel remaining in the fuel return line enters the combustion chamber while disassembling the injector, it must either be sucked out using a hand pump or discharged by cranking the starter motor with the fuel shut off.

CAUTION:

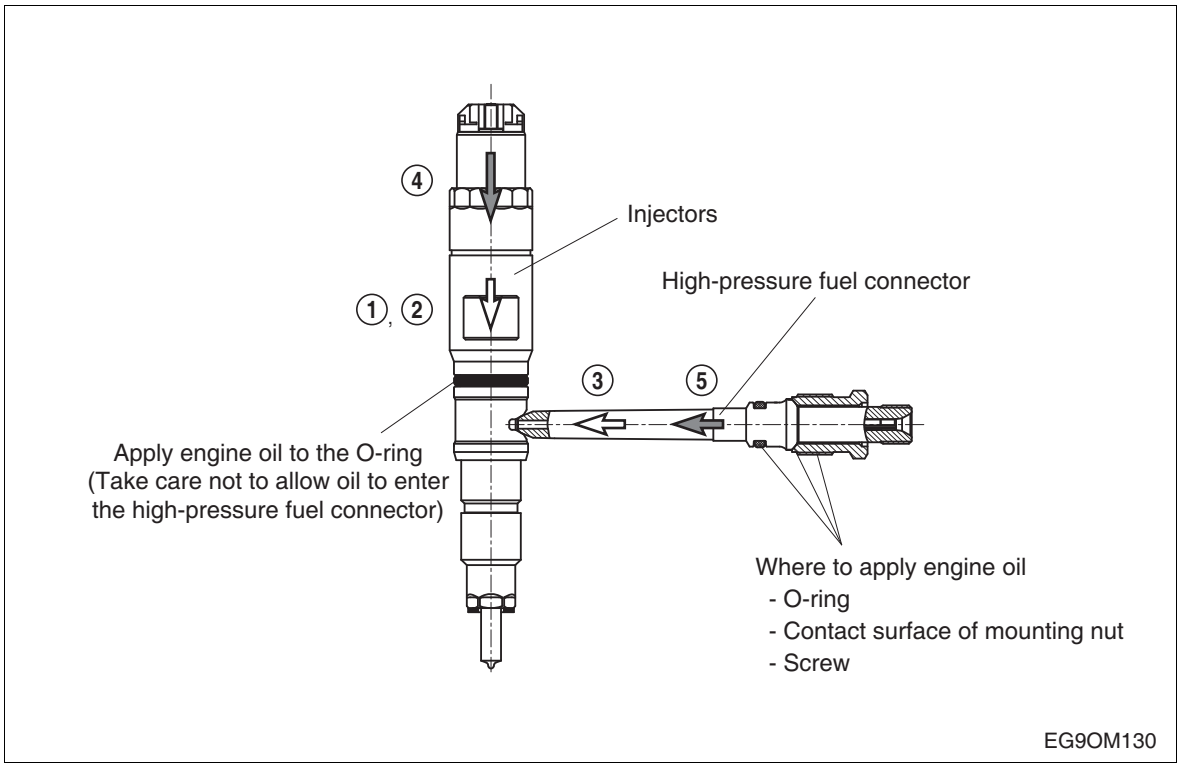
When installing a new high-pressure fuel pipe after disconnecting the high-pressure fuel pipe connected to a high-pressure fuel connector (HPC), make sure to retighten the HPC mounting nuts to the specified torque.

In addition, do not reuse high-pressure fuel pipes as the seal for high-pressure fuel is deformed while tightening them.

HPC nut Tightening torque	Temporary tightening: 0.3 ±0.1 kg·m
	Final tightening: 5.3 ±0.3 kg·m
High-pressure fuel pipe Tightening torque	4.0 ±0.4 kg·m

<Injector assembly order>

1) The injectors must be assembled precisely in the following order.

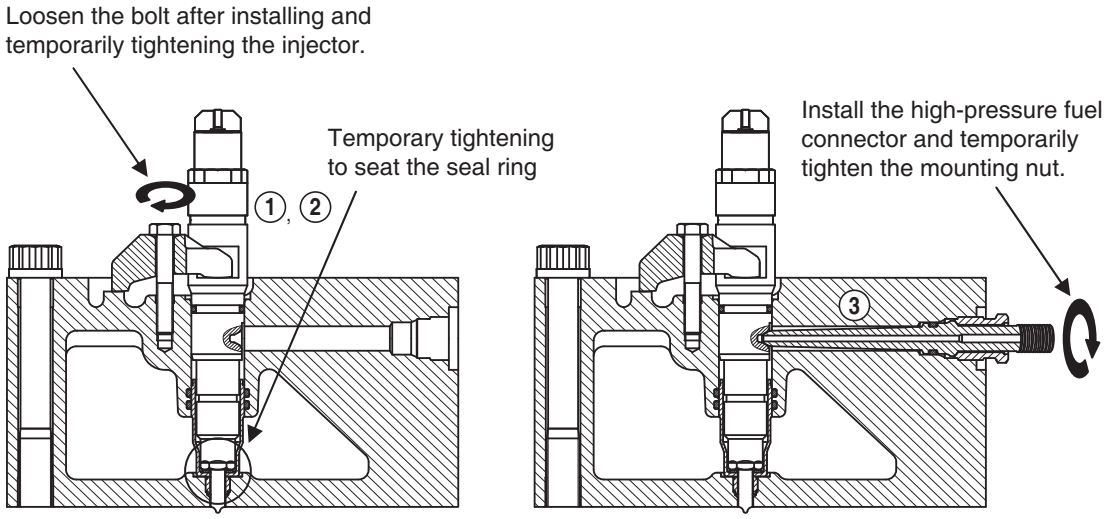


2) Fit an O-ring onto the injector and apply engine oil to the outer circumference. Be careful not to contaminate the connection hole in the high-pressure fuel connector on the side of the injector with water or foreign matter at this time.

3) Insert the injector carefully after aligning the seal ring with the injector hole in the cylinder head. Align the injector mounting bolt with the threaded section on the head and turn the bolt two to three threads by hand to tighten it.

4) Seat the injector in the mounting position on injector mounting brackets ① and ② using the mounting bolts; then, tighten it temporarily. After tightening the injector temporarily, loosen the mounting bracket bolts enough to allow it to move without applying excessive force to the injector.
(Injector axial load of 0 kg·m)

5) Hold the ball on high-pressure fuel connector ③ in the vertical position and check that it is aligned with the groove in the hole on the side of the head of the intake manifold; then, align it with the high-pressure fuel connector using the hole in the side of the head and push the high-pressure fuel connector in as far as possible. After tightening the mounting nut (M22 × 1.5) on the high-pressure fuel connector two to three threads by hand, use a torque wrench to tighten it temporarily.



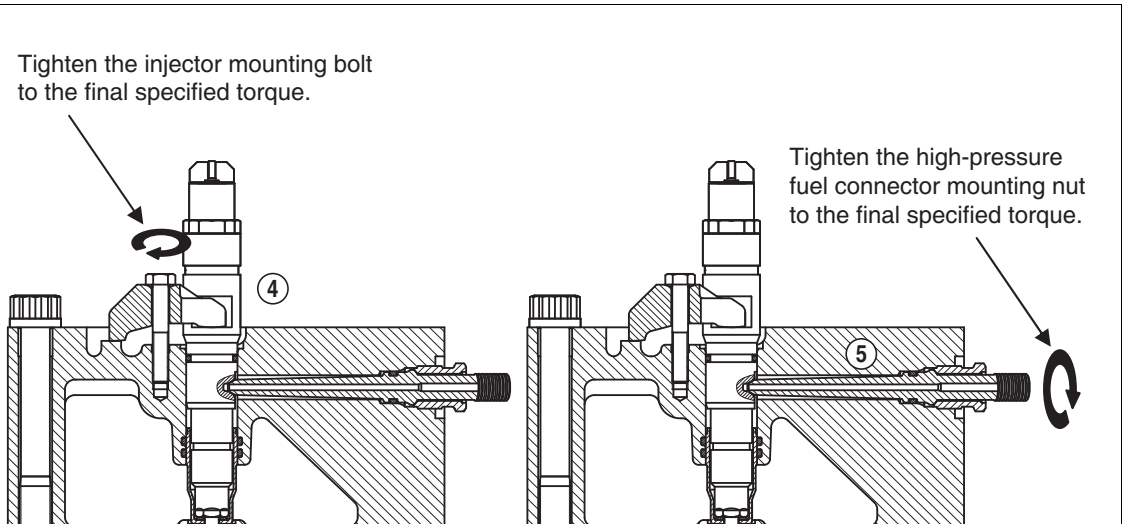
Step one: Installing and temporarily tightening the injector

Step two: Installing and temporarily tightening the high-pressure fuel connector

EDX12190098

Temporary tightening torque	Injector mounting bracket bolt	High-pressure fuel connector mounting nut
	0.3 kg·m	0.3 kg·m

6) Finish tightening injector mounting bracket mounting bolt ④ and high-pressure fuel connector mounting nut ⑤ to their specified torque in order.



Final step: Tightening the injector to the specified torque

Final step: Installing the high-pressure fuel connector mounting nut

EDX12190099

Final torque	Injector mounting bracket bolt	High-pressure fuel connector mounting nut
	3.8 ±0.4 kg·m	5.3 ±0.3 kg·m

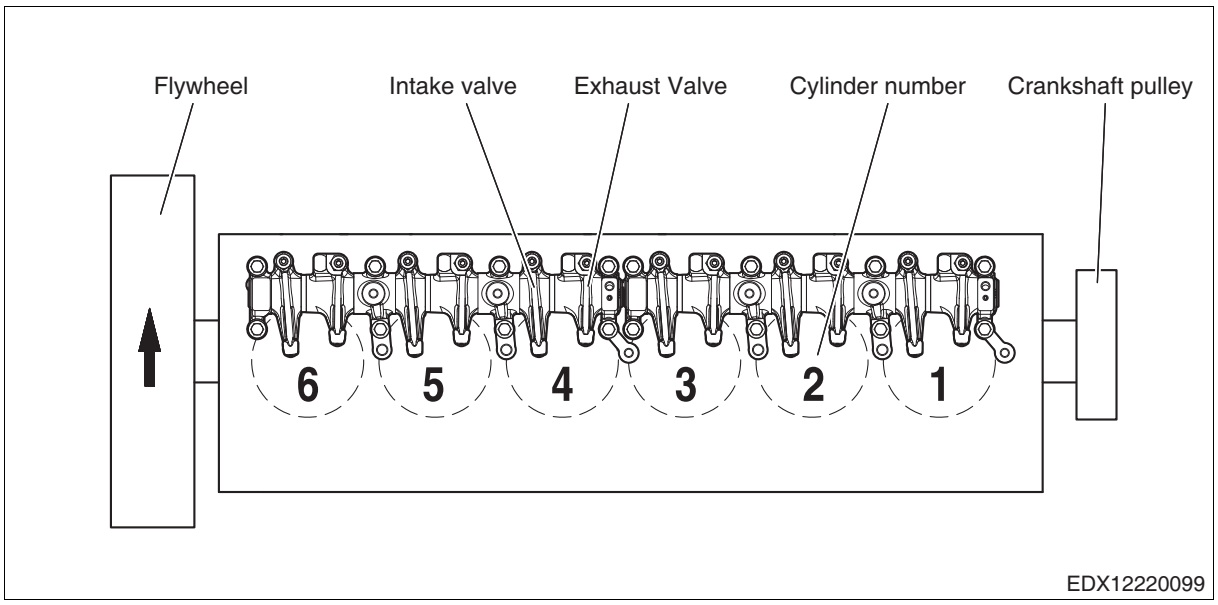
<Valve clearance adjustment guide>

- Turn the crankshaft to set the piston of cylinder no.1 at TDC on the compression stroke. Then, adjust the valve clearance. (Cylinder no. 1 starts at the front of the engine while cylinder no. 6 starts at the rear where the flywheel is mounted.)
- Unscrew the rocker arm mounting nut and fit the feeler gauge between the rocker arm and valve. Adjust each clearance with the adjusting screw, then tighten the mounting nut.
- Adjust the valve clearance as follows when the engine is cold:

Reference value		Allowable measuring tolerance	
Intake valve	**Exhaust Valve**	**Intake valve**	**Exhaust Valve**
0.4 mm	0.7 mm	±0.05 mm	

< How to Adjust Valve Clearance 1 >

- After turning the crankshaft to have cylinder no.1 align with the TDC position, adjust the valve in position "O" in the following image. At this time, cylinder no.1 must be in the TDC position of the ignition stroke (O.T.).



