

Operation & Maintenance Manual

DIESEL POWER UNIT ENGINE

DX08, DX08P, DX08V

Preface

This Operation and Maintenance Manual provides information on engine management and maintenance techniques to customers and technicians of HD Construction Equipment's DX08 industrial, electronically controlled diesel engine.

To provide our customers with the best engine possible, we have designed the DX08 industrial, electronically controlled diesel engine to satisfy all requirements for low noise, economic fuel consumption, high speed and durability with the latest technology and quality.

The engine must be operated and maintained both precisely and appropriately in order to maintain the engine in its optimal condition and performance over long periods of time. This Operation and Maintenance Manual contains detailed specifications, reference values, diagnostic techniques, part information and figures for easier and more accurate understanding, maintenance and troubleshooting.

Performing the service work recommended by HD Construction Equipment properly and in the correct order can ensure greater effectiveness of service techniques and protect the safety of workers. Hence, make sure to familiarize yourself with the contents of this Operation and Maintenance Manual thoroughly before handling the engine.

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

We will continue striving tirelessly to satisfy the needs of customers and to provide customers with information on safe and convenient maintenance techniques.

Please do not hesitate to contact us regarding misprints or inquiries concerning the contents of this Operation and Maintenance Manual.

Thank you for purchasing a HD Construction Equipment engine. We hope that this Operation and Maintenance Manual will be useful.

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HD Construction Equipment

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

- * The contents of this operation and maintenance manual are the exclusive property of HD Construction Equipment. Any unauthorized reproduction, printing and distribution thereof are strictly prohibited.

Table of Contents

1. General Preface	1
General Information	3
Danger, Warning, Caution, and Note	4
Emission Information	7
Engine Care	12
2. Engine Operation and Care	15
Starting and Stopping the Engine	17
Engine Break-in	19
Running the Engine in Winter	20
Engine Inspections and Maintenance	21
3. Performance and Specifications	23
Engine Specifications and Performance	25
Engine Performance Curve (LEP00/MFP00/OOP00)	29
Engine Performance Curve (LEP01/MFP01/OOP01)	30
Engine Performance Curve (LEP02/MFP02/OOP02)	31
Outside Drawing of Engine (LEP00/MFP00)	32
Outside Drawing of Engine (LEP01/LEP02/MFP01/MFP02)	35
Outside Drawing of Engine (OOP00)	38
Outside Drawing of Engine (OOP01/OOP02)	41
Engine Serial Number	44
4. Regular Inspections	45
General Information	47
Maintenance Schedule	48
Cooling System	49
Lubrication System	53
Fuel System	57
Intake/Exhaust System	58
Electrical System	60
Other/Driving System	61
5. General Engine Information	63
Method of Indicating Units	65
Tightening Torque	66
Engine Disassembly	69
Engine Assembly	81
6. Cooling System	101
General Information	103
Thermostat	105

7. Lubrication System	107
General Information	109
Oil Pump	111
8. Fuel System	113
General Information	115
High-Pressure Fuel System Components	116
Injector	116
Common Rail	118
Fuel Injection Pump	120
Fuel Delivery Pump	122
9. Intake/Exhaust System	123
General Information	125
Turbocharger	125
10. Cylinder Block/Head	135
General Information	137
Cylinder Block	138
Inspecting the Cylinder Head	140
Rocker Arms	144
Roller Tappets and Pushrods	145
Camshaft	146
11. Electrical System	149
Electronic Components	151
Circuit Diagram	155
Switches and sensors	169
Engine Control Unit (ECU)	185
Starter Motor	188
Alternator	190
12. Other/Driving System	193
General Information	195
Crankshaft	196
Pistons	199
Connecting Rods	201
Miscellaneous	202
13. Aftertreatment System	203
Exhaust Gas Reduction System (LEP00/LEP01/LEP02/MFP00/MFP01/MFP02)	205

1. General Preface

General Information	3
General Information	3
Danger, Warning, Caution, and Note	4
General Information	4
General Precautions	4
Cautions for Starting the Engine	5
Cautions for Inspections and Maintenance	5
General Information	6
Other Safety Instructions and Environmental Pollution.....	6
Use of Genuine Parts.....	6
Emission Information	7
Regulation (EU) 2017/654 ANNEX XV (Applies to customers using equipment in EU only.).....	7
Engine Care	12
Preventing Damage and Wear.....	12
Preventing Pollution	12
Handling Engine Oil	12
Biodiesel Blend Fuel	13
HVO (Hydro treated Vegetable Oil)	13
GTL (Gas To Liquids)	13

General Information

General Information

This Operation and Maintenance Manual provides the most efficient methods for engine maintenance as well as quick, efficient methods to determine the cause of engine faults to ensure that any actions taken by professionally certified maintenance technicians are performed in the most efficient and safest way possible. In the event that the engine is serviced by an untrained technician or in facilities which are not equipped with the specified tools and equipment, the operator and/or others around the engine may sustain life-threatening physical injuries and severe faults may occur in engine performance.

Regular inspections and maintenance are required to maintain long-term optimal engine conditions and performance.

In the event that a part must be replaced, only genuine parts as defined by the parts on the list (PARTS BOOK) should be used.

Using non-genuine imitation parts or recycled parts may cause critical damage and faults in engine performance.

HD Construction Equipment shall not be held liable for any damage or faults resulting from the use of such parts.

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

Some work procedures require special tools.

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

This Operation and Maintenance Manual includes 'Danger,' 'Warning' and 'Caution' items intended to reduce the risk of possible injuries during operation of the engine. Failing to heed this information may lead to severe faults in engine performance and operation, as well as severely injuring workers. Hence, make sure to heed the 'Danger,' 'Warning' and 'Caution' items. Please note that it is not possible for this Operation and Maintenance Manual to include information about every possible danger or unanticipated risk which may occur while handling and servicing the engine.

1. General Preface

Danger, Warning, Caution, and Note

General Information

Instructions which require absolute compliance while performing the inspection, service and troubleshooting procedures provided in this Operation and Maintenance Manual are classified more specifically as 'Danger,' 'Warning' and 'Caution' items. In addition, **Note** is used to provide additional descriptions and information required for maintenance technicians to successfully operate our engines. Complying with the proper service methods and 'Danger,' 'Warning' and 'Caution' items recommended by HD Construction Equipment can both enhance the effectiveness of engine maintenance and prevent physical injuries to workers. However, not every possible danger can be anticipated.

DANGER

Make sure to comply with these instructions; failure to do so may result in life-threatening physical injuries to workers and/or people around the engine.

WARNING

Make sure to comply with these instructions; failure to do so may result either in physical injuries to workers and/or people around the engine or severe environmental pollution.

CAUTION

Make sure to comply with these instructions; failure to do so may result in severe faults in engine performance and operation.

Note) Additional descriptions, information, and references are provided for ease of understanding.

General Precautions

1. To use the engine safely and with optimal performance over long periods of time, engine operators must familiarize themselves with the contents of this Operation and Maintenance Manual and perform both daily and routine inspections.
2. We have divided the contents of this manual into causes of bodily injury, property damage, and causes of pollution. Make sure to comply with all instructions concerning the specified regulations and mounting locations.

WARNING

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

WARNING

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

WARNING

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

WARNING

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

WARNING

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

WARNING

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

WARNING

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

Cautions for Starting the Engine

1. Before starting the engine, make sure to read this Operation and Maintenance Manual carefully and familiarize yourself with the 'Danger,' 'Warning' and 'Caution' items. Please contact HD Construction Equipment if there is any uncertainty regarding the contents of this manual or you have any questions.
2. For the sake of safety, attach a warning to the engine prohibiting anyone but workers from approaching the engine while it is in operation. Make sure to notify the engine operators that the safety of the engine room is their responsibility.
3. Only authorized personnel may start and operate the engine. Never allow an unauthorized person to handle the engine.
4. Do not approach rotating or moving parts while the engine is in operation.
5. Be careful not to touch or come in contact with the engine during operation since it becomes hot during operation.
6. Exhaust gas is poisonous. Before starting the engine, ventilate the workspace sufficiently; when working in an enclosed space, check to ensure that the space is ventilated.
7. Keep vicinity of engine, ladders and stairways free of oil and grease. Accidents caused by slipping can have serious consequences.

Cautions for Inspections and Maintenance

1. Make sure to perform inspections and service work only with the engine stopped. If it is absolutely necessary to perform inspections or service work with the engine running, be careful of any possible accidents and scalding.
2. If performing inspections or service work while the engine is running cannot be avoided, do not get too close to any rotating parts.

DANGER

Severe injuries may occur if gloves or accessories such as necklaces, rings or watches are caught in rotating parts during service work while the engine is running.

WARNING

Do not replace or disconnect any pipes or hoses (engine fuel circuit, engine oil circuit, coolant circuit and compressed air circuit, etc.) while the engine is running. Spurting fluid may cause physical injuries.

3. When draining engine oil, make sure to prepare a container of sufficient size to ensure that engine oil does not overflow.
4. When replacing or refilling engine coolant, open the coolant cap after cooling the engine sufficiently.

WARNING

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

5. Fuel is highly flammable. Smoking or using an open flame near the engine may cause a fire.

WARNING

When fuel needs to be refilled, make sure to add fuel while the engine is stopped.

6. Label and store coolant containers separately to avoid confusion with beverage containers. If coolant is ingested, seek medical assistance immediately.
7. Follow the instructions provided by the battery manufacturer when checking or handling batteries.

WARNING

Battery fluid is toxic, corrosive and explosive. Hence, it should be handled by trained technicians.

8. Only certified service technicians should service and handle the engine.
9. Use proper tools only according to their intended use. Using a worn wrench with a split tip may lead to injuries due to slipping of the tool while working.
10. When lifting the engine with a crane, never allow anyone to stand or pass beneath it. Make sure to check the surroundings and ensure that there is enough safe space to work before lifting the engine.

1. General Preface

11. Before inspecting and replacing parts in electrical systems, disconnect the battery ground cable first. To prevent a short circuit, connect the battery ground cable only after all other work is complete.
12. Before performing arc welding, stop the engine, shut off the power source and disconnect the wire harness connected to the engine control unit (ECU).
13. Do not apply any form of electric or mechanical shock or perform welding on electrical systems or the engine control unit (ECU).

General Information

1. Working on the engine while it is hot may cause burns, so make sure to perform work on the engine only after it has cooled sufficiently.
Before working on fuel lines, use a diagnostic device to check the common rail pressure and engine temperature first.
2. Disconnect the ground cable from the battery to prevent damage to wires and sensors resulting from short circuits.
3. Engine oil and coolant may damage painted surfaces, so label and store them separately in appropriate containers.
4. Store removed parts in a designated area to avoid damaging or contaminating them.
5. For the sake of efficient and safe service work, use the specified tools and special tools.
6. When replacing parts, make sure to replace them with genuine HD Construction Equipment parts. Using imitation or recycled parts may cause severe faults with an impact on engine performance.
7. During service work, replace all parts such as cotter pins, gaskets, O-rings, seal rings, oil seals and washers with new ones. Reusing parts may cause faults in the engine and hinder normal engine performance.
8. To reassemble parts after removing them, make sure to store them in groups in their order of disassembly. In particular, bolts and nuts have different strengths, shapes and tightening torques depending on their mounting locations, so make sure to organize and store them properly.
9. Make sure to clean removed parts in order to remove any foreign matter before inspecting or reassembling them. Use compressed air to clean out oil holes and other holes.
10. Before assembling parts, apply a thin layer of suitable oil or grease to rotating parts or parts requiring lubrication.
11. If necessary, use a designated adhesive when installing gaskets in order to prevent oil or coolant leakage.
12. Tighten bolts and nuts to their specified tightening torque.
13. After completing service work, perform a final inspection and test run to check whether all service work was performed correctly.

Other Safety Instructions and Environmental Pollution

Make sure to comply with the following instructions during engine service work to protect the safety of workers and prevent environmental pollution.

1. The workspace must have low humidity and be well-ventilated.
2. The workspace must be clean, well-organized and free of any open flames.
3. Smoking within the workspace is strictly prohibited.
4. Workers must wear work clothes, protective glasses and safety shoes.
5. Workers may not wear any accessories such as necklaces, rings, watches or earrings.
6. When the engine must be started, ventilate the area sufficiently to prevent carbon monoxide poisoning; then, start the engine in a well-ventilated area.
7. Working on the engine while it is hot may cause burns, so make sure to perform work on the engine only after it has cooled sufficiently.
8. During service work while the engine is running, avoid working on any rotating or moving parts.
9. Dispose of used oil according to the regulations of local public institutions.
10. Spilling or allowing engine oil or fuel to leak into the ground may cause severe environmental pollution of seas, rivers and groundwater.
11. Dispose of anticorrosive agents, antifreeze, filter elements, cartridges, etc. which cannot be diluted, as special waste.
12. Dispose of coolant and special waste according to the regulations of local public institutions.

WARNING

Failing to comply with the regulations of local public institutions may result in legal sanctions for violating regulations on the disposal of environmental contaminants.

Use of Genuine Parts

The engine is a mechanically balanced assembly comprising a large number of parts. Accordingly, regular maintenance and replacement of consumable parts are essential for preventing engine failure and maintaining long-term optimal performance.

We recommend using genuine HD Construction Equipment parts when replacing parts. Using imitation or recycled parts may cause severe engine faults and damage for which HD Construction Equipment shall not be held liable.

Emission Information

Tampering with the engine voids the US and EU type-approval of that particular engine.

Regulation (EU) 2017/654 ANNEX XV (Applies to customers using equipment in EU only.)

HD Construction Equipment provide to the customer all information and necessary instructions for the correct operation of the engine in order to maintain the gaseous and particulate pollutant emissions of the engine within the limits of the approved engine type or engine family. The customer should operate machine in accordance with the following information and instruction.

The customer should operate machine in accordance with the following information and instruction.

Engine operation and maintenance

You must comply with the following things when you operate an engine.





- The engine, including the emissions control system, shall be operated, used and maintained in accordance with the instructions provided to the end users in order to maintain the emissions performance of the engine within the requirements applicable to the engine's category.
- This machine is equipped with an engine exhaust emission control system. The operator is responsible for proper operation and maintenance of the emission controls system. For details, see "Engine Exhaust Emission Control System" in the Operation and Maintenance Manual.
- It is essential to take prompt action to rectify any incorrect operation, use or maintenance of the emissions control system in accordance with the rectification measures indicated by the warnings referred to "Malfunctions & Inducement"
- Where the engine is to be operated within the Union on diesel or non-road gas-oil, a fuel with sulphur content not greater than 10 mg/kg (20 mg/kg at point of final distribution) cetane number not less than 45 and a FAME content not greater than 8% v/v shall be used.
- Use the correct lubrication oil to maintain the performance of the emissions control system. For details, see "Engine Oil Standards" in the Lubrication system.
- Maintain in accordance with the scheduled emission-related maintenance requirements. For details, see "General Conditions" in the Regular inspection table.

1. General Preface

Malfunctions and inducement

The operator will be informed by the operator warning system when the emission control system does not function correctly. Ignoring the operator warning signals will lead to the activation of the operator inducement system, resulting in an effective disablement of machine operation.

Operator warning system and inducement

Diagnosis		Warning Symbols	Action	
Functions	Detection Targets		Low Level Inducement	Severe level Inducement
NOx control diagnosis (NCD)	Regent availability		2.5% after warning, Torque reduction 25%	0% after low level inducement, Torque reduction 50% & engine rpm reduction 60%
	Regent quality		10hr after warning, Torque reduction 25%	10hr after low level inducement, Torque reduction 50% & engine rpm reduction 60%
	Interruption of dosing		10hr after warning, Torque reduction 25%	10hr after low level inducement, Torque reduction 50% & engine rpm reduction 60%
	Malfunction of monitoring		36hr after warning, Torque reduction 25%	64hr after low level inducement, Torque reduction 50% & engine rpm reduction 60%
Particulate control diagnosis (PCD)	Removal of the particulate after-treatment system	Check engine lamp. It's up to the decision of Vehicle maker(s).	PCD related faults are stored in ECU ROM from fault healing during 40 warming up cycle. (=Typically over 20 hours engine operation). Authority must have capability to confirm. (Can be through service tool)	
	Loss of function of the particulate after-treatment system			
	Failures of the PCD system			

1. General Preface

Malfunction table

(P: Plausibility fault, E: Electric fault)

Component	Fault Detection Type*	Actions after fault confirmation						Fault code			
		Check engine lamp activation	Depends on NCD inducement level	Torque reduction (level1 30%)	Torque reduction (level2 50%)	Speed limit	Engine stop	P-code	SPN	FMI	NCD or PCD
CAN communication	E	ON	●					P029D	520656	12	N
	E	ON	●					P029E	520657	12	N
	E	ON	●					P0110	520201	12	N
Nox sensor	P	ON	●					P1205	520794	12	N
	P	ON	●					P1206	520795	12	N
	E	ON	●					P2203	520794	5	N
	E	ON	●					P2216	520795	5	N
	P	ON	●					P2201	520662	0	N
	P	ON	●					P1201	520662	1	N
Supply module	P	ON	●					P1703	520751	12	N
	P	ON	●					P1702	520753	12	N
	P	ON	●					P1105	520752	12	N
	P	ON	●					P20E8	520757	12	N
	P	ON	●					P1106	520209	12	N
	P	ON	●					P1712	520669	12	N
	P	ON	●					P1719	520767	12	N
	P	ON	●					P171C	520769	12	N
	P	ON	●					P1736	520810	12	N
	P	ON	●					P1764	520632	7	N
	P	ON	●					P1765	520632	12	N
	P	ON	●					P1766	520632	31	N
	P	ON	●					P1767	520632	0	N
	P	ON	●					P1768	520632	2	N
	P	ON	●					P1769	520632	1	N
	P	ON	●					P176A	520632	15	N
	E	ON	●					P204D	4334	3	N
	E	ON	●					P204C	4334	4	N
SCR up/down stream temperature sensor	E	Flashing	●					P043D	4363	3	N
	E	Flashing	●					P043C	4363	4	N
	E	ON	●					P0438	4360	3	N
	E	ON	●					P0437	4360	4	N

1. General Preface

Component	Fault Detection Type*	Actions after fault confirmation						Fault code			
		Check engine lamp activation	Depends on NCD inducement level	Torque reduction (level1 30%)	Torque reduction (level2 50%)	Speed limit	Engine stop	P-code	SPN	FMI	NCD or PCD
Urea dosing valve	E	ON	●					P1739	520828	5	N
	E	ON	●					P1718	520765	3	N
	E	ON	●					P1716	520765	4	N
Urea hose line heater	P	ON	●					P1730	520822	12	N
	E	ON	●					P202A	4358	5	N
	E	ON	●					P202F	4358	12	N
	E	ON	●					P202C	4358	3	N
	E	ON	●					P202B	4358	4	N
	E	ON	●					P20C5	4357	5	N
	E	ON	●					P10C5	4357	12	N
	E	ON	●					P20C8	4357	3	N
	E	ON	●					P20C7	4357	4	N
	E	ON	●					P20B1	3363	5	N
	E	ON	●					P10B1	3363	12	N
	E	ON	●					P20B4	3363	3	N
	E	ON	●					P20B3	3363	4	N
Urea pressure pump	P	ON	●					P1723	520771	12	N
	E	ON	●					P208A	520772	5	N
	E	ON	●					P1724	520772	12	N
	E	ON	●					P208D	520772	3	N
	E	ON	●					P208C	520772	4	N
	P	ON	●					P204B	4334	0	N
	P	ON	●					P104B	4334	1	N
Urea quality sensor	P	ON	●					P206C	520811	1	N
Urea reverting valve	E	Flashing	●					P20A0	4376	5	N
	E	ON	●					P20A3	4376	3	N
	E	ON	●					P20A2	4376	4	N
Exhaust temperature Sensor	P	ON	●					P147A	520517	2	N
	P	ON	●					P147B	520518	2	N
DPF differential pressure sensor	P	ON	●					P1456	520621	1	N
	E	ON	●					P2465	4767	3	N
	E	ON	●					P2464	4767	4	N

1. General Preface

Component	Fault Detection Type*	Actions after fault confirmation						Fault code			
		Check engine lamp activation	Depends on NCD inducement level	Torque reduction (level1 30%)	Torque reduction (level2 50%)	Speed limit	Engine stop	P-code	SPN	FMI	NCD or PCD
DOC upstream temperature sensor	P	Flashing						P1457	520621	0	P
	E	Flashing						P0546	4765	3	P
	E	Flashing						P0545	4765	4	P
	E	Flashing						P2084	3242	0	P
DOC/DPF related	P	ON						P1478	520515	2	P
	P	ON						P1479	520516	2	P

The value of the Carbon Dioxide(CO₂) Emissions

This CO₂ measurement results from testing over a fixed test cycle under laboratory conditions a(n) (parent) engine representative of the engine type (engine family) and shall not imply or express any guarantee of the performance of a particular engine.

Engine family name	DX08V
50 Hz	657.0 g/kWh
60 Hz	658.4 g/kWh

1. General Preface

Engine Care

Preventing Damage and Wear

Using the engine for any purpose other than that for which it was designed may cause severe faults in the engine for which HD Construction Equipment shall not be held liable.

For details regarding the intended uses and purposes of the engine, please contact our sales department. Do not adjust, convert or change the engine control unit (ECU) without the authorization of HD Construction Equipment.

When a problem occurs in the engine, locate the cause and resolve the issue immediately to prevent any severe faults.

We recommend using genuine HD Construction Equipment parts when replacing parts. Using imitation or recycled parts may cause severe engine faults and damage for which HD Construction Equipment shall not be held liable.

Make sure to maintain the engine according to the following instructions.

1. Only use clean fuel with the specified grade. Please use the fuel recommended in this Operation and Maintenance Manual.

CAUTION

Using imitation or unspecified fuel may cause severe faults in the engine.

2. Do not operate the engine without lubricant or coolant. Use only the products (engine oil, coolant, anticorrosive agents, etc.) recommended by HD Construction Equipment.
3. Always keep the engine and its surroundings clean.
4. Make sure to use the fuel recommended in this Operation and Maintenance Manual.
5. Use the maintenance schedule to perform inspections and replacements at the specified intervals.
6. Do not stop the engine immediately while it is hot. Instead, idle it for at least 5 minutes so that the engine temperature drops sufficiently.

WARNING

If the radiator cap is opened to add or replace coolant while the engine is overheated, hot coolant will spurt out and may cause serious burns.

7. Check the engine oil level on flat, level ground. Do not fill oil past the upper limit mark on the oil level gauge.

CAUTION

Add engine oil immediately if the engine oil level falls below the lower limit mark on the oil level gauge.

8. If gauges for the battery, oil pressure, coolant temperature, etc. are installed in the machine, always check whether the gauges indicate normal levels.
9. Do not operate the engine without coolant.

CAUTION

Use a mixture of antifreeze and coolant. Using regular water in winter causes coolant flow paths in the cylinder block to freeze, possibly leading to engine damage.

CAUTION

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

Preventing Pollution

Note the following instructions to prevent environmental pollution during engine maintenance.

1. Drain used oil and coolant, etc. into suitable containers.
2. Dispose of used oil and coolant according to the regulations of local public institutions.
3. Be especially careful to ensure that drained oil and coolant do not spill onto the ground or into drains. Otherwise, drinking water sources may be severely contaminated.
4. Set aside oil, filters, filter cartridges, etc. as environmental contaminants and handle and dispose of them according to the specified procedures.
5. Handle and dispose of antifreeze, coolant, and anticorrosive agents as hazardous waste.

Handling Engine Oil

If engine oil comes into contact with skin repeatedly over long periods of time, the skin contracts and dries out, possibly leading to skin irritation. Engine oil contains harmful substances. Hence, make sure to comply with the following safety rules when handling engine oil.

1. Do not come into contact with used engine oil repeatedly over long periods of time.
2. Always wear work clothes and gloves.
3. If engine oil comes into contact with skin, use water and soap or hand cleaner to wash it off immediately.
4. Do not use gasoline, fuel, thinners, solvents, etc. to wipe off skin.
5. Wipe off oil and put on protective skin cream.
6. Do not keep oily gloves or rags in pockets.

WARNING

Dispose of used oil according to the regulations of local public institutions. Engine oil can cause severe environmental pollution if it is spilled on the ground, in drains, sewers, rivers, or seas. Failing to dispose of engine oil properly according to disposal regulations is punishable by law.

Biodiesel Blend Fuel

Note) Biodiesel blend fuel may also be used in this machine.

Biodiesel blend fuel must contain no more than five percent biodiesel mixed with ultra low sulfur petroleum based diesel.

This biodiesel blend fuel is commonly marketed as B5/B7 (US/EU) blended diesel fuel. B5/B7 (US/EU) blended diesel fuel must meet ASTM D975 (US Standard) or EN590 (EU Standard) specifications.

Biodiesel blend fuel unique qualities that should be considered before using in engine.

- Cold weather conditions can lead to plugged fuel system components and hard starting.
- Biodiesel blend fuel is excellent medium for microbial growth and contamination that can cause corrosion and plugging of fuel system components.
- Use of biodiesel blend fuel may result in premature failure of fuel system components, such as: plugged fuel filters and deteriorated fuel lines.
- Shorter maintenance intervals may be required, such as: cleaning the fuel system and replacing fuel filters and fuel lines.
- Using biodiesel blended fuels containing more than five percent biodiesel can affect engine life and cause deterioration of hoses, tubelines, injectors, injection pump, and seals.

Apply the following guidelines if biodiesel blend fuel is used:

- Ensure the fuel tank is as full as possible at all times to prevent moisture from collecting in the fuel tank.
- Ensure that the fuel tank cap is securely tightened.
- Biodiesel blend fuel can damage painted surfaces, remove all spilled fuel from painted surfaces immediately.
- Drain all water from the fuel filter daily before operating the engine.
- Do not exceed engine oil change interval. Extended oil change interval can cause engine damage.
- Before vehicle storage: drain the fuel tank, refill with 100% petroleum diesel fuel, add fuel stabilizer, and operate the engine for at least 30 minutes.

Note) Biodiesel blend fuel does not have long term stability and should not be stored for more than 3 months.

HVO (Hydro treated Vegetable Oil)

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

To the user, HVO is reminiscent of diesel in accordance with EN590, apart from HVO having a somewhat lower density. HD Construction Equipment approves the use of up to 100% HVO for engines in accordance with the EU standard EN15940.

GTL (Gas To Liquids)

GTL is a synthetic fuel that is often refined from natural gas.

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

HD Construction Equipment approves the use of up to 100% GTL in accordance with the EU standard EN15940.

1. General Preface

2. Engine Operation and Care

Starting and Stopping the Engine	17
Preparing to Start.....	17
Starting the Engine	17
Running in.....	17
During Operation.....	17
Stopping the Engine.....	18
Engine Break-in	19
General Information	19
Breaking In New Engines.....	19
Inspection Items.....	19
Operation After Break-in Period.....	19
Inspection After Starting the Engine	19
Engine Oil Pressure	20
Coolant Temperature	20
Engine Speed (rpm).....	20
Running the Engine in Winter	20
Preventing Coolant Freezing	20
Preventing Engine Overcooling	20
Engine Oil	20
Engine Inspections and Maintenance	21
Checking Engine Parts After Prolonged Operation.....	21
Turbocharger Inspections and Maintenance.....	21
Intake System	21
Exhaust System	21
Lubrication System	21

Starting and Stopping the Engine

Preparing to Start

Inspect the following before starting the engine for the first time after purchasing it.

1. Check the fuel, coolant and oil levels before starting the engine; add as necessary.
2. Check whether the engine oil level lies between the upper and lower limit lines on the oil level gauge. The upper and lower limit lines on the oil level gauge indicate the maximum and minimum engine oil levels.

CAUTION

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

3. When adding fuel, oil or coolant, take care not to allow foreign matter to enter the engine; store them in a clean place when not in use in order to prevent contamination. Use only fuel, oil, coolant, etc. recommended by HD Construction Equipment. Otherwise, severe engine faults may occur.

Starting the Engine

Observe the following when starting the engine.

1. Insert key in starting lock.
2. Moving control lever to idle speed.
3. Key switch rotate clockwise.
4. Do not operate for longer than 10 seconds at a time.
5. After ignition of the engine, take-off the hands in key switch.
6. and adjust control lever for desired speed.
7. If engine fails to start, release the key, wait about 1 minute, then operate starter again.
8. Avoid running the cold engine for any length of time since in any internal combustion engine this is liable to cause increased wear due to corrosion. Prolonged idling is harmful to the environment.

CAUTION

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

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

Running in

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

During Operation

CAUTION

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

1. Oil pressure
 - 1) During operation the oil pressure in the engine lubrication system must be monitored. if the monitoring devices register a drop in the lube oil pressure, switch off the engine immediately.
2. Coolant temperature
 - 1) Operating an engine with too low coolant temperature increases fuel consumption, abrasion of the cylinder bore, and shortens the engine's life span.
3. Alternator

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

 - 1) Do not switch off the main battery.
 - 2) Do not disconnect the battery or pole terminals or the cables.

2. Engine Operation and Care

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

Stopping the Engine

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

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

Engine Break-in

General Information

In order to provide only engines of the highest quality, HD Construction Equipment ensures that engines undergo a final acceptance test before releasing them from the factory. However, since the engines are not run for an extended period of time, they must complete a break-in procedure during the initial 50 hours of operation after being delivered. Proper engine break-in ensures long-term optimal engine performance.

Breaking In New Engines

As the bearings in a new engine are not sufficiently broken in initially, they tend to be broken easily due to overload or running at a high speed, thereby shortening the engine life as well. Hence, make sure to follow the instructions below during the initial 50 hours of operation after receiving the engine.

1. Before running the engine, make sure to warm it up sufficiently until the engine temperature is suitable for normal operating conditions.
2. Avoid running the engine at a high rpm under overloaded conditions or for a prolonged period of time.
3. Do not run the engine at a high speed without a load.
4. Do not start or stop the engine abruptly.
5. Do not exceed 70% of the maximum engine load.
6. Inspections, maintenance and service work must be performed by certified technicians at accredited service centers according to the applicable standards.

Inspection Items

Check and inspect the following during the break-in period of a new engine.

1. Check periodically whether the engine oil lies within the specified range between the upper and lower limit lines on the oil level gauge.

CAUTION

In the event that the oil level cannot be checked accurately on the oil level gauge, rotate the oil level gauge 180° and stick the guide tube back in the oil level gauge; then, remove it and check the oil level again.

2. In the event that the oil warning lamp installed in the machine turns on or blinks, it means that the oil pressure is too low. Hence, check the oil level and refill if necessary. When refilling engine oil, do not exceed the upper limit line on the oil level gauge. If the oil level is normal, check related parts, such as the oil pressure sensor, oil pump and oil lines.

CAUTION

The oil pressure may increase and decrease along with the engine speed (rpm). In addition, cold oil generally indicates a higher oil pressure at certain engine speeds (rpm) than warm oil—a phenomenon which occurs even in normal engine operating conditions.

3. Check the coolant temperature gauge installed in the machine and check whether coolant is circulating properly. If the coolant level in the auxiliary tank is too low, the needle on the coolant temperature gauge may vibrate.
4. Replace the engine oil and oil filter after the break-in period.

CAUTION

Replace the engine oil and oil filter with engine oil and a genuine part recommended by HD Construction Equipment.

Operation After Break-in Period

When starting the engine in extremely cold regions, the engine must be warmed up slowly. Do not increase the engine rpm abruptly before the engine has been preheated sufficiently. Oil consumption is higher until the piston rings are seated properly and the engine is running normally. Hence, the engine oil level must be checked periodically during the initial 50 hours of the break-in period.

Inspection After Starting the Engine

While the engine is in operation, always check the pressure in the engine lubrication system with the engine oil pressure gauge installed in the machine. If low oil pressure is indicated on the engine oil pressure gauge, stop the engine immediately. In addition, make sure to check whether the charge warning indicator of the generator is turned off while the engine is in operation.

1. Connect the positive (+) and negative (-) battery terminals securely to ensure that they do not come loose. The sheath on battery connector cables should not be torn or ripped.
2. If the battery charge warning indicator blinks or turns on and the engine stops suddenly while driving, check the electrical system for malfunctions.
3. If an abnormal condition, such as an abnormal emission color or odor, occurs while driving, stop the engine, locate the cause, and correct the issue.
4. Check the state of the engine during operation using the warning indicators and gauges installed in the machine.

2. Engine Operation and Care

Engine Oil Pressure

If the engine oil pressure is inconsistent while idling or the engine oil pressure does not reach the specified amount while driving at a high speed, stop the engine immediately, check the oil level and check the oil lines for leakage.

Coolant Temperature

Operating the engine with an excessively low coolant temperature increases fuel consumption and wear of the cylinder bore, thereby shortening the engine life.

Engine Speed (rpm)

In electronically controlled engines, the engine control unit (ECU) has a function which prevents the engine from running at engine speeds (rpm) exceeding the specified amount in order to protect the engine. A variety of functions—such as controlling fuel flow, delaying ignition time, and blocking fuel and ignition—are set by the memory in the engine control unit (ECU) and cannot be changed arbitrarily by the operator.

Running the Engine in Winter

Preventing Coolant Freezing

When water alone is used as coolant without mixing in antifreeze, corrosion in the engine, degradation of cooling efficiency, and freezing of the engine in winter may occur. Before stopping the engine for a prolonged period of time in extremely cold regions, make sure to completely drain the coolant from the engine. Frozen coolant can cause critical damage to the engine. When adding and replacing coolant, make sure to use coolant mixed with the specified ratio of antifreeze. Antifreeze prevents coolant from freezing.

Preventing Engine Overcooling

If the engine is cooled below the normal operating temperature, fuel efficiency drops and fuel consumption and wear of the cylinder bore increase. Hence, make sure to keep the engine running within the normal operating temperature range. If the coolant temperature remains below the normal operating temperature range in spite of running the engine for a sufficient amount of time, check the thermostat or other parts related to the cooling system.

Engine Oil

If the engine oil viscosity increases due to cold temperatures in winter or in extremely cold regions, the engine rpm may be unstable after starting the engine. In order to prevent this phenomenon, make sure to replace the engine oil with engine oil intended for use in winter or extreme cold. When replacing engine oil, please use genuine oil recommended by HD Construction Equipment.

Engine Inspections and Maintenance

Checking Engine Parts After Prolonged Operation

The function of engine parts may be degraded by wear, corrosion, and thermal deterioration in engine parts and assemblies. In order to maintain optimal engine performance, check the engine after prolonged operation to enhance engine durability.

Even if the engine is operated normally, faults may occur in certain unpredictable and vulnerable parts as the engine is used over time. In such cases, it is difficult to maintain engine performance simply by repairing certain parts. In order to locate the causes of problems more accurately and maintain optimal engine performance, it is best to replace or repair all related parts as a whole.

In order to prevent engine malfunction in advance, performing replacements and inspections periodically enables the engine to be used safely for a longer period of time.

We recommend performing engine adjustments and preventive inspections in the spring after winter or cold temperatures have passed. In doing so, the engine can be used economically and without faults for extended periods of time.

As the following parts affect the engine output and performance, these parts should be checked and inspected periodically.

1. Components that can affect intake and exhaust
 - Air filter
 - Air cooler
 - Turbocharger, muffler
 - Misc.
2. Components that can affect lubrication and cooling performance
 - Air filter
 - Oil filter
 - Antifreeze
 - Misc.

Turbocharger Inspections and Maintenance

As turbocharger performance has a significant impact on engine performance, it is important to perform periodic inspections and maintenance, as well as to comply with the specified instructions for handling the turbocharger.

Intake System

Be careful when handling the air filter of the intake system. In the case of wet-type air filters, filtration performance is degraded when the oil level drops below the specified amount, whereas oil may enter and contaminate the case if the oil level is higher than the specified amount. With dry-type air filters, the intake resistance must be low to enable air to be drawn in smoothly.

Exhaust System

With regard to the exhaust system, if exhaust gas leaks from the connection between the exhaust manifold and the turbocharger, the efficiency of the turbocharger drops, causing a corresponding reduction in engine power. In severe cases, related parts may seize up. Parts in the exhaust system and turbocharger are used at high temperatures. Hence, it is important to keep parts organized during service work to avoid confusing bolts and nuts, etc. with ones used in other parts of the engine.

Lubrication System

Inspection and replacement of the lubrication system should be performed according to the replacement schedule for oil and the oil filter. Overheated engine oil can affect not only the engine itself, but also the engine performance.

2. Engine Operation and Care

3. Performance and Specifications

Engine Specifications and Performance	25
Engine Specifications.....	25
Engine Performance Curve (LEP00/MFP00/OOP00)	29
Engine Performance Curve (LEP01/MFP01/OOP01)	30
Engine Performance Curve (LEP02/MFP02/OOP02)	31
Outside Drawing of Engine (LEP00/MFP00)	32
Structural Diagram	32
Left/Right Sectional View	33
Top View	34
Outside Drawing of Engine (LEP01/LEP02/MFP01/MFP02)	35
Structural Diagram	35
Left/Right Sectional View	36
Top View	37
Outside Drawing of Engine (OOP00)	38
Structural Diagram	38
Left/Right Sectional View	39
Top View	40
Outside Drawing of Engine (OOP01/OOP02)	41
Structural Diagram	41
Left/Right Sectional View	42
Top View	43
Engine Serial Number	44
Engine Code and Manufacturing Number.....	44
Engine Serial Number (Stamped)	44

3. Performance and Specifications

Engine Specifications and Performance

Engine Specifications

Item	Specifications						Note
	LEP00	MFP00	LEP01	MFP01	LEP02	MFP02	
General							
Engine type	Four-stroke, inline, water-cooled, turbocharged and air-cooled						
Combustion chamber type	Direct injection						
Cylinder liner type	No liner						
Timing gear system	Gear driven type						
No. of piston rings	Two compression rings and one oil ring						
Number of cylinders	6						
Cylinder I.D.	110 mm						
Cylinder stroke	132 mm						
Total displacement	7,527 cc						
Compression ratio	18.4 : 1						
Compression pressure	46.0 bar						at 200 rpm
Engine dimensions (length × width × height)	1,304 × 989 × 1,180 mm		1,304 × 934 × 1,133 mm		1,304 × 883 × 1,133 mm		
Engine weight	802 kg		780 kg				
Direction of rotation	Counterclockwise						When seen from flywheel
Ignition order	1 - 5 - 3 - 6 - 2 - 4						
Cooling system							
Cooling method	Radiator						
Coolant capacity	18 L						Inside the engine
Coolant pump type	Centrifugal (pulley type)						
Thermostat	Type	Unit (wax pellet type)					
	Opening temperature	71°C					
	Full opening temp.	85°C					
Coolant temperature sensor installed							
Lubrication system							
Lubrication method	Forced lubrication						
Oil pressure	Idle (bar)	1.0 bar					
	Maximum (bar)	3.0 bar					
Oil specification	Oil class	API CK-4					
	SAE viscosity	SAE 10W40					

3. Performance and Specifications

Item		Specifications						Note
		LEP00	MFP00	LEP01	MFP01	LEP02	MFP02	
Oil capacity	Total	38.0 L						
	Maximum	35.0 L						
	Minimum	18.0 L						
Allowable tilt angle of oil pan		35.0° / 35.0° / 35.0° / 35.0°						Front/Rear/ Left/Right
Oil pump type		Gerotor Type						
Oil cooler type		Water-cooled layered plate						
Oil strainer type		Full flow (cartridge)						
Oil separator type		Impact (OCV)						
Hydraulic pressure indicator		Oil pressure sensor						
Fuel system								
Type of high-pressure fuel pump		Bosch CP4 high-pressure pump (common rail system)						
Engine control		E.C.U. (Bosch, MD1CC898)						
Fuel injection starting pressure		Controlled by ECU						Operating pressure
Injector nozzle type		Multi-hole type						
Fuel filter type		Full flow (cartridge)						
Cylinder block/head								
Valves		Over head valve						
Valve clearance	Intake	0.0 mm						
	Exhaust	0.0 mm						
Electrical system								
Intake/exhaust system								
Starter motor	Type	Auxiliary rotation system						
	Capacity	24.0 V, 6.0 kW						

3. Performance and Specifications

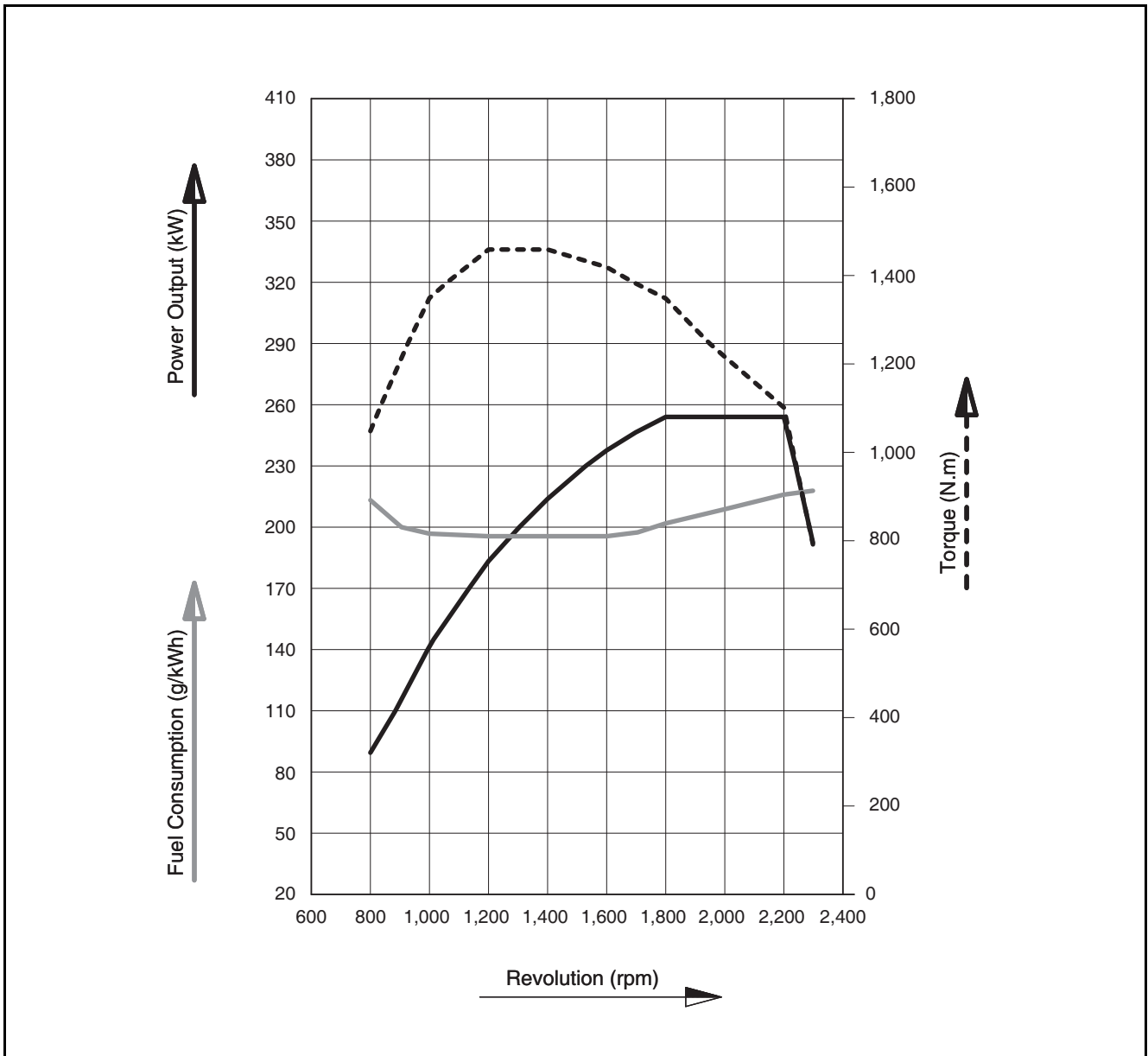
Item	Specifications			Note
	OOP00	OOP01	OOP02	
General				
Engine type	Four-stroke, inline, water-cooled, turbocharged and air-cooled			
Combustion chamber type	Direct injection			
Cylinder liner type	No liner			
Timing gear system	Gear driven type			
No. of piston rings	Two compression rings and one oil ring			
Number of cylinders	6			
Cylinder I.D.	110 mm			
Cylinder stroke	132 mm			
Total displacement	7,527 cc			
Compression ratio	18.4 : 1			
Compression pressure	46.0 bar			at 200 rpm
Engine dimensions (length x width x height)	1,304 x 988 x 1,182 mm	1,304 x 934 x 1,134 mm		
Engine weight	862 kg	821 kg		
Direction of rotation	Counterclockwise			When seen from flywheel
Ignition order	1 - 5 - 3 - 6 - 2 - 4			
Cooling system				
Cooling method	Radiator			
Coolant capacity	18 L			Inside the engine
Coolant pump type	Centrifugal (pulley type)			
Thermostat	Type	Unit (wax pellet type)		
	Opening temperature	71°C		
	Full opening temp.	85°C		
Coolant temperature sensor installed				
Lubrication system				
Lubrication method	Forced lubrication			
Oil pressure	Idle (bar)	1.0 bar		
	Maximum (bar)	3.0 bar		
Oil specification	Oil class	API CI-4		
	SAE viscosity	SAE 10W40		

3. Performance and Specifications

Item		Specifications			Note
		OOP00	OOP01	OOP02	
Oil capacity	Total	38.0 L			
	Maximum	35.0 L			
	Minimum	18.0 L			
Allowable tilt angle of oil pan		35.0° / 35.0° / 35.0° / 35.0°			Front/Rear/ Left/Right
Oil pump type		Gerotor Type			
Oil cooler type		Water-cooled layered plate			
Oil strainer type		Full flow (cartridge)			
Oil separator type		Impact (OCV)			
Hydraulic pressure indicator		Oil pressure sensor			
Fuel system					
Type of high-pressure fuel pump		Bosch CP4 high-pressure pump (common rail system)			
Engine control		E.C.U. (Bosch, MD1CC898)			
Fuel injection starting pressure		Controlled by ECU			Operating pressure
Injector nozzle type		Multi-hole type			
Fuel filter type		Full flow (cartridge)			
Cylinder block/head					
Valves		Over head valve			
Valve clearance	Intake	0.0 mm			
	Exhaust	0.0 mm			
Electrical system					
Intake/exhaust system					
Starter motor	Type	Auxiliary rotation system			
	Capacity	24.0 V, 6.0 kW			

3. Performance and Specifications

Engine Performance Curve (LEP00/MFP00/OOP00)

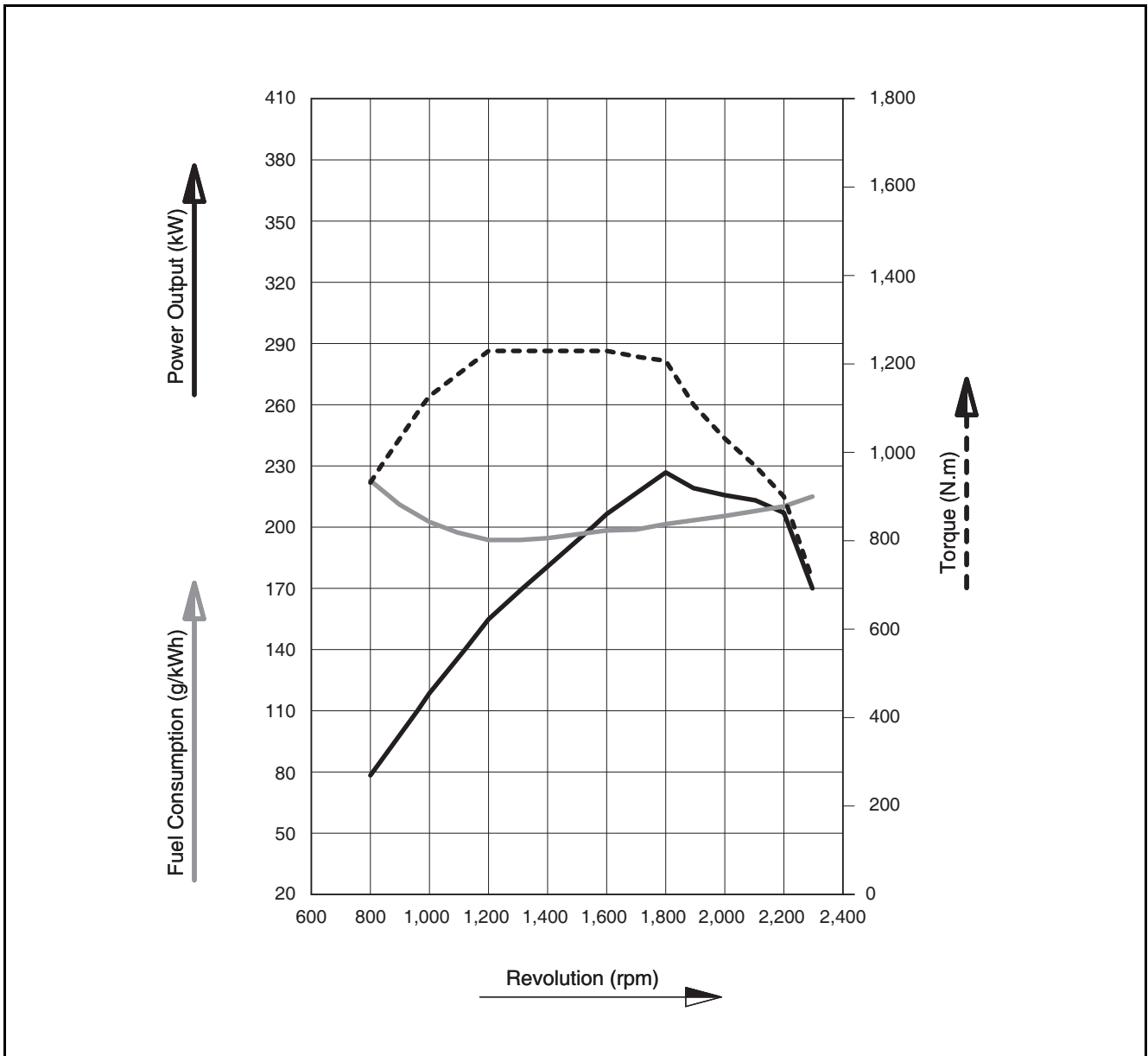


EDX08250033

Engine power (maximum, rated)	254.4 kW / 2,200 rpm
Torque (Max.)	1,460 N.m / 1,300 rpm
Fuel consumption (minimum, rated)	215.7 g/kWh

3. Performance and Specifications

Engine Performance Curve (LEP01/MFP01/OOP01)

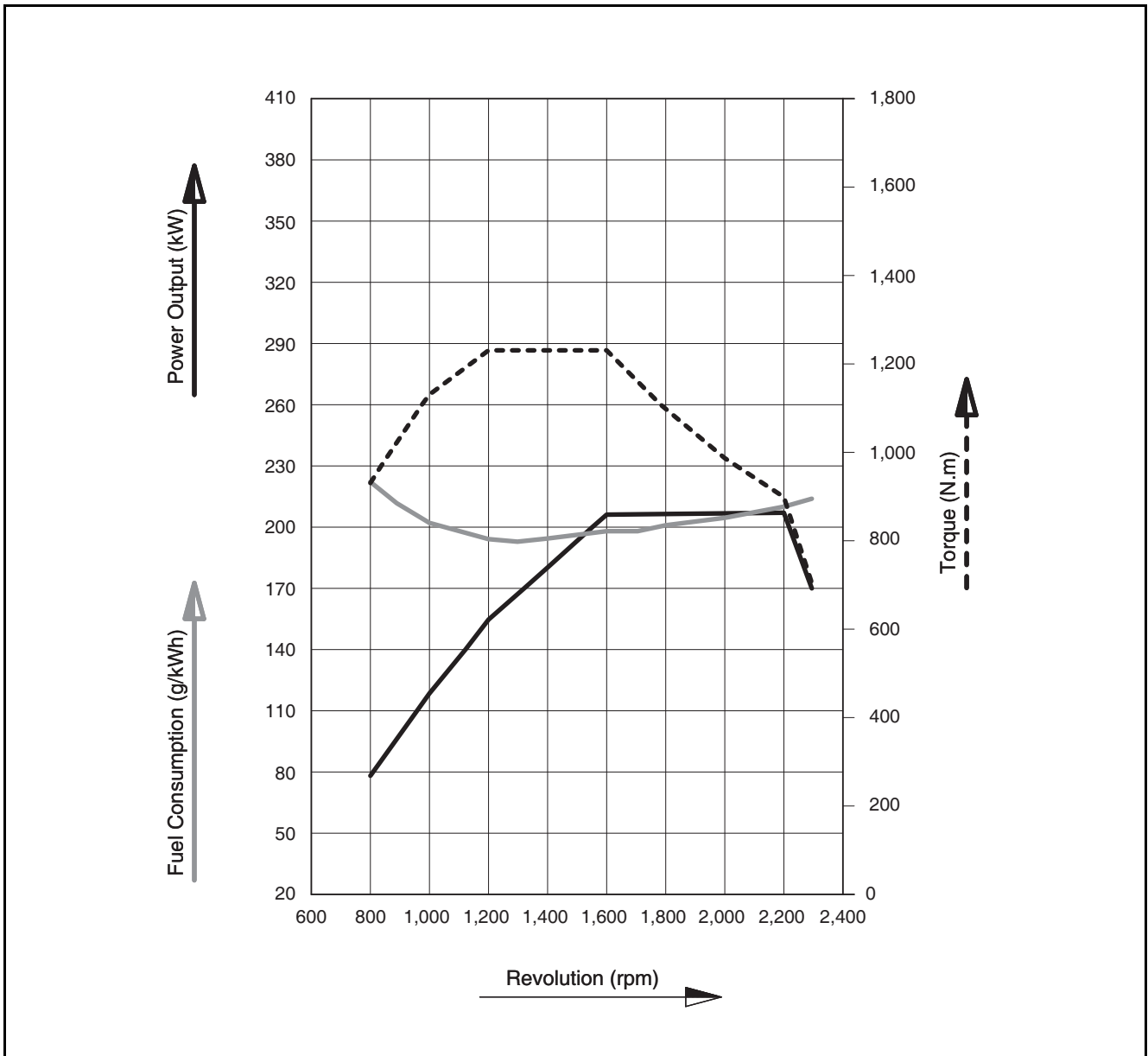


EDX08250034

Engine power (maximum, rated)	227.1 kW / 1,800 rpm
Torque (Max.)	1,230 N.m / 1,300 rpm
Fuel consumption (minimum, rated)	201.0 g/kWh

3. Performance and Specifications

Engine Performance Curve (LEP02/MFP02/OOP02)



EDX08250035

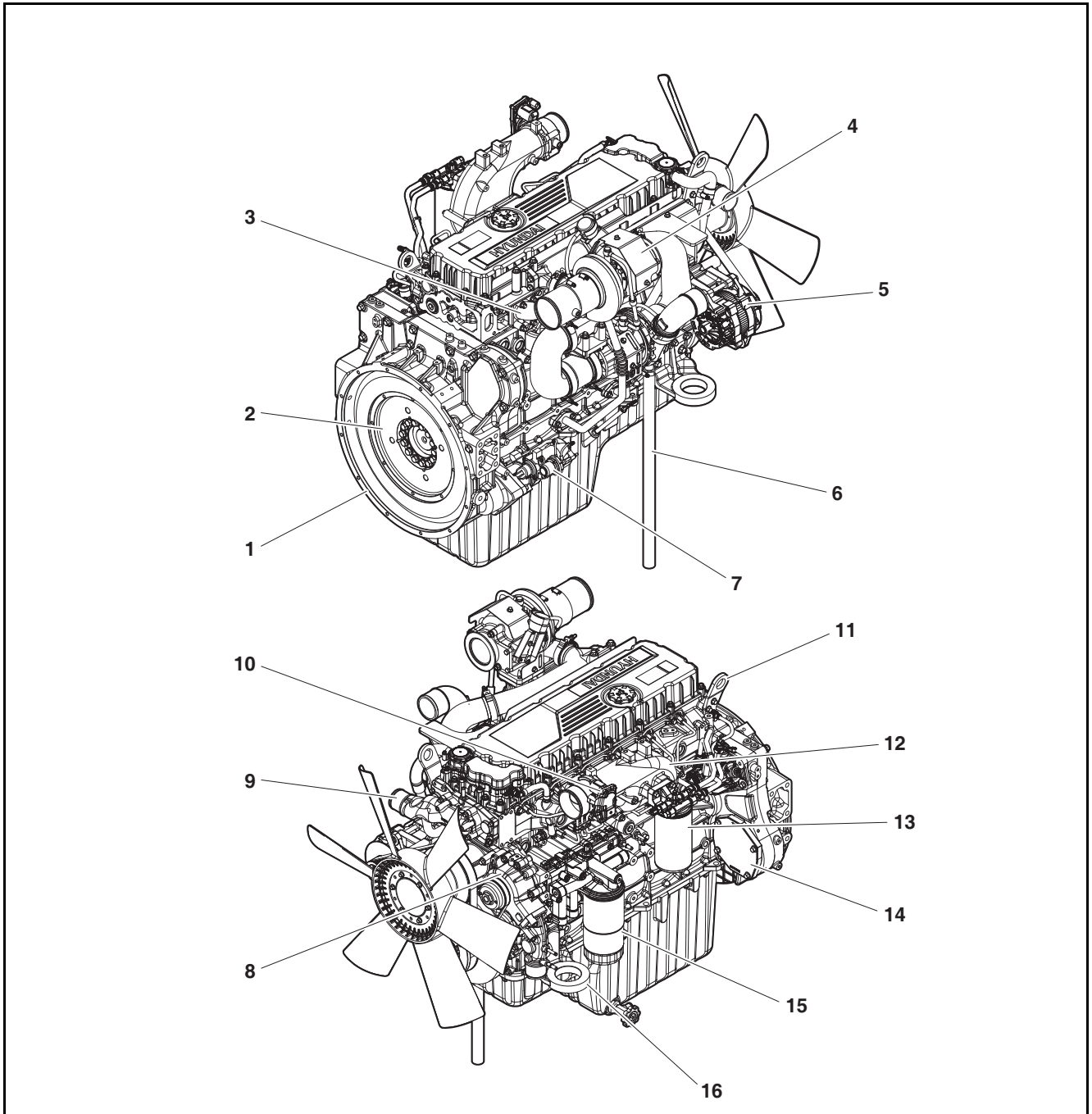
Engine power (maximum, rated)	207.3 kW / 2,200 rpm
Torque (Max.)	1,230 N.m / 1,300 rpm
Fuel consumption (minimum, rated)	209.6 g/kWh

3. Performance and Specifications

Outside Drawing of Engine (LEP00/MFP00)

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

Structural Diagram

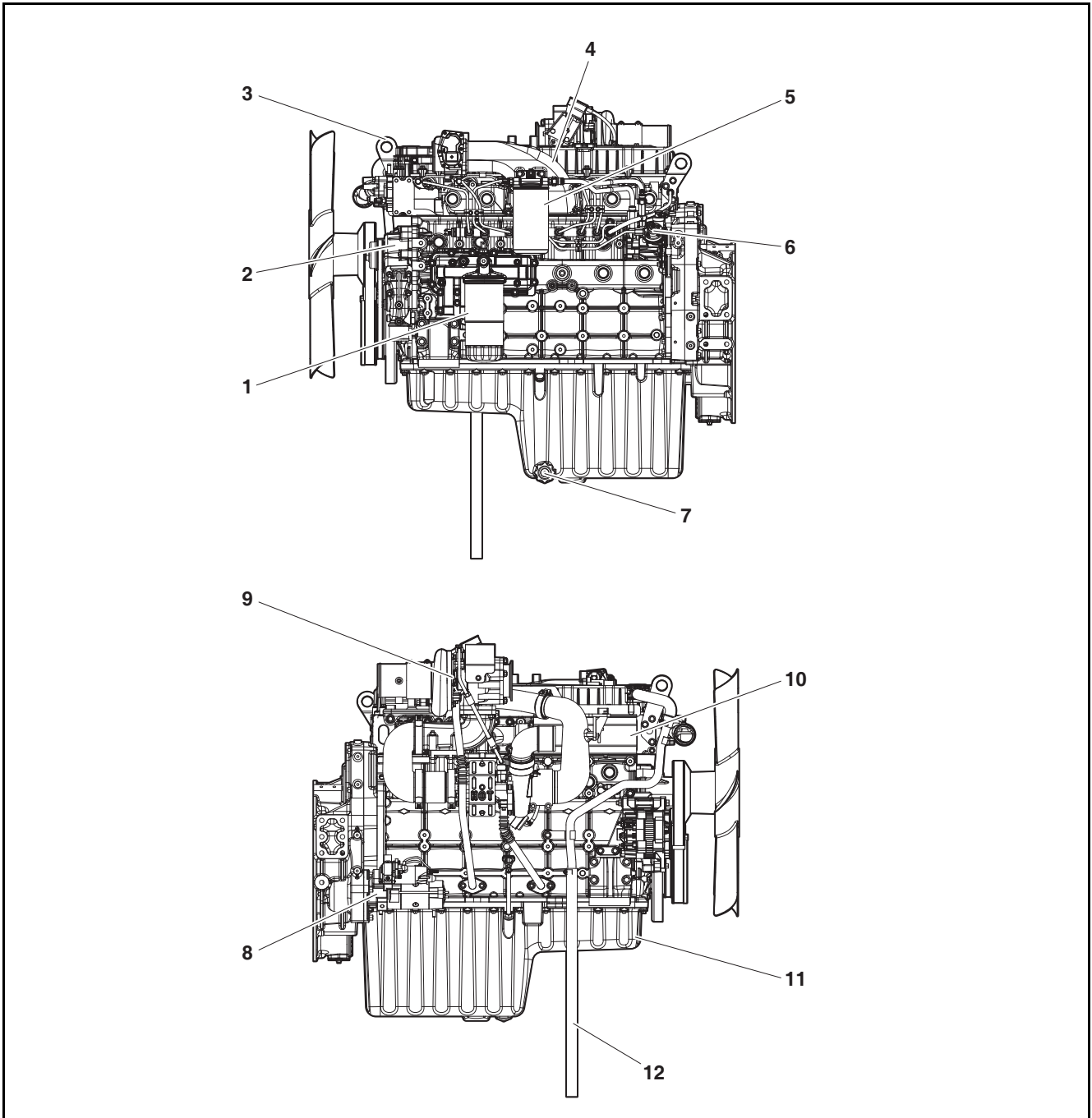


EDX08250036

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|---------------------|--------------------|----------------------|
| 1. Flywheel housing | 7. Starter motor | 13. Fuel filter |
| 2. Flywheel | 8. Coolant pump | 14. PTO cover |
| 3. Exhaust manifold | 9. Thermostat | 15. Oil filter |
| 4. Turbocharger | 10. Throttle valve | 16. Mounting bracket |
| 5. Alternator | 11. Lifting hook | |
| 6. Breather hose | 12. Intake stake | |

3. Performance and Specifications

Left/Right Sectional View

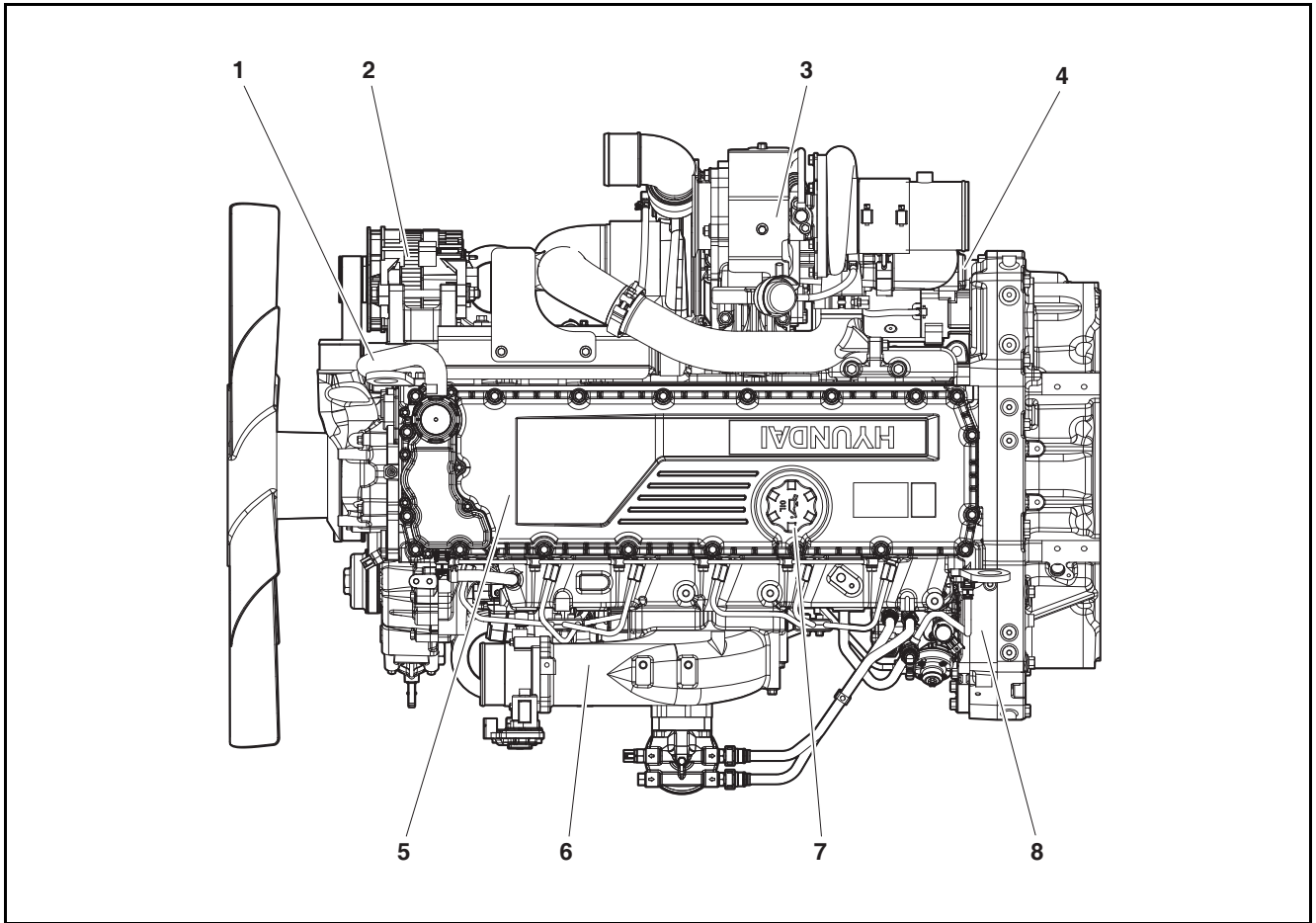


EDX08250037

- | | | |
|-----------------|------------------|----------------------|
| 1. Oil filter | 5. Fuel filter | 9. Turbocharger |
| 2. Coolant pump | 6. Fuel pump | 10. Exhaust manifold |
| 3. Lifting hook | 7. Drain valve | 11. Oil pan |
| 4. Intake stake | 8. Starter motor | 12. Breather hose |

3. Performance and Specifications

Top View



EDX08250038

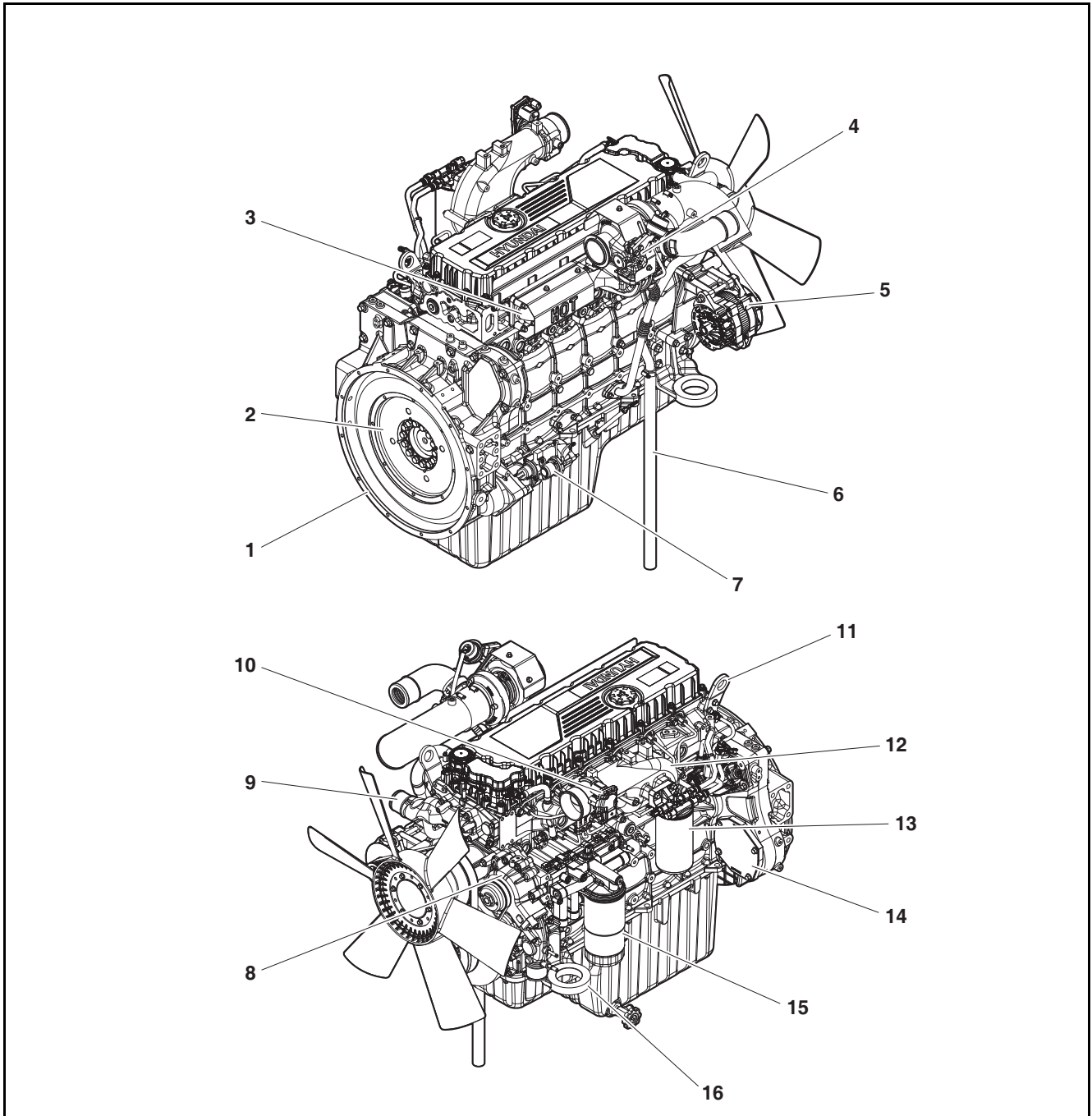
- | | | |
|------------------|------------------------|---------------------|
| 1. Breather hose | 4. Starter motor | 7. Oil filler cap |
| 2. Alternator | 5. Cylinder head cover | 8. Timing gear case |
| 3. Turbocharger | 6. Intake stake | |

3. Performance and Specifications

Outside Drawing of Engine (LEP01/LEP02/MFP01/MFP02)

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

Structural Diagram

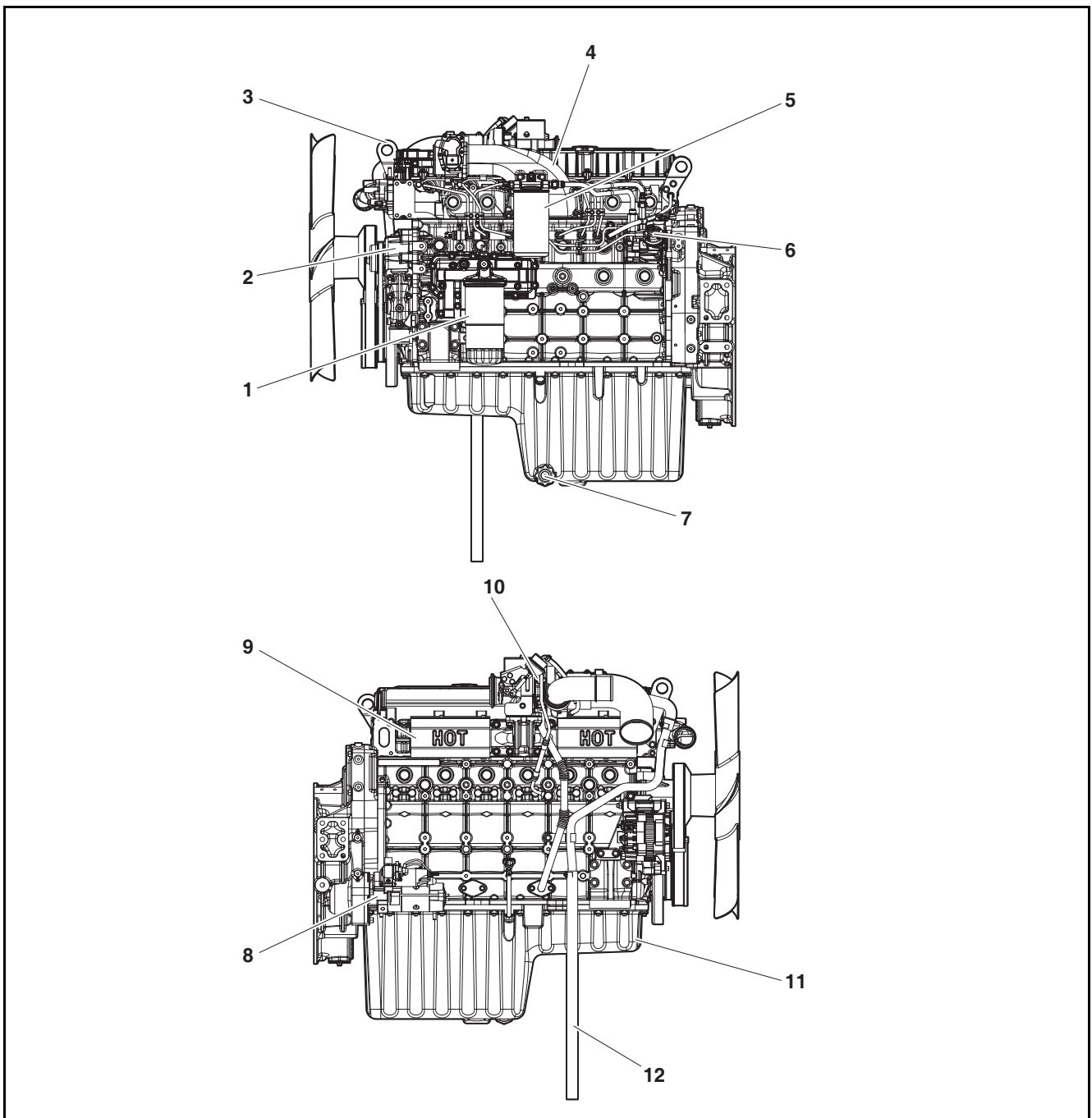


EDX08250039

- | | | |
|---------------------|--------------------|----------------------|
| 1. Flywheel housing | 7. Starter motor | 13. Fuel filter |
| 2. Flywheel | 8. Coolant pump | 14. PTO cover |
| 3. Exhaust manifold | 9. Thermostat | 15. Oil filter |
| 4. Turbocharger | 10. Throttle valve | 16. Mounting bracket |
| 5. Alternator | 11. Lifting hook | |
| 6. Breather hose | 12. Intake stake | |

3. Performance and Specifications

Left/Right Sectional View

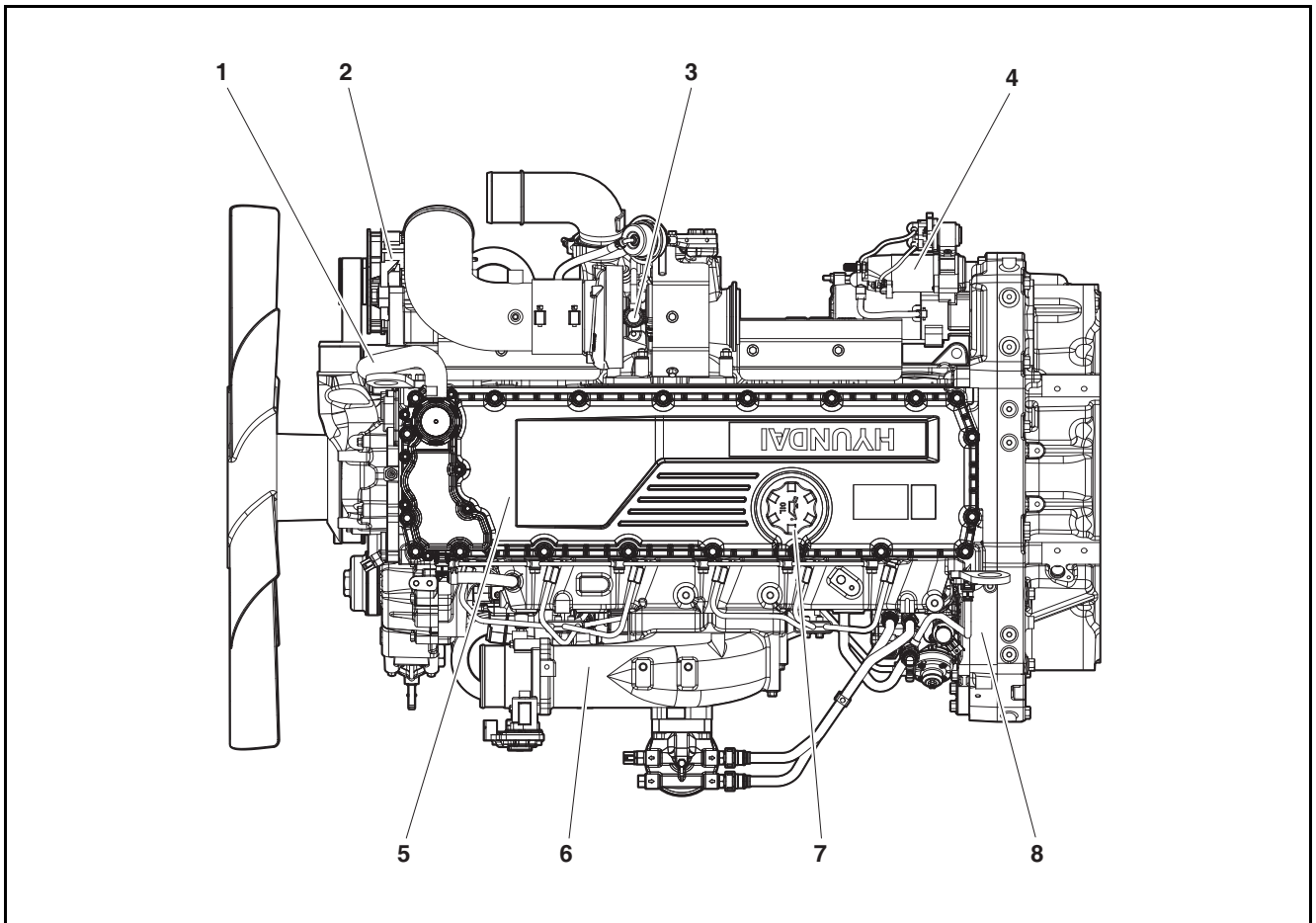


EDX08250040

- | | | |
|-----------------|------------------|---------------------|
| 1. Oil filter | 4. Fuel filter | 9. Exhaust manifold |
| 2. Coolant pump | 6. Fuel pump | 10. Turbocharger |
| 3. Lifting hook | 7. Drain valve | 11. Oil pan |
| 4. Intake stake | 8. Starter motor | 12. Breather hose |