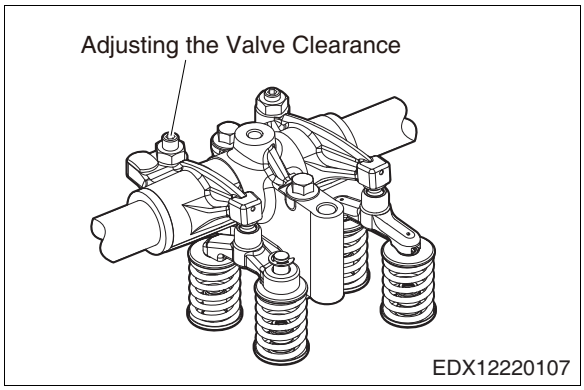
< How to Adjust Valve Clearance 2 >

- Valve adjustments for the valve overlap of each cylinder are to be performed as follows.

Valve overlap of each cylinder (Cylinder firing order)	1	5	3	6	2	4
Valve adjustment cylinder number	6	2	4	1	5	3

- Use a feeler gauge to adjust the valve clearance and tighten the mounting nuts to the specified torque.

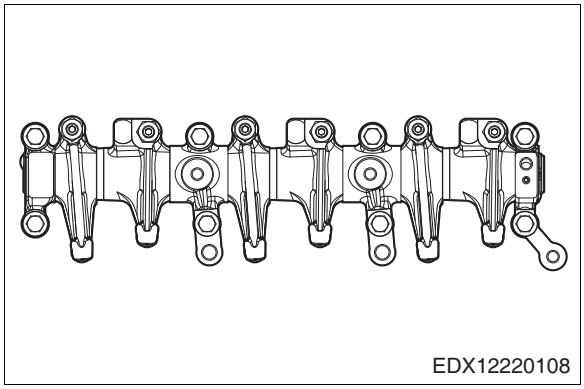
Torque	4.4 kg·m



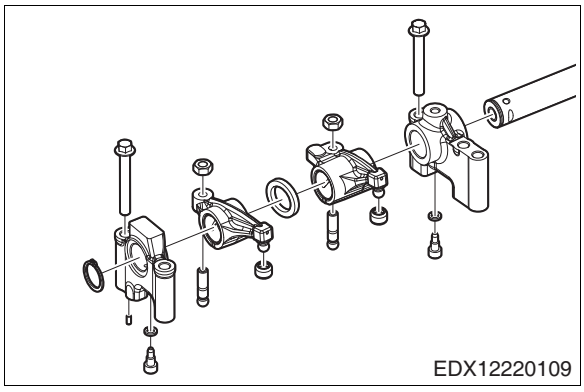
9.3.20. Rocker arm assembly

- Apply oil to the rocker arm bushing and shaft, use mounting bolts to align the parallel pins installed on the bracket with the top of the cylinder head, then tighten the bolts.
- When tightening bolts, tighten them to the specified torque in a zig-zag tightening pattern.

Torque	M10(x8) : 6.2 kg·m M8: 2.2 kg·m

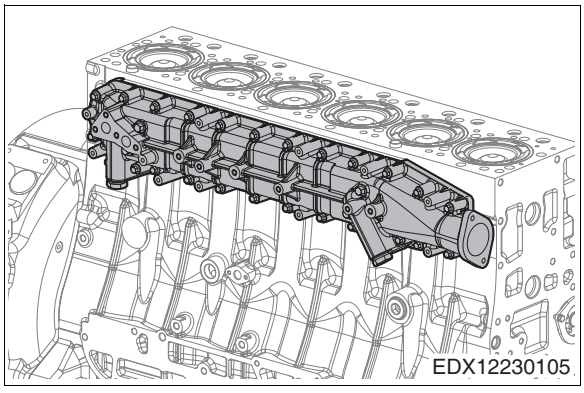


- Temporarily fit the valve clearance adjustment screw into the rocker arm.
- Install the spring, rocker arm, bracket, rocker arm, spring, washer and snap ring in the sequence described.
- Install the rocker arm and bracket in the same direction.



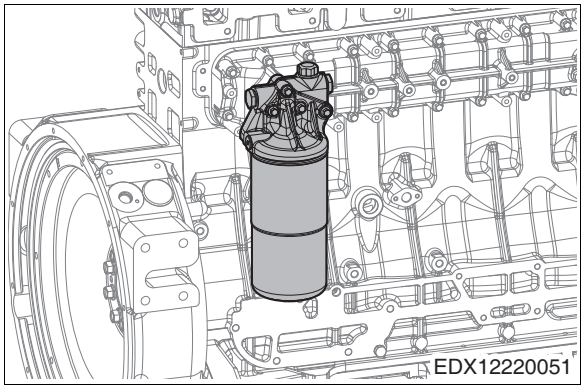
9.3.21. Oil cooler

- Install the oil cooler in the oil cooler cover.
- Insert the gaskets carefully so that there are no oil leaks.
- Install the cover on the cylinder block while taking care not to damage the gaskets.
- Install the connecting pipe between the water pump and oil cooler.



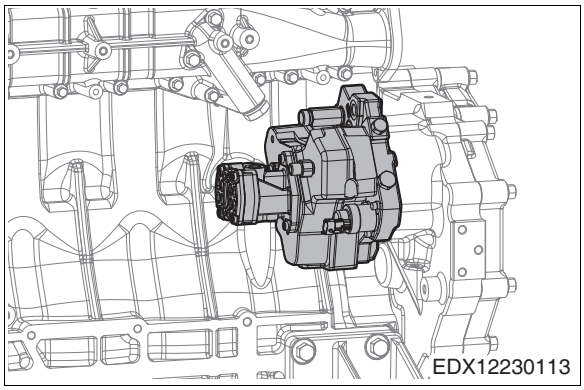
9.3.22. Oil filter

- Install the oil filter in the cylinder block and tighten the mounting bolts.
- Install the packing and use a filter wrench to tighten the cartridge.



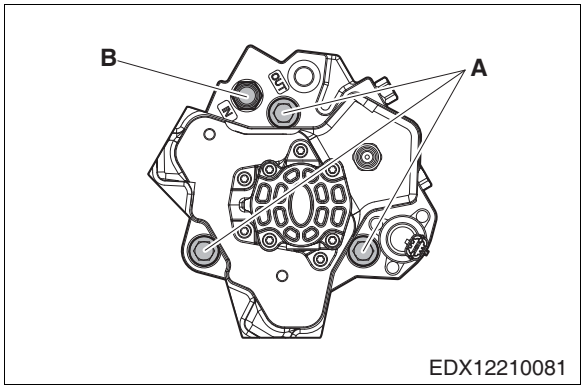
9.3.23. Injection pump

- After greasing the O-ring on the high-pressure fuel pump, align the drive gear spline teeth with the timing gear case and insert it. (Assemble the spline teeth and high-pressure pump teeth regardless of the timing.)



- After inserting the high-pressure pump, assemble mounting bolts (A).
- Install fuel delivery inlet adapter (B) of the fuel pump.

Torque	Mounting bolt (A)	6.5 ±0.5 kg·m
	Adapter (B)	2.5 ±0.2 kg·m

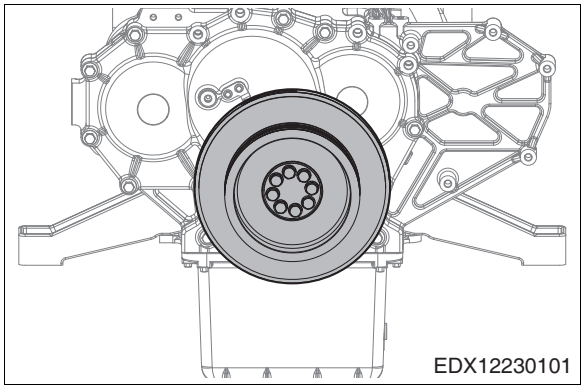


Note:
Install one rubber coated washer on the adapter as well.

9.3.24. Vibration Damper End Play

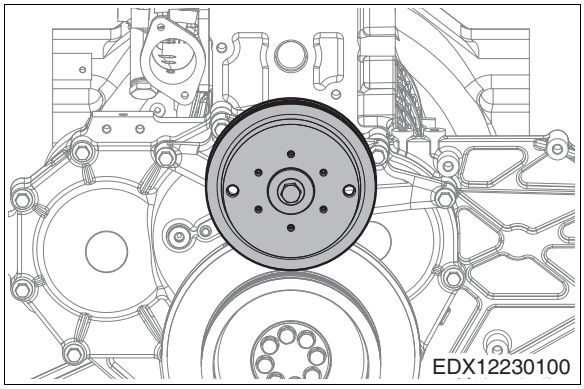
- Install a vibration damper on the crankshaft pulley.
- After installing the crankshaft pulley assembly on the crankshaft, tighten the bolts and thrust washers.

Torque	22 kg·m



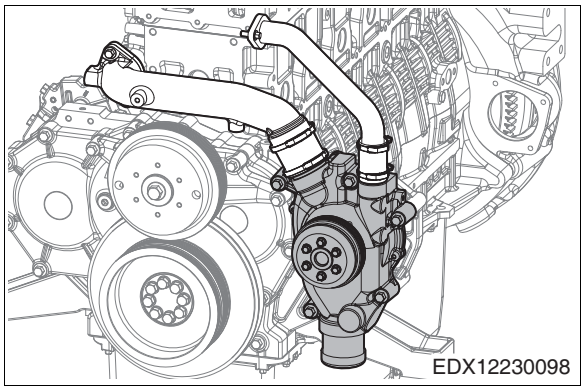
9.3.25. Fan Drive Pulley

- After fitting a long bolt into the mounting hole on the pulley, install the pulley on the fan mounting bracket.



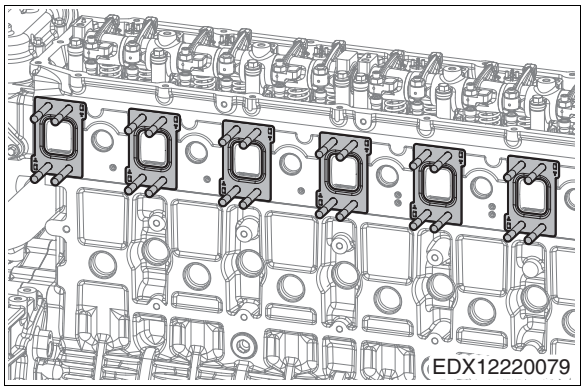
9.3.26. Water Pump

- Connect the coolant pipe and bypass pipe to the water pump.
- Connect the coolant pipe to the expansion tank.



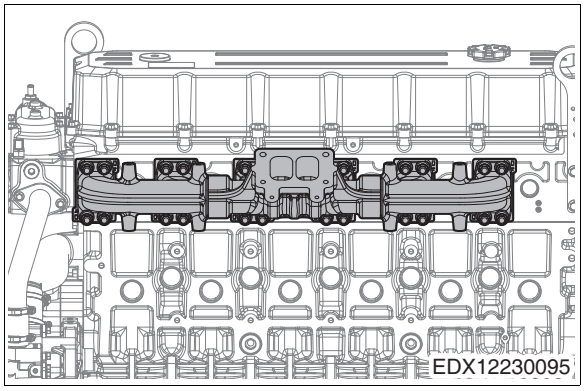
9.3.27. Exhaust manifold

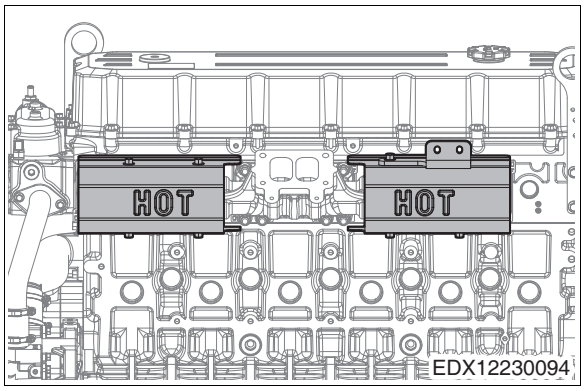
- Align the gasket and exhaust port of the cylinder head so that the "T" marking on the gasket is at the top, then install the exhaust manifold gasket on top of the stud bolts.



- Install the exhaust manifold and then install the heat shield.

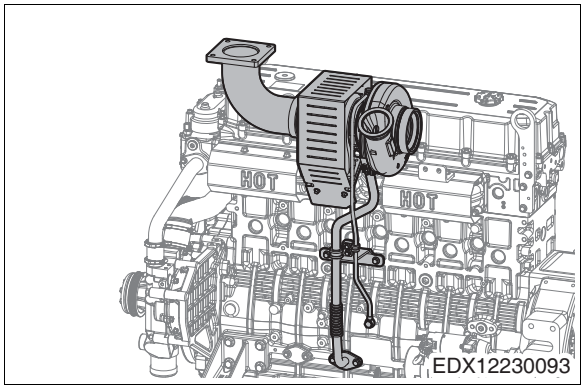
Name	Torque
Exhaust manifold	6.6 ±0.66 kg·m
Heat shield mounting bolt	4.4 ±1.1 kg·m





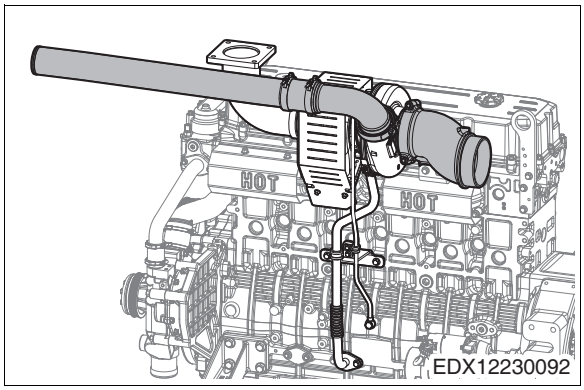
9.3.28. Turbocharger

- Before tightening the nut, install a new gasket. Then, install the turbocharger.
- Install the heat shield and the periphery pipes.
- Install the oil delivery pipe and return pipe.



Name	Torque
Turbocharger	6.6 ±0.66 kg·m
Heat shield	2.2 ±0.55 kg·m
Oil delivery and return pipes	2.2 ±0.22 kg·m
	3.0 ±0.30 kg·m (Hollow screw)
V-clamp	0.8 ±0.08 kg·m
Compressor inlet pipe	2.2 ±0.55 kg·m
Pipe bracket	4.4 ±1.1 kg·m

- Assemble the brackets around halfway with the intake pipe, use a rubber hose to connect the turbocharger and intake pipe, then finally, install the brackets completely.

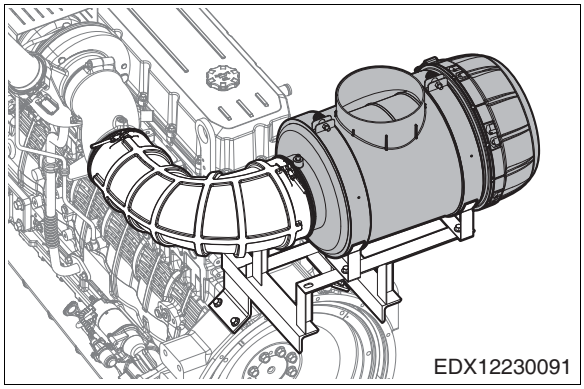


Name	Torque
Compressor inlet pipe	2.2 ±0.55 kg·m
Pipe bracket	4.4 ±1.1 kg·m
V-clamp	0.8 ±0.08 kg·m
Hose clamp	0.6 ±0.06 kg·m

9.3.29. Air cleaner (optional)

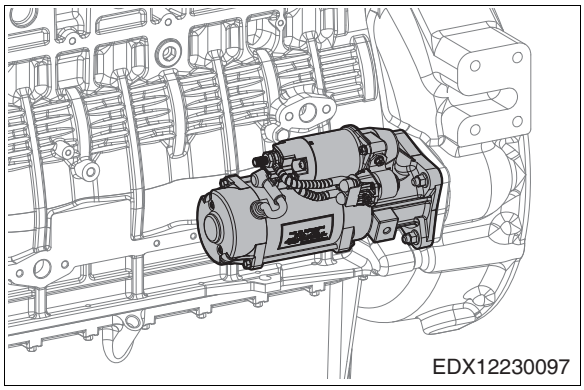
- After installing the air cleaner bracket, install the air cleaner mounting clamp.
- Connect the hose between the air cleaner and pipe, and then tighten the clamp.

Name	Torque
Air cleaner bracket	2.2 ±0.55 kg·m
Air cleaner clamp	2.2 ±0.55 kg·m
Hose clamp	0.6 ±0.06 kg·m



9.3.30. Starter

- Assemble the starter in its proper position in the flywheel housing.

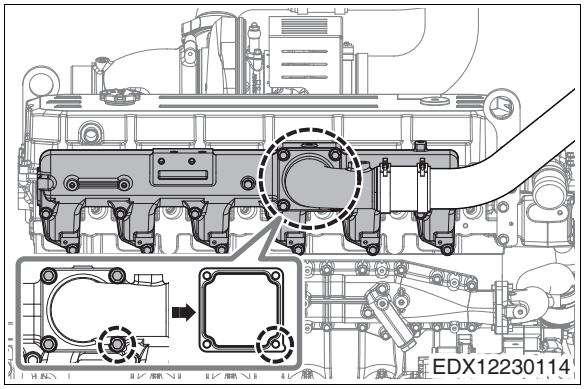


9.3.31. Intake manifold

- Before assembling the intake manifold, install the gaskets on the intake manifold.

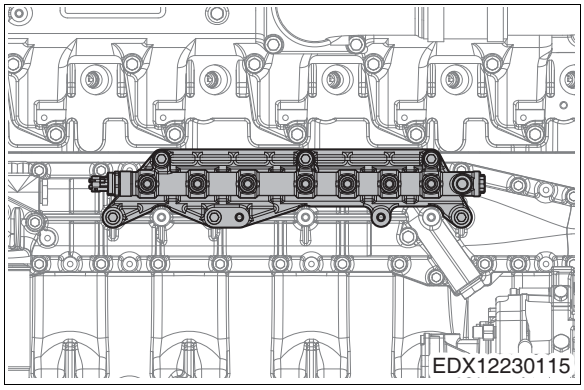
Name	Torque
Intake manifold	4.4 ±1.1 kg·m
Intake pipe	4.4 ±1.1 kg·m

Note:
Check the direction of the protrusion on the steel gasket before its installation.



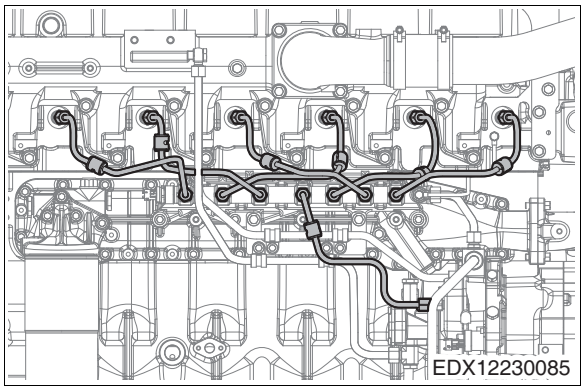
9.3.32. Common rail and high-pressure fuel pipes

- Install the common rail bracket and the common rail on the oil cooler.
- Install the high-pressure pipe between the common rail and the fuel pump.



- Install the high-pressure pipes between the high-pressure fuel connectors and the common rail.

Name	Torque
Common rail bracket, Common rail mounting bolts	2.2 kg·m
High-pressure fuel pipe nut torque	4.0 ±0.4 kg·m

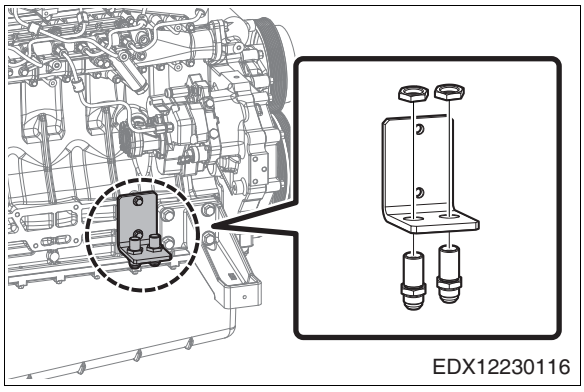


9.3.33. Fuel delivery pipe and fuel return pipe

Fuel delivery/return bracket

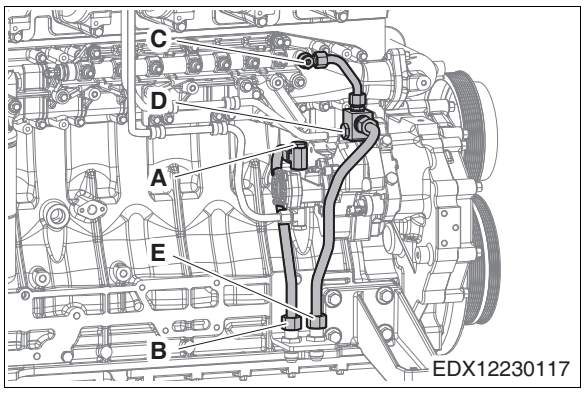
- Assemble the fuel delivery/return bracket using mounting bolts.
- Install the fuel delivery/return adapter and nuts.