3. Performance and Specifications

Top View



EDX08250041

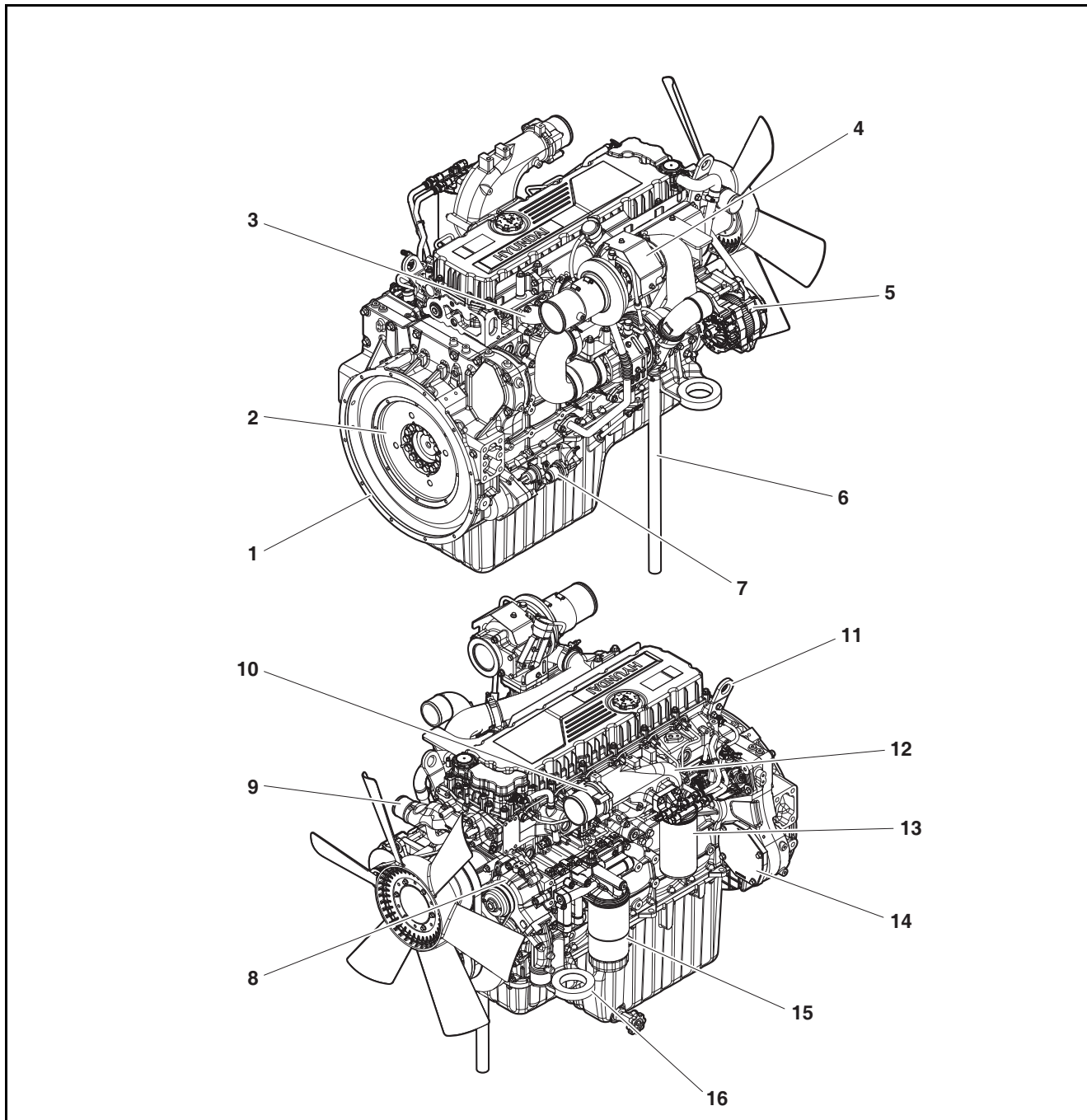
- | | | |
|------------------|------------------------|---------------------|
| 1. Breather hose | 4. Starter motor | 7. Oil filler cap |
| 2. Alternator | 5. Cylinder head cover | 8. Timing gear case |
| 3. Turbocharger | 6. Intake stake | |

3. Performance and Specifications

Outside Drawing of Engine (OOP00)

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

Structural Diagram

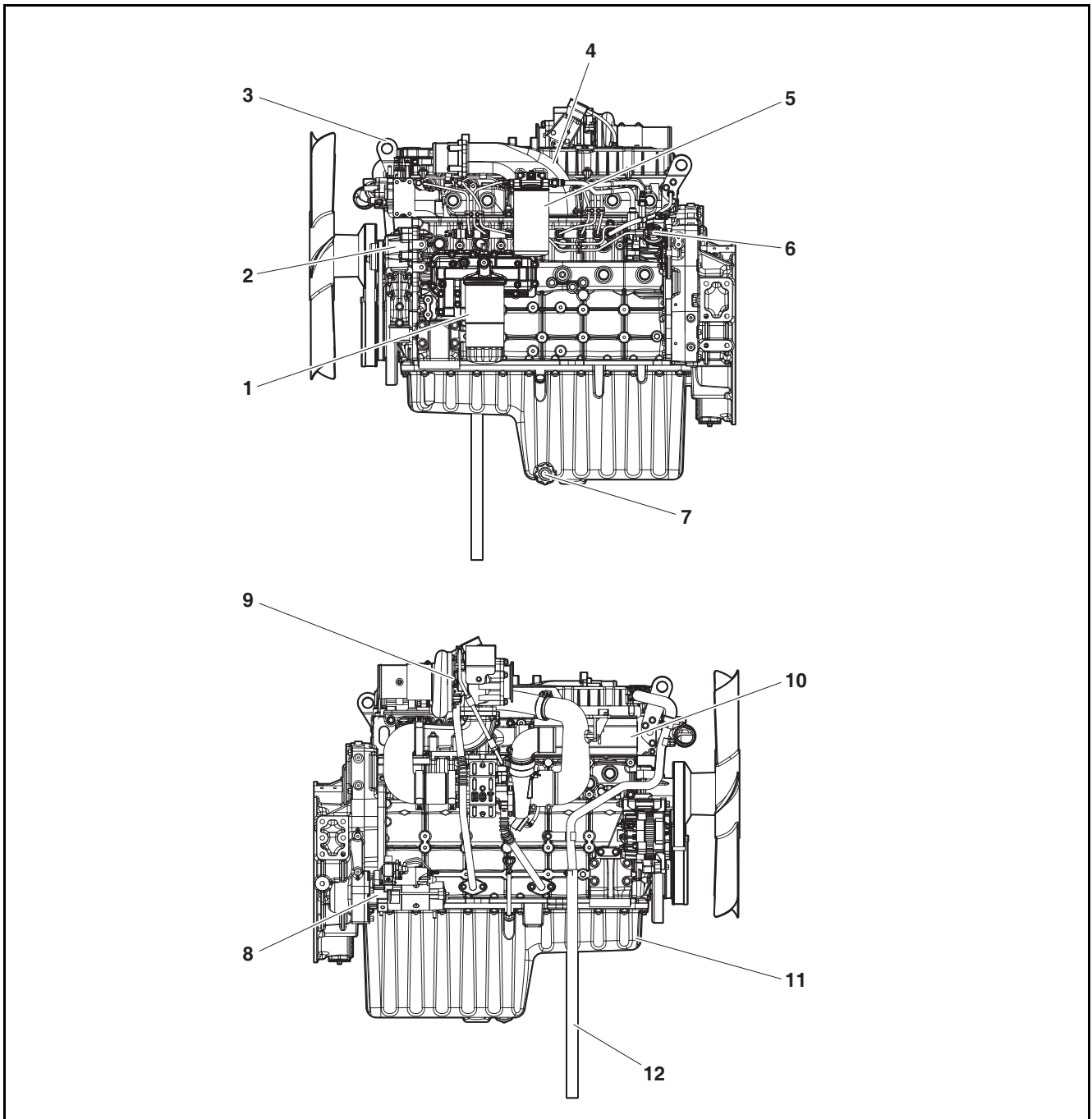


EDX08250105

- | | | |
|---------------------|--------------------|----------------------|
| 1. Flywheel housing | 7. Starter motor | 13. Fuel filter |
| 2. Flywheel | 8. Coolant pump | 14. PTO cover |
| 3. Exhaust manifold | 9. Thermostat | 15. Oil filter |
| 4. Turbocharger | 10. Air inlet pipe | 16. Mounting bracket |
| 5. Alternator | 11. Lifting hook | |
| 6. Breather hose | 12. Intake stake | |

3. Performance and Specifications

Left/Right Sectional View

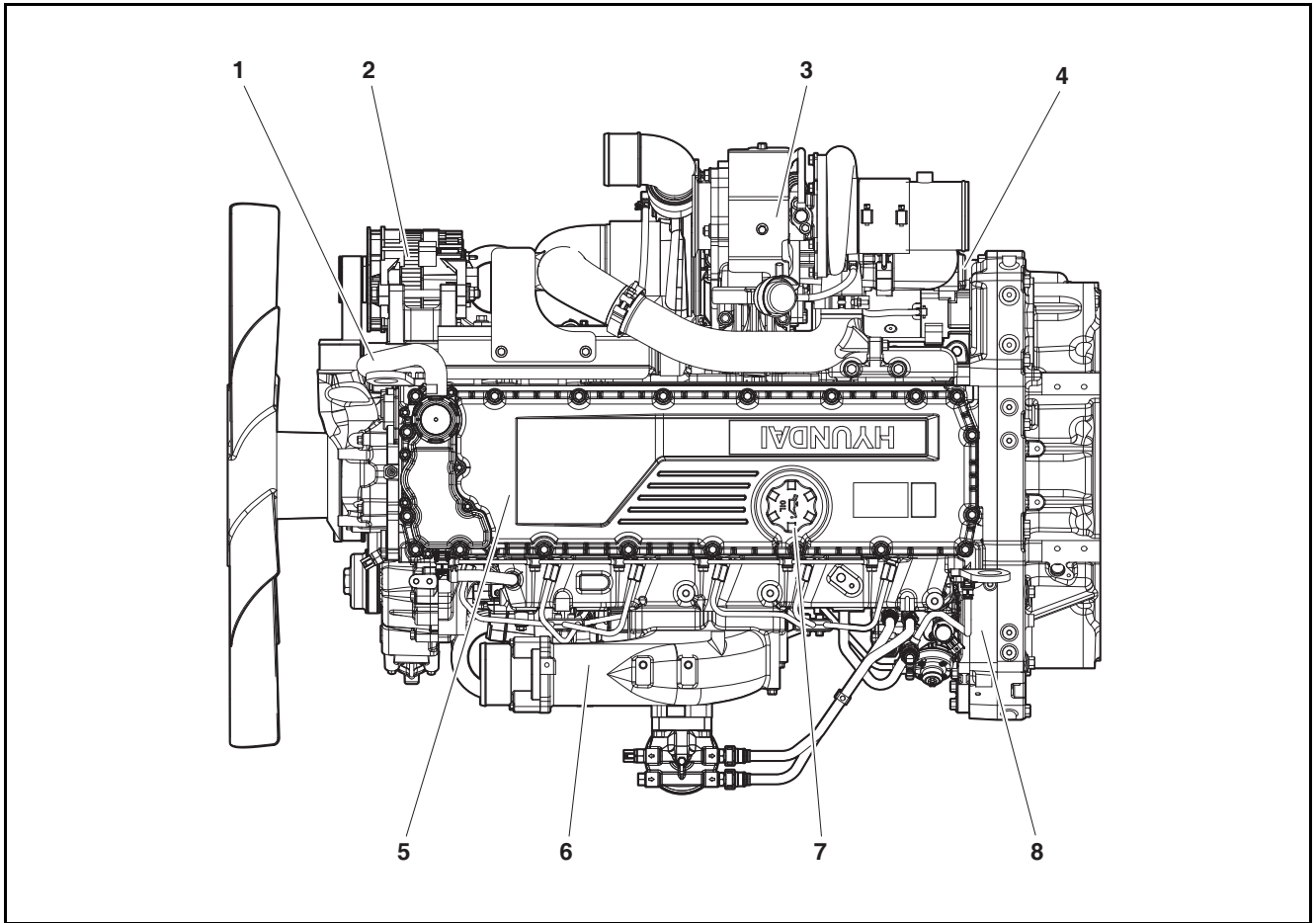


EDX08250106

- | | | |
|-----------------|------------------|----------------------|
| 1. Oil filter | 5. Fuel filter | 9. Turbocharger |
| 2. Coolant pump | 6. Fuel pump | 10. Exhaust manifold |
| 3. Lifting hook | 7. Drain valve | 11. Oil pan |
| 4. Intake stake | 8. Starter motor | 12. Breather hose |

3. Performance and Specifications

Top View



EDX08250107

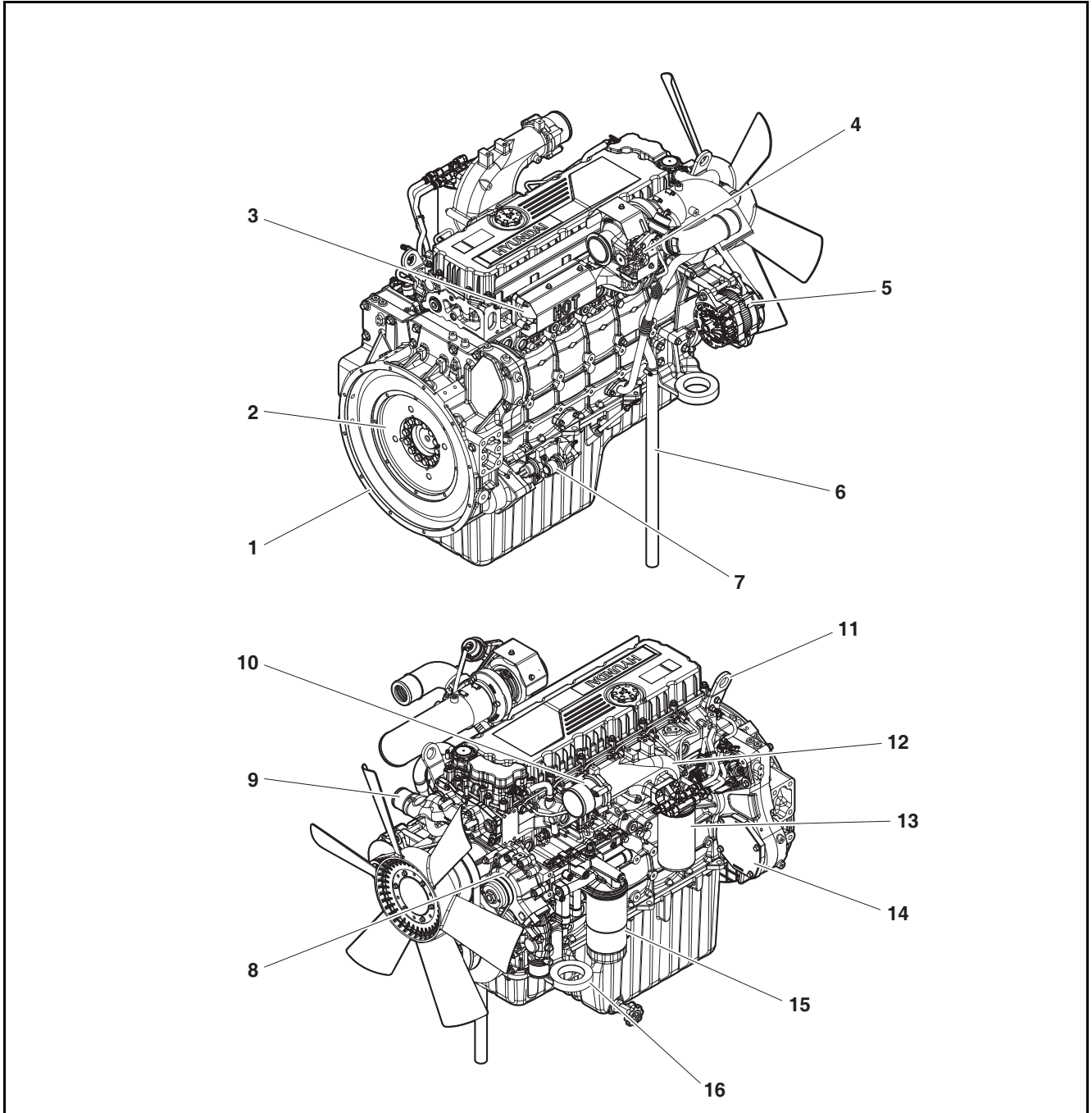
- | | | |
|------------------|------------------------|---------------------|
| 1. Breather hose | 4. Starter motor | 7. Oil filler cap |
| 2. Alternator | 5. Cylinder head cover | 8. Timing gear case |
| 3. Turbocharger | 6. Intake stake | |

3. Performance and Specifications

Outside Drawing of Engine (OOP01/OOP02)

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

Structural Diagram

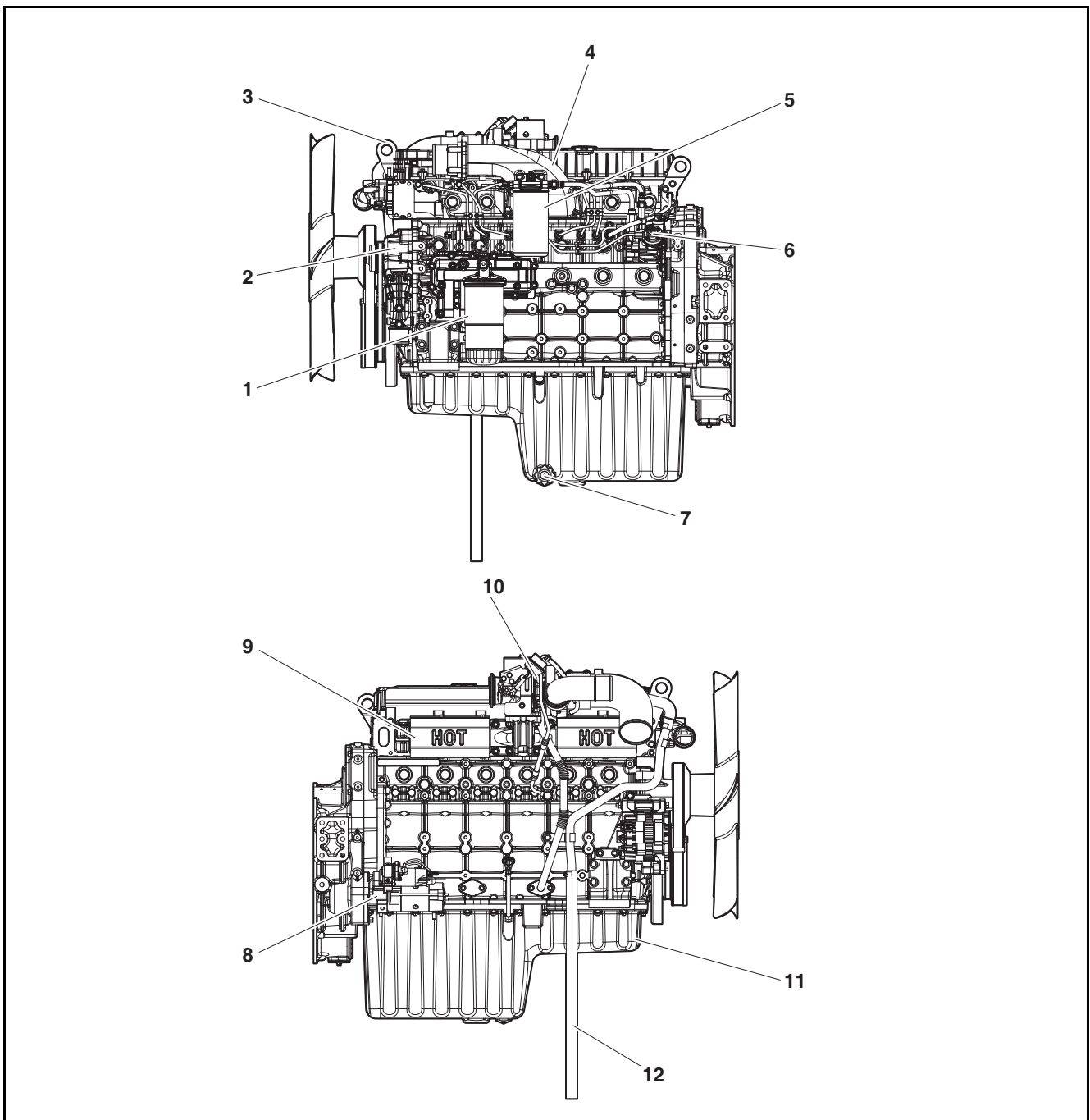


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- | | | |
|---------------------|--------------------|----------------------|
| 1. Flywheel housing | 7. Starter motor | 13. Fuel filter |
| 2. Flywheel | 8. Coolant pump | 14. PTO cover |
| 3. Exhaust manifold | 9. Thermostat | 15. Oil filter |
| 4. Turbocharger | 10. Air inlet pipe | 16. Mounting bracket |
| 5. Alternator | 11. Lifting hook | |
| 6. Breather hose | 12. Intake stake | |

3. Performance and Specifications

Left/Right Sectional View

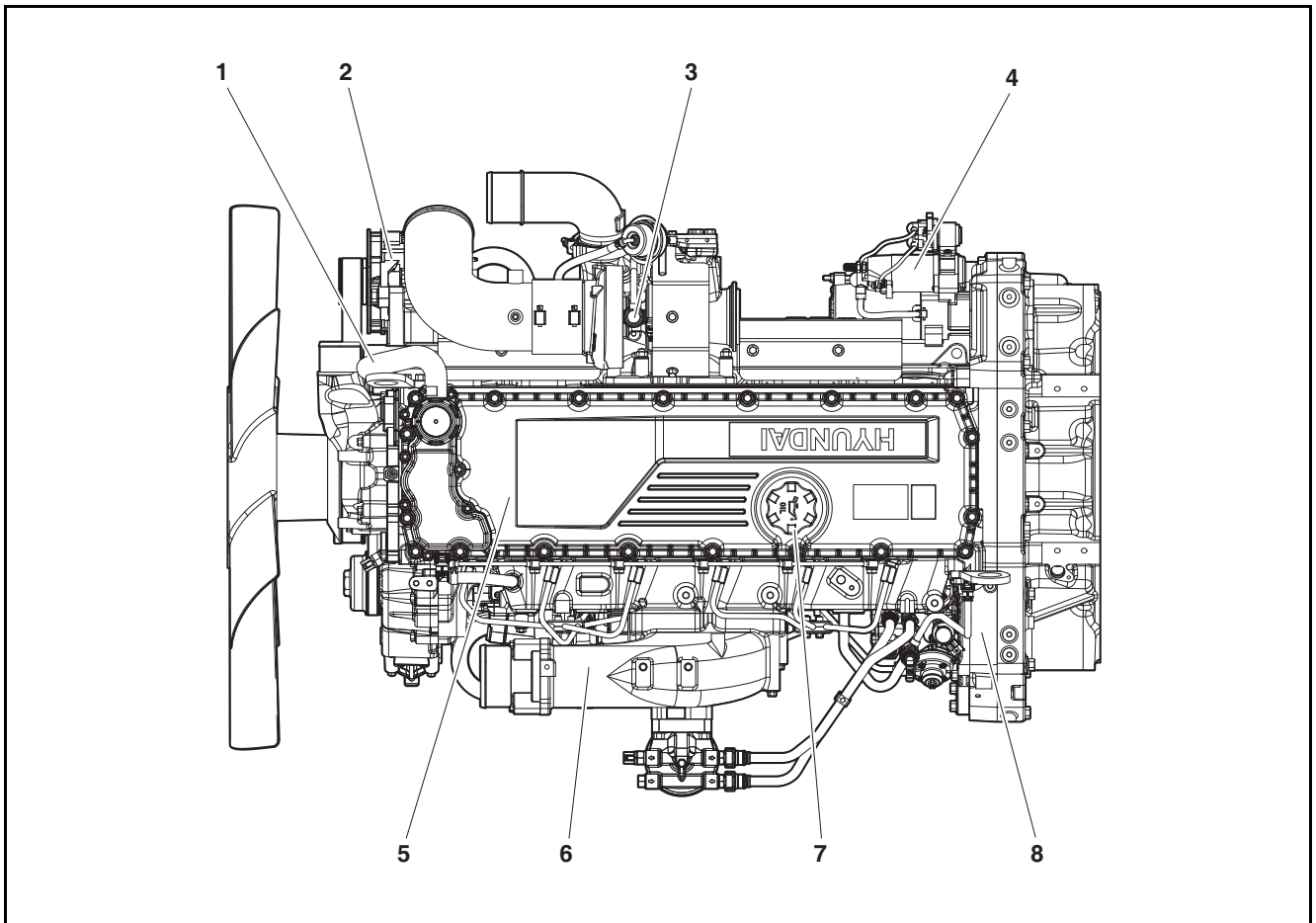


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- | | | |
|-----------------|------------------|---------------------|
| 1. Oil filter | 5. Fuel filter | 9. Exhaust manifold |
| 2. Coolant pump | 6. Fuel pump | 10. Turbocharger |
| 3. Lifting hook | 7. Drain valve | 11. Oil pan |
| 4. Intake stake | 8. Starter motor | 12. Breather hose |

3. Performance and Specifications

Top View



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- | | | |
|------------------|------------------------|---------------------|
| 1. Breather hose | 4. Starter motor | 7. Oil filler cap |
| 2. Alternator | 5. Cylinder head cover | 8. Timing gear case |
| 3. Turbocharger | 6. Intake stake | |

3. Performance and Specifications

Engine Serial Number

Engine Code and Manufacturing Number

The engine code and production number are required for warranty claims and part orders.

Engine Serial Number (Stamped)

- **Type 1**

(A) (B) (C)

- A. Engine model suffix (5 digits)
- B. Manufacturing year (1 digit)
- C. Series (5 digits)

- **Type 2**

(A) (B) (C) (D)

- A. Model name (4 - 7 digits)
- B. Year (1 digit)
- C. Series (5 digits)
- D. Engine model suffix (last 2 digits)

- **Type 3**

(A) (B) (C) (D) (E)

- A. Model name (5 digits)
- B. Power (3 digits)
- C. Year (1 digit)
- D. Series (5 digits)
- E. Engine model suffix (last 2 digits)

- **Type 4**

(A) (B) (C)

- A. New representative spec. (last 9 digits)
- B. Year (1 digit)
- C. Series (5 digits)

- **Type 5**

(A) (B) (C) (D)

- A. Model name (4 - 7 digits)
- B. Year (1 digit)
- C. Series (5 digits)
- D. New representative spec. (last 3 digits)

- **Type 6**

(A) (B) (C) (D) (E)

- A. Model name (5 digits)
- B. Power (3 digits)
- C. Year (1 digit)
- D. Series (5 digits)
- E. New representative spec. (last 3 digits)

4. Regular Inspections

General Information	47
General Information	47
Daily Inspections.....	47
Maintenance Schedule	48
General Conditions	48
Cooling System	49
General Information	49
Coolant Specifications	49
Coolant Capacity.....	49
Checking the Coolant.....	49
Antifreeze Specifications.....	49
Measuring the Coolant Concentration	50
Adding Coolant	51
Changing the Coolant	51
Cleaning the Cooling Circuit	52
Lubrication System	53
General Information	53
Engine Oil Specifications	54
Engine Oil Capacity	55
Checking Engine Oil	55
Adding Engine Oil	55
Changing Engine Oil.....	56
Fuel System	57
General Information	57
Fuel Specifications.....	57
Fuel Filter	57
Bleeding Fuel Delivery Lines	57
Intake/Exhaust System	58
General Information	58
Cleaning the Air Filter	58
Cleaning the Air Cleaner Element.....	58
Replacing the Air Cleaner Element.....	59
Electrical System	60
Battery.....	60
Other/Driving System	61
Belt Tension	61

General Information

General Information

After purchasing the engine, the initial engine performance degrades over time due to aging of the various parts of the engine.

By performing regular inspections and part replacements according to the maintenance schedule recommended by HD Construction Equipment, the engine can be maintained in its optimal state for long periods of time and unanticipated accidents can be prevented.

It is the responsibility of the engine operator to operate and maintain the engine correctly. Inspections and replacements should be performed by certified technicians in service centers equipped with the specified tools and facilities. Make sure to follow the instructions below during inspections.

1. Perform inspections on flat, level ground.
2. Unless otherwise unavoidable, make sure to stop the engine before performing inspections.
3. Disconnect the negative (-) battery cable before performing inspections.
4. Perform inspections in a well-ventilated workspace.
5. When working underneath the engine, make sure to support the engine with chocks or lifters.

DANGER

- **Before inspecting the engine after it has been running, make sure to wait until it has cooled off sufficiently. Otherwise, there is a risk of being burnt.**
 - **Running the engine in an enclosed space may cause poisoning due to exhaust gas. Make sure to perform inspections in a well-ventilated workspace.**
 - **Unless otherwise unavoidable, do not perform inspections underneath the engine.**
 - **Keep the engine away from open flames during inspections. Otherwise, there is a danger of a fire starting due to evaporative emissions from fuel, oil, or the battery.**
 - **In the event that the engine must be inspected while it is running, do not wear gloves or accessories such as necklaces, rings, or watches. Severe injuries may occur if anything is caught in rotating parts.**
 - **People with an artificial heart or artificial organs should not approach the engine while it is in operation. Artificial organs may malfunction due to the high-pressure current running through injectors and the engine control unit.**
-

CAUTION

- **Performing inspections incorrectly may lead to engine failure.**
 - **Cleaning an engine with liquids such as water or wax may cause electrical parts to malfunction.**
 - **Note that batteries, cables, and electrical wiring have current running through them.**
 - **Do not place heavy objects or apply excessive force or shock to fuel-related parts.**
 - **Before connecting battery terminals, make sure to check the polarity (positive '+' and negative '-') of the terminals. Connecting terminals with the polarity reversed may damage parts in electrical systems and cause a fire.**
-

Daily Inspections

Daily inspections refer to inspections performed by the engine user every day before running the engine. These inspections must be performed for the safety of the engine and the operator.

The following inspection items are the minimum daily inspection items which must be checked.

1. Check whether the engine starts smoothly and whether the fuel, oil and coolant levels are normal.
2. Check the color of the exhaust gas and whether any toxic fumes are discharged from the engine.
3. Check for any abnormal noises after starting the engine.
4. Check for any oil or coolant leaks.

4. Regular Inspections

Maintenance Schedule

General Conditions

Periodic inspections and replacements are absolutely necessary to ensure the optimum state of the engine during its service life and to prevent any unexpected engine failure.

The maintenance schedule may differ depending on the operating conditions of the engine.

○ : Inspect and adjust ● : Replace

Finished		Daily	Every 50 hours	Every 100 hours	Every 200 hours	Every 400 hours	Every 500 hours	Every 800 hours	Every 1,000 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 ^a	
	Adjust tension of Micro V-belt (Position of pointer on auto tensioner)					○					Every 2,000 hours	
	Cleaning the radiator									○		
Lubrication System	Check for leaks	○										
	Check the oil level gauge	○										
	Change the lubricant	CK-4		○ Initial						●		1 year/1,000 hours whichever occurs first
		CI-4		○ Initial				●		●		1 year/500 hours whichever occurs first
	Replace the oil filter cartridge	CK-4								●		Every 1,000 hours
CI-4							●		●		Every 500 hours	
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								●		Every 1,000 hours	
	Inspect fuel injection nozzle										Whenever necessary	
Engine Adjust	Check emission condition	○										
	Check the battery charge level	○										
	Check the compression pressure									○	Whenever necessary	
After treatment System	Replacing the DEF filter										4,500 hours or 3 years	

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

a. The replacement intervals may be extended for the following specifications certified according to DIES-MT-0067 (prev. RES-C0198).

2 years/4,000 hours	LLC3	Donga Chemical	Ethylene Glycol (Low Phosphate Type)
	CROWN DS-36	Kukdong Jeyen	
	SKAF 1020	ZICOS	

Cooling System

General Information

Coolant plays an important role in the prevention of overheating and freezing of the engine. However, as the engine is used over time, the antifreeze and anticorrosive performance of coolant deteriorates. Make sure to check the condition of coolant during daily inspections and replace it periodically.

Engine coolant should have a mixture of 40% antifreeze. The water used in coolant should either be clean tap water or distilled water. Make sure to inspect coolant periodically to maintain the correct concentration of antifreeze.

CAUTION

By maintaining the mixture ratio of coolant recommended by HD Construction Equipment, engine corrosion can be prevented effectively and the engine can be maintained in optimum condition for long periods of time. Using contaminated water or unspecified antifreeze or additives may cause critical faults in the cooling system.

Coolant Specifications

- Amount of antifreeze in winter

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

Coolant Capacity

Engine Model and Product Code	Coolant capacity (L)
DX08	18

Checking the Coolant

DANGER

If the radiator cap is opened to add or replace coolant while the engine is overheated, hot coolant will spurt out and may cause serious burns. In the event that the radiator cap must be opened, wrap it in a cloth and turn it slowly in two steps to release the steam pressure inside. Remove the radiator cap after all steam pressure inside has been released.

- Check the level on the auxiliary tank.
- Check whether the engine and radiator are cool.
- The coolant level should lie between the upper and lower limits indicated on the auxiliary tank.
- Add coolant if necessary.
- Open the radiator cap and check the condition of the coolant.

Measure the coolant concentration if the coolant is contaminated or if necessary. Replace the coolant if the concentration exceeds the specified coolant concentration.

Antifreeze Specifications

- We recommend using HD Construction Equipment genuine antifreeze, and since HD Construction Equipment genuine antifreeze satisfies the global standard, there is no need to add a separate additive.
 - SAE J1034, ASTM D3360, ASTM D6210, JIS K2234
- If you do not use HD Construction Equipment genuine antifreeze, you must select a product that satisfies the global standard, and you must not mix different types of antifreeze.
 - Among products that meet the global standard, we recommend specifications that do not contain "Amin" and "Borate" as additives.

4. Regular Inspections

Adding Coolant

If the coolant level indicated on the auxiliary tank is below the lower limit, add coolant as follows.

1. Remove the cap on the auxiliary tank.
2. Add coolant until the coolant level is between the upper and lower limits on the auxiliary tank.
3. Install the cap on the auxiliary tank.

CAUTION

Be careful not to allow foreign matter to enter the engine while adding coolant.

If there is no coolant in the auxiliary tank, add coolant as follows.

1. Remove the radiator cap while the engine and radiator are cold.
2. Add coolant up to the radiator inlet.
3. Start the engine to circulate the coolant throughout the engine; then, check the coolant level. Add more coolant if necessary.
4. Install the radiator cap.
5. Remove the cap on the auxiliary tank.
6. Add coolant until the coolant level is between the upper and lower limits on the auxiliary tank.

CAUTION

- **Do not open the radiator cap while the engine is overheated. Otherwise, hot coolant will spurt out and may cause severe burns. Open the radiator cap only after ensuring that the engine has cooled off sufficiently.**
 - **Label and store coolant containers separately to avoid confusion with beverage containers. If coolant is ingested, seek medical assistance immediately.**
-

Changing the Coolant

CAUTION

Be careful not to spill coolant on any belts or electrical components when replacing the coolant.

1. Check whether the engine and radiator are cold.
2. Place a container in front of the coolant drain plug.
3. Remove the radiator cap.
4. Remove the coolant drain plug from the radiator and drain the coolant.
5. After draining the coolant, reinstall the coolant drain plug.
6. Drain the coolant from the auxiliary coolant tank and wash out the tank.
7. Fill the radiator inlet with water and install the radiator cap.

Note) After adding coolant slowly to allow air inside the radiator to be discharged, press on the hose connected to the radiator to drain the air inside more easily.

8. Run the engine until the cooling fan rotates 2 ~ 3 times. Then, increase the engine rpm 2 ~ 3 times once the engine has warmed up.
9. Stop the engine and wait until the engine cools off.
10. Remove the radiator drain plug and drain the water.
11. Repeat steps 1 ~ 8 until the water drained is clean.
12. Press on the hose connected to the radiator to drain the air in the radiator more easily; then, slowly fill the radiator inlet with coolant mixed to the specified ratio.

Note) Make sure to use genuine antifreeze recommended by HD Construction Equipment.

CAUTION

- **Do not use a mixture of antifreezes from different manufacturers.**
 - **Do not use a mixture of coolants with different concentrations.**
 - **Do not add an anti-rust agent which is not recommended by HD Construction Equipment.**
 - **A low coolant concentration may cause corrosion or freezing, whereas a high concentration may degrade cooling performance. Use a mixture of 40% anti-freeze in coolant.**
-

13. Idle the engine after starting it. Once the cooling fan is running and coolant has circulated, remove the radiator cap and add coolant through the inlet.

14. Add coolant until the cooling fan rotates 3 ~ 5 times.

4. Regular Inspections

15. Add coolant up to the upper limit on the auxiliary tank; then, install the radiator cap.
16. Idle the engine until the cooling fan rotates 2 ~ 3 times.
17. Stop the engine and wait until the engine and radiator cool off.
18. Check the coolant level in the auxiliary tank and add coolant repeatedly until the coolant level in the auxiliary tank remains consistently between the upper and lower limits.

Note) Check the coolant level in the auxiliary tank for at least 2 ~ 3 days after changing the coolant.

CAUTION

Check the coolant level in the auxiliary tank for at least 2 ~ 3 days after changing the coolant.

WARNING

Dispose of used coolant according to the regulations of local public institutions. Coolant can cause severe environmental pollution if it is spilled on the ground, in drains, sewers, rivers, or seas. Failing to dispose of coolant properly according to disposal regulations is punishable by law.