Name	Torque
Nut tightening torque	7.5 kg·m



Fuel delivery pipe

- Install the fuel delivery pipe between the fuel pump and the fuel delivery/return bracket.
- Temporarily tighten the fuel pump using hollow screw (A), and temporarily tighten the bracket using union nut (B).



Note

When installing hollow screw (A), assemble one rubber coated washer on each side of the banjo union as well.

Fuel Return Pipe

- Install the fuel delivery pipe between the common rail, the fuel pump and the fuel delivery/return bracket.
- Temporarily tighten the common rail and fuel pump using hollow screws (C, D), and temporarily tighten the bracket using pipe union nut (E).

Note

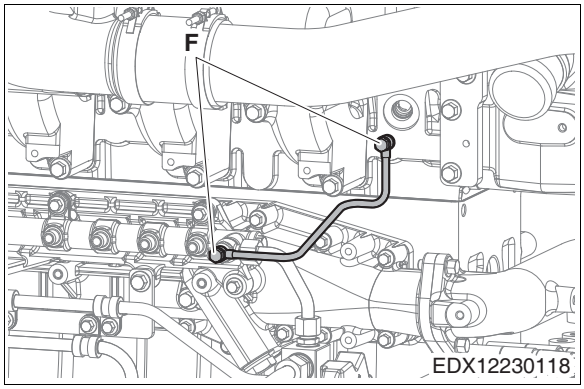
When installing hollow screws (C, D), assemble one rubber coated washer on each side of the banjo union as well.

- Finish tightening the hollow screws on the common rail and fuel pump.

Name	Torque
Hollow screw tightening torque	2.5 kg·m

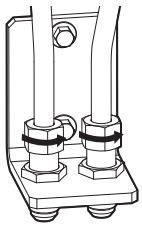
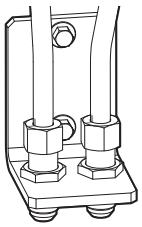
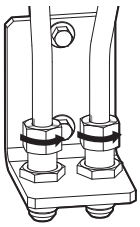
- Install pipe union nut (E) in the same way as the cutting rings.
- Install the injector fuel return pipe between the cylinder head and the common rail.
- Install it using hollow screws (F).

Name	Torque
Hollow screw tightening torque	0.8 kg·m



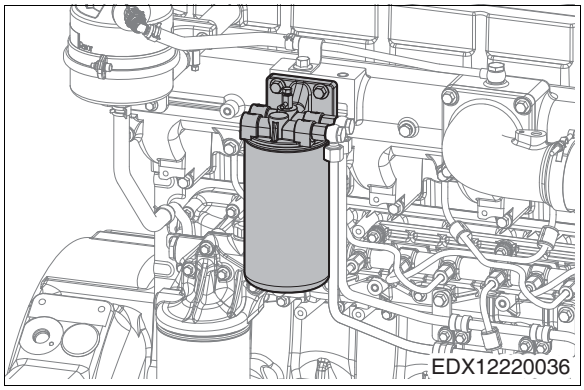
Note

When installing hollow screws (C, D), assemble one rubber coated washer on each side of the banjo union as well.

		
Turn the union nut by hand as far as it will go.	Align the union nut with the pipe in a straight line.	Turn the union nut 120°. (Two movements of the edges of the union nut)

9.3.34. Fuel Filter

- Assemble the fuel filter and intake manifold.
- Assemble the fuel supply hose in the direction indicated on the fuel filter head in order for fuel to be delivered in the following order: **primary fuel filter → fuel supply pump → secondary fuel filter → fuel injection pump**.

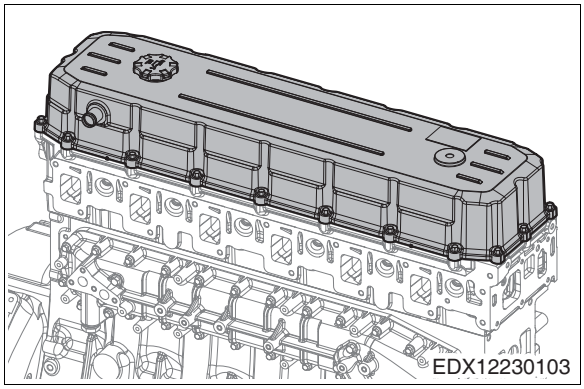


9.3.35. Cylinder head cover

- Assemble the cover packing with the cover and install the cover on top of the head, then tighten the mounting bolts to the specified torque in the following sequence.

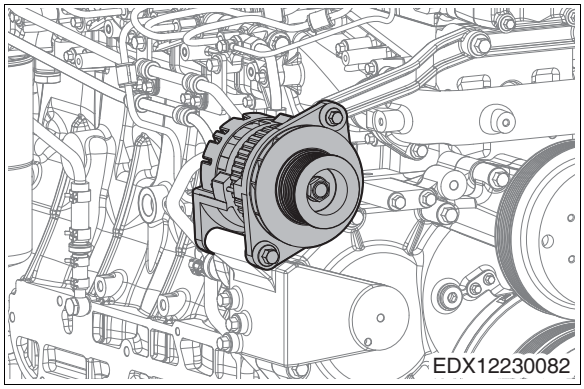
Torque	2.2 kg·m

- Assemble the breather hose and PCV valve.



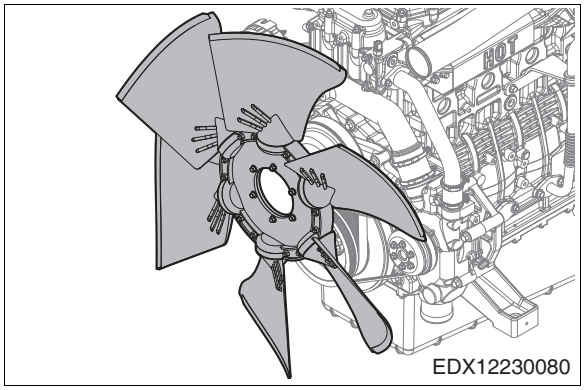
9.3.36. Alternator

- Install the alternator mounting brackets.
- Install the alternator (including the mounting bolts) in the mounting brackets.



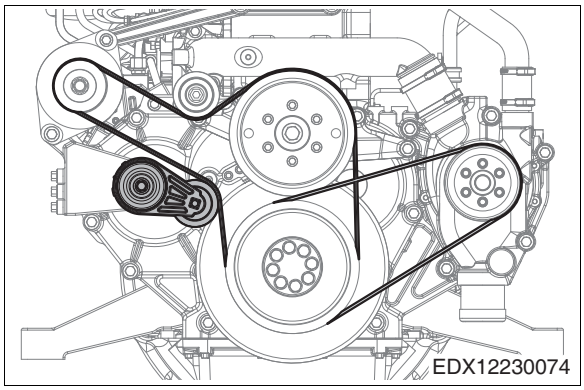
9.3.37. Cooling fan

- Install the cooling fan and flange, then tighten the mounting bolts.



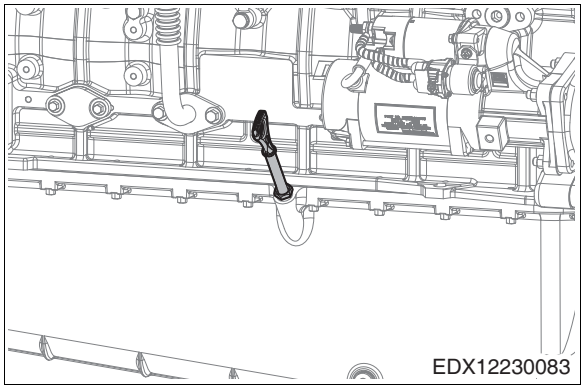
9.3.38. V-Belt

- Use a tool in the square groove of the auto tensioner to rotate the tensioner clockwise, then install the Micro V-Belt on the crank pulley, alternator pulley and fan drive pulley.



9.3.39. Oil level gauge

- Assemble an oil dipstick and guide tube on the oil pan.



9.4. Engine Break-In

Refer to "Engine Break-In" in the chapter "Initial Start-Up and Operation".

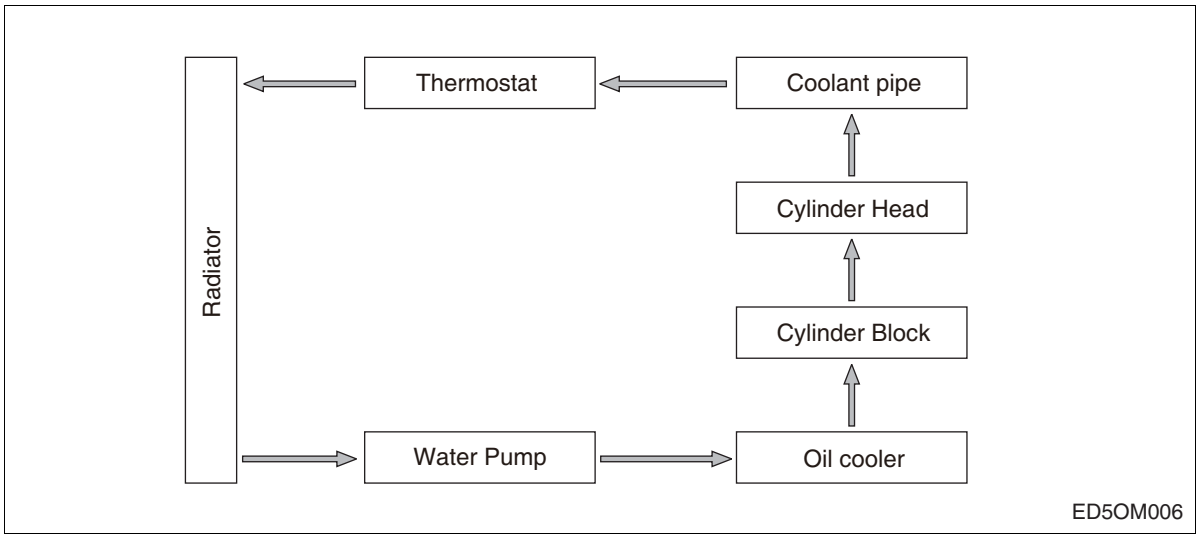
10. Maintenance for Main Components

10.1. Cooling System

10.1.1. General Information

This engine is water-cooled. Heat formed during the heating of the combustion chamber and engine oil is cooled by the coolant and released to the outside, the result of which is that the engine operates normally.

In the cooling system, the coolant supplied by the water pump circulates around the oil cooler through a coolant pipe and absorbs heat from the oil before then flowing through the water jacket in the cylinder block and water passage in the cylinder head to absorb the heat in the combustion chamber. Coolant absorbs heat from both oil and the combustion chamber as it passes through the coolant pipe to the thermostat. It circulates through the water pump, where the coolant temperature is lower than the thermostat's valve opening temperature, and then circulates through the radiator if the coolant temperature is higher than the valve opening temperature. Heat absorbed by the coolant is released and cooled in the radiator, then the coolant is recirculated into the water pump.



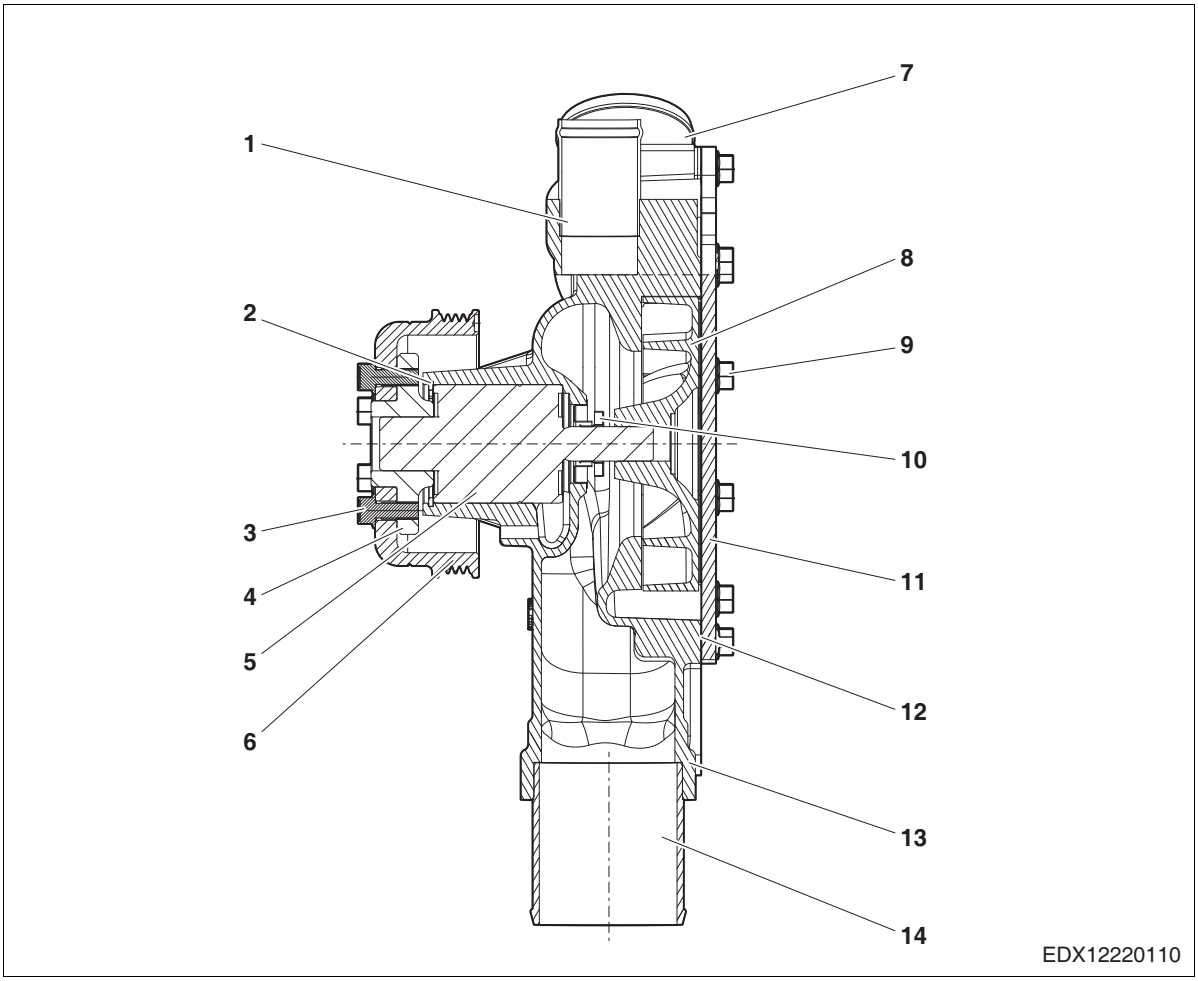
● **Specification**

Item	Specification
1. Water Pump	Centrifugal
Type	
Delivery	Around 540 L/min.
Pump delivery speed	3,150 rpm
Pump delivery back pressure	760 mmHg
2. Thermostat	
Operating temperature	71 ~ 85°C
3. Coolant fan and belt	
Fan diameter - number of blades	∅810 - 7
Fan belt tension	15 mm / bends when pressed down with the thumb

10.1.2. Water Pump

- Loosen the bolts (3) and disconnect the pulley (6).
- After slightly heating the hub (4), use a puller jig to remove it.
- Loosen bolt (9) and remove housing cover (7).
- After slightly heating the impeller (8), use a puller jig to remove it.
- Remove the mechanical seal (10).
- Remove the snap ring (2) and the unit bearing (5).
- Reassemble in the reverse order.

In order to reassemble the impeller (8), use a gauge to maintain a consistent clearance (5 ~ 9).



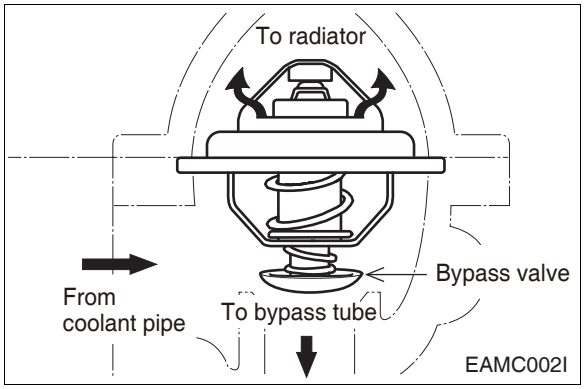
1. Return pipe
2. Snap ring
3. Pulley mounting bolt
4. Hub
5. Unit bearing
6. Pulley
7. Outlet pipe
8. Impeller
9. Cover mounting bolt
10. Mechanical seal
11. Housing cover
12. Gasket
13. Water pump housing
14. Inlet pipe

10.1.3. Thermostat

● General Description and Main Data

The thermostat maintains a consistent coolant temperature (71 ~ 85˚C / 83 ~ 95˚C) while preventing heat loss in order to enhance the thermal efficiency of the engine.

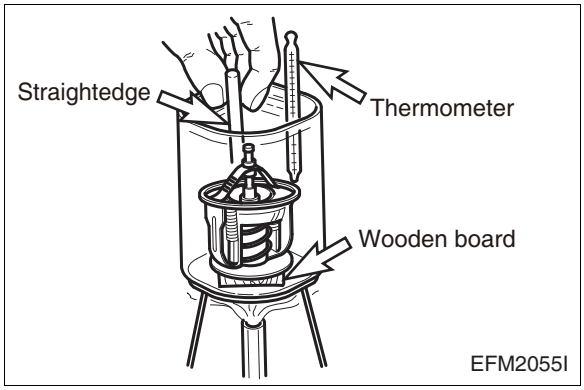
In other words, if the coolant temperature is low, the thermostat valve closes so that the coolant bypass goes directly into the water pump. Thus, when the coolant temperature rises and the thermostat valve opens completely, the bypass circuit closes and a water passage opens in the direction of the radiator so that coolant is forced to flow into the radiator.



Item	Specifications
Type	Wax pellet
Opening temp.	71˚C
Full opening temp.	85˚C
Valve lift	8 mm or higher

● Finished

1) Check whether the wax pellet and spring are damaged.
2) After placing the thermostat in a container of coolant, heat the coolant slowly and inspect the temperature along with the thermostat. The thermostat is normal if the valve lift is 0.1mm (start of opening) at 71˚C and over 8mm (completely open) at 85˚C.



● **Precautions when replacing and handling the thermostat**

1) Handling Precautions

Wax pellet thermostats do not respond to fluctuations in coolant temperature as quickly as bellows-type thermostats. The reason that the reaction is relatively slow is because wax pellet thermostats usually have a high thermal capacity. Thus, in order to keep the coolant temperature from rising suddenly, be sure to idle the engine sufficiently before operating it. In cold weather, do not run the engine with an excessive load or speed immediately after starting the engine.

2) When draining or refilling coolant, do it slowly in order to allow enough air to leave the entire cooling system.
3) Replacing the thermostat

If a defect is found in the thermostat, replace it with a new one.

10.1.4. Diagnosing and Troubleshooting Problems

Problem	Possible cause	Troubleshooting measures
1. Overheated engine	● Insufficient coolant	● Add coolant.
	● Weak radiator cap pressure valve spring	● Replace cap.
	● Loose or damaged fan belt	● Adjust or replace fan belt.
	● Fan belt contaminated with oil	● Replace fan belt.
	● Thermostat not working	● Replace thermostat.
	● Defective water pump	● Repair or replace.
	● Scale buildup clogging coolant passage	● Clean radiator and coolant Clean.
	● Imprecise injection timing	● Adjust injection timing core.
	● Restricted radiator core	● Clean radiator exterior.
	● Damaged cylinder head gasket causing gas leak in water jacket	● Replace cylinder head gasket.
2. Overcooling engine	● Thermostat not working	● Replace thermostat.
	● Ambient temperature too low	● Install a radiator curtain.
3. Insufficient coolant	● Leaky radiator	● Fix or replace.
	● Loosely connected or damaged radiator hose	● Retighten clamp or replace hose.
	● Weak radiator cap valve spring	● Replace cap.
	● Leaky water pump	● Repair or replace.
	● Loosely connected or damaged heater hose Damaged	● Tighten or replace hose.
	● Leaky cylinder head gasket	● Replace cylinder head gasket.
	● Cracked cylinder head or cylinder block	● Replace cylinder head block.
4. Noise occurring in cooling system	● Defective water pump bearing	● Replace bearing.
	● Loosely mounted or bent fan	● Retighten or replace fan.
	● Imbalanced fan	● Replace fan.
	● Defective fan belt	● Replace fan belt.