Cleaning the Cooling Circuit

If the internal cooling circuit is corroded or contaminated, its cooling efficiency is degraded. Resistance in the cooling circuit can damage the mechanical seal of the coolant pump. Using improper antifreeze or anti-corrosive or not using them can affect the cooling circuit negatively. If the coolant pump leaks or coolant is severely contaminated (cloudy or brown, gray or black according to its contamination level) after a short period of operating time (6 months), wash the cooling system as follows before removing the coolant pump.

1. Drain the coolant.
2. To wash the cooling circuit quickly, remove the thermostat.
3. Fill the cooling circuit with a mixture of water and 1.5% cleanser (Henkel P3T5175).
4. Apply a load to the engine. Once the coolant temperature reaches 60°C, run the engine for approx. 15 minutes.
5. Drain the cleanser.
6. Repeat steps 3 and 4 above.
7. Fill the cooling circuit with hot water.

8. Idle the engine for 30 minutes to check the drain plugs and coolant lines for leakage. Add coolant as necessary.

CAUTION

Wash the cooling circuit periodically using cleanser.

Lubrication System

General Information

Engine oil serves to enhance engine performance and prolong engine life by lubricating, cooling, sealing, preventing corrosion and cleaning the inside of the engine.

Running the machine continuously without sufficient engine oil may cause moving parts in the engine to seize up, leading to engine failure.

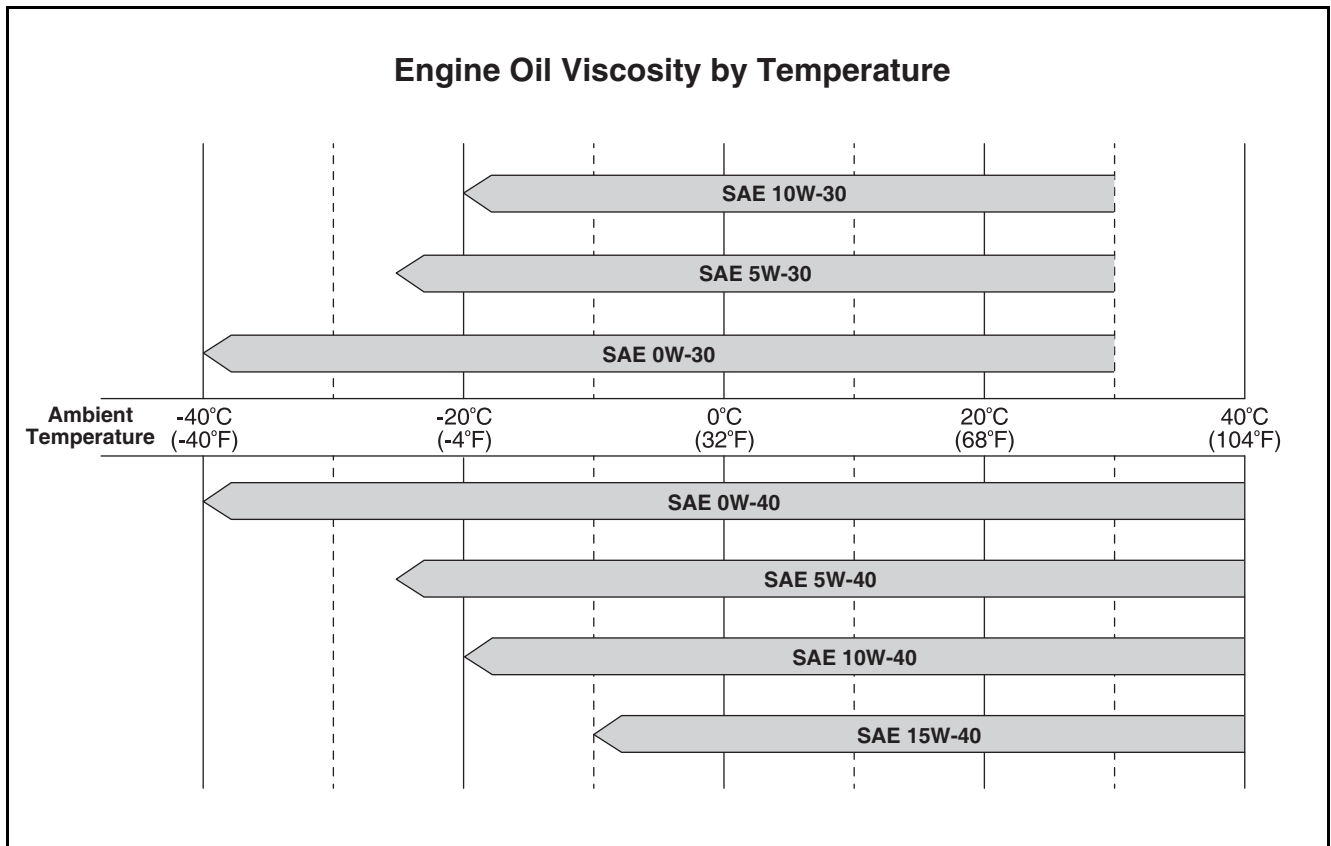
Check the engine oil level with an oil level gauge and add more engine oil if necessary. Check the oil level with the engine stopped. If the engine is running, stop the engine and measure the oil level after waiting 5 ~ 10 minutes for the engine oil to return to the oil pan. The oil level must lie between the upper and lower limits on the oil level gauge.

Engine oil must be changed regularly according to the maintenance schedule. Make sure to also replace the oil filter and cartridge when changing the engine oil.

4. Regular Inspections

Engine Oil Specifications

Use the specified engine oil suited to the environment and conditions where the engine will be used.



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The following engine oil specifications are recommended:

Engine Models	SAE Classification	Oil Class
LEP00/LEP01/LEP02/ MFP00/MFP01/MFP02	SAE 10W40	API CK-4
OOP00/OOP01/OOP02		API CI-4

Note) Use genuine oil recommended by HD Construction Equipment.

4. Regular Inspections

Engine Oil Capacity

Make sure to fill engine oil to the level recommended below.

Engine Models and Product Code	Engine Oil Capacity (L)		
	Inside The Oil Pan		Total ^a
	Maximum	Minimum	
DX08	35.0	18.0	38.0

- a. Including 3.0 L in the engine

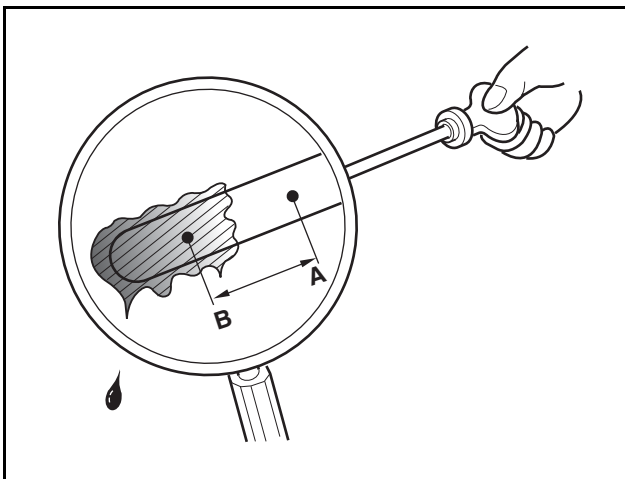
Checking Engine Oil

1. Move the engine to flat, level ground where the engine will remain horizontal.
2. After starting the engine, turn the engine off once it reaches a normal temperature.
3. Wait 5 ~ 10 minutes.
4. Pull out the oil level gauge.
5. Wipe off the indicator line on the oil level gauge with a clean cloth.

⚠ CAUTION

Wiping the engine oil gauge with a contaminated cloth causes foreign matter to enter the engine, leading to engine failure.

6. Reinsert the oil level gauge.
7. Pull the oil level gauge out again and check the level and condition of the oil.



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- 1) Check whether engine oil is smeared between the upper limit (A) and lower limit (B) on the oil level gauge.

- 2) If engine oil is smeared below the lower limit (B) or is not smeared on the gauge at all, add engine oil.

⚠ CAUTION

Do not add engine oil past the upper limit mark on the oil level gauge. Overfilling oil can cause engine damage.

- 3) Check the viscosity and condition of the engine oil; replace the oil if necessary.

Adding Engine Oil

⚠ CAUTION

Be careful not to allow foreign matter to enter the engine while removing the oil filler cap and adding oil.

1. Remove the oil filler cap on the top of the engine.
2. Add genuine oil recommended by HD Construction Equipment.
 - 1) Add the oil a small amount at a time.
 - 2) Wait 1 ~ 2 minutes and check the engine oil.
 - 3) Check whether engine oil is smeared between the upper and lower limits on the oil level gauge.
 - 4) Repeat until the engine oil reaches the proper level.

⚠ CAUTION

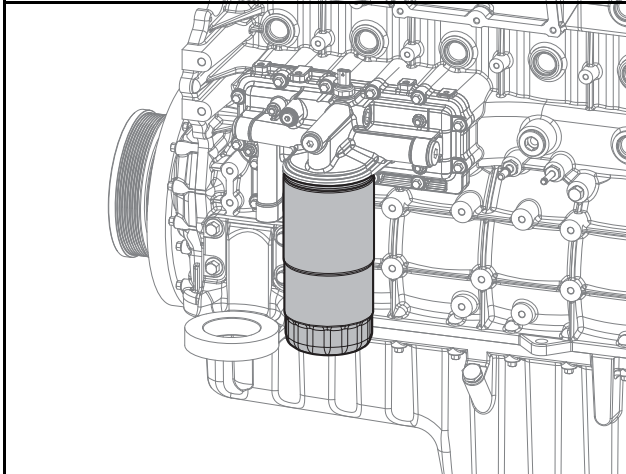
- Be careful not to allow foreign matter to enter the engine while adding engine oil.
- Adding engine oil past the upper limit on the oil level gauge may cause engine faults. If engine oil is filled past the upper limit, the engine oil must be drained until the oil level lies between the upper and lower limits on the oil level gauge.
- Do not use unspecified engine oil additives.

3. Install the oil filler cap after adding engine oil.

4. Regular Inspections

Changing Engine Oil

1. Drain the engine oil.
 - 1) Place a container for draining engine oil under the engine.
 - 2) Remove the drain plug and drain the engine oil.
 - 3) Remove the oil filler cap.
2. Replace the oil filter.



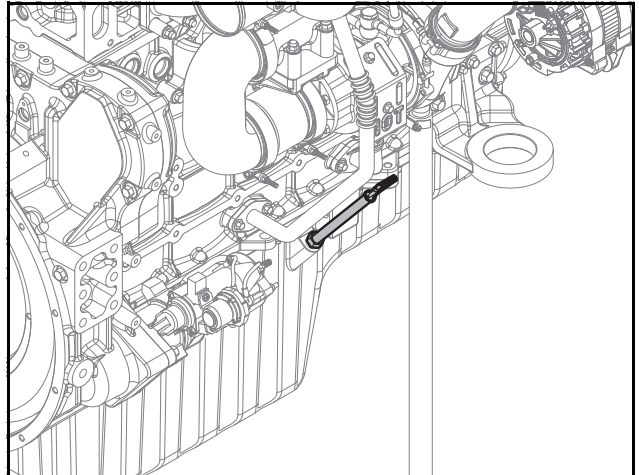
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- 1) Use a filter wrench to remove the oil filter.
- 2) Wipe off the head and cartridge contact surface of the oil filter thoroughly.
- 3) Make sure the oil filter cartridge is seated properly.
- 4) Apply a thin layer of oil to the O-ring on the cartridge.
- 5) Tighten the new oil filter by hand.
- 6) Use a filter wrench to finish tightening the oil filter.

⚠ CAUTION

- When replacing the oil filter cartridge, make sure to use a new genuine HD Construction Equipment cartridge.
- The new oil filter must not contain any oil when it is installed. Do not fill the new oil filter with oil from the replaced oil filter.

3. Add engine oil.



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- 1) Install the drain plug.
- 2) Add the specified amount of engine oil through the oil filler port.

⚠ CAUTION

While adding oil, be careful not to allow dust or foreign matter to enter the system.

- 3) Check that the oil level is at the upper limit mark on the dipstick.
4. Once this is complete, perform a final inspection.
 - 1) Idle the engine for a few minutes to distribute oil throughout the lubrication circuit of the engine.
 - 2) Stop the engine and wait approx. 10 minutes.
 - 3) Check the oil level and add oil if necessary.

⚠ CAUTION

Adding engine oil past the upper limit on the oil level gauge may cause engine faults. If engine oil is filled past the upper limit, the engine oil must be drained until the oil level lies between the upper and lower limits on the oil level gauge.

Fuel System

General Information

Fuel quality is crucial for engine performance, engine life, and satisfying emissions standards. HD Construction Equipment engines are designed to be used with diesel fuel in the region of sale.

CAUTION

- Only use clean fuel with the specified grade. Using imitation or unspecified fuel may cause severe faults in the engine.
- When fuel needs to be refilled, make sure to add fuel while the engine is stopped.

Fuel Specifications

In order to maintain optimum engine performance, make sure to use the correct fuel by referring to the following recommended fuel selection table.

- Ultra-low-sulfur diesel (ULSD)

Fuel Ingredients		Standard
Specific gravity	(kg/lit)	0.820 ~ 0.845
Flash point	(°C)	40 or more
Kinematic viscosity (40°C)	(cSt)	1.9 ~ 5.5
Sulfur content	(wtppm)	15 or less
Cloud point	(°C)	-
Pour point	(°C)	-17.5 or less
Low-temperature filter clogging temperature	(°C)	-16 or less
Color (ASTM)		2.5 or less
Carbon residue (10%) Distillation residue (wt)	(%)	0.15 or less
Total acid number	(mg KOH/g)	0.40 or less
Copper corrosion (100°C, 3 hours)		1 or less
Ash	(mass %)	0.01 or less
Water & sediment	(vol. %)	0.02 or less
Cetane number		45 or more
Distillation test temperature	50% distillation point	-
	90% distillation point	360 or less

Note) Fuel product standards are based on SK (Inc.) ultra-low-sulfur diesel

Fuel Filter

Remove the moisture and impurities in the fuel and pump the fuel to the fuel injection pump.

CAUTION

- Failing to check the fuel filter periodically and drain the water in the fuel filter causes moisture to enter the engine fuel system, leading to severe faults in the fuel injection pump, fuel injection pipe, common rail, and injectors. In addition, the performance of the fuel filter may be degraded or the filter may be damaged.
- When draining water from the fuel filter, fuel may 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 cause water to accumulate in the fuel filter.
- If water is not drained from the fuel filter when the fuel filter warning light is turned on, moisture may enter the fuel system and cause the engine to turn off.
- New fuel filters must not contain any fuel when they are installed. Do not fill a new fuel filter with fuel from a replaced fuel filter or fuel in the fuel tank.

Bleeding Fuel Delivery Lines

To bleed the air in fuel lines, open the valve on the top of the secondary fuel filter and operate the priming pump of the primary fuel filter.

4. Regular Inspections

Intake/Exhaust System

General Information

The air filter serves to supply the engine with clean air by filtering out dust and foreign matter found in atmospheric air. The air filter has a direct impact on engine life, exhaust gas, and engine power. Hence, it must be inspected, cleaned and replaced periodically.

CAUTION

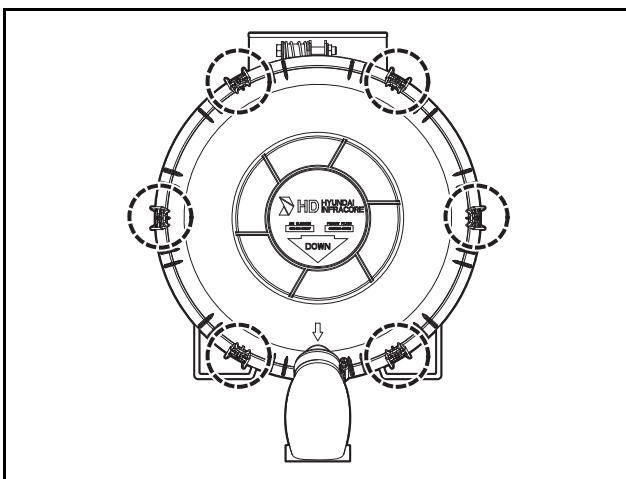
- Do not run the engine without an air filter.
- Only use specified air filters. Using an imitation or unspecified air filter may cause severe faults in the engine.
- If foreign matter enters the engine, it may cause wear inside the engine.
- Be careful not to damage related electrical parts or to allow foreign matter to enter the engine while replacing the air filter.
- Replace the air filter immediately if it is damaged.
- Be careful not to allow dust to enter the engine while installing the air filter.
- If the air cleaner element is deformed, damaged or cracked, replace it with a new one.
- Clean and replace the element at regular intervals.

Cleaning the Air Filter

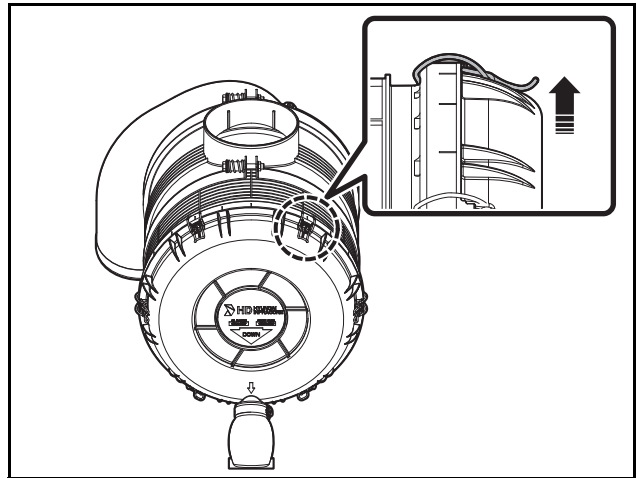
1. Clean the air filter.
- 1) Empty the dust canister periodically.

CAUTION

Do not allow the dust canister to fill more than halfway with dust.



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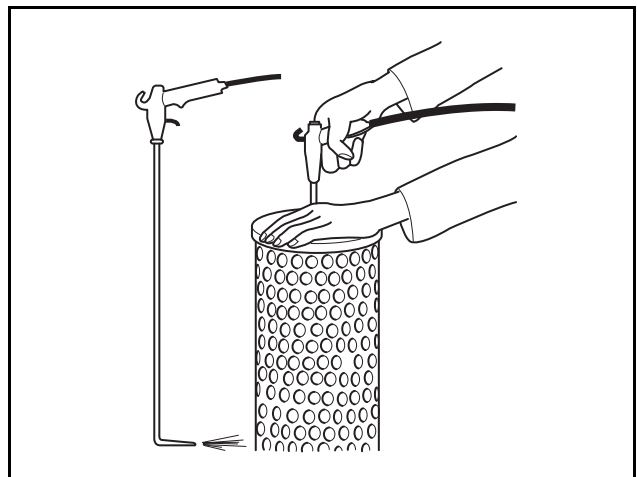
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- 2) Disassembled by loosening the 6 fixing clips.
- 3) Remove the dust canister cover and empty the canister.
- 4) Install the cover and dust canister correctly and with care.
- 5) Align the positions and fixed with 6 clips.

Cleaning the Air Cleaner Element

Clean the air filter element using whichever of the following three methods is most suited to the work environment.

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



EDL022155A

- 1) Use an air gun to clean the element thoroughly. Compressed air should be shot at a right angle to the bottom of the element.
- 2) Move the air gun up and down along the element to blow compressed air from the inside toward the outside until dust is no longer blown out.

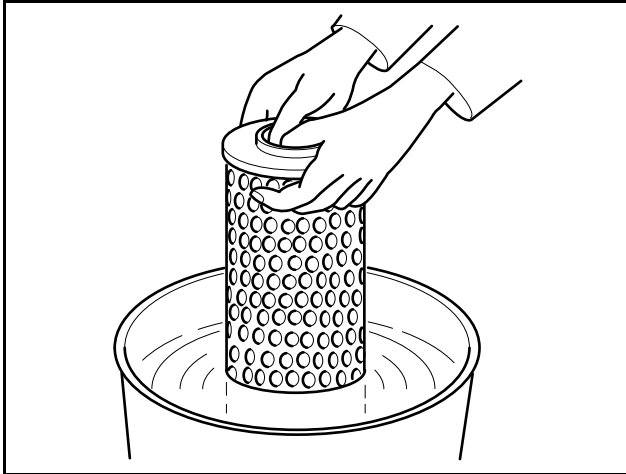
4. Regular Inspections

- 3) The pressure of compressed air should not exceed 5 bar.

⚠ DANGER

Make sure to put on protective glasses before performing this task. Otherwise, dust or foreign matter from the element may enter your eyes and cause injuries.

2. Wash the element.



EDL022156A

- 1) Before washing the element, clean it with compressed air as described above.
- 2) Then, soak the element in warm cleaning solvent for 10 minutes and shake it back and forth for approx. 5 minutes.
- 3) Rinse it with clean water, remove water from it, and leave it to air-dry. Make sure to dry the element completely before reinstalling it.

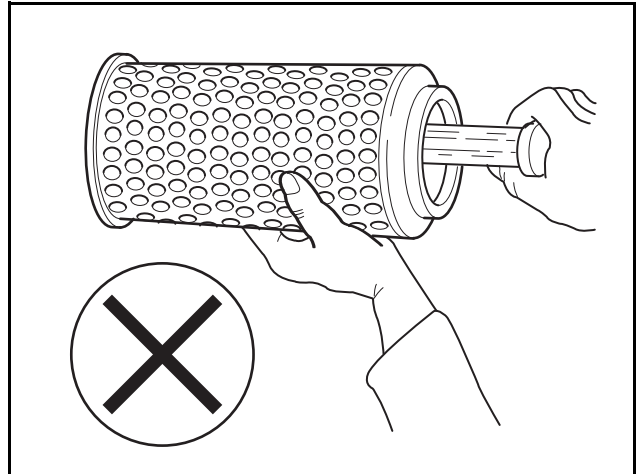
⚠ CAUTION

Never use a steam spray, gasoline, alkaline liquid or hot cleaning agent to wash the air cleaner element.

3. In emergencies, clean the element temporarily using the following method.
 - 1) Tap the end plate of the element with your thumb to clean it temporarily.

⚠ CAUTION

- This method should only be used in emergency situations where the element must be cleaned but there is no compressed air or cleaner available.
- Never use a hard object to tap the element in order to remove dust residue.



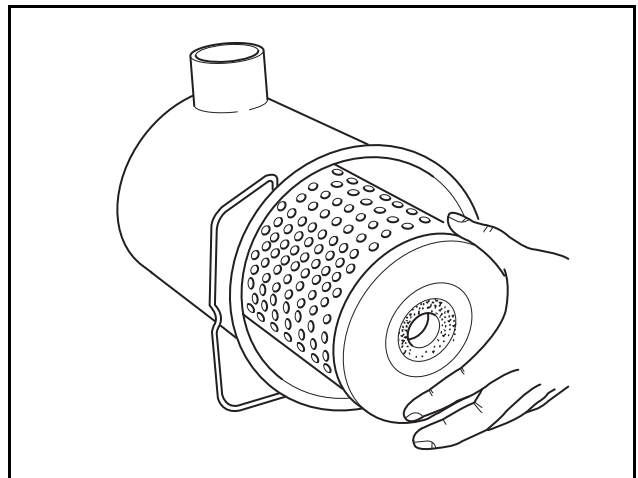
EDL022157A

Note) Before reinstalling the element, check it for folded paper, the condition of the rubber seal ring, and deformation.

Note) Never use a damaged element. If the quality of the element is suspicious, replace the element with a new one.

Replacing the Air Cleaner Element

1. Replace the air filter element.



EK00025A

- 1) Unscrew the hex nut and remove the dirty element. Clean or replace it with a new one.
- 2) Wipe the inside of the cleaner housing and the contact surface of the element seal ring with a wet rag thoroughly.

⚠ CAUTION

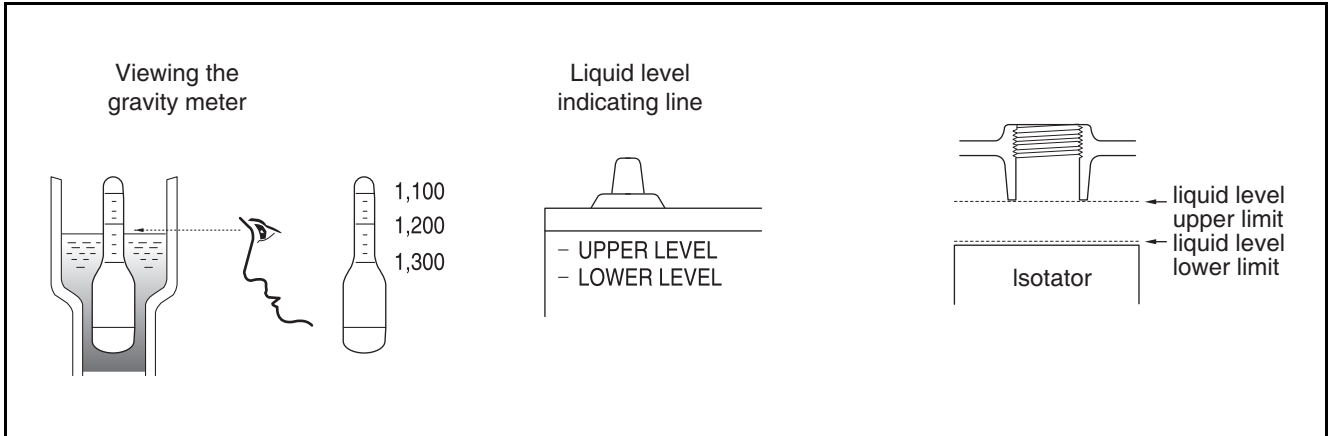
Make sure that dust does not enter the tip of the air cleaner.

4. Regular Inspections

Electrical System

Battery

1. Check the battery for electrolyte leakage due to cracks. If it is cracked, replace it with a new one.
2. Check the battery fluid level and add distilled water as necessary.
3. Measure the specific gravity of electrolyte. If the measurement is below the specified range (1.12 ~ 1.28), add more.



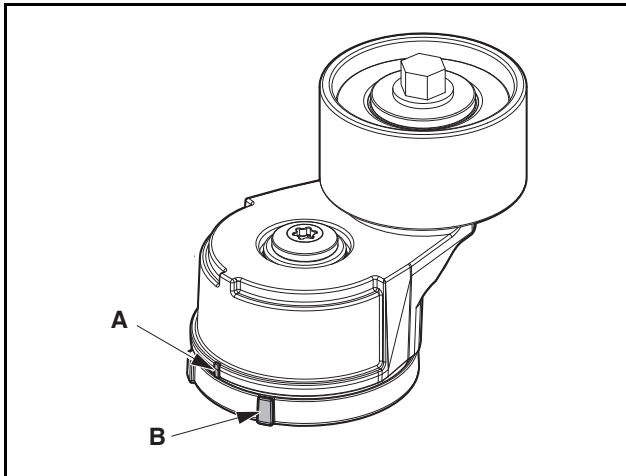
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Other/Driving System

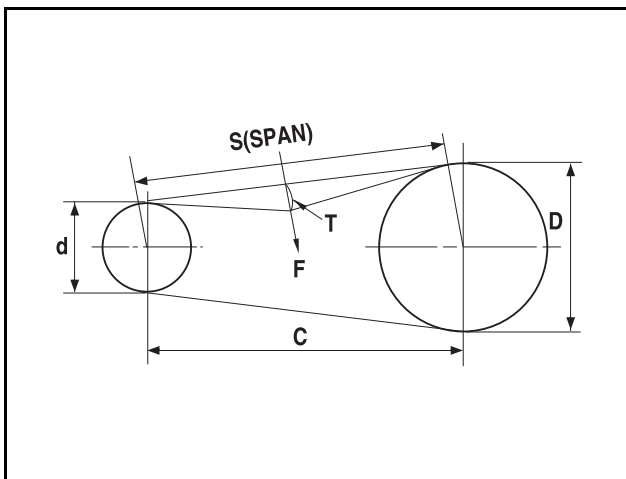
Belt Tension

Belt tension is maintained by an auto tensioner, so there is no need to adjust it. The belt must be replaced when the pointer indicates that a replacement interval is approaching.

1. Inspection conditions
 - 1) Check the belt for cracks, oil residue, and deformation due to heat and wear.
 2. The vertical bar (A) of the arrow is the "pointer", and if the distance between A and B is less than 1 cm (about the width of a finger), check and replace if necessary. (Checking list: noise generation, increase in coolant temperature, deterioration of power charging performance)



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EDL022140A

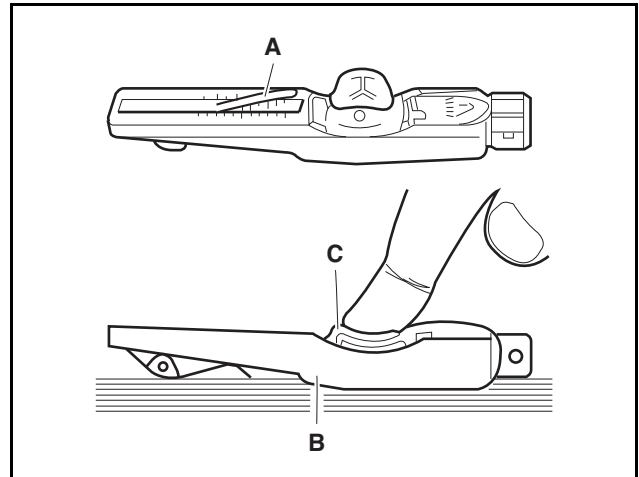
- 1) The tension of the belt can be inspected by checking the amount of deflection of the belt when applying the specified force (F) to it.
- 2) Adjust the belt so that the deflection (T) equals $0.015 \times S$ (1.5 mm for 100 mm).

Note) T : Deflection amount, S : Distance

$$3) \quad *S = \sqrt{C^2 + \frac{(D-d)^2}{2}}$$

Note) C : Center distance (mm), D : Large pulley dia. (mm),
d : Small pulley dia. (mm)

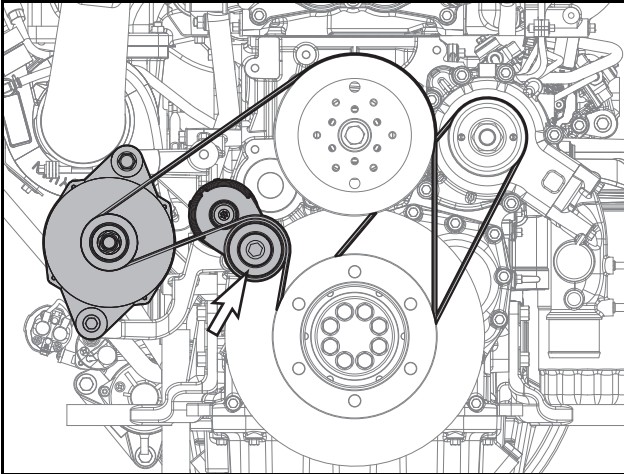
3. Measuring tension



EDL022141A

- 1) Insert the belt in the protrusion (A) of the tension measuring instrument.
 - Set the measuring instrument between the pulleys and set its contact end (B) to push the belt.
 - Press the pad (C) until the sound of the spring unscrewing is heard. This force pushes the tension measuring instrument upwards.
 - If there is still tension left on the belt after removing the pad (C), the measurement is not accurate.
- 2) Measuring tension
 - Read the value where the top of the protrusion (A) of the tension measuring instrument is aligned with the scale.
 - Before reading the value, make sure that the needle of the measuring instrument is returned back to the original position.
- 3) Adjusting tension and replacing the Micro-V belt
 - Rotate the auto tensioner clockwise using the square groove located in the center of the idle pulley of the auto tensioner.
 - Remove the old belt.
 - After fitting the new belt onto all of the pulleys (check to make sure the belt covers all belt grooves), rotate the auto tensioner clockwise to wrap the belt around the auto tensioner; then, fit the tightened auto tensioner in place.

4. Regular Inspections

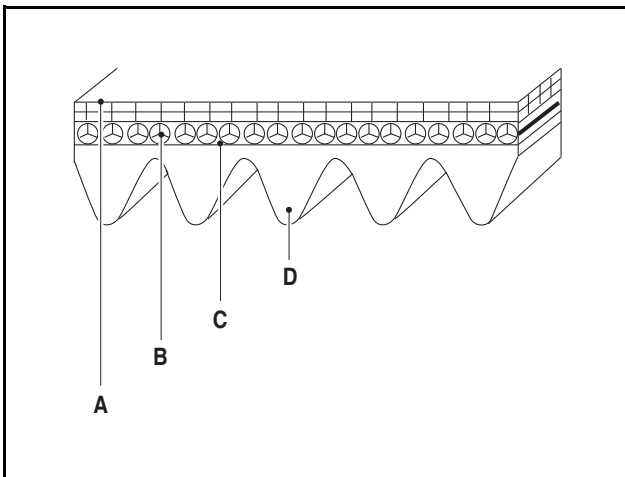


EDX08250046

4. The belt tension is as follows:

Type	Drive belt width	Tension on the tester	
		Installation (10 minutes after operation)	During service after prolonged operation (replacement interval)
8PK Micro-V	27.62 mm	326 ~ 390 N	282 N

5. The belt consists of the following components:



EDL022142A

1) The belt consists of the cover layer (A), cord (B), adhesive rubber (C) and belt reinforcement rubber shim (D).

5. General Engine Information

Method of Indicating Units	65
Unit Conversion Methods.....	65
Tightening Torque	66
Tightening Torque of Main Parts.....	66
Tightening Torque of General Bolts.....	67
Tightening Torque of Plug Screws.....	68
Tightening Torque of Hollow Screws (Four Holes)	68
Engine Disassembly	69
Order of Engine Disassembly	69
Engine Assembly	81
Order of Engine Assembly	81

Method of Indicating Units

Unit Conversion Methods

This is a method for converting between SI and US units.

1. Multiply the SI unit by the numbers in the table below to obtain the US unit.

Note) (SI unit) X (number) = (US unit)

Note) 1 mm X 0.03937 = 0.03937 in

2. Divide the US unit by the numbers in the table below to obtain the SI unit.

Note) (US unit) ÷ (number) = (SI unit)

Note) 1 in ÷ 0.03937 = 25.4 mm

Item	Number	SI Unit	US Unit
Length	0.03937	mm	in
	3.28084	m	ft
	1.093613	m	yd
	0.621371	km	mile
Area	0.00155	mm ²	in ²
	0.1550	cm ²	in ²
	10.76391	m ²	ft ²
	1.19599	m ²	yd ²
Weight	2.204623	kg	lb
	0.001	kg	t (ton)
Volume	0.061024	cc	in ³
	0.061024	ml	in ³
	0.061024	cm ³	in ³
	61.023744	L	in ³
	0.264172	L	gal
force ^a	2.204622	kgf	lbf
	0.2248089	N	lbf
Acceler- ation	3.28084	m/s ²	ft/s ²
	39.37008	m/s ²	in/s ²
torque ^b	7.233014	kgf.m	lbf.ft
	86.79619	kgf.m	lbf.in
	0.7375621	N.m	lbf.ft
	8.850748	N.m	lbf.in
Power	1.340483	kw	Hp
Pressure	0.01	kPa	bar
	7.500615	kPa	mmHg
	20.88543	kPa	lb/ft ²
	14.2233	psi	kg/cm ²

Item	Number	SI Unit	US Unit
Power	1.3596	kw	PS
	0.98635	ps	hp
Fuel con- sumption	0.00162	g/kwh	lb/psh
Energy	0.000947817	J	BTU
	0.7375621	J	lbf.ft
	0.0002777778	J	Wh
Light	0.09290304	lm/m ²	lm/ft ²
Speed	0.6213712	km/h	mph
Tempera- ture	c	°C	°F

- a. $9.806 \times (\text{kg.f}) = (\text{N})$
- b. $9.806 \times (\text{kgf.m}) = (\text{N.m})$
- c. $\{(9/5) \times (^\circ\text{C}) + 32\} = (^\circ\text{F})$
 $\{(^\circ\text{F}) - 32\} \times (5/9) = (^\circ\text{C})$

5. General Engine Information

Tightening Torque

Tightening Torque of Main Parts

Main Parts	Name (Dia. × Pitch)	Tightening Torque
Cylinder block bearing cap bolt	M16 × 1.5	9.0 kgf.m + 90° + 90°
Oil spray nozzle	M8	3.1 ±0.31 kgf.m
Flywheel housing mounting bolt	M12 × 1.75	11.2 +1.12 kgf.m
Flywheel housing cover: timing pointer	M8	3.1 ±0.78 kgf.m
Crankshaft pulley mounting bolt	M14 × 1.5	22 ±2.2 kgf.m
Vibration damper	M10 × 1.5	6.2 ±0.9 kgf.m
Flywheel fixing bolt	M14 × 1.5	9.0 kgf.m + 90°
Connecting rod cap bolt	M14 × 1.5	8.16 kgf.m + 120°
Cylinder head bolt	M14 × 1.5	6.0 kgf.m + 90° + 90° + 45°
Cylinder head cover bolt	M8	2.7 ±0.27 kgf.m
Injector cable mounting nut	M4	0.125 ~ 0.175 kgf.m
Rocker arm bracket mounting bolt	M8 × 1.0	3.35 ±0.34 kgf.m
Oil pump mounting bolt	M8	3.1 ±0.31 kgf.m
Oil cooler mounting bolt	M8	3.1 ±0.31 kgf.m
Oil pan mounting bolt	M8	3.1 ±0.31 kgf.m
Oil drain valve	M30	10 ±1.0 kgf.m
Exhaust manifold mounting nut	M10 × 1.25	6.6 ±0.66 kgf.m
Intake stake mounting bolt	M10 × 1.5	3.1 ±0.31 kgf.m
Starter motor	M12 × 1.75	10.5 ±1.05 kgf.m
Alternator mounting bolt (Upper)	M12 × 1.5	8.0 ±0.8 kgf.m
Alternator mounting bolt (Lower)	M10 × 1.5	6.2 ±0.62 kgf.m
Engine mounting bracket	M12 × 1.75	11.2 ±2.8 kgf.m
High-pressure fuel pump gear nut (CP pump)	M18 × 1.5	8.0 ±1 kgf.m
Fuel injector mounting bracket bolt	M8	3.8 ±0.4 kgf.m
High-pressure fuel pump mounting bolt (cylinder block)	M8	2.2 +0.2 kgf.m
	M10	6.2 +0.62 kgf.m
High-pressure fuel connector nut	M22 × 1.5	5.5 ±0.55 kgf.m
Common rail mounting bolt	M8	3.1 +0.78 kgf.m
High-pressure fuel pipe - High-pressure fuel connector	M14 × 1.5	4.0 ±0.4 kgf.m
High-pressure fuel pipe - Common rail	M14 × 1.5	4.0 ±0.4 kgf.m
High-pressure fuel pipe - High-pressure fuel pump	M16 × 1	4.0 ±0.4 kgf.m
Fuel filter mounting bolt	M10	6.2 ±1.55 kgf.m

Note) Do not reuse bolts.

5. General Engine Information

Tightening Torque of General Bolts

Refer to the following tightening torques for bolts whose tightening torque is not included in the list of the main parts.

1. Tightening torque of general bolts

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

Note) The standard torque values specified above are based on 70% of the elastic limit of bolts.

Note) The tensile force is the tensile strength multiplied by the cross-sectional area of the screw.

Note) Special screws should be tightened to only 85% of the standard value. For example, a screw coated with MoS2 should be tightened to only 60% of the standard value.