10.2. Lubrication System

10.2.1. General Description and Main Data

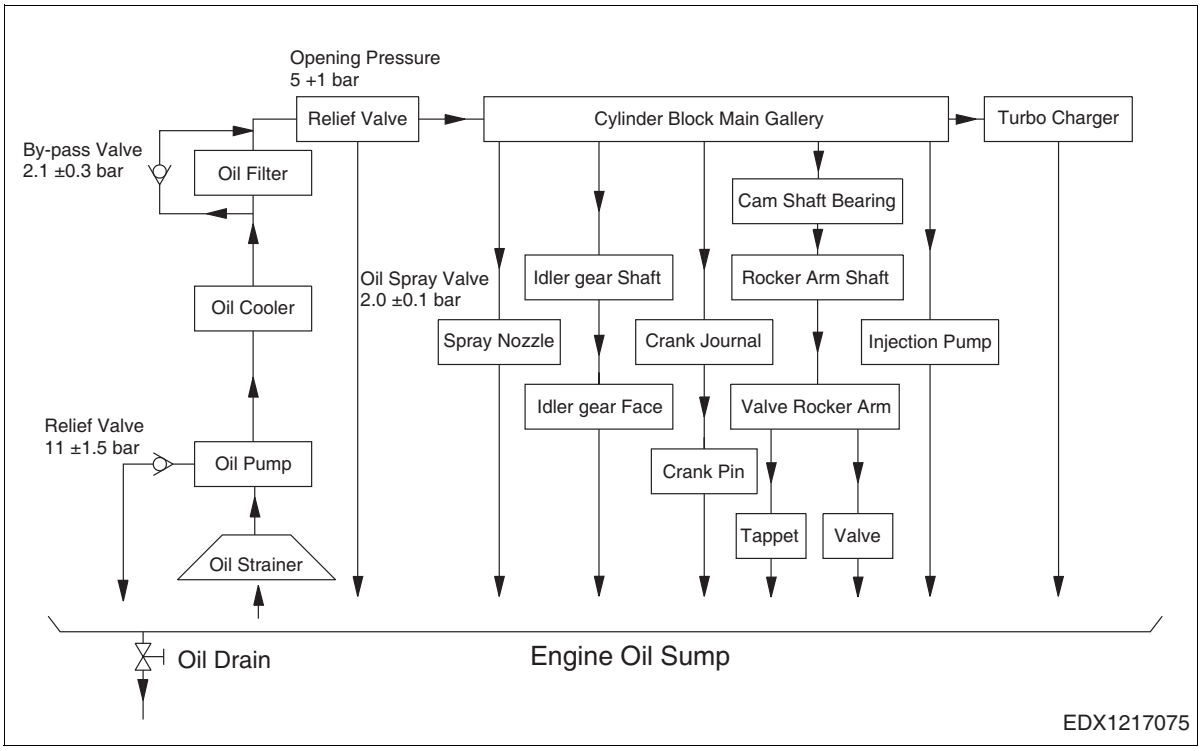
● **General Description**

All engine oil delivered from the oil pan by the gear-operated oil pump is filtered through the oil cooler and oil filter. Oil filtered in this way is distributed by force through the main oil gallery of the cylinder block which lubricates various sliding components, as well as through the fuel injection pump, thereby achieving normal engine performance.

● **Specifications**

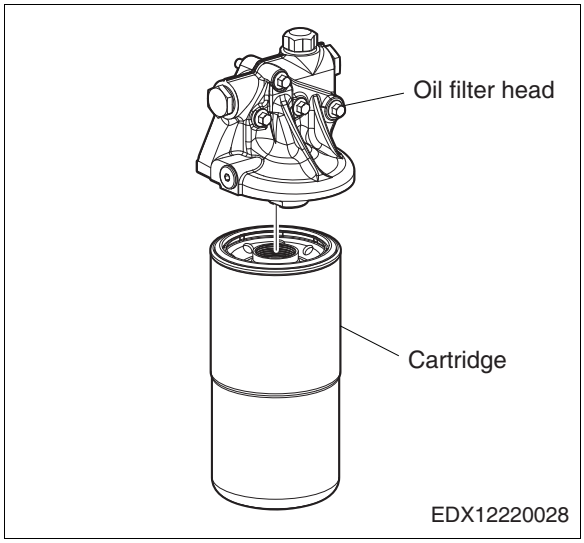
Item	Specifications	Item	Specifications
Lubrication System	Forced pressure Circulation	Filter element bypass valve opening pressure	3.2 ±0.3 kg/cm^2
Type of oil pump	Gear type	Main oil gallery relief valve opening pressure	5.0 ~ 1.0 bar
Relief valve opening pressure	11 ±1.5 kg/cm^2		
Spray nozzle valve opening pressure	2.0 ±0.1 kg/cm^2 Full flow		
Oil filter			

● **Schematic Diagram of Lubrication System**



10.2.2. Oil filter

The oil filter installed in this engine is a cartridge-type filter which must be replaced with a new filter at the specified intervals.



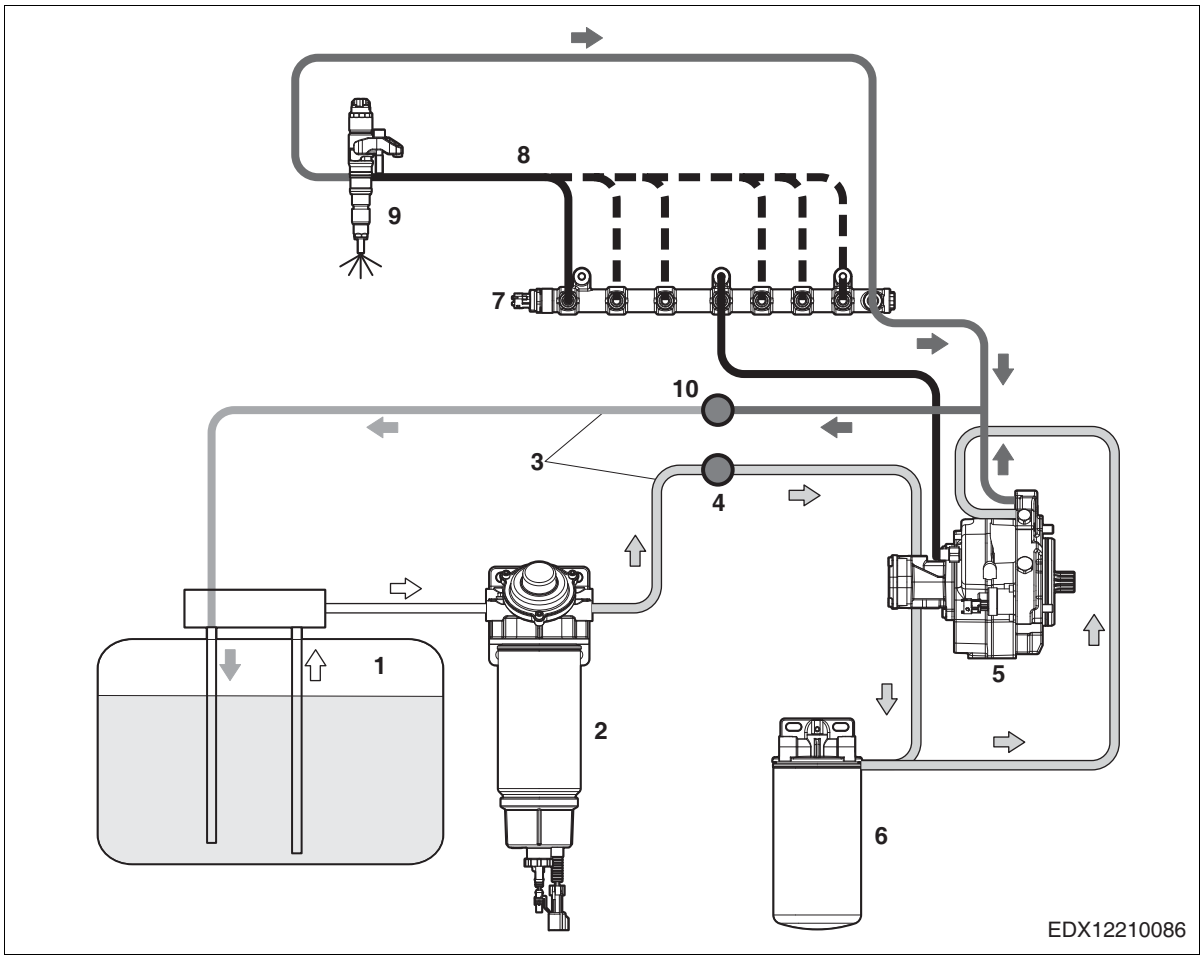
10.2.3. Diagnosing and Troubleshooting Problems

Problem	Possible cause	Troubleshooting measures
1. Excessive oil consumption	● Poor oil quality ● Leaky oil seal or packing ● Worn piston or piston ring ● Worn cylinder liner ● Seized piston ring ● Worn valve guide oil seal, valve guide or valve stem	● Use the recommended oil. ● Replace. ● Replace piston or piston ring. ● Replace cylinder liner. ● Replace piston or piston ring. ● Replace.
2. Excessively low oil pressure	● Poor oil quality ● Seized relief valve ● Restricted oil pump strainer ● Worn oil pump gear ● Cracked oil pump delivery pipe ● Defective oil pump ● Defective oil pressure gauge ● Various worn bearings	● Use the recommended oil. ● Replace. ● Clean strainer. ● Replace. ● Replace. ● Fix or replace. ● Fix or replace. ● Replace.
3. Oil performance quickly degraded	● Restricted oil filter ● Gas leak ● Using incorrect oil	● Replace filter element. ● Replace piston ring and cylinder liner. ● Use the recommended oil.

10.3. Fuel system

10.3.1. Fuel system information

This engine is equipped with a high-pressure common rail fuel injection system and consists of the components shown in the "fuel system schematic diagram" below. The system is designed to function optimally according to the engine performance.
After leaving the fuel tank and passing through the primary fuel filter (oil-water separator), fuel is filtered of all water and large particles of foreign matter; then, the fuel is sent to the secondary fuel filter by the low-pressure gear pump installed in the high-pressure fuel pump. Here, small particles of foreign matter which may cause problems in the injection system are removed. Then, after the fuel is pressurized to a suitably high pressure for the required engine performance, the fuel is sent to the common rail where it is injected into the combustion chamber at a high pressure by injectors controlled by the ECU. The fuel remaining after combustion is complete and the fuel used to lubricate and cool the high-pressure pump, common rail and injectors are gathered together and returned to the fuel tank.

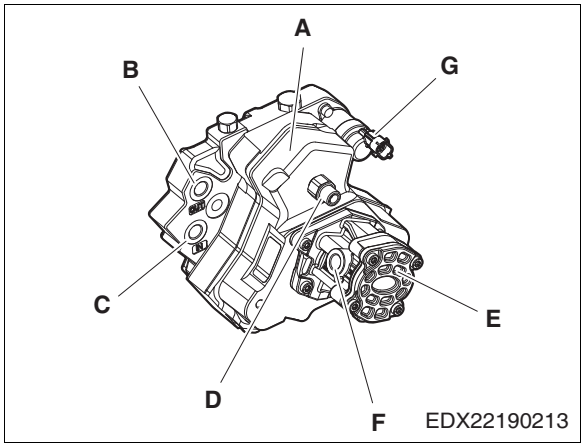


No.	Part Name
1.	Fuel Tank
2.	Primary Fuel Filter
3.	Fuel hose SAE J516 37° FLARE COUPLING (7/8-14 UNF)
4.	Engine fuel inlet port (7/8-14 UNF SAE J516 37° MALE CONE)
5.	High-pressure fuel pump

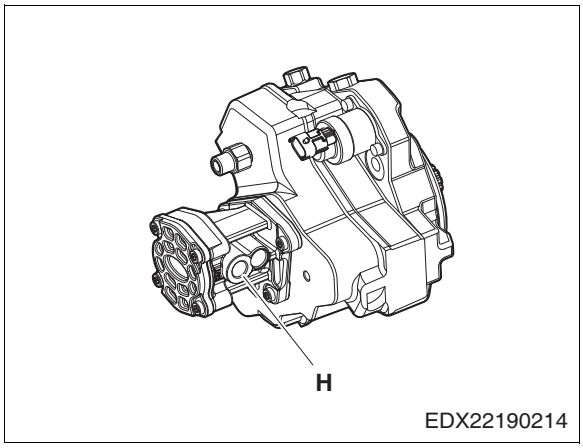
No.	Part Name
6.	Secondary fuel filter
7.	Common rail
8.	High-pressure fuel pipe
9.	Injectors
10.	Engine fuel outlet port (7/8-14 UNF SAE J516 37° MALE CINE)

10.3.2. High-pressure fuel pump

The high-pressure fuel pump consists of the pump body, the low-pressure fuel pump, and the metering unit.
The high-pressure fuel pump pressurizes fuel from the low-pressure fuel pump and secondary fuel filter to the high pressures (DX12: 1,800 bar) required for engine operation and supplies this high-pressure fuel to the common rail and injectors. The metering unit controls the amount of fuel supplied to the common rail depending on the engine load conditions.

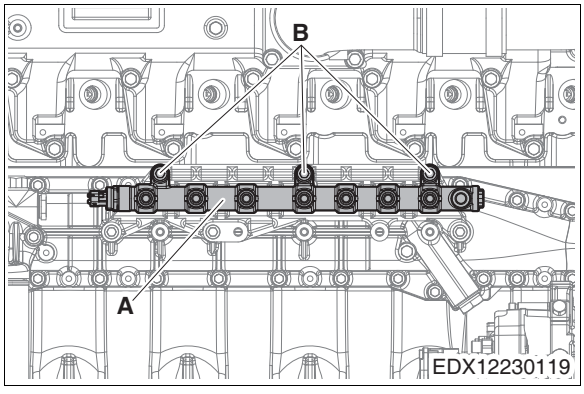


A	High-pressure fuel pump
B	High-pressure fuel pump return fuel outlet (To. Engine fuel outlet port)
C	High-pressure fuel pump inlet (From. Secondary fuel filter)
D	High-pressure fuel pump inlet (To. Common rail)
E	Low-pressure fuel pump
F	Low-pressure fuel pump inlet (From. Engine fuel inlet port)
G	Metering unit
H	Low-pressure fuel pump outlet (To. Secondary fuel filter)



10.3.3. Common rail

The common rail consists of the common rail body, pressure sensor, and pressure limiter valve. The common rail maintains a constant fuel pressure (DX12: 1,800 bar) required by the injectors for fuel injection regardless of the engine load and operating mode.

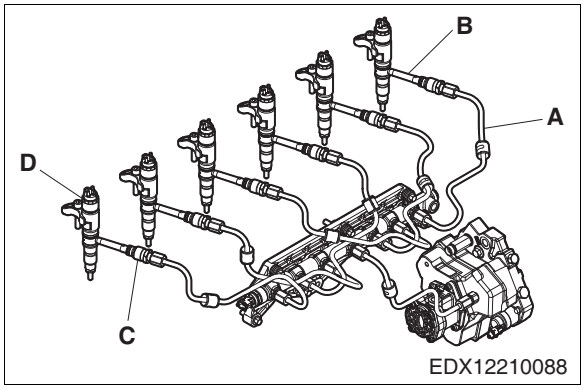


A	Common rail
B	Bolts (M8 x 1.25 x 35 mm)

10.3.4. High-pressure fuel pipe

The high-pressure fuel pipes consist of pipes for transporting fuel, nuts for securing the pipes, and washers for distributing stress between the nuts and pipes. They serve to deliver high-pressure fuel compressed in the common rails to the injectors.

A	High-pressure fuel pipe
B	High-pressure fuel connector
C	High-pressure fuel connector nut
D	Injectors



10.3.5. Injectors, High-Pressure Fuel Connectors

The injectors serve to inject fuel into the combustion chamber by controlling the solenoid valves based on signals from the ECU. The high-pressure fuel connectors consist of the connector body, edge filter, and O-ring for preventing leaks in the return fuel. The connectors are used to deliver fuel from the high-pressure fuel pipes to the injectors through connections between the high-pressure fuel pipes and injectors.

- Fuel lines connecting the common rail to the injectors require particular cleanliness as they lack a filtration function.
- Clean and remove all foreign matter from the holes drilled in the cylinder head for inserting high-pressure fuel connectors and holes for injectors.
- When the injector is disassembled, the high-pressure fuel connector must be replaced with a new one.
- In the event that fuel remaining in the fuel return line enters the combustion chamber while disassembling the injector, it must either be sucked out using a hand pump or discharged by cranking the starter motor with the fuel shut off.

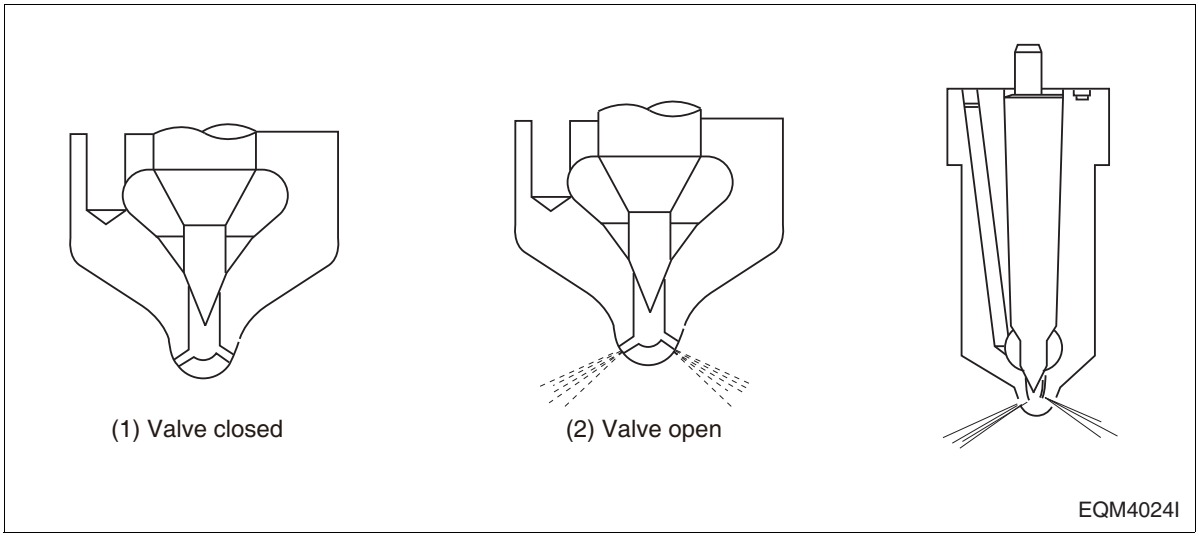
CAUTION

When installing a new high-pressure fuel pipe after disconnecting the high-pressure fuel pipe connected to a high-pressure fuel connector (HPC), make sure to retighten the HPC mounting nuts to the specified torque.
In addition, do not reuse high-pressure fuel pipes as the seal for high-pressure fuel is deformed while tightening them.

10.3.6. Injection nozzle

1) General Description

The pressurized fuel delivered from the fuel injection pump passes through the injection nozzle at a suitable injection pressure and is injected into the combustion chamber, where it is completely combusted to provide effective engine performance.



Appendix

● Tightening Torque for Main Components

Main Components	Screws (Diameter X Pitch)	Strength (Grade)	Tightening Torque	Remarks
Cylinder head bolt	M14 x 1.5	10.9T	1st tightening: 6 kg·m 2nd tightening : 90° 3rd tightening : 90° Final tightening : 30° (Angle torque)	Dodecagon
Cylinder head cover bolt	M8	8.8T	1.2 kg·m	
Connecting rod bearing cap bolt	M16 x 1.5	12.9T	1st tightening: 8 kg·m 2nd tightening: 60°	
Crankshaft main bearing cap bolt	M16 x 1.5	12.9T	1st tightening: 15 kg·m 2nd tightening: 25 kg·m 3rd tightening: 30 kg·m	
Flywheel mounting bolt	M14 x 1.5	10.9T	20.0 kg·m	
Crankshaft pulley mounting bolt	M14 x 1.5	12.9T	22.0 kg·m	
Oil spray nozzle	M8 x 1.25	-	3.1 kg·m	

● Tightening Torque for Injection Pump System

Main Components	Screws (Diameter X Pitch)	Strength (Grade)	Tightening Torque	Remarks
Injection nozzle fixture bolt	M8	12.9T	3.8 kg·m	
Injection nozzle HPC nut	M22 x 1.5		3.5 kg·m	
Injection pump bracket bolt A	M10 x 1.5	10.9T	6.2 kg·m	
Injection pump bracket bolt B	M12 x 1.5		8.0 kg·m	
Injection pump flange bolt	M12 x 1.5	-	11.2 kg·m	
Injection pump drive gear bolt	M24 x 1.5	8.8T	22.0 kg·m	
Injection pump bolt	M10 x 1.5	8.8T	4.4 kg·m	
High-pressure injection pipe mounting cap nut	M8	8.8T	4.0 kg·m	
Injection pump delivery valve holder	-	-	11.5 kg·m	

● Standard Tightening Torque of Bolts

Refer to the following chart for bolts other than those described above.

	Strength										
	3.6	4.6	4.8	5.6	5.8	6.6	6.8	6.9	8.8	10.9	12.9
	(4A)	(4D)	(4S)	(5D)	(5S)	(6D)	(6S)	(6G)	(8G)	(10K)	(12K)
	Elastic limit (kg/mm²)										
	20	24	32	30	40	36	49	54	64	90	108
	Tightening torque (kg·m)										
M5	0.15	0.16	0.25	0.22	0.31	0.28	0.43	0.48	0.5	0.75	0.9
M6	0.28	0.30	0.45	0.4	0.55	0.47	0.77	0.85	0.9	1.25	1.5
M7	0.43	0.46	0.7	0.63	0.83	0.78	1.2	1.3	1.4	1.95	2.35
M8	0.7	0.75	1.1	1	1.4	1.25	1.9	2.1	2.2	3.1	3.8
M8 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

Notes:

1. The torque ratings above were measured to around 70% of the elastic limit of the bolts.
2. Tension is measured by multiplying the tensile strength by the cross section of the threaded area.
3. Special screws should be tightened to only 85% of the standard value.

   For example, MoS2-coated screws should be tightened to 60% of the standard value.