5. General Engine Information

Tightening Torque of Plug Screws

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

Tightening Torque of Hollow Screws (Four Holes)

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

a. Installed in HD Construction Equipment engines

Engine Disassembly

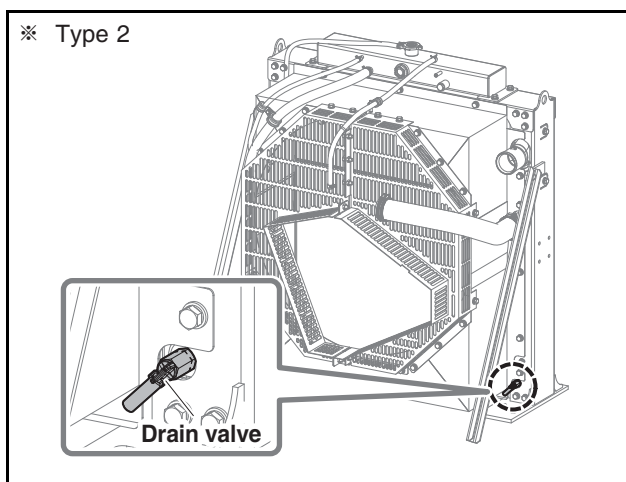
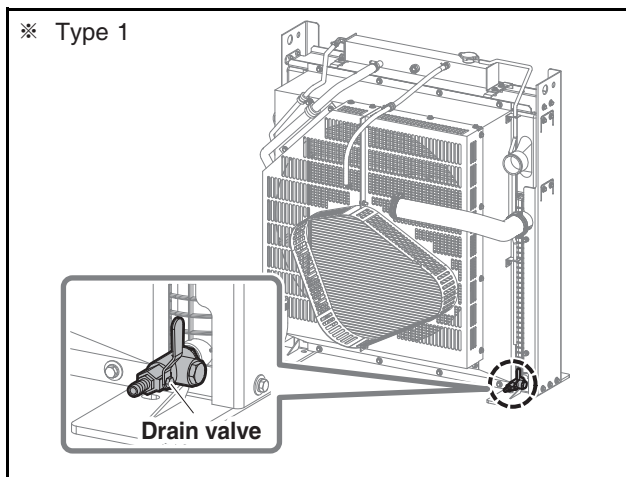
Order of Engine Disassembly

CAUTION

- Before disassembling the engine, prepare the necessary tools and genuine parts.
- Prepare a shelf for the storage of removed parts.
- Perform service work in a bright, clean space.
- Always keep your hands clean while performing service work.
- Store removed parts in the order of disassembly.
- Be careful not to allow removed parts to come into contact or mix with each other.

Disassemble the engine in the following order.

1. Drain coolant.



- 1) Check whether the engine and radiator have cooled off.
- 2) Place a container in front of the coolant drain plug.
- 3) Remove the radiator cap.

- 4) Open the drain valve located on the bottom of the radiator to drain the coolant.
- 5) Remove the coolant drain plug from the cylinder block and the oil cooler.
- 6) Drain coolant into the prepared container.
- 7) After draining the coolant, reinstall the coolant drain plug.

DANGER

- Do not open the radiator cap while the engine is overheated. Otherwise, hot coolant will spurt out and may cause severe burns. Open the radiator cap only after ensuring that the engine has cooled off sufficiently.
- Label and store coolant containers separately to avoid confusion with beverage containers. If coolant is ingested, seek medical assistance immediately.

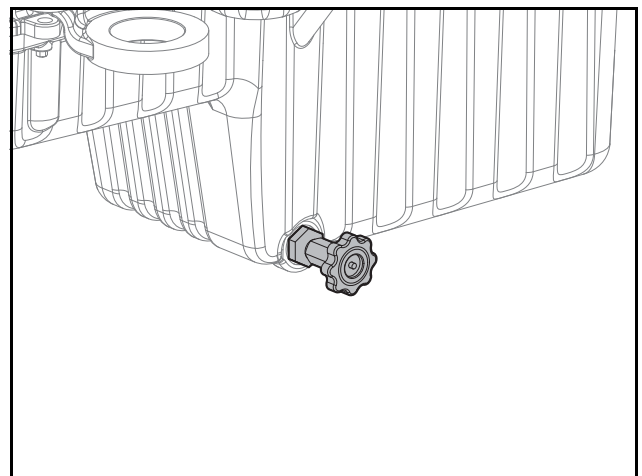
WARNING

Dispose of used coolant according to the regulations of local public institutions. Engine oil can cause severe environmental pollution if it is spilled on the ground, in drains, sewers, rivers, or seas. Failing to dispose of engine oil properly according to disposal regulations is punishable by law.

CAUTION

Be careful not to spill coolant on any belts or electrical components when replacing the coolant.

2. Remove the oil level gauge.
 - 1) Pull out the oil dipstick.
 3. Drain the engine oil.



5. General Engine Information

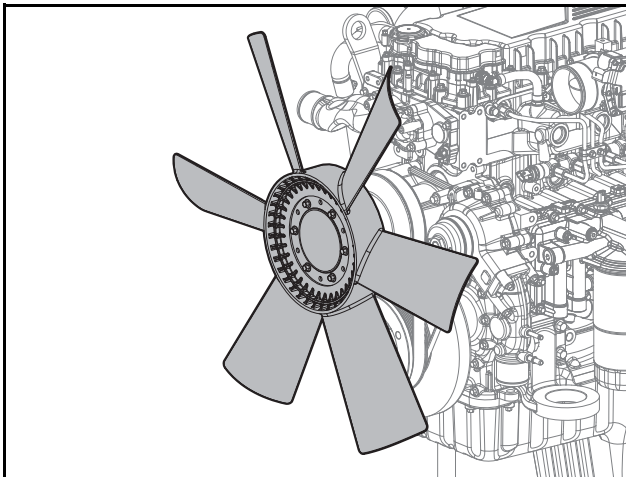
- 1) Place a container for draining engine oil under the engine.
- 2) Open the drain valve on the oil pan and drain the engine oil into the prepared container.
- 3) Remove the oil filler cap.
- 4) Remove the engine oil filter.
- 5) Once engine oil has been drained, assemble the engine oil filter and drain plug.

WARNING

Dispose of used oil according to the regulations of local public institutions.

Engine oil can cause severe environmental pollution if it is spilled on the ground, in drains, sewers, rivers, or seas. Failing to dispose of engine oil properly according to disposal regulations is punishable by law.

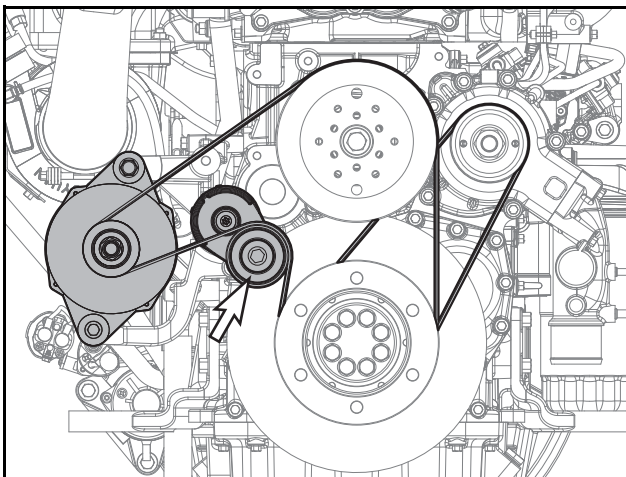
4. Remove the cooling fan.



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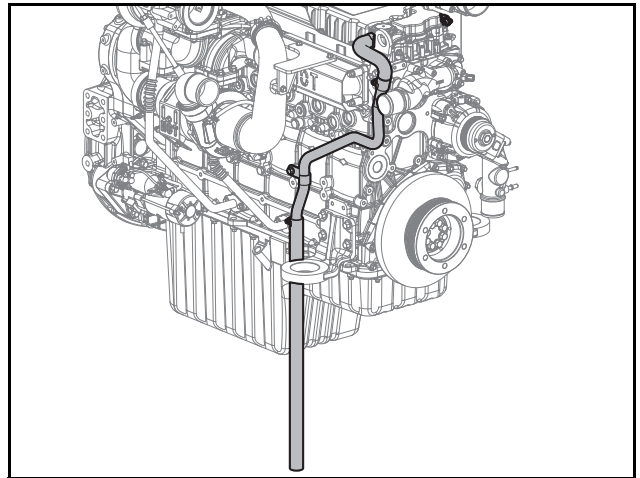
- 1) After removing the flange mounting bolt, remove the flange and cooling fan.

5. Remove the belt and alternator.



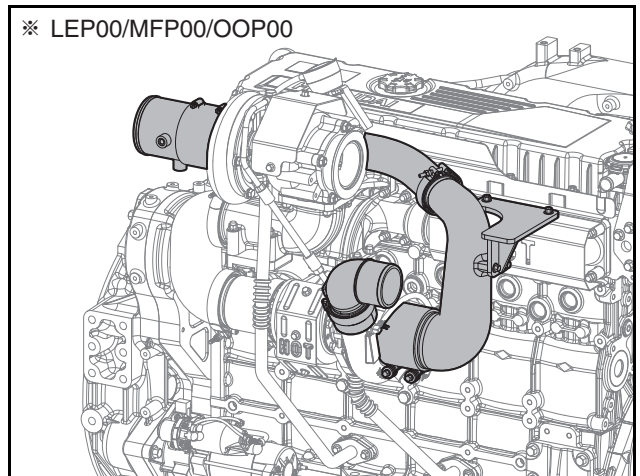
EDX08250046

- 1) Rotate the auto tensioner clockwise to remove the belt.
- 2) Loosen the alternator bracket fixing bolt.
6. Remove the breather hose and pipe.



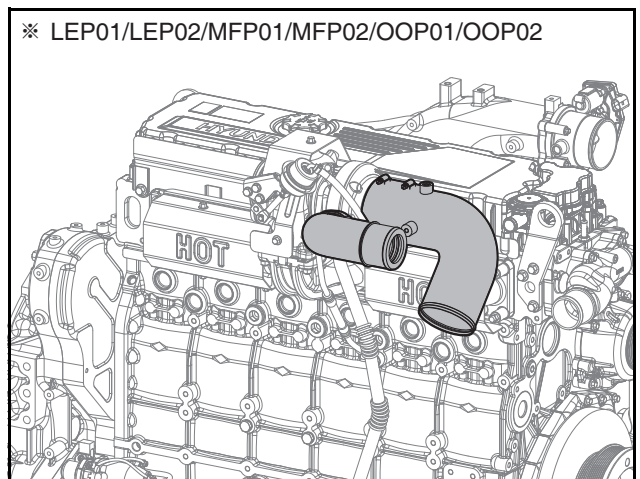
EDX08250047

- 1) Unscrew the mounting clamp screws and disconnect the rubber hose.
- 2) Remove the breather hose and pipe.
7. Disconnect the air pipe.



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※ LEP00/MFP00/OOP00



EDX08250114

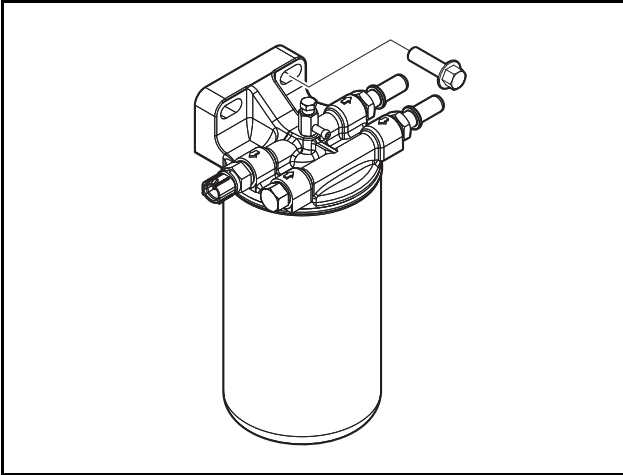
- 1) Loosen the mounting bolts and disconnect the air pipe.

5. General Engine Information

CAUTION

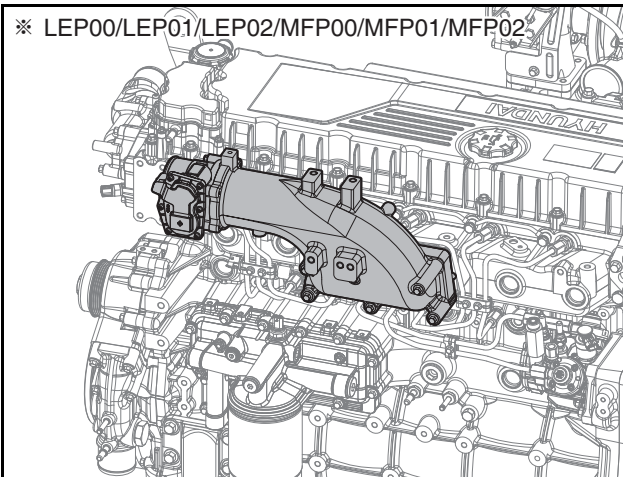
Be careful not to allow foreign matter to enter the turbo-charger.

8. Remove the fuel filter.



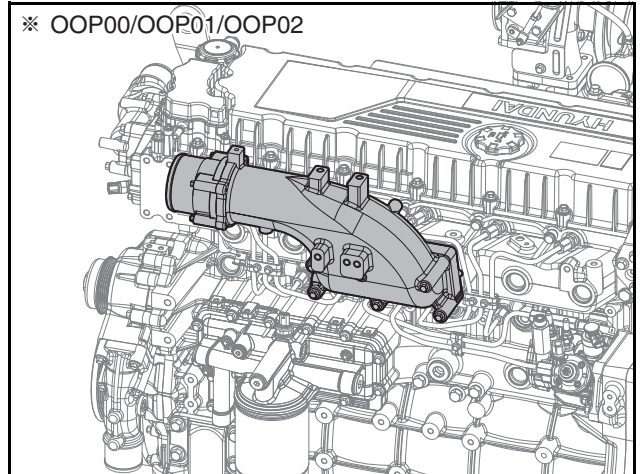
EDX05250040

- 1) Unscrew the hollow screw on the fuel filter and disconnect the fuel hose.
 - 2) Unscrew the mounting bolt on the fuel filter and remove the filter.
9. Remove the intake stake.



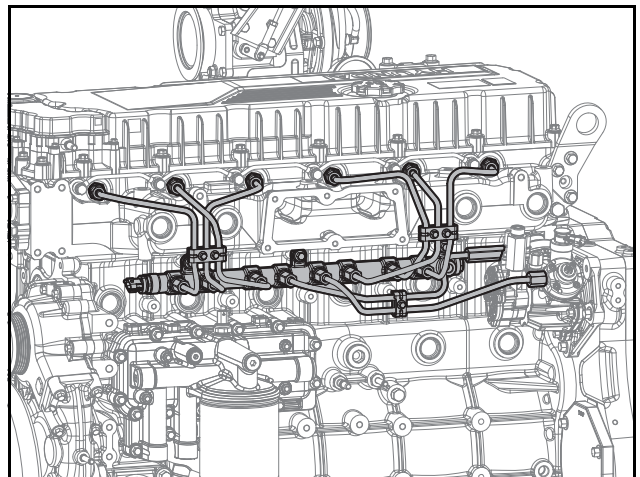
EDX08250115

※ OOP00/OOP01/OOP02



EDX08250116

- 1) Loosen the intake stake mounting bolts and remove the intake stake from the cylinder block.
 - 2) Remove the gasket and clean the gasket mounting surface with a scraper thoroughly.
10. Remove the common rail and high-pressure pipes.



EDX08250051

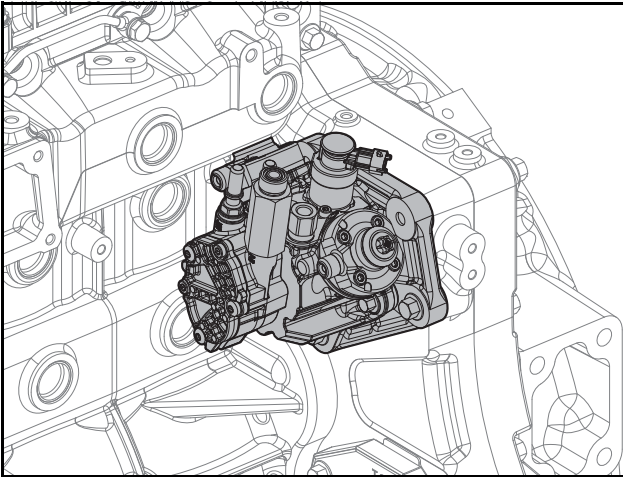
- 1) Disconnect the high-pressure pipes between the high-pressure fuel connectors and the common rail.
- 2) Loosen the common rail mounting bolts and remove the common rail.

CAUTION

- After disassembling the common rail, seal it to prevent foreign matter from entering.
- High-pressure fuel pipes cannot be reused once they have been removed.

5. General Engine Information

11. Remove the high-pressure fuel pump.



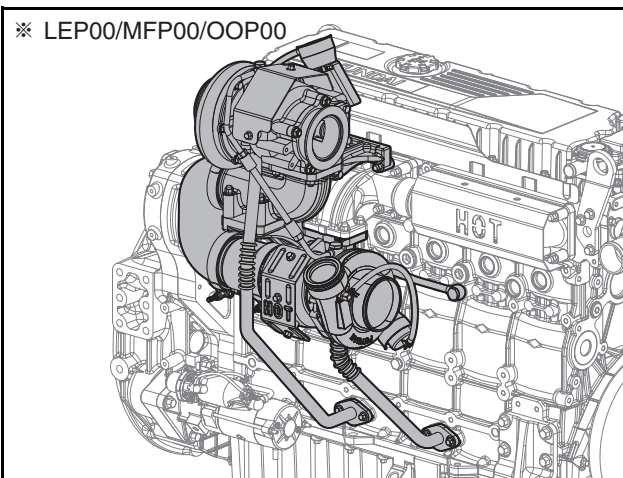
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- 1) Loosen the mounting bolts on the high-pressure fuel pump and remove the high-pressure fuel pump.

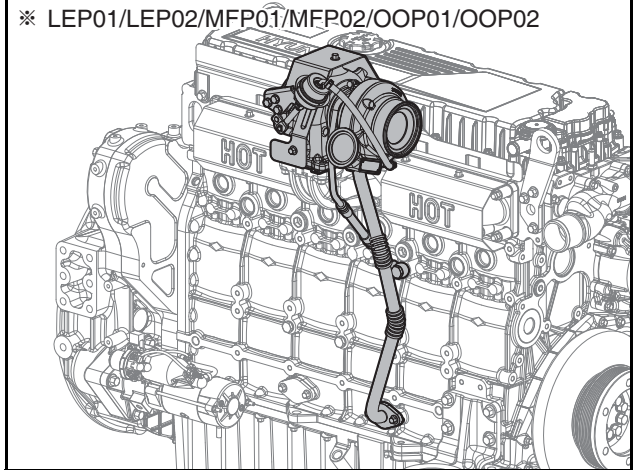
⚠ CAUTION

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

12. Remove the turbocharger.

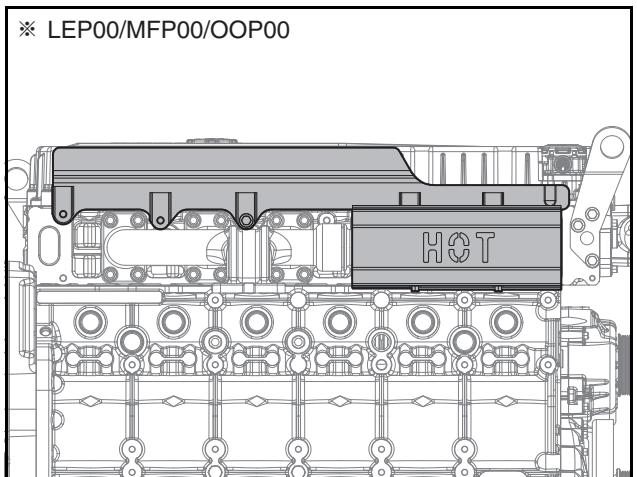


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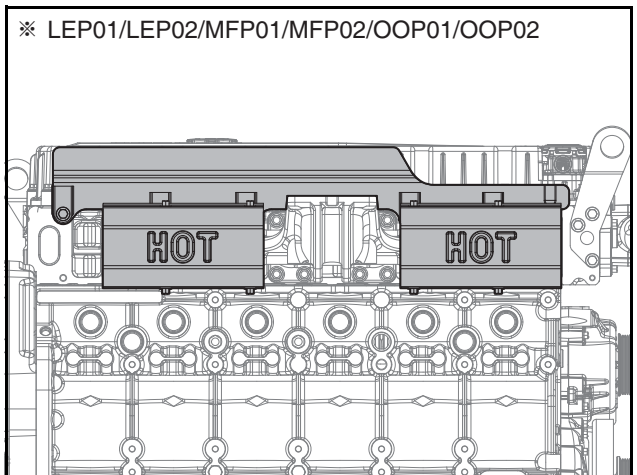


EDX08250118

- 1) Disconnect the air pipe connected to the turbocharger.
 - 2) Disconnect the oil delivery pipe between the cylinder block and turbocharger and the oil pipe between the turbocharger and cylinder block.
 - 3) Loosen the turbocharger mounting bolts and remove the turbocharger from the exhaust manifold.
13. Remove the exhaust manifold.

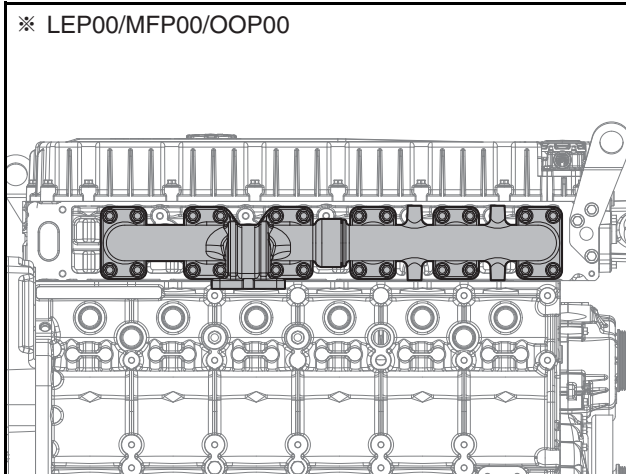


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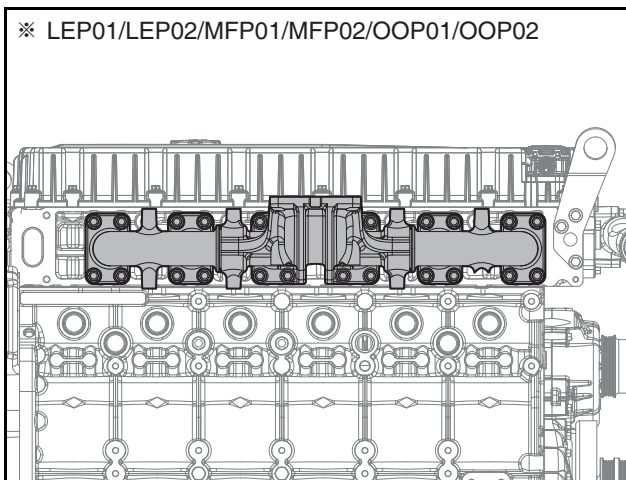


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5. General Engine Information



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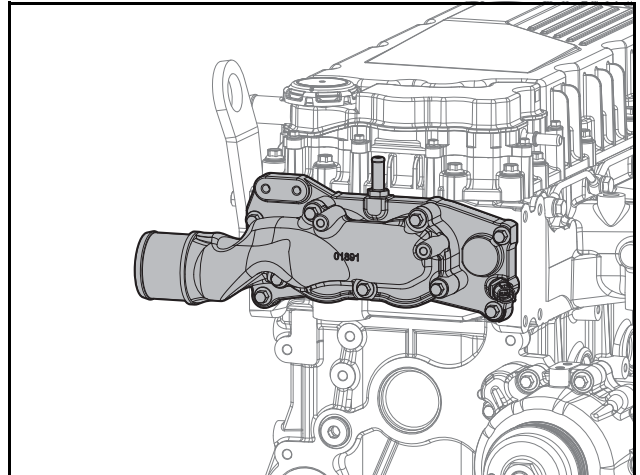
EDX08250122

- 1) Loosen the heat shield mounting bolts to remove the heat shield.
- 2) Loosen the exhaust manifold mounting bolts and remove the exhaust manifold.

CAUTION

Do not reuse any gaskets.

14. Remove the coolant pipe and thermostat.



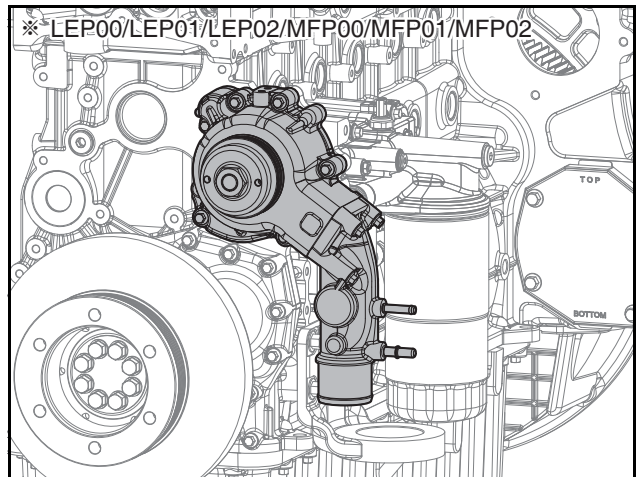
EDX08240056

- 1) Loosen the coolant pipe mounting bolts and disconnect the coolant pipe from the thermostat housing.
- 2) Remove the coolant thermostat and O-ring.
- 3) Remove any gasket residue on the coolant pipe with a scraper completely.

CAUTION

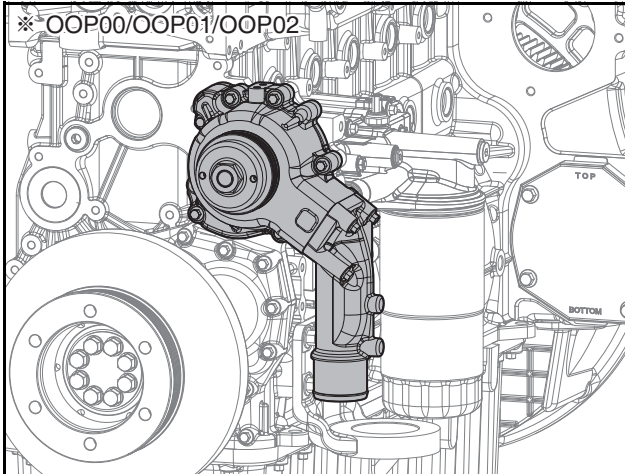
Make sure that gasket residue does not enter the coolant passage.

15. Remove the coolant pump.



EDX08250123

5. General Engine Information



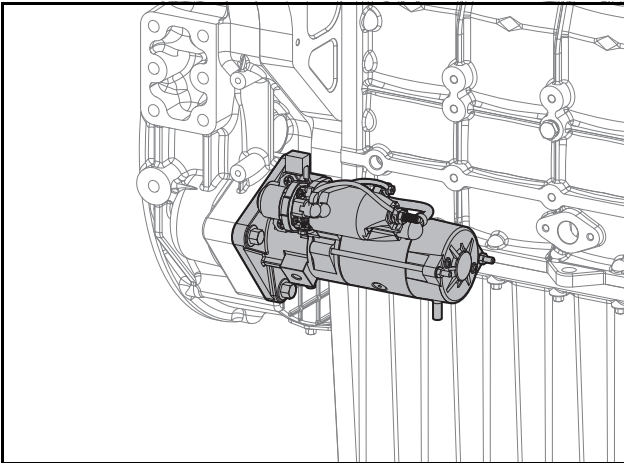
EDX08250124

- 1) Loosen the mounting bolts on the bracket holding the coolant pump and oil cooler in place.
- 2) Loosen the oil cooler mounting bolt (1).
- 3) Loosen the coolant pump mounting bolts and remove the coolant pump.
- 4) Remove the coolant pump O-ring.

CAUTION

Do not reuse O-rings.

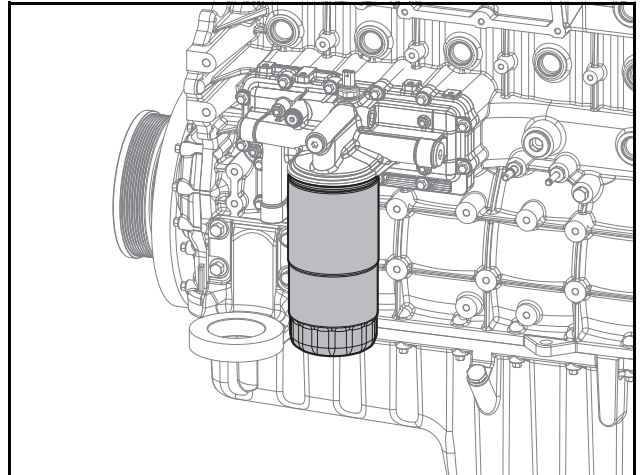
16. Remove the starter motor.



EDX08240058

- 1) Loosen the mounting bolts on the starter motor and remove the motor, taking care not to damage its gear.

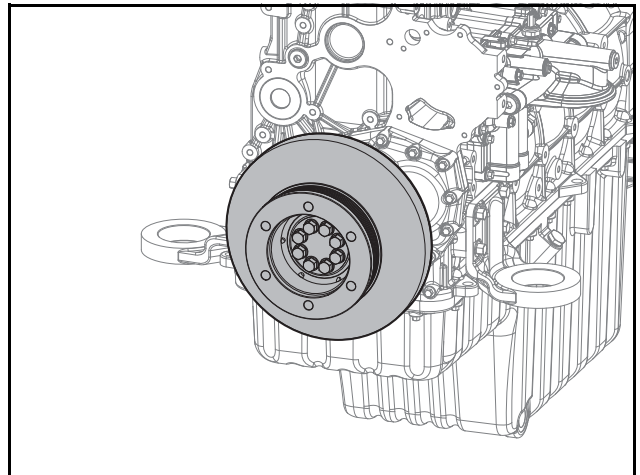
17. Remove the oil filter.



EDX08250060

- 1) Use a special tool for the oil filter cartridge to remove the cartridge.

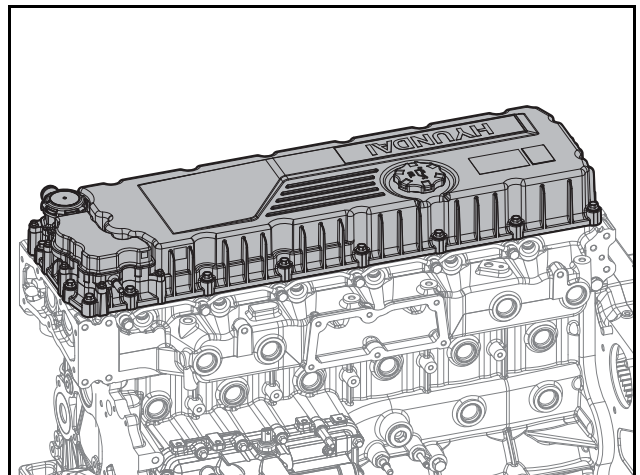
18. Remove the vibration damper.



EDX08250061

- 1) Loosen the mounting bolts on the vibration damper and crank pulley in the reverse order of their mounting order to remove the vibration damper assembly.

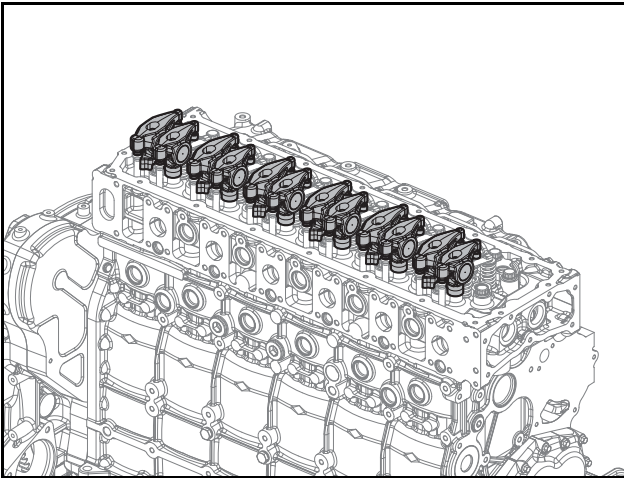
19. Remove the cylinder head cover.



EDX08240061

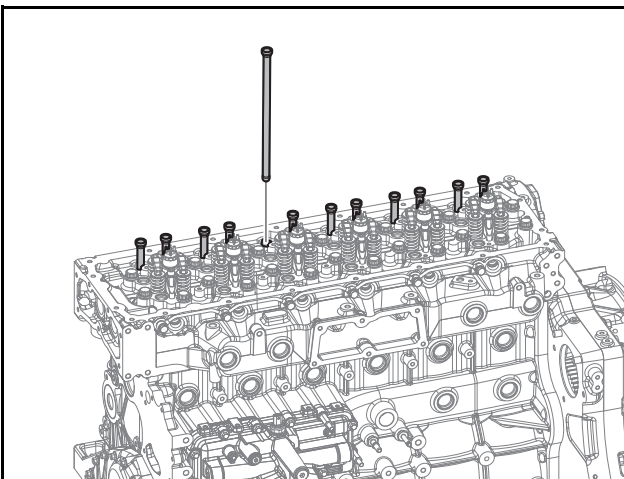
5. General Engine Information

- 1) Loosen the cylinder head cover mounting bolts and remove the cylinder head cover.
20. Remove the rocker arms.



EDX08240016

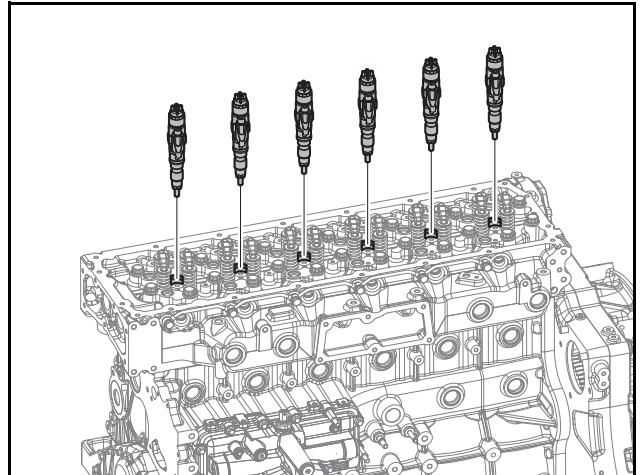
- 1) Loosen the rocker arm bracket mounting bolts in the reverse order of their mounting order and remove the rocker arm assembly.
21. Remove the pushrods.



EDX08240017

- 1) Remove the pushrods.

22. Remove the fuel injectors.



EDX08240018

- 1) Loosen the mounting nuts on the high-pressure fuel connectors and remove the high-pressure fuel connectors.
- 2) Remove the harness connected to the injectors.
- 3) Loosen the injector mounting bracket bolts and remove the injectors.

CAUTION

Be careful not to damage the nozzles while removing the injectors.

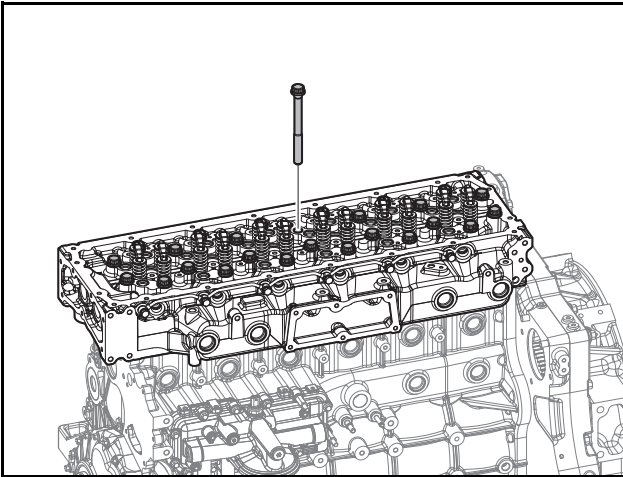
- 4) Remove the seal rings from the nozzle holes in the cylinder head.

CAUTION

To remove the injectors, loosen the mounting nuts on the high-pressure fuel connectors and remove the high-pressure fuel connectors completely; then, loosen the caliper mounting bolts on the injectors and remove the injectors.

5. General Engine Information

23. Remove the cylinder head.



EDX08240019

- 1) Loosen the cylinder head bolts over several steps in the reverse order of their mounting order and remove the cylinder head.
 - Step 1: Loosen the bolt 1 ~ 2 threads.
 - Step 2: Loosen the bolt completely and remove it.
- 2) Remove the cylinder head bolts by following steps 1 and 2 above.

CAUTION

Do not reuse head bolts.

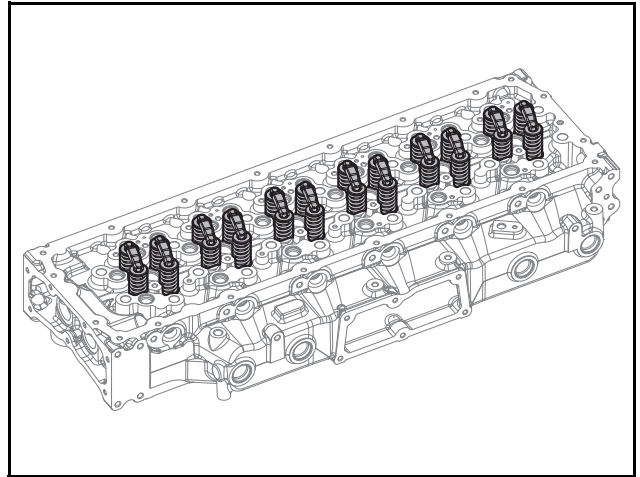
- 3) Remove the cylinder head gasket.
- 4) Remove any foreign matter on the surfaces of the cylinder head and block.

CAUTION

Be careful not to damage the mating surfaces.

- 5) Loosen the mounting bolts on the lifting hooks installed on the cylinder head and remove the lifting hooks.

24. Remove the valves and valve stem seals.



EDX08240062

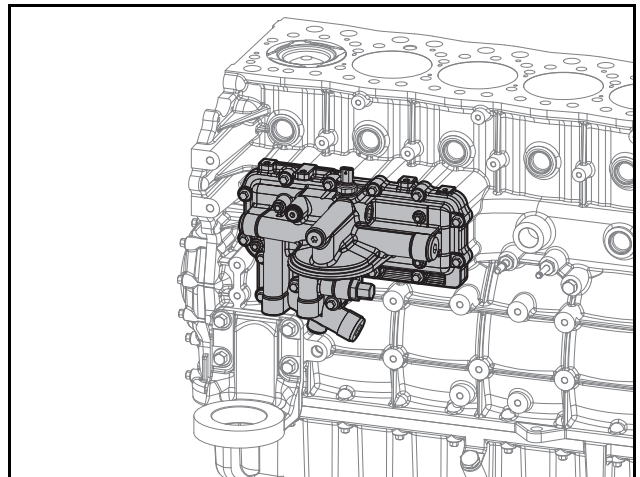
- 1) Use a valve spring compressor to press down the valve springs and retainers and remove the valve cotter pins.
- 2) Remove the valve springs and retainers.
- 3) Remove the calipers.
- 4) Use a normal tool to remove the valve stem seals.