● Chart of Maintenance Standards

Unit : mm

Group	compo-nents	Inspection Items		Standard Value Assembly	Limit Purpose	Repairs	Remarks
Engine Body	Cylinder Block and Liner	Worn inside diameter of cylinder liner		Ø123 ~ Ø123.023	Ø123.223	Replace liner.	Measure non-worn part under upper rim
		Liner projection		0.03 ~ 0.08	-		
		Flatness of upper surface of cylinder block		0.05 / 200	-	Every 200 mm of surface length	Correct with surface grinder
		One-minute Hydraulic Pressure Test (kg/cm^2)		4	-		
	Cylinder Head and Valve	Valve seat recession	Intake	0.66 ~ 0.96	-		For new valve and seat
			Exhaust	0.60 ~ 0.90	-		
		Height		154.7 ~ 155.3	153.9	Replace the cylinder head.	
		One-minute Hydraulic Pressure Test (kg/cm^2)		4	-	Replace if leaking.	Coolant temp. 70°C
Major Moving components	Pistons	Pistons Diameter	25 mm	Ø122.870±0.007	-		
			78.5 mm	Ø122.696±0.009	-		
			122 mm	Ø121.490±0.010	-		
		Clearance between the piston and liner		0.123 ~ 0.162	-		
		Width of piston ring groove	Top ring	3.5	-	If the width of the groove exceeds the specified value, replace the piston.	
			2nd ring	3.060 ~ 3.080	-		
			Oil ring	4.040 ~ 4.060	-		
		Piston protrusion from top of cylinder block		0.204 ~ 0.757	-		Measure non-worn part under upper rim
		Allowable weight difference among pistons		±15g	Max. 96g	Replace piston.	
	Piston ring	Piston ring clearance	Top ring	0.30 ~ 0.45	0.7		Standard gauge I.D.: Ø123
			2nd ring	1.0 ~ 1.2	1.45		
			Oil ring	0.30 ~ 0.45	0.7		
		Piston ring groove clearance	Top ring	0.105 ~ 0.155	-	Replace ring or piston.	Usable clearance limit for standard clearance
			2nd ring	0.070 ~ 0.105	0.125		
			Oil ring	0.050 ~ 0.090	0.110		
		Direction of ring clearance		-	-	Install rings at 120° intervals.	

Unit : mm

Group	compo-nents	Inspection Items	Standard Value Assembly	Limit Purpose	Repairs	Remarks
Major Moving compo-nents	Crank-shaft	Axial runout of journal and pin	0.05	0.1	Correct with a grinder.	Horizontal and vertical direction
		Journal O.D.	Ø95.966 ~ Ø95.988	Ø95.916	Replace crankshaft.	Ø96
		Pin O.D.	Ø85.966 ~ Ø85.988	Ø85.916	Replace crankshaft.	Ø83 g6
		Roundness of journal and pin	0.008	0.025		
		Allowable radial runout of journal and pin	0.01	0.03		
		Allowable parallelism of journal and pin	0.01	0.02		
		Clearance between crankshaft and main bearing	0.072 ~ 0.142	0.20	Replace bearing.	Measure at crown.
		Crankshaft end play	0.1 ~ 0.3	0.5	Replace thrust bearing.	
		Crankshaft main journal runout	0.05	0.1 or less	Correct with press if bent.	Bearing No. 4 (Spare no.1 and 7)
		Crankshaft balance	60	60 or less	At 400rpm	Check the dynamic balance
	Crank-shaft	Journal cap bolt tightening torque (kg·m)	30	-	Apply oil to bolts.	No foreign matter on bearing cap mounting surface.
		Journal bearing crush	0.15 ~ 0.23	-		Tighten the metal cap and unscrew one stud bolt for measurement
		Worn oil seal	-	-	Replace oil seal if oil is leaking.	Use the shim connecting rod to replace it with a new one.

Unit : mm

Group	compo-nents	Inspection Items	Standard Value Assembly	Limit Purpose	Repairs	Remarks
Major Moving compo-nents	Connecting Rod	Clearance between connecting rod bearing and crank pin	0.048 ~ 0.118	0.18	Replace bearing.	
		End play of connecting rod crush	0.220 ~ 0.319	0.5	Replace connecting rod.	
		Clearance between small-end bushing and piston pin	0.050 ~ 0.080	0.1		
		Height of connecting rod bearing crush	0.130 ~ 0.210	-		Once the bearing installation is complete, loosen one of the stud bolts and measure it.
		Allowable weight difference between connecting rods	±9 g	-		
		Connecting rod bearing cap bolt tightening torque (kg·m)	8 kg·m +60°	-	Do not apply oil to the bolt.	Tighten using angle tightening.
	Camshaft	Camshaft O.D.	∅59.860 ~ ∅59.880	∅59.56		∅60
		Clearance between camshaft and bushing	0.045 ~ 0.100	0.20		
		Camshaft axial play	0.14 ~ 0.25	0.30	Replace thrust plate.	
	Timing gear Gear	Clearance between idler gear shaft and insertion hole	0.048 ~ 0.096	0.19		
		End play of idler gear shaft	0.107 ~ 0.203	0.25	Replace thrust collar.	
		Clearance between crank gear and oil pump idler gear	0.060 ~ 0.184	0.26	Replace gear.	
		Between oil pump idler gear and oil pump gear	0.020 ~ 0.292	0.41		
		Crank gear and idler gear A	0.062 ~ 0.194	0.27		
		Between idler gear B and camshaft gear	0.090 ~ 0.236	0.33		
		Clearance between idler gear and fuel injection pump gear	0.090 ~ 0.236	0.33		

Unit : mm

Group	com-ponents	Inspection Items			Standard Value Assembly	Limit Purpose	Repairs	Remarks
Valve System	Valve	Intake valve stem O.D.			Ø7.963 ~ Ø7.977	Ø7.94	Replace valve and valve guide.	When replacing the valve, replace the valve guide as well.
		Exhaust valve stem O.D.			Ø7.950 ~ Ø7.964	Ø7.93		
		Clearance between valve stem and valve guide		Intake	0.023 ~ 0.052	0.10	Replace valve and guide.	
				Exhaust	0.036 ~ 0.065	0.15	Replace	
		Valve Thickness		Intake	3.3 ~ 3.7	2.8	Replace	
				Exhaust	4.0 ~ 4.4	3.5		
		Clearance between valve guide and cylinder head mounting hole			0.01 ~ 0.39			Apply oil to the valve guide and press.
		Allowable radial runout between valve stem and valve head		Intake	0.04 ~ 0.07	0.2	Replace	
				Exhaust	0.06 ~ 0.09	0.25		
		Clearance between valve guide and cylinder head mounting hole			0.01 ~ 0.39	-		Apply oil to the valve guide and press.
		Intake spring	Exterior	Free length	62.5	-		
				Spring tension (P1/P2) kg	44.0 31.6	37.4 ~ 41.4 63.3 ~ 68.3	Replace valve spring.	
				Straightness (compared to free length)	1.6	2.0		
		Exhaust spring	Exterior	Free length	62.5	-		
				Spring tension (P1/P2) kg	44.0 31.6	37.4 ~ 41.4 63.3 ~ 68.3	Replace valve spring.	
				Straightness (compared to free length)	1.6	2.0		
		Valve clearance (when cold)		Intake	0.4 ±0.05	-	Adjust.	
				Exhaust	0.7 ±0.05	-		
		Contact surface of valve stem and rocker arm			-	-	Repair or replace if the end of the arm and stem is severely stained.	
		Clearance between rocker arm shaft and rocker arm bushing			0.015 ~ 0.059	0.12	Replace bushing or shaft.	
		Worn rocker arm shaft			Ø24.953 ~ Ø24.976	Ø24.916	Replace	
		Allowable pushrod taper			0.3	-	Replace	

Unit : mm

Group	com-pone nts	Inspection Items	Standard Value Assembly	Limit Purpose	Repairs	Remarks
Valve System	Tappet	Clearance between tap-pet and cylinder block	0.035 ~ 0.077	0.15	Replace tappet.	
		Tappet O.D.	Ø19.944 ~ Ø19.965	-	Replace tappet.	
		Contact surface of tappet and cam	-	-	If it is exces-sively deformed or worn, ensure to replace it.	
Lubrica-tion Sys-tem	Oil Pres-sure	Oil pressure (normal speed) (kg/cm^2)	4.5 or less	3.0	Correct any oil leaks and/or gaps between each part.	
		Oil pressure (idling) (kg/cm^2)	0.8 ~ 1.4	0.6	Use the recom-mended oil.	
	Oil tem-perature	Max. allowable oil temp. (°C)	-	120		The tempera-ture must not exceed this.
		Allowable short-term oil temperature (°C)	-	130		
	Valve Open-ing Pres-sure	Filter element bypass valve (kg/cm^2)	1.8 ~ 2.4	-	Replace valve.	
		Opening pressure of main oil gallery relief valve (bar)	5.0 ~ 1.0	-		
		Oil pump relief valve (kg/cm^2)	9.5 ~ 12.5	-		
		Control valve for spray nozzle (kg/cm^2)	1.9 ~ 2.1	-		
	Oil filter	Damaged oil filter element	-	-	Clean or replace.	

Unit : mm

Group	compo-nents	Inspection Items	Standard Value Assembly	Limit Pur-pose	Repairs	Remarks
Cooling System	Radiator	Worn, damaged or incor-rectly connected radiator and water pump	-	-	Fix or replace.	
		Leak test (air pressure) (kg/cm^2)	1.0	-	Submerge in water and repair if bubbles form.	
		Pressure valve opening pressure (kg/cm^2)	0.9	-		
		Opening pressure of nega-tive pressure valve (kg/cm^2)	0.2	-		
	Water Pump	delivery rate in liters/ minute - Pump delivery speed 2,250 rpm - Operating temp. 83 ~ 95 °C - Back pressure: 1 kg/cm^2	Approx. 540 ℓ	-		
		Clearance between pump impeller and pump body	0.3 ~ 0.6	-	Replace if the impeller and pump body are touching.	
	Coolant tempera-ture	Operating temperature (allowable temperature) (°C)	71 ~ 85	100	The tempera-ture must not exceed this.	
		Allowable short-term tem-perature (°C)	105	105		
	Thermostat	Thermostat opening temp. (°C) (Less than atmospheric pressure)	71	-	Replace if defective.	
		Fully operational temp. (°C)	85 or less	-		Stroke: Min. 8 mm

Unit : mm

Group	compo-nents	Inspection Items	Standard Value Assembly	Limit Purpose	Repairs	Remarks
Fuel System	Pipes, etc.	Damaged, cracked, loose or incorrectly packed fuel pipe, injection pipe and nozzle holder	-	-	Fix or replace.	
		Damaged fuel filter element	-	-	Clean or replace.	
	Injection pressure of injection nozzle (kg/cm²)		300	-	Adjust with shim.	
	Opening pressure of overflow valve (kg/cm²)		1.5	-	Replace valve.	
	Height of nozzle protrusion on cylinder head (mm)		2.53	-	Replace cylinder head and nozzle.	
	Clearance between injection pump coupling and coupling (mm)		0.2 ~ 0.4	-		
Inspect When Finished	Engine break-in operation		-	-	Refer to attachment "Break-In Operation"	Tighten the head bolts again after breaking in the engine.
	Cylinder Pressure	Cylinder compression pressure of cylinder (kg/cm²)	25 ~ 28	24 or less	Engine overhaul	
		Compressed vs. average	Pressure difference ±10% or less	-	At 200 rpm or higher (20°C)	Repair.