CAUTION

Do not reuse valve stem seals.

- 5) Remove the valves.
- 6) Loosen the mounting bolts on the lifting hooks installed on the cylinder block and remove the lifting hooks.

25. Remove the oil cooler.

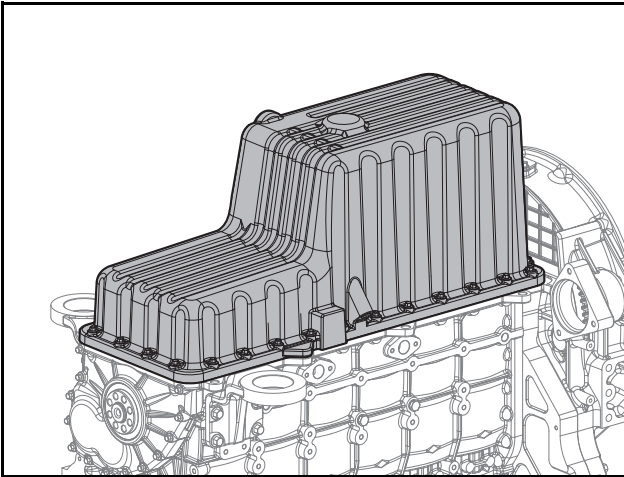


EDX08250062

- 1) Loosen the oil cooler mounting bolts and remove the oil cooler.

5. General Engine Information

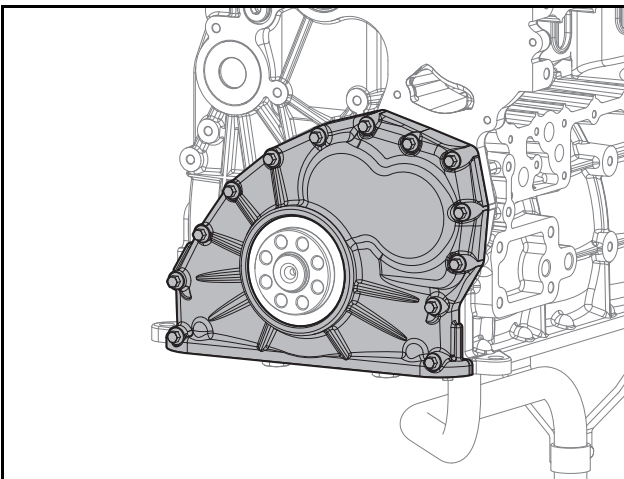
26. Remove the oil pan.



EDX08250063

- 1) Loosen the oil pan mounting bolts and remove the oil pan.
- 2) Remove the oil pan gasket.

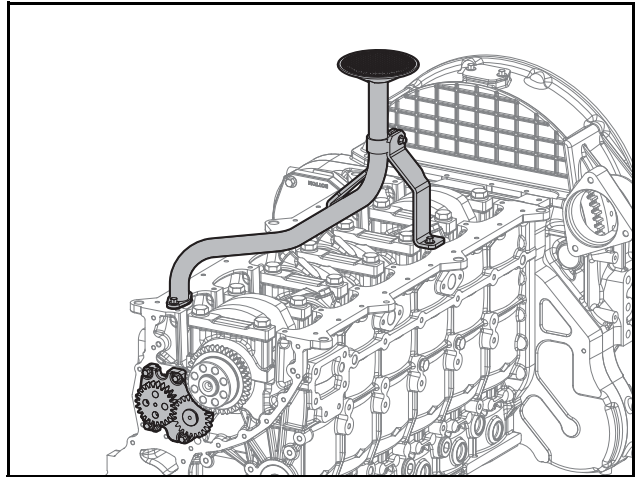
27. Remove the oil seal and front oil seal cover.



EDX08240065

- 1) Use an oil seal remover to remove the oil seal.
- 2) Loosen the gear case cover mounting bolts and remove the oil seal cover.

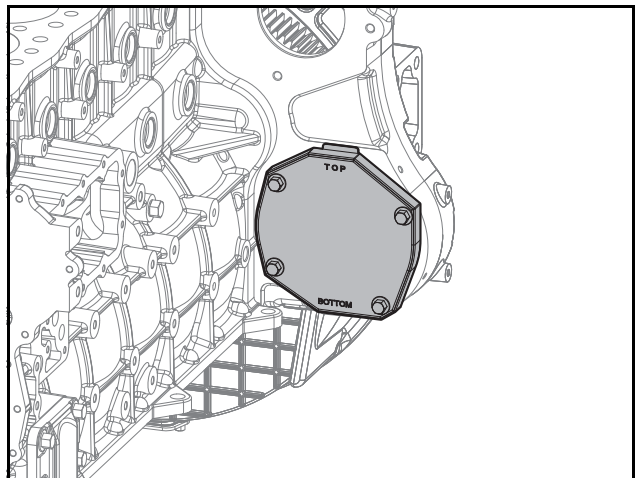
28. Remove the oil pump and pipe.



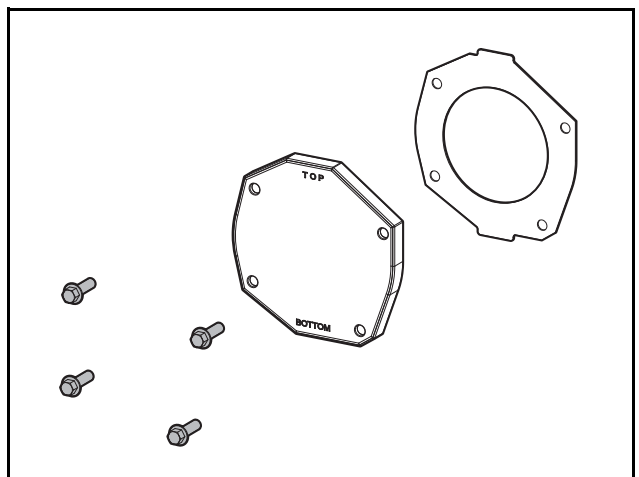
EDX08250064

- 1) Loosen and separate the bracket fixing bolts of the oil suction pipe.
- 2) Loosen the fixing bolts of the oil suction pipe assembled to the block and separate the suction pipe.
- 3) Loosen the oil pump assembly bolts and separate the oil pump.

29. Remove the PTO (Power Take Off) cover & gasket.



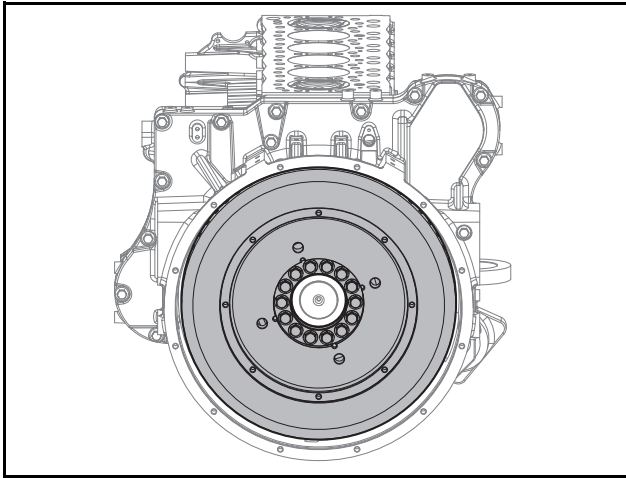
EDX08250065



EDX05250041

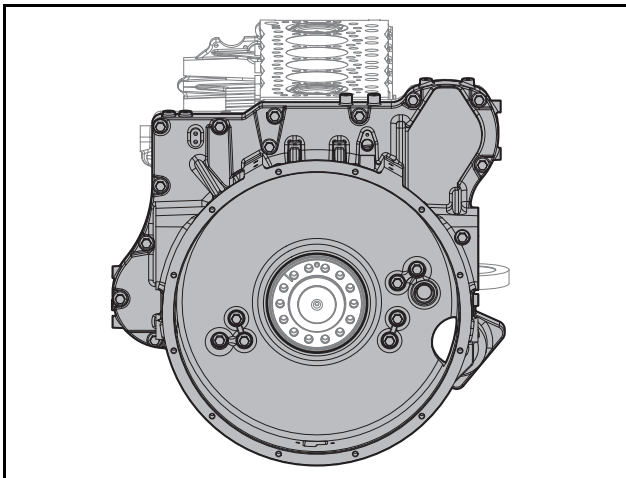
5. General Engine Information

- 1) Remove 4 inner socket bolts from the PTO (Power Take Off) cover & gasket.
- 2) Remove the PTO (Power Take Off) cover & gasket.
30. Remove the flywheel.

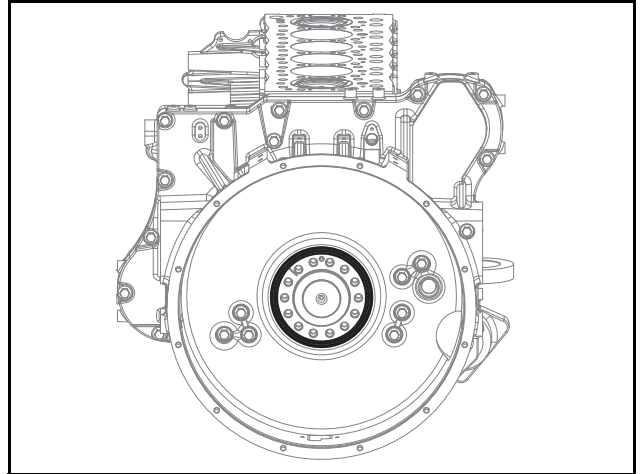


EDX08250066

- 1) Loosen the flywheel mounting bolts and install temporary guide bolts in their place; then, remove the flywheel.
- 2) Loosen bolts over several steps in the reverse order of their installation order and remove the flywheel.
31. Remove the flywheel housing.

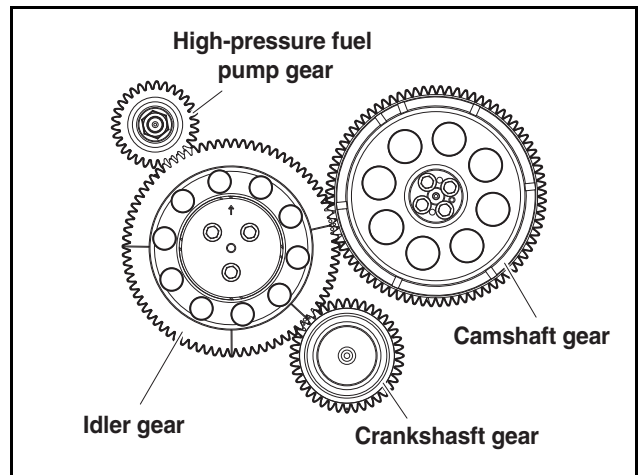


EDX08250072



EDX08250073

- 1) Loosen the flywheel housing mounting bolts and remove the flywheel housing.
- 2) Remove the flywheel housing oil seal.
32. Remove the cam gear and idler gear.

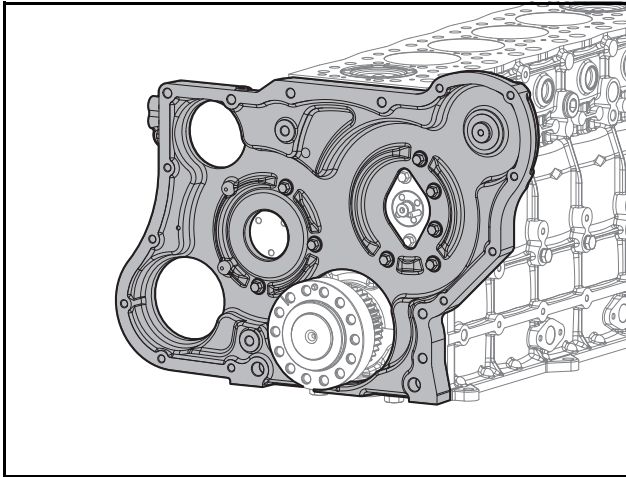


EDX08240028

- 1) Loosen the camshaft gear mounting bolts and remove the camshaft gear.
- 2) Loosen the idler gear mounting bolts and remove the idler gear pin.

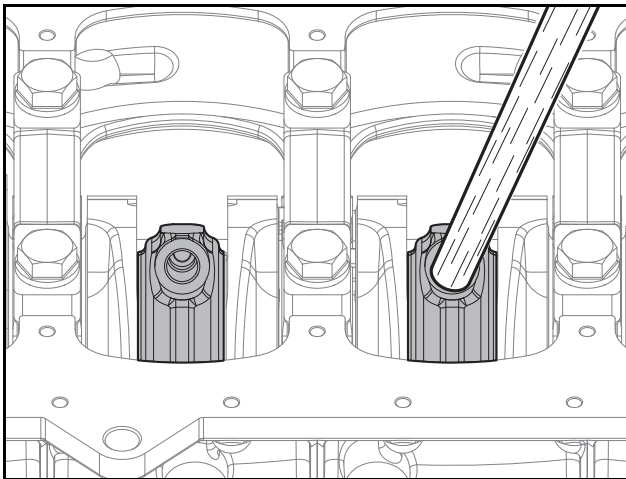
5. General Engine Information

33. Remove the timing gear case.



EDX08240195

- 1) Loosen the timing gear case mounting bolts.
 - 2) 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.
34. Remove the pistons and connecting rods.

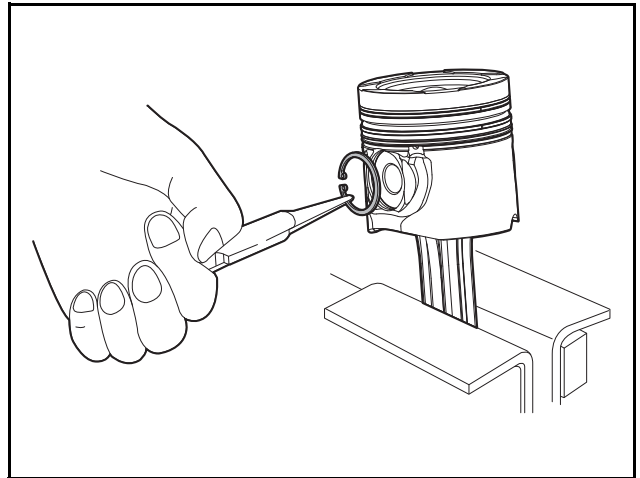


EDX08240022

- 1) Loosen the connecting rod cap bolts in the reverse order of their mounting order.
- Note) Loosen the bolts in two steps as with the cylinder head bolts.
- 2) Tap the top and bottom of the connecting rod caps with a urethane hammer gently to remove the bearing caps and bearings.
 - 3) Push the connecting rods from the direction of the oil pan towards the cylinder head with a wooden stick to remove the piston assemblies.
 - 4) Removed pistons should be stored in their corresponding cylinder order so that they do not touch each other.
 - 5) Install the connecting rod caps on their corresponding rods temporarily to avoid mixing them up.

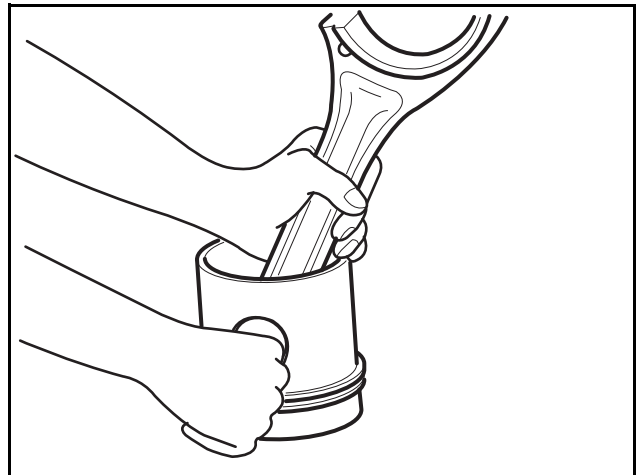
35. Remove the pistons.

- 1) Remove the snap rings of the piston pins with pliers.



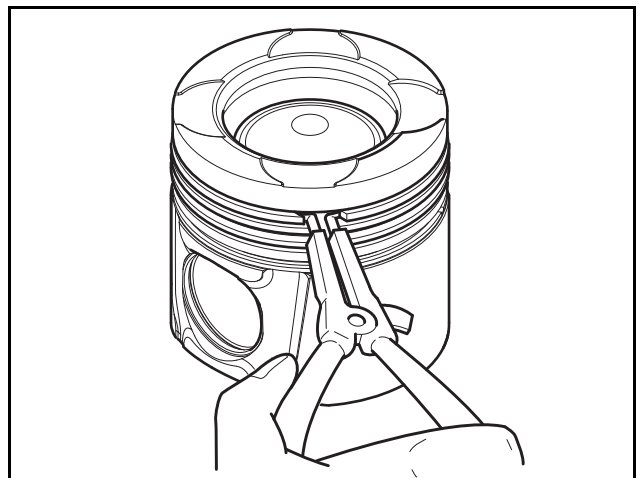
EDL06200081

- 2) Separate the piston and connecting rod by lightly tapping the piston pin with a wooden hammer or stick.



EAMD0881

- 3) Use piston ring pliers to remove the piston rings.

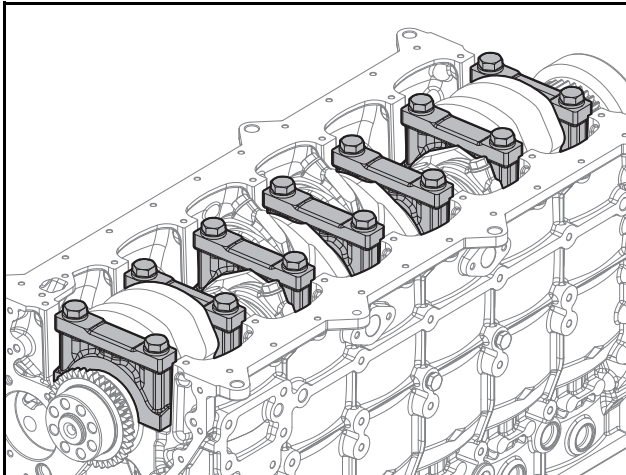


EH40M048

- 4) Remove carbon residue from the pistons and clean them thoroughly.

5. General Engine Information

36. Remove the bearing caps.



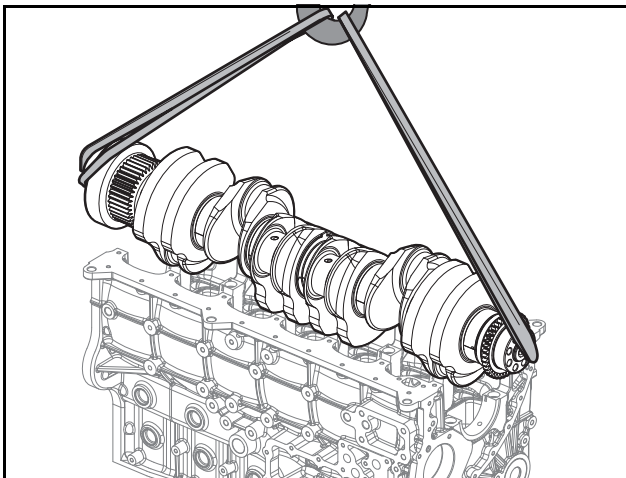
EDX08240023

- 1) Loosen the bearing cap mounting bolts in several steps in the reverse order of their installation order and remove the bearing caps.

Note) Loosen them in the same way as the cylinder head bolts.

- 2) Keep the bearing caps in order.

37. Remove the crankshaft.



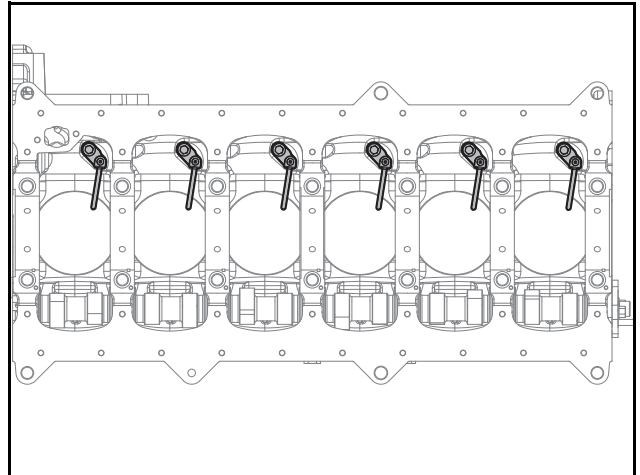
EDX08240024

- 1) Install bolts temporarily on either side of the crankshaft.
- 2) Attach ropes to the bolts and lift the crankshaft with a crane, taking care not to damage the crankshaft.
- 3) Store the removed crankshaft on a special shelf to prevent it from being bent or damaged.
- 4) Remove the main bearings in order and store them safely.

⚠ CAUTION

- Make sure that the main bearings and bearing caps are not mixed up.
- To avoid mixing parts up, temporarily install the main bearings in the bearing caps in order.

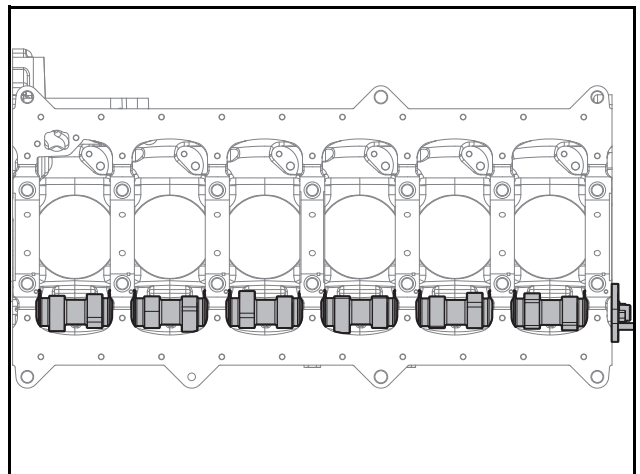
38. Remove the oil spray nozzles.



EDX08240025

- 1) Loosen the valve mounting screws on the oil spray nozzles and remove the oil spray nozzles.

39. Remove the camshaft and tappets.



EDX08240026

- 1) Turn the camshaft while removing it to prevent damage to the camshaft.
- 2) Store the removed camshaft on a special shelf to prevent it from being bent or damaged.
- 3) Remove the tappets.

⚠ CAUTION

Check for damage, scratches and wear; replace if necessary.

Engine Assembly

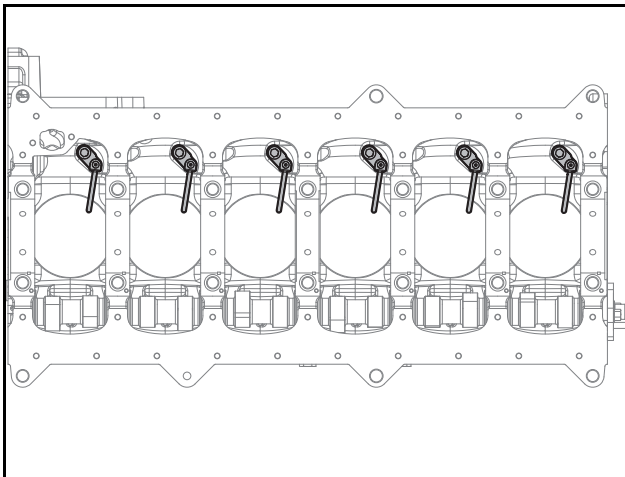
Order of Engine Assembly

CAUTION

- Clean all the removed components thoroughly. In particular, clean the oil and coolant passages with compressed air and check whether there is any resistance.
- Prepare general tools and special service tools for engine assembly.
- Prepare clean engine oil to be applied to each sliding section.
- Prepare service items, such as sealant and gaskets.
- Replace used gaskets, seal rings and other consumables with new parts.
- Each bolt should be tightened to its specified torque in order and should not be overtightened.
- After installing engine components, check that they operate smoothly.
- After the initial assembly, check each bolt for looseness.
- Keep your hands clean at all times during work.

Assemble the engine in the following order.

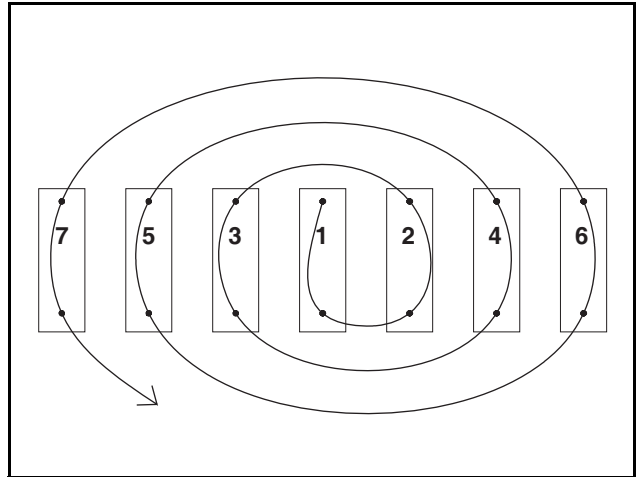
1. Assemble the cylinder block.
 - 1) Place a wooden block or thick paper on the floor of the workspace to prevent damage to the cylinder head mounting surface. Face the head mounting surface downwards.
2. Assemble the oil spray nozzles.



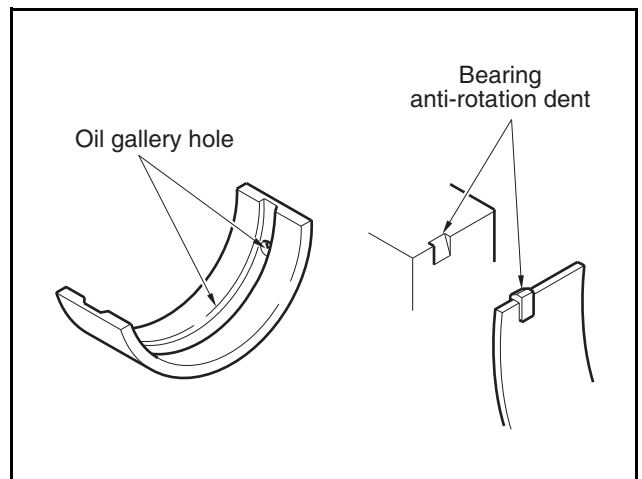
EDX08240025

- 1) Assemble the oil injection nozzle bolt with a tightening torque of 3.1 kgf.m.

3. Assemble the crankshaft.
 - 1) Assemble the main bearings so that their holes align with the pairs of oil holes in the cylinder block.



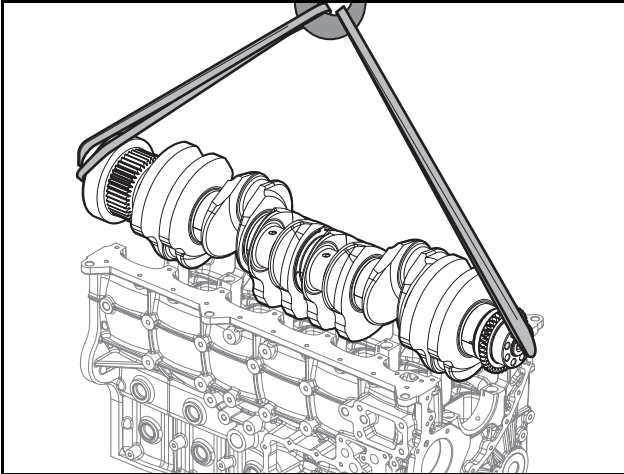
EH6OM062



EAOM4083

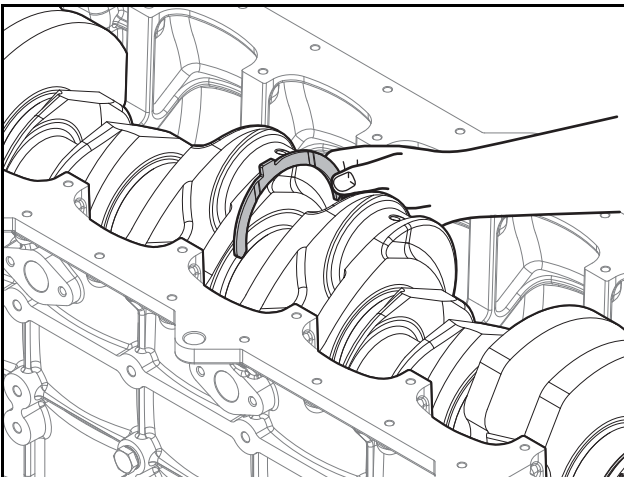
- 2) Apply clean engine oil to the surface of the bearings.
- 3) Fit bolts into both sides of the crankshaft temporarily and use the mounting bolts to place the crankshaft on the cylinder block.

5. General Engine Information



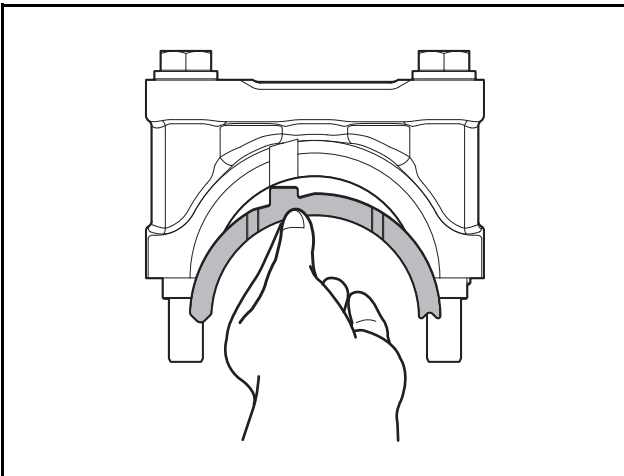
EDX08240024

- 4) Apply engine oil to the pin and journal sections of the crankshaft.
- 5) After applying oil, assemble the thrust washers with the oil grooves facing outwards.



EDX08240137

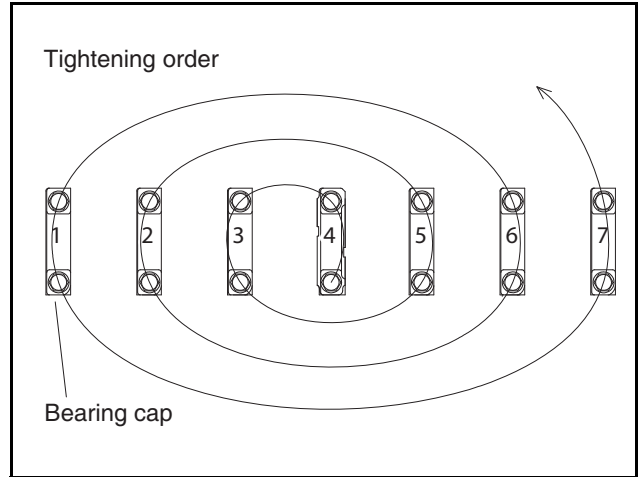
- 6) Assemble the bearings and thrust washers with the bearing caps.



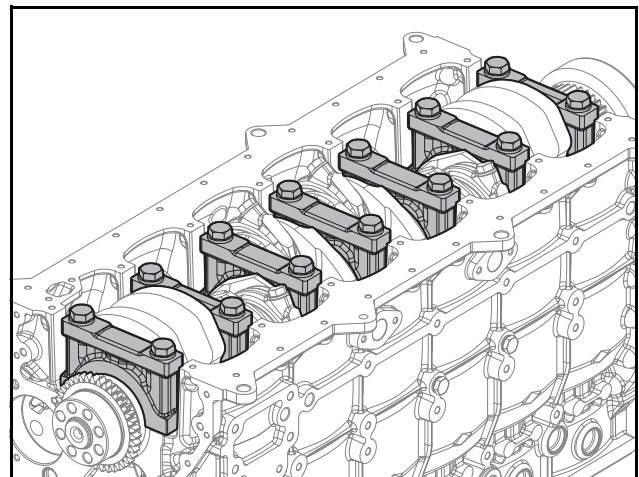
EDX08240136

- 7) Apply oil to the bearings and thrust washers.

- 8) Assemble the bearing caps with the numbers on the cylinder block matching the numbers on the bearing caps.
- 9) Tighten the bearing cap bolts to the specified tightening torque in the order of assembly.



EH8OM018

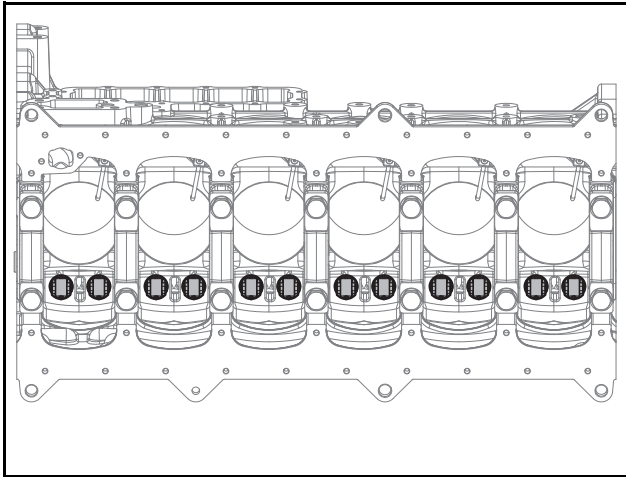


EDX08240023

- 10) Tighten the bolts on both sides evenly until the bearing caps are seated securely.
- 11) Use a torque wrench to assemble them in the following order.
 - Step 1: Tighten the bolts to a torque of 9 kgf.m until they are seated securely.
 - Step 2: Tighten the bolt by turning it an additional 90°.
 - Step 3: Tighten the bolt by turning it an additional 90°.
- 12) Tighten the bearing caps in the following order: 4-3-5-2-6-1-7.
- 13) Rotate the assembled crankshaft 2 ~ 3 times, checking whether it rotates smoothly.

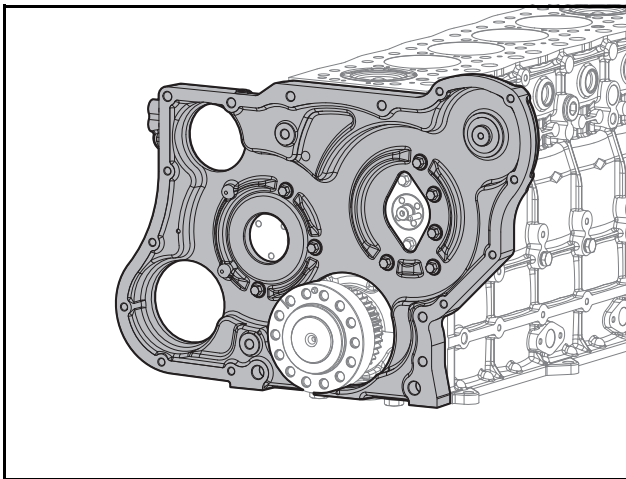
5. General Engine Information

4. Assemble the tappets and camshaft.



EDX08240098

- 1) Cool the new bushings in dry ice for approx. two hours.
 - 2) Use a bench press to press-fit them into the cam bushing positions on the cylinder block.
 - 3) After installation, measure the inside diameter of the cam bushing to check for deformation.
 - 4) Apply engine oil to the face of the tappets and insert the tappets into the tappet holes in the cylinder block.
 - 5) Apply engine oil to the camshaft holes and camshaft journals on the cylinder block.
 - 6) Insert the camshaft into the camshaft holes in the cylinder block.
5. Assemble the timing gear case.



EDX08240195

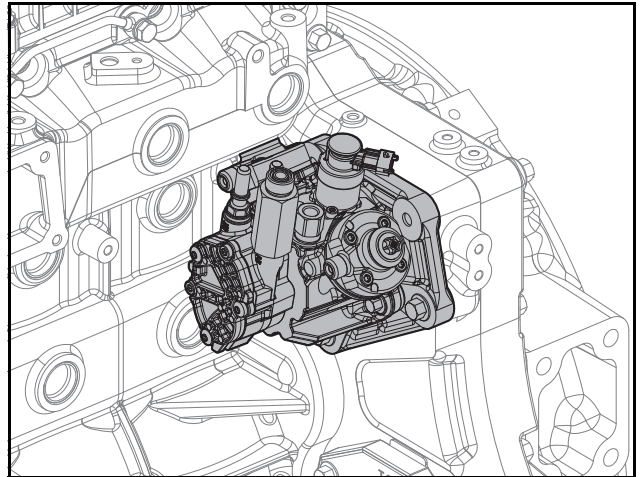
- 1) Applied liquid gasket with a thickness of 2.5 mm to 3 mm and assemble within 5 minutes.
 - Liquid gasket spec: TB1217H
- 2) Align the pin holes in the timing gear case with the guide pins.
- 3) Install the timing gear case on the cylinder block.
- 4) Tap both sides gently with a urethane hammer to seat it securely on the cylinder block.

- 5) Tighten the timing gear case mounting bolts to a tightening torque of 6.2 kgf.m.

⚠ CAUTION

Tighten the bolts on both sides first; then, tighten the remaining bolts.

6. Assemble the high-pressure fuel pump.

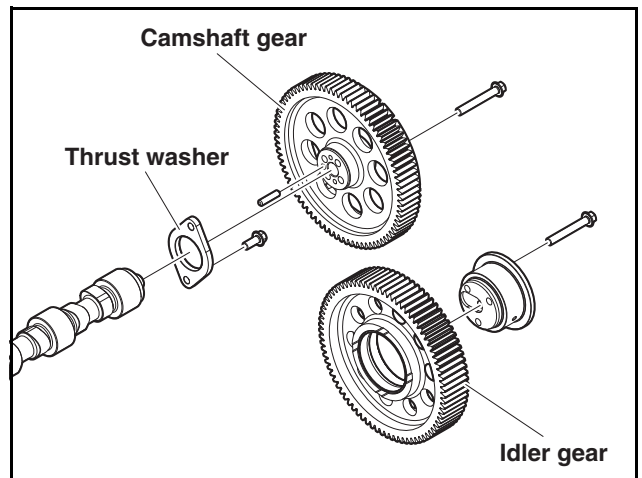


EDX08250052

- 1) Apply oil to the high-pressure fuel pump O-ring.
- 2) Install the high-pressure fuel pump idler gear on the timing gear case.
- 3) Assemble bolts in the correct gears from which they were removed.

Torque	M8 (10.9T)	2.2 kgf.m
	M8 (10.9T)	2.2 kgf.m
	M10 (10.9T)	6.2 kgf.m
	M10 (12.9T)	7.4 kgf.m

7. Assemble the gear system.



EDX08240027

- 1) Install a thrust washer on the camshaft.
- 2) Assemble the cam gear in line with the camshaft pin hole.

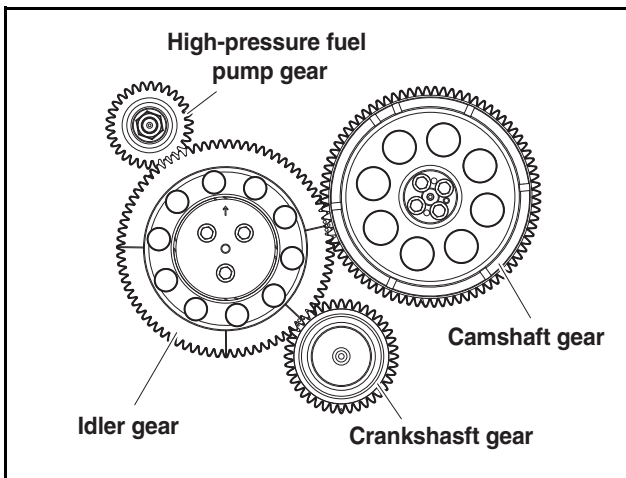
5. General Engine Information

- 3) Tighten the camshaft thrust washer to a tightening torque of 1.0 kgf.m.
- 4) Tighten the camshaft gear mounting bolt to a tightening torque of 3.1 kgf.m.

⚠ CAUTION

Assemble the gears in the following order: camshaft gear → idler gear → high-pressure fuel pump idler gear → high-pressure fuel pump.

- 5) Assemble the idler gear, aligning the marks on the crankshaft gear, camshaft gear, and idler gear.



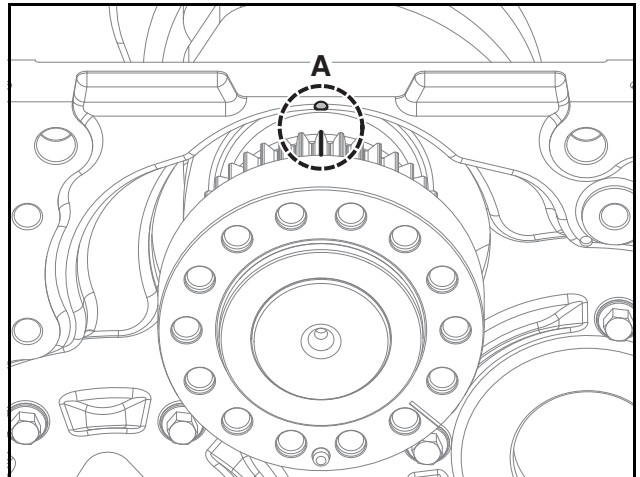
EDX08240028

- Step 1: Rotate the CRS to the TDC state.
Rotate the CRS so that the painted teeth and align on the bottom of the CRS gear align with the "BDC marker (A)" engraved on the bottom-center of the TGC.

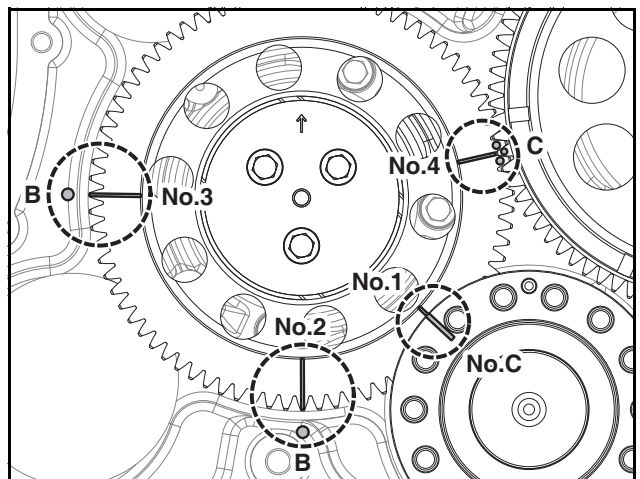
Note) If the TDC position is assembled correctly, the long red slot "No.C" on the front of the CRS rear flange aligns with the CRS direction slot "No.1" of the main idle gear.

- Step 2: Assemble the main idle gear to the timing position.
Assemble the idle gear so that the long red slots "No.2" and "No.3" engraved on the front of the main idle gear align with the "Timing hole mark (B)" engraved on the front of the TGC.
(If necessary, the main idle gear can be assembled after the CAM gear is assembled first. In this case, rotate the CAM gear's 1 EA "Dot marker (C)" so that they face the center of the main idle gear, and then assemble the main idle gear.)

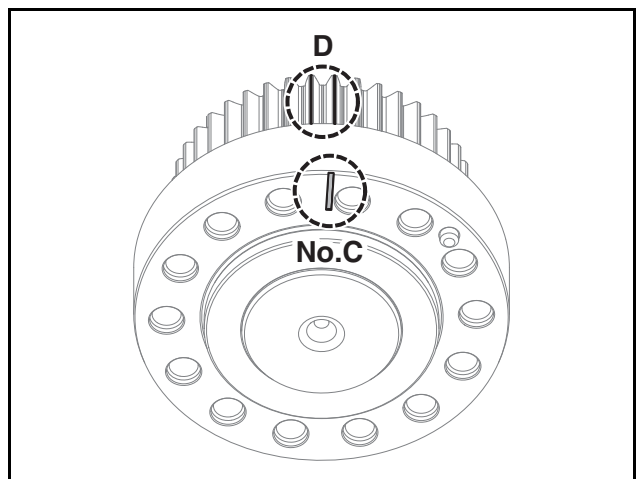
Note) If the timing position is assembled normally, the "Dot marker (C)" of the main idle gear will be located between the 2 EA "Timing paint markers (D)" at the teeth-edge of the CRS gear. And 1 EA "Dot marker (C)" of the CAM gear will face the "No.4" slot of the main idle gear and be located between the 2 EA "Dot marker (C)".



EDX08240260



EDX08240258



EDX08240259

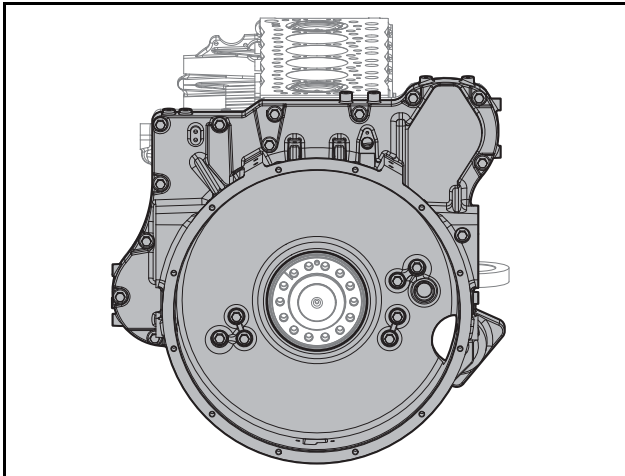
5. General Engine Information

- 6) Tighten the idler gear and CAM gear to a tightening torque of 7.4 kgf.m.
- 7) Assemble the high-pressure fuel pump idler gear at a tightening torque of 8.0 +1 kgf.m.
- 8) Use a feeler gauge to check the gear backlash and end play.

- Backlash

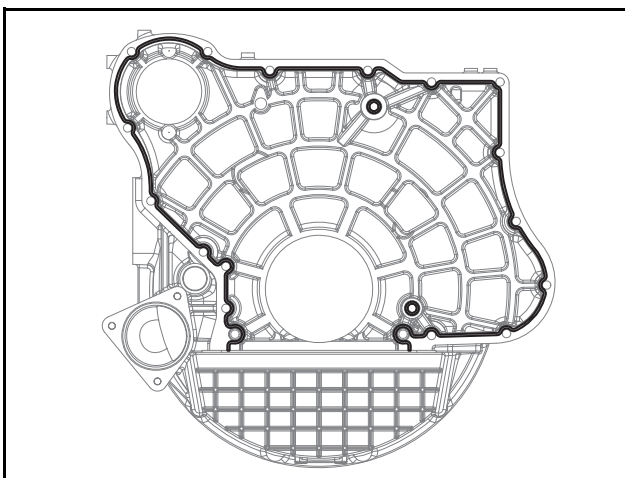
PISTON	Specified value (mm)
Crankshaft gear and idler gear	0.071 ~ 0.210
Idler gear and camshaft gear	0.089 ~ 0.194
Idler gear and high-pressure fuel pump gear	0.081 ~ 0.204

8. Assemble the flywheel housing.



EDX08250072

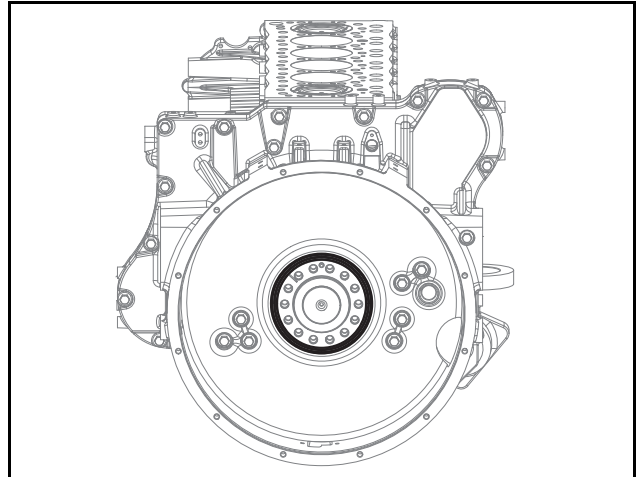
- 1) Install a guide bar on the cylinder block temporarily.
- 2) Apply a new liquid gasket with a diameter of 2.5 ± 0.5 mm to the flywheel housing according to the guidelines. install it on the cylinder block within 5 minutes after application.



EDX08240232

- 3) Use the dowel pins and guide bar to assemble the flywheel housing.

- 4) Tighten the mounting bolts to a tightening torque of 11.2 kgf.m in the order of assembly.
- 5) Remove the guide bar.
- 6) Apply a thin layer of engine oil to the outer surface of the oil seal and press-fit it into the flywheel housing.
9. Assemble the rear oil seal.

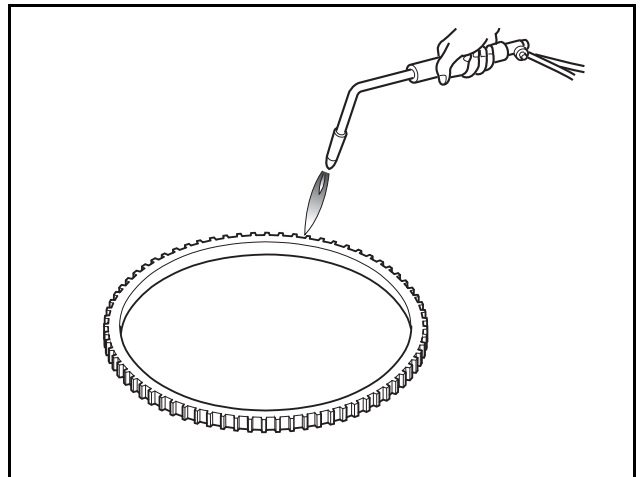


EDX08250073

- 1) Align the oil seal with the crankshaft.
- 2) Use an oil seal jig to assemble the oil seal.

10. Assemble the flywheel.

- 1) Heat the ring gear evenly with a gas burner to expand it; then, use a hammer to tap it into place.



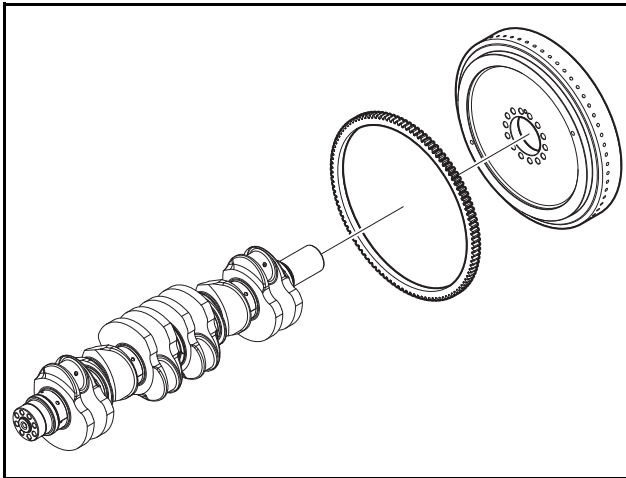
EA0M4029

CAUTION

- Do not heat the ring gear past 200°C.
- Heat the wear ring to 150°C with a heater; then, apply Loctite #262 and use an assembly jig to assemble it.

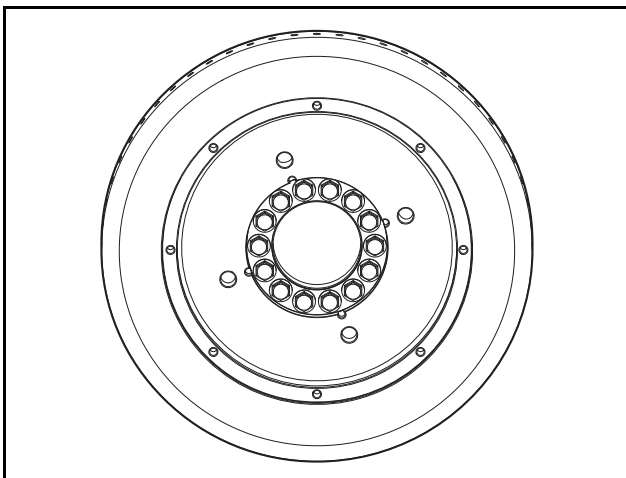
5. General Engine Information

- 2) Assemble the wear ring with the side with the beveled edge around the outer circumference facing forward.



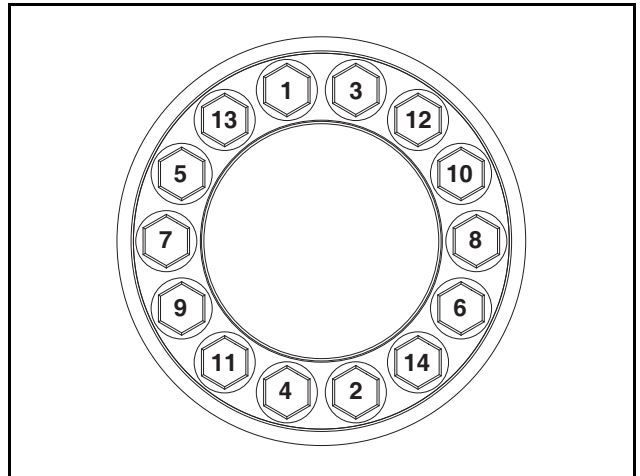
EDX08240082

- 3) Install a guide bar in the crankshaft bolt hole.
 4) Assemble the flywheel temporarily, aligning it with the guide pins.
 5) Apply an adhesive (Loctite #587) to the mounting bolts.
 6) Assemble the bolts whose holes do not have guide pins in them; then, assemble the remaining bolts after removing the guide pins.



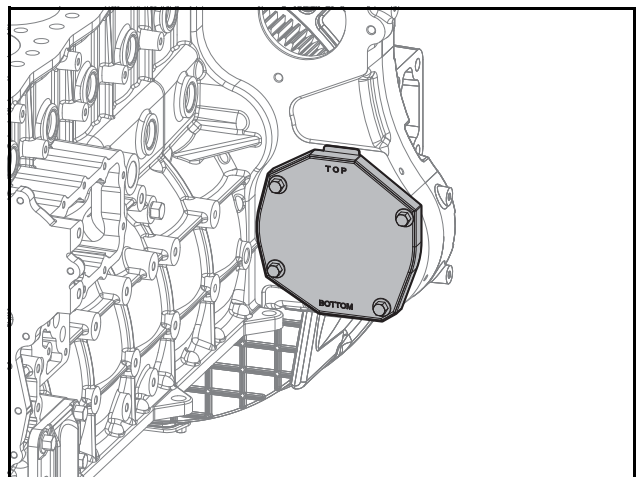
EDX08250067

- 7) Use a torque wrench to tighten the M14 x 1.5 bolts to a tightening torque of 9 kgf.m + 90° in the order of assembly.

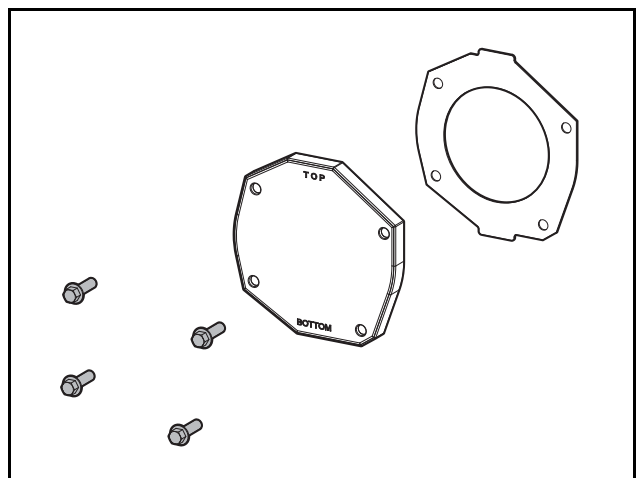


EDX08240134

11. Assemble the PTO (Power Take Off) cover & gasket.



EDX08250065



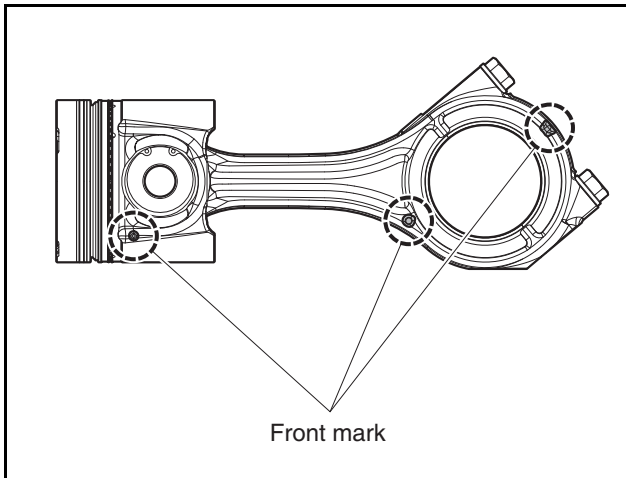
EDX05250041

- 1) Assemble the PTO (Power Take Off) cover & gasket.
 2) Tighten 4 inner socket bolts to a tightening torque of 4.4 ±0.4 kgf.m.

5. General Engine Information

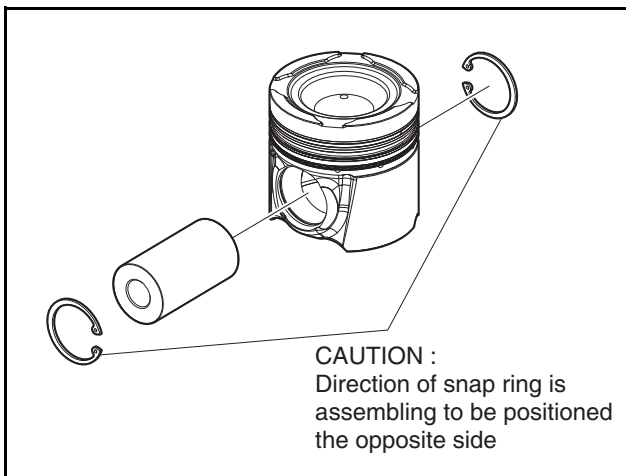
Note) Gaskets are intended for single use and should not be reused.

12. Assemble the pistons and connecting rods.



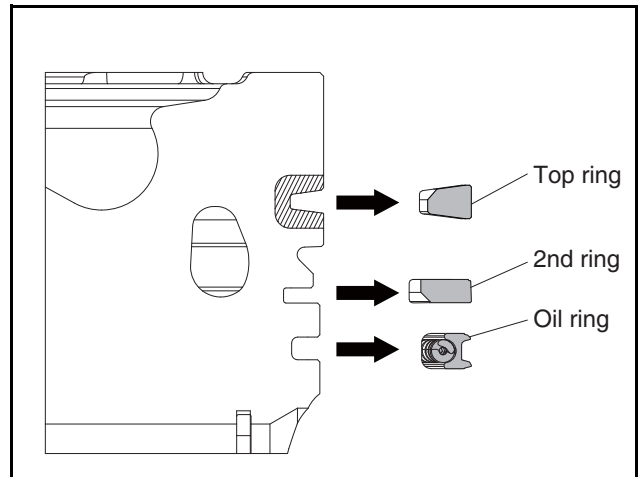
EDX08240139

- 1) The assembly direction of the piston and connecting rod is such that the front mark of the connecting rod end and the front mark on the oil box side of the piston are in the same direction.
- 2) Apply oil to the piston pin holes and align them with the small ends of the connecting rods. Then, tap the piston pins with a rubber hammer gently to install the connecting rods and pistons.
- 3) Install the snap ring assembly openings so that the top and bottom face opposite directions.



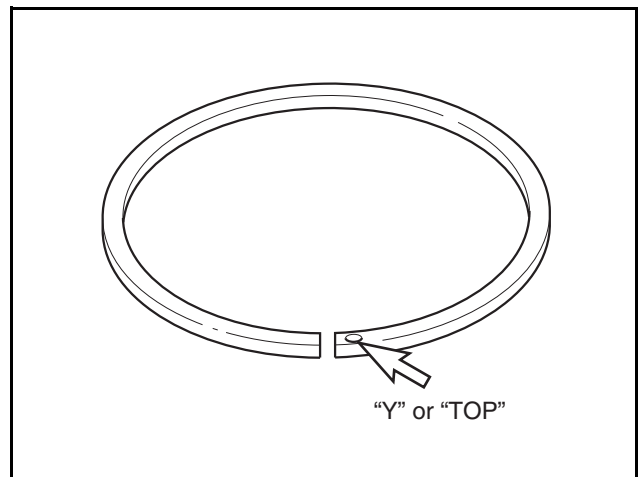
EDX08240140

- 4) Install the snap ring. Make sure to check its installation condition.
- 5) Use piston ring pliers to install the piston rings on the pistons.



EDX08240141

- 6) Make sure not to install the piston ring upside down. The mark "Y" or "TOP" on top of the ring connection should face up.



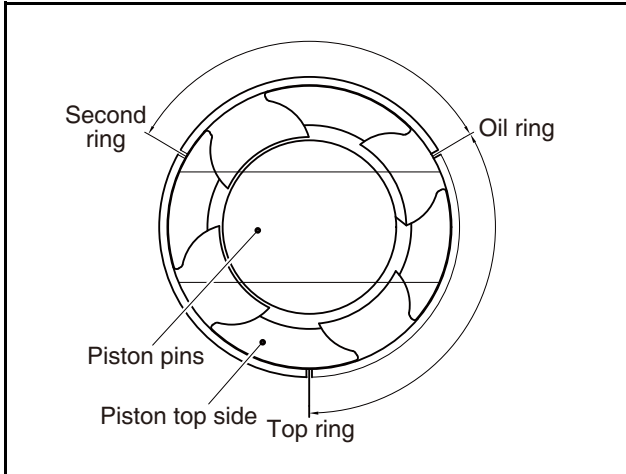
EAMD090I

- 7) Adjust each angle of the piston ring connections to 120° and fit a piston insertion jig into the pistons.

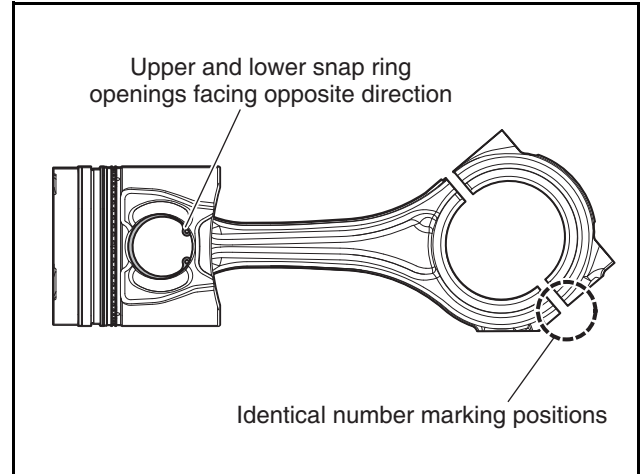
CAUTION

The connection of the piston ring should not be aligned with the pin direction.

5. General Engine Information



EE10M083

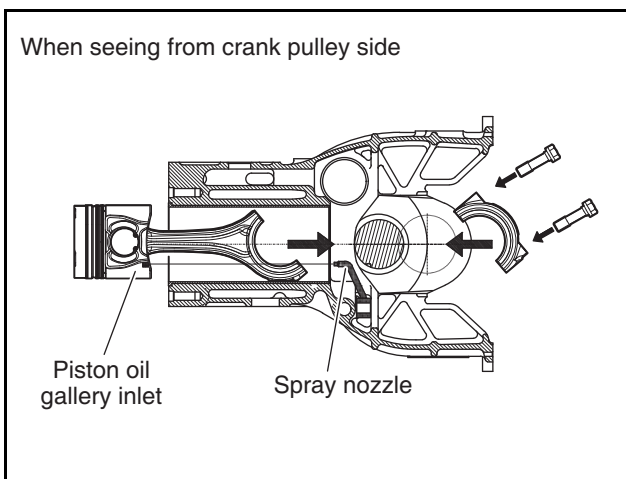


EDL08190077

- 8) Install the connecting rod bearing, aligning it with the key groove. Then, apply oil to the bearing and piston.
- 9) Insert the pistons so that the piston oil gallery inlets are aligned with the spray nozzles.
- 10) Use a piston inserter to press-fit the pistons into the cylinder bore, taking care not to damage the rings on the edge of the cylinder bore.

⚠ CAUTION

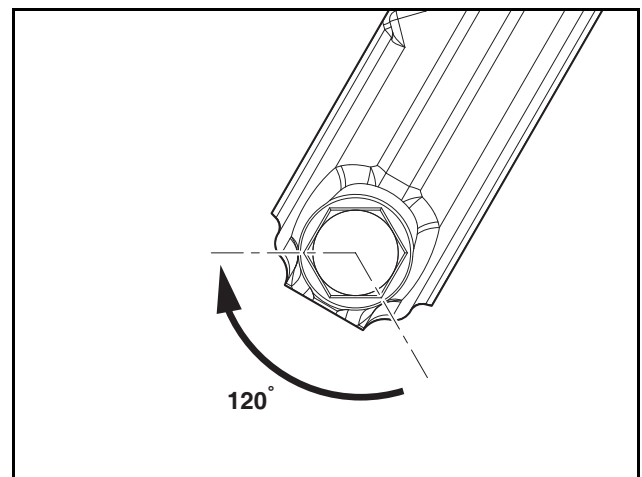
Take care not to damage the cylinder bore and pistons.



EDL08190076

- 11) Fit the bearing onto the connecting rod cap and apply oil to it.
- 12) Check that the manufacturer serial numbers stamped on the connecting rod caps and connecting rod big ends are identical.

- 13) Assemble the connecting rod caps, aligning them with the guide pins.
- 14) Use a torque wrench to tighten them to the specified tightening torque in the order of assembly.
 - Step 1: Wipe the oil off the mounting bolts and assemble them temporarily.
 - Step 2: Assemble the connecting rod bolts manually in the correct order until the connection on the bolt heads comes into contact with the bolt seat surfaces on both sides of the connecting rods.
 - Step 3: Use a torque wrench to tighten the bolts to a torque of 8.16 kgf.m.
 - Step 4: Mark the bolt heads and seat surfaces.
 - Step 5: Use a torque wrench to tighten the bolts so that the marks from step 4 rotate another 120°.



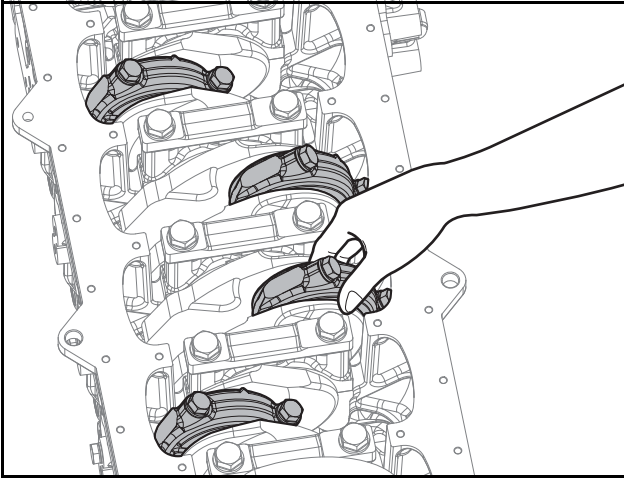
EDX08240142

⚠ CAUTION

Do not reuse connecting rod bolts.

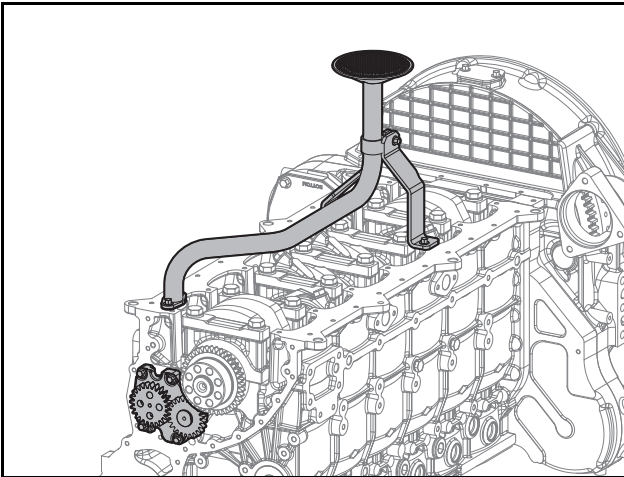
5. General Engine Information

- 15) Shake the bearing cap by hand. If it does not move, unscrew it and install it again.



EDX08240084

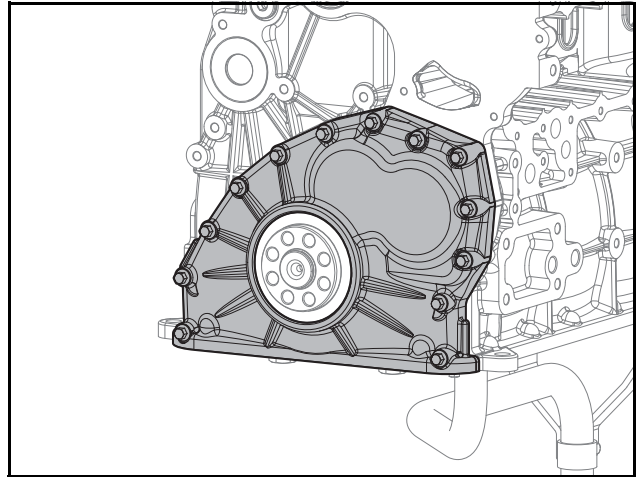
13. Assemble the oil pump and oil pipe.



EDX08250064

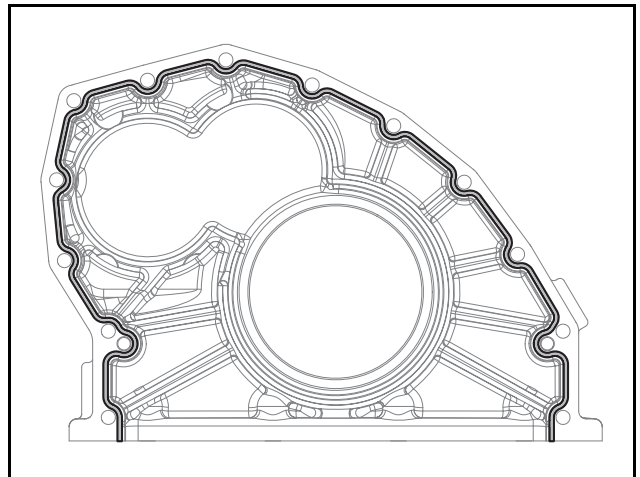
- 1) Assemble the oil pump to the front of the cylinder block.
- 2) Assemble the oil pump by lightly hitting it with a urethane hammer.
- 3) Assemble the oil supply pipe and two brackets to the cylinder block with a tightening torque of 3.1 kgf.m, and tighten the clip fixing bolts of the bracket and pipe & gasket connection with a tightening torque of 2.2 kgf.m.

14. Assemble the front oil seal.



EDX08240065

- 1) Apply sealant to the inside of the seal cover and assemble it to align it with the block's positioning pin.
- 2) Apply a new liquid gasket with a diameter of 2.5 ± 0.5 mm to the seal cover according to the guideline. Install it on the cylinder block within 5 minutes after application.

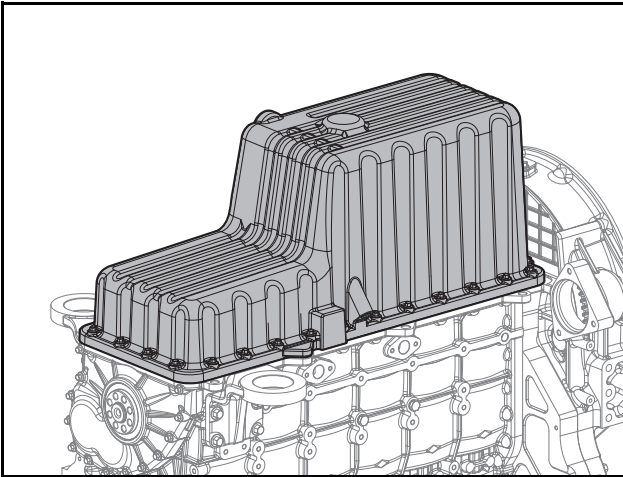


EDX08240233

- 3) Tighten the seal cover bolts with 3.1 kgf.m.
- 4) Apply engine oil to the inner/outer surface of the new seal.
- 5) Assemble the oil seal using the assembly jig.

5. General Engine Information

15. Assemble the oil pan.



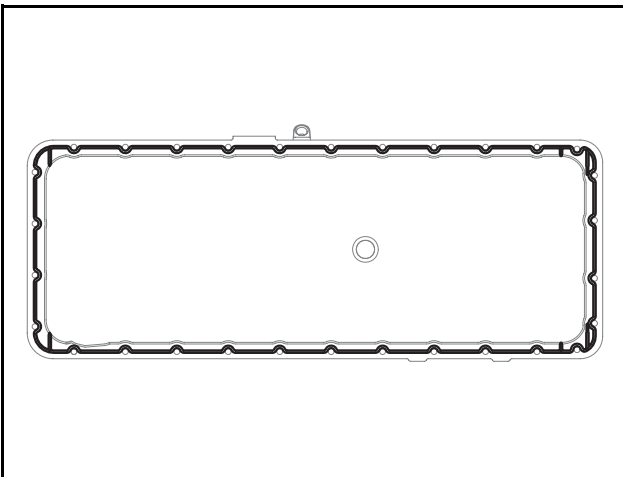
EDX08250063

- 1) Remove the protruding gasket from the contact surface of the timing gear case, cover, cylinder block and flywheel housing with a scraper.

CAUTION

Take care to ensure that the gasket does not fall into engine at this time.

- 2) Apply a new liquid gasket with a diameter of 2.5 ± 0.5 mm to the oil pan according to the guide line. After application, it will start to harden after 5 minutes, so immediately place the oil pan on the block after application.



EDX08240234

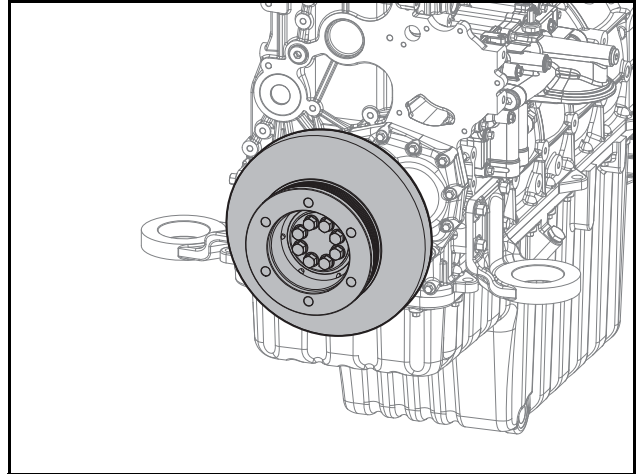
- 3) Assemble the oil pan.
- 4) Tighten the four bolts on both sides of the oil pan first; then, tighten the remaining bolts.

- 5) Tighten the oil pan mounting bolts to a tightening torque of 3.1 kgf.m.

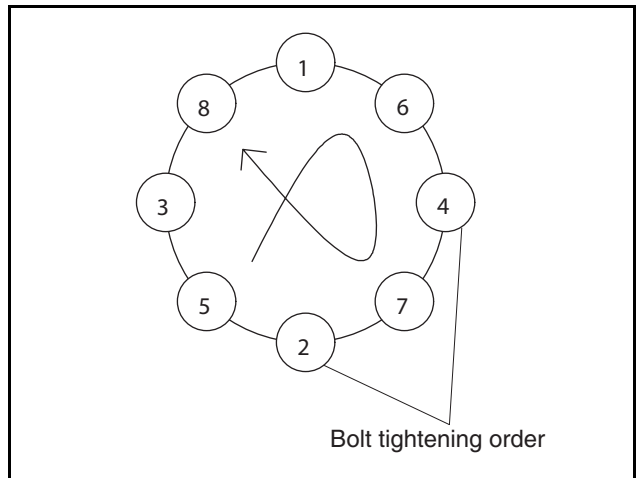
CAUTION

Tighten the mounting bolts after aligning the bolt holes with the gasket holes, taking care not to damage the gasket.

16. Assemble the crankshaft pulley and vibration damper.



EDX08250061



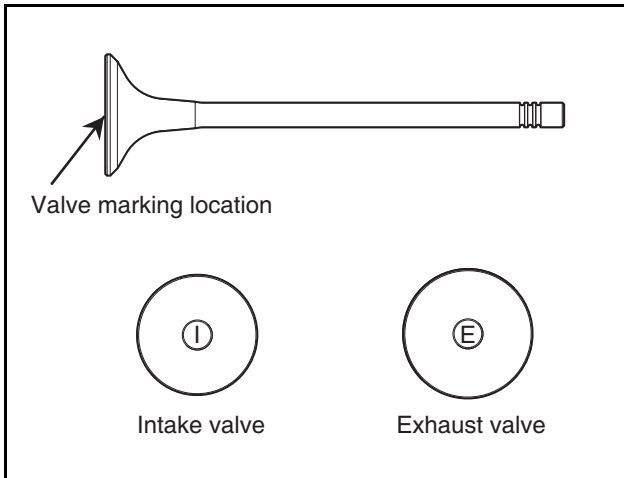
EE10M155

- 1) Assemble the vibration damper with the crankshaft pulley.
- 2) Tighten the bolts in order.
- 3) Tighten the crankshaft pulley to a tightening torque of 22 kgf.m.

5. General Engine Information

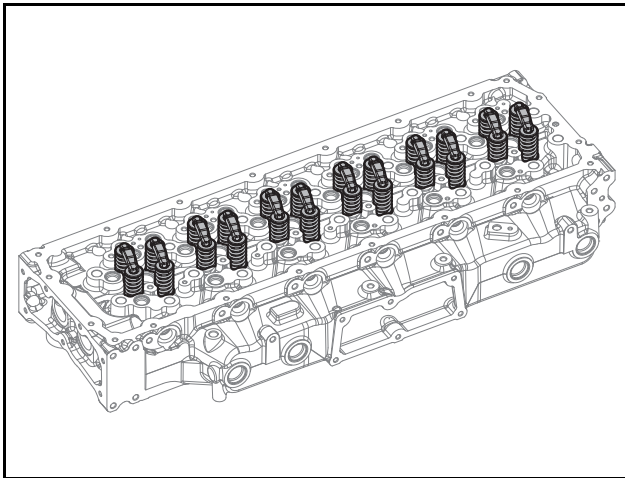
17. Assemble the intake and exhaust valves.

- 1) Before installing the valves in the cylinder head, check the "I" and "E" marks on the valve heads.



EDX22190122

- 2) Use a valve stem seal installation jig to install the valve stem seals on the valve guides.
- 3) After installing the valve spring and retainer, press the retainer with a valve spring compressor to install the valve cotter.



EDX08240062

- 4) Tap the valve stems gently with a rubber hammer to ensure that the valves are assembled securely and correctly.

18. Assemble the cylinder head.

- 1) Clean foreign matter out of the bolt holes in the cylinder head with compressed air.
- 2) Clean the cylinder head gasket contact surface thoroughly.

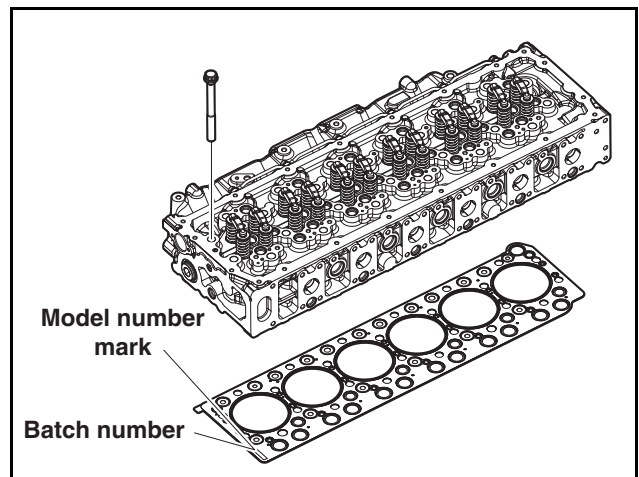
CAUTION

Make sure that no foreign matter enters the combustion chamber at this time.

- 3) Align the bolt holes in the new gasket with the guide pins on the cylinder block.
- 4) Assemble the gasket with the mark on the right side of the gasket facing upwards.

CAUTION

Always replace gaskets with new ones.



EDX08240030

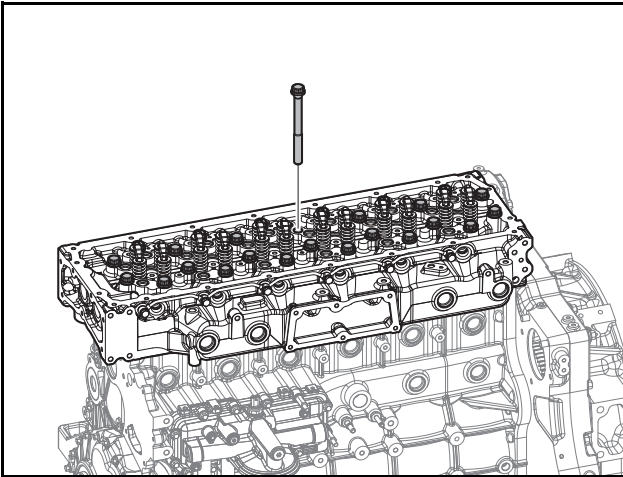
- 5) Check the inside of the combustion chamber for foreign matter.
- 6) Assemble the cylinder head, aligning it with the mounting pins.

CAUTION

- Be careful not to damage the gasket.
- If the pin hole is not aligned, lift it and put it down again.

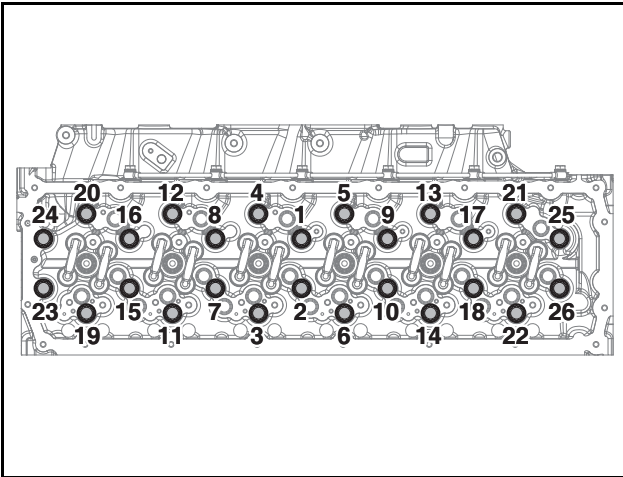
5. General Engine Information

7) Install the cylinder head bolts.



EDX08240019

8) Tighten the cylinder head bolts to the specified tightening torque in the correct order.



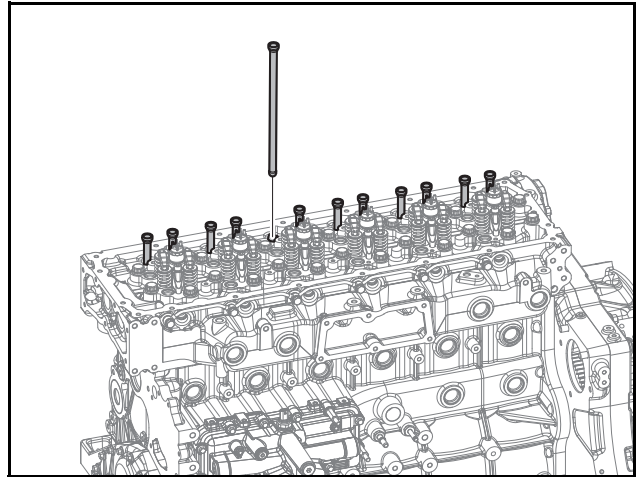
EDX08240031

- Step 1: Tighten the bolts 1 ~ 2 threads by hand; then, tighten them temporarily to a torque of 4 kgf.m or less.
- Step 2: Use a torque wrench to tighten the bolts to a torque of 6.0 kgf.m.
- Step 3: Use a torque wrench to rotate the bolts 90°.
- Step 4: Use a torque wrench to rotate the bolts 90°.
- Step 5: Finally, use a torque wrench to rotate the bolts 45°.

CAUTION

- For all bolts, keep the above specified tightening sequence.
- Do not reuse cylinder head bolts.

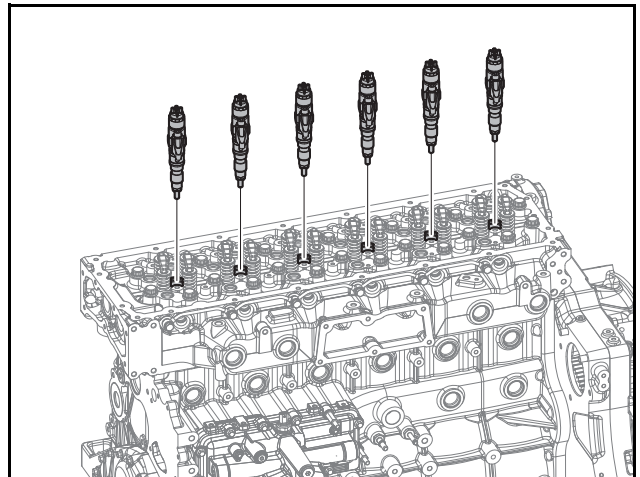
19. Assemble the pushrods.



EDX08240017

1) Apply engine oil to the pushrods.
2) Press-fit them into the pushrod holes in the cylinder head.

20. Assemble the injectors.

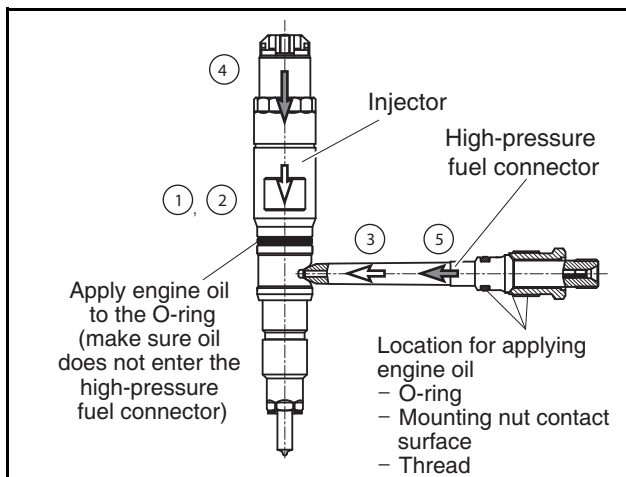


EDX08240018

⚠ CAUTION

- When installing a new injection pipe after disconnecting the fuel injection pipe connected to a high-pressure fuel connector (HPC), make sure to retighten the HPC mounting nuts to the specified torque.
 - Tightening torque of HPC nuts: 5.5 ± 0.55 kgf·m
 - Tightening torque of injection pipes: 4.0 ± 0.4 kgf·m
- In addition, do not reuse injection pipes as the sealing for high-pressure fuel is deformed during tightening.
 - Tightening torque of HPC nuts: 5.5 ± 0.55 kgf·m
 - Tightening torque of injection pipes: 4.0 ± 0.4 kgf·m
- Wash all parts thoroughly and keep them free of 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 disassembling injectors, make sure to replace high-pressure fuel connectors with new ones.
- If fuel remaining in a fuel return line enters the combustion chamber while disassembling the injectors, it must be drained either with a hand pump or by cranking the starter motor with the fuel shut off.

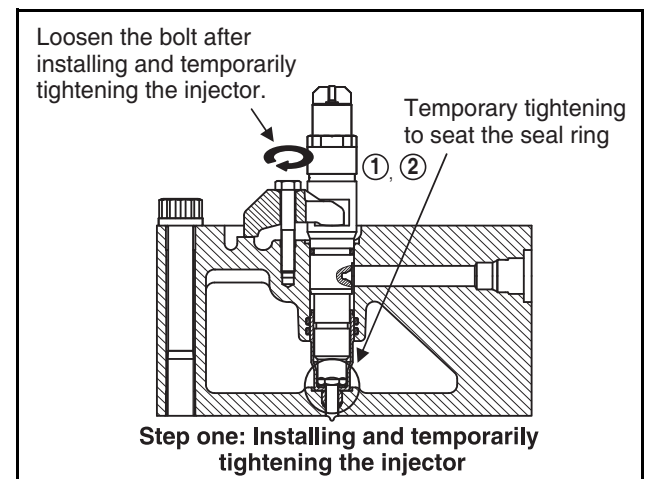
1) Assemble the injectors precisely in the following order.



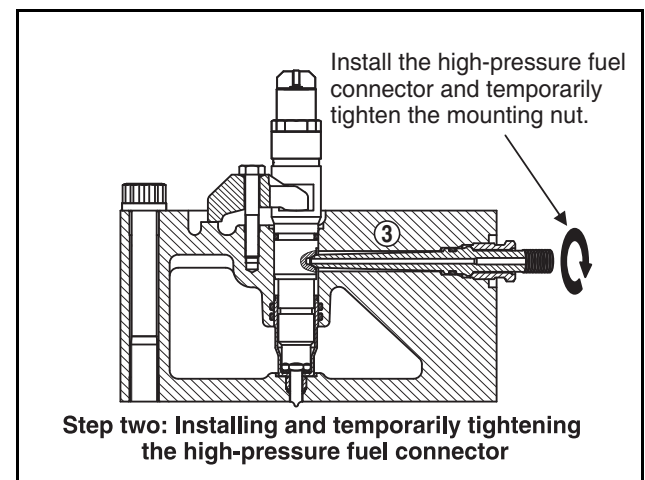
EG9OM130

- 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, 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 stake; 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.



EDX08240224

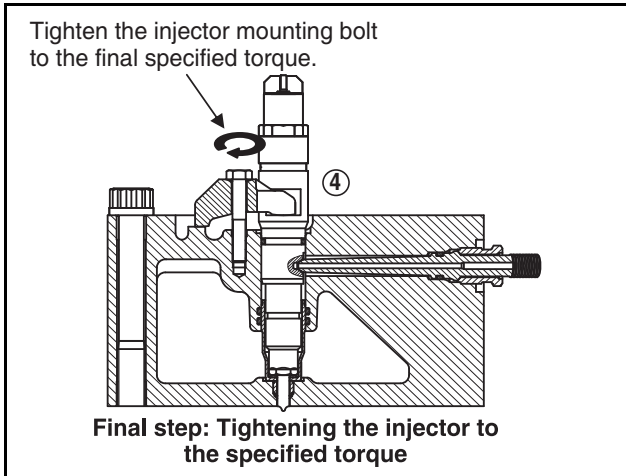


EDX08240225

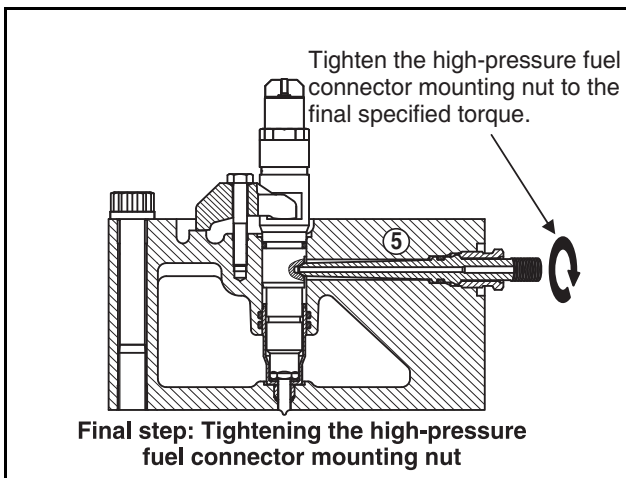
5. General Engine Information

Temporary tightening torque	Injector mounting bracket bolt	High-pressure fuel connector mounting nut
	0.3 kgf.m	0.3 kgf.m

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



EDX08240226



EDX08240227

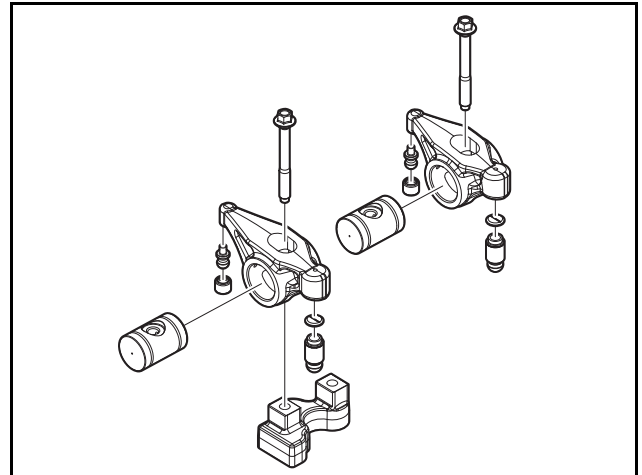
Final torque	Injector mounting bracket bolt	High-pressure fuel connector mounting nut
	3.8 ±0.4 kgf.m	5.5 ±0.55 kgf.m

21. Assemble the rocker arms.

- 1) To assemble the rocker arm components, assembled the rocker arm, rocker arm shaft, bracket, and fixing bolt in order.

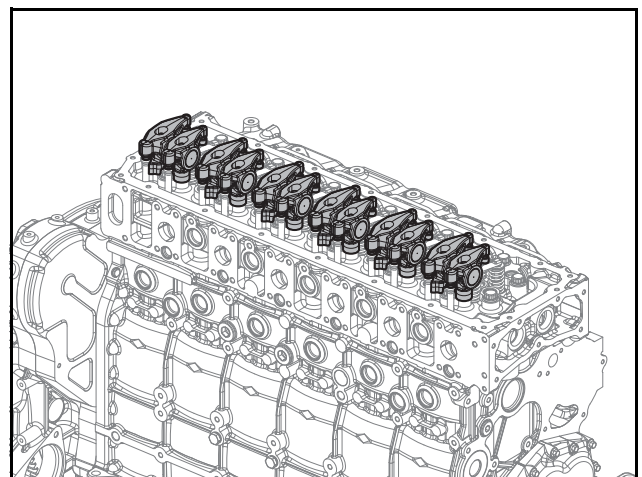
CAUTION

Make sure to install the rocker arm and bracket in the same direction.



EDX08250101

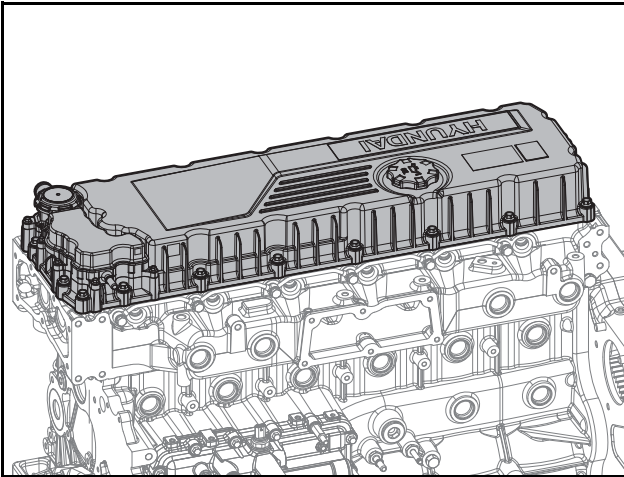
- 2) Apply oil to the inside of the rocker arm and the shaft.
 3) Using the fixing bolt, slowly tighten the rocker arm and bracket to 1 kgf.m from the long rocker arm (intake) on the cylinder head.
 4) Once the rocker arm is in place while pressing the push rod and valve, slowly tighten to the specified tightening torque of 3.35 kgf.m from the long rocker arm (intake).



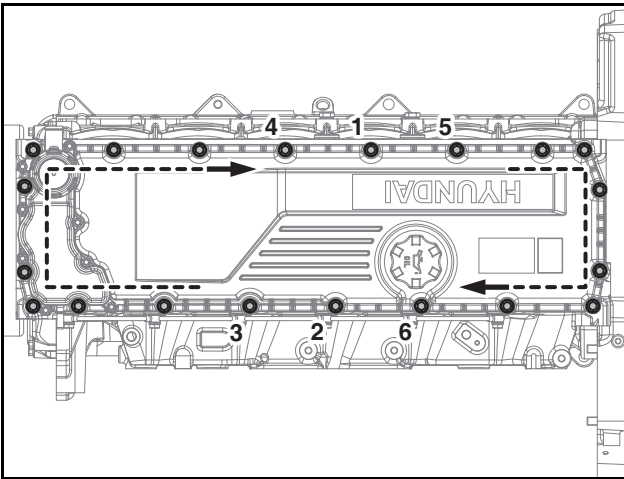
EDX08240016

5. General Engine Information

22. Assemble the cylinder head cover.



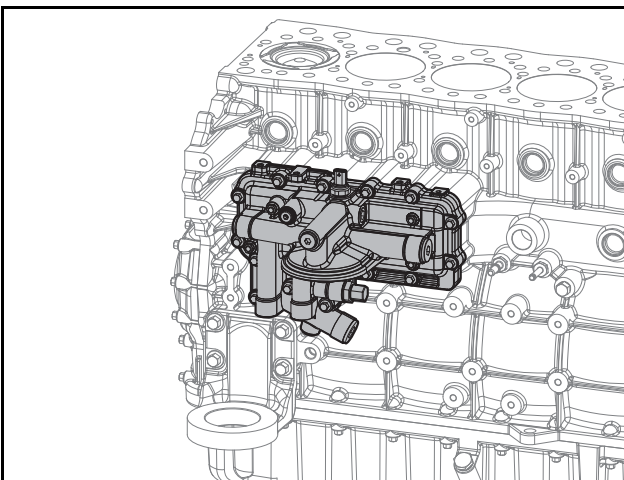
EDX08240061



EDX08240127

- 1) Install a new rubber gasket on the cylinder head cover.
- 2) Install the cylinder head cover on the cylinder head.
- 3) Tighten the mounting bolts to a tightening torque of 2.7 kgf.m.
- 4) Install the oil filler cap on the cylinder head cover.

23. Assemble the oil cooler.

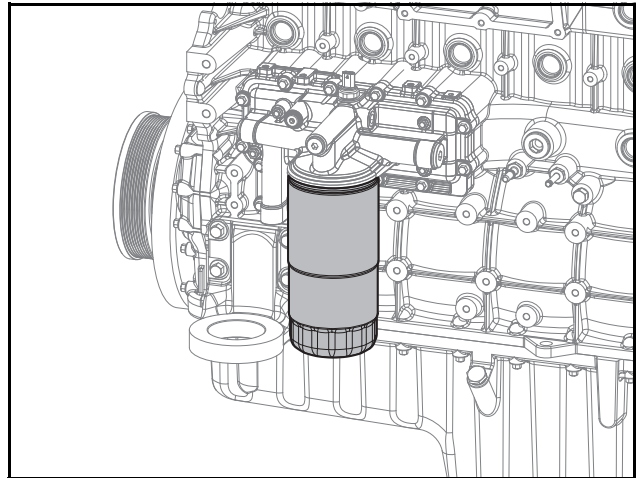


EDX08250062

- 1) Assemble the oil cooler & gasket to the cylinder block.

2) Tighten the bolts to a tightening torque of 3.1 kgf.m.

24. Assemble the oil filter.



EDX08250060

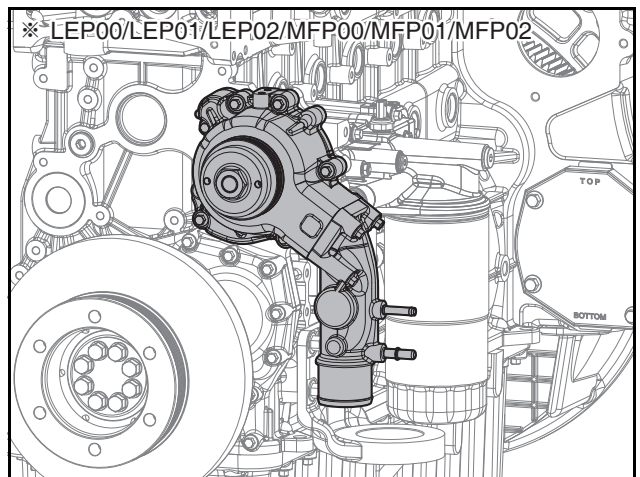
- 1) Use a special tool for the oil filter cartridge to install the cartridge.

CAUTION

The new oil filter must not contain any oil when it is installed. Do not fill the new oil filter with oil from the replaced oil filter.

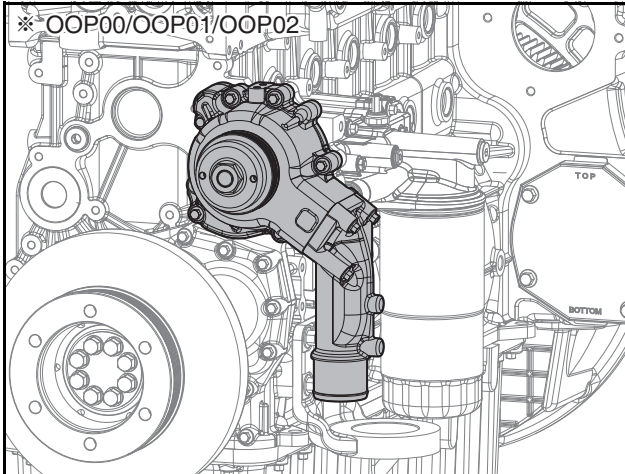
25. Assemble the coolant pump.

- 1) Assemble the coolant pump cover and coolant pump gasket.
- 2) Install the coolant pump on the cylinder block.



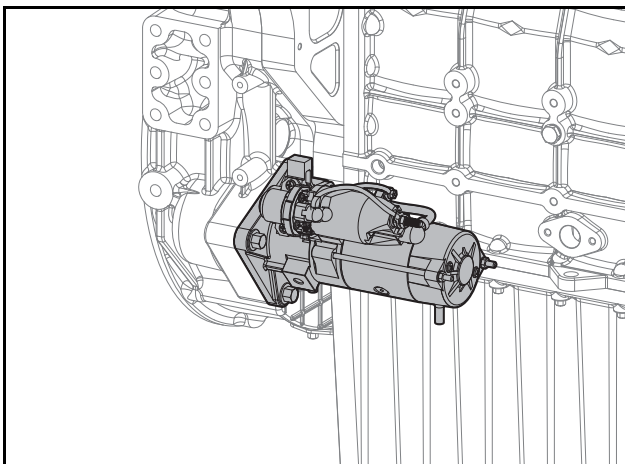
EDX08250123

5. General Engine Information



EDX08250124

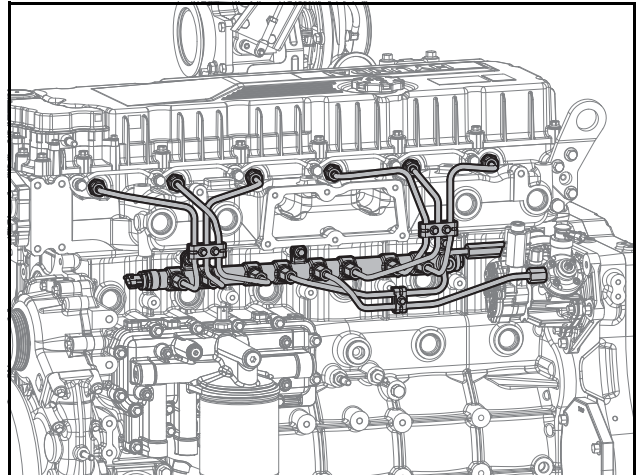
- 3) Tighten the mounting bolts to the specified tightening torque of 3.1 ± 0.31 kgf.m.
 - 4) Assemble the idler pulley bracket.
26. Assemble the starter motor.



EDX08240058

- 1) Install the starter motor on the stud bolts of the flywheel housing.
- 2) Tighten the mounting bolts to a tightening torque of 10.5 ± 1.05 kgf.m.

27. Assemble the common rail and high-pressure pipes.



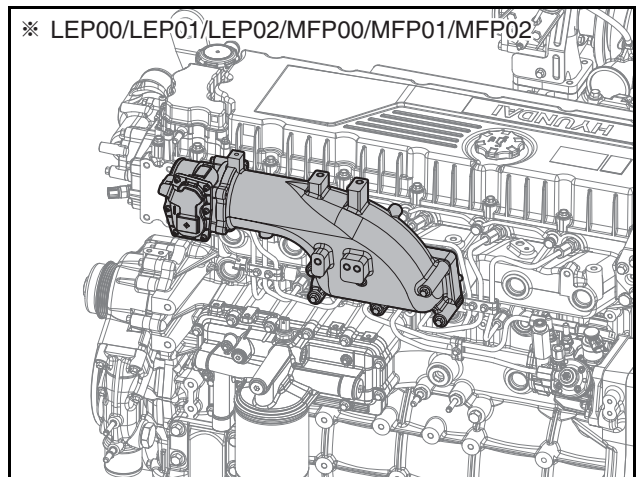
EDX08250051

- 1) Install the common rail on the cylinder block.
- 2) Install the fuel delivery pipes between the common rail and high-pressure fuel connectors.
- 3) Tighten the high-pressure fuel pipes on the common rail to a tightening torque of 4.0 kgf.m.
- 4) Tighten the high-pressure fuel pipes connected to the high-pressure fuel connectors to a tightening torque of 4.0 kgf.m.
- 5) Tighten the high-pressure fuel pipes connecting the high-pressure fuel pump and common rail to a tightening torque of 4.0 kgf.m.
- 6) Tighten the common rail mounting bolts to a tightening torque of $3.1 + 0.78$ kgf.m.

⚠ CAUTION

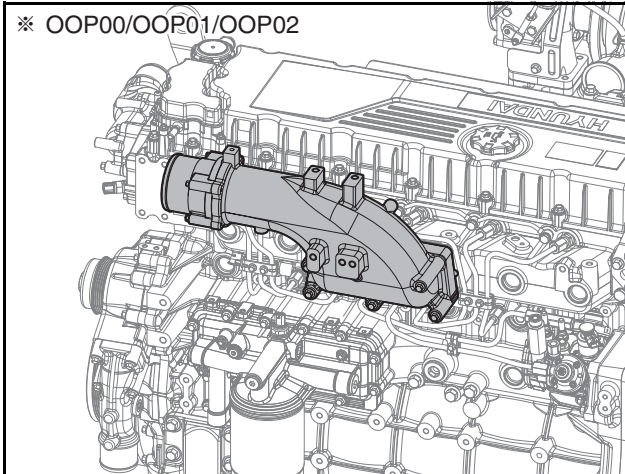
- Do not reuse high-pressure fuel pipes.
- Tighten high-pressure fuel pipes one at a time to the specified tightening torque.

28. Assemble the intake stake.



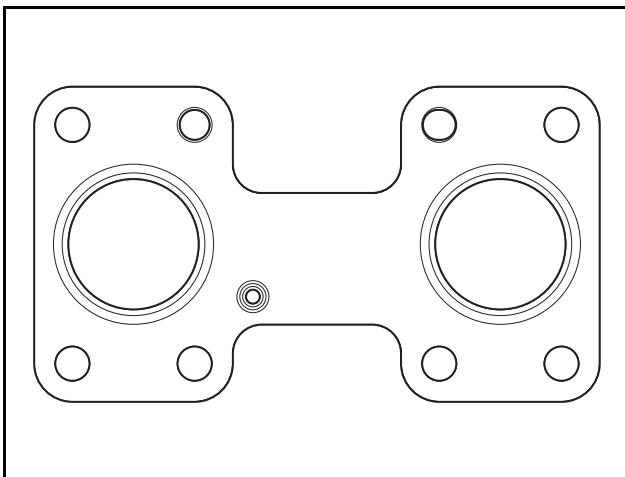
EDX08250115

5. General Engine Information



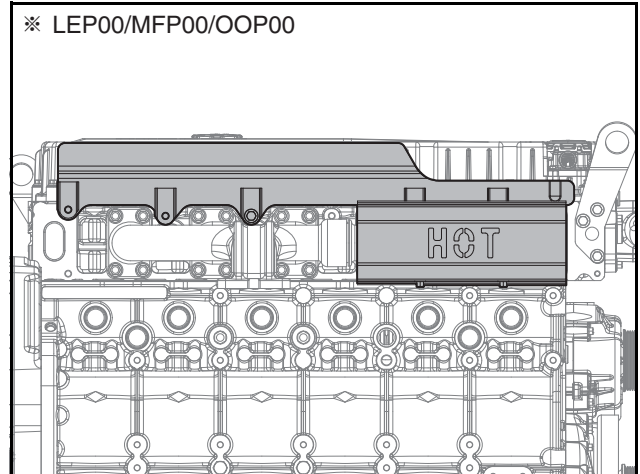
EDX08250116

- 1) Insert a new gasket between the cylinder head and intake stake.
 - 2) Tighten the mounting bolts to a tightening torque of 3.1 kgf.m.
29. Assemble the exhaust manifold.
- 1) Install an exhaust manifold gasket on the cylinder head stud bolts.

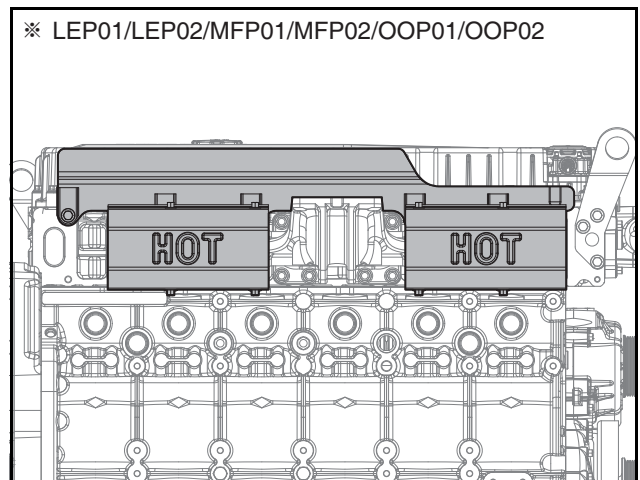


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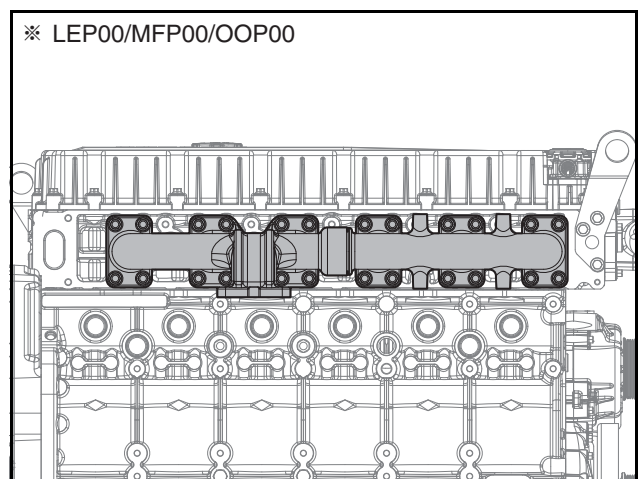
- 2) Align the cylinder head gas outlet with the hole in the gasket.
- 3) Install the exhaust manifold and then install the heat shield.
- 4) Assemble the exhaust manifold.



EDX08250119



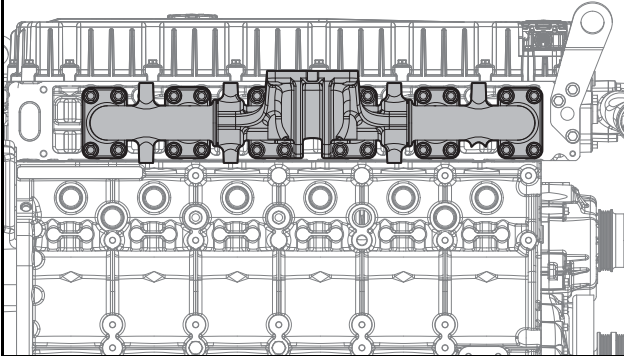
EDX08250120



EDX08250121

5. General Engine Information

※ LEP01/LEP02/MFP01/MFP02/OOP01/OOP02

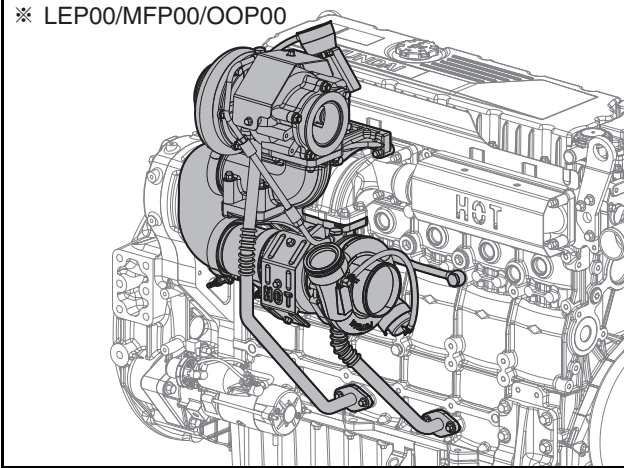


EDX08250122

- 5) Tighten the mounting nuts to a tightening torque of 6.6 kgf.m.

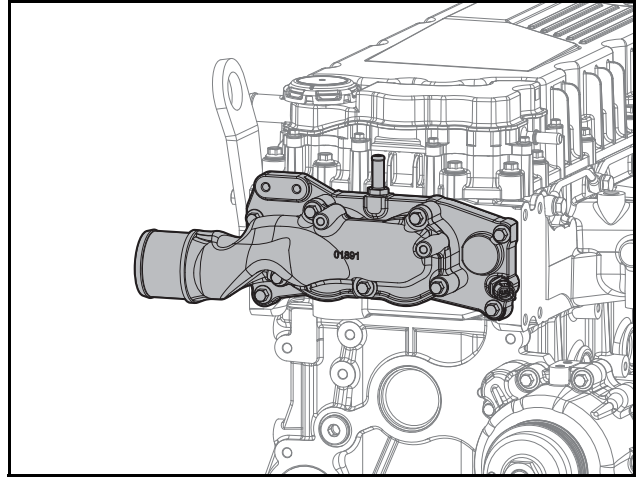
30. Assemble the turbocharger.

※ LEP00/MFP00/OOP00



EDX08250117

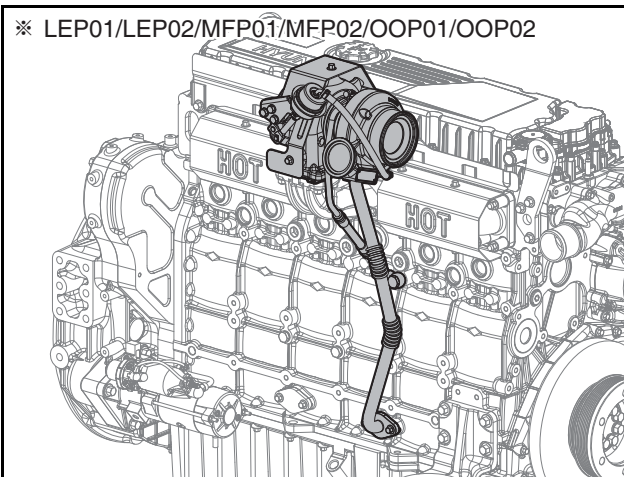
- 4) Tighten the clamp to connect the air pipe and turbocharger.
 - 5) Tighten the mounting bolts to a tightening torque of 6.6 kgf.m.
31. Assemble the coolant pipe and thermostat.



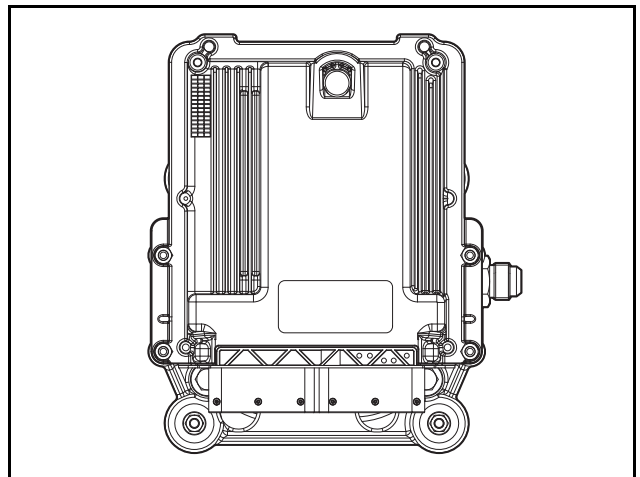
EDX08240056

- 1) Install a gasket on the cylinder head.
 - 2) Assemble the thermostat housing.
 - 3) Install an O-ring on the thermostat.
 - 4) Install the coolant pipe.
 - 5) Tighten the bolts to a tightening torque of 3.1 ± 0.31 kgf.m.
32. Assemble the electronic control unit (ECU).

※ LEP01/LEP02/MFP01/MFP02/OOP01/OOP02



EDX08250118



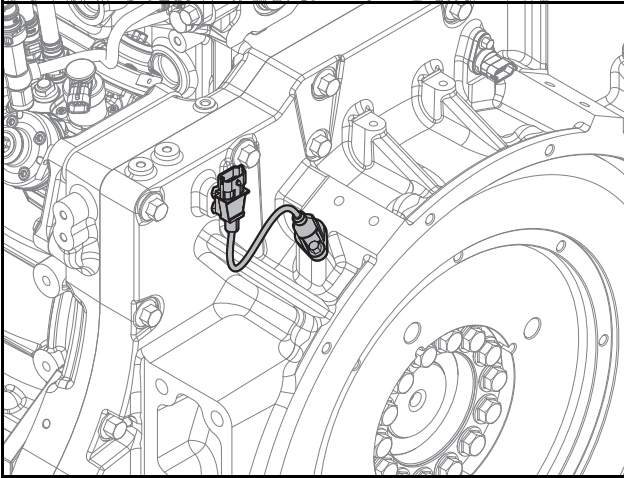
EDX08240085

- 1) Install a new gasket on the exhaust manifold stud bolts.
- 2) Assemble the turbocharger.
- 3) Connect the oil delivery pipe and discharge pipe.

- 1) Assemble the ECU mounting plate.
- 2) Assemble the ECU.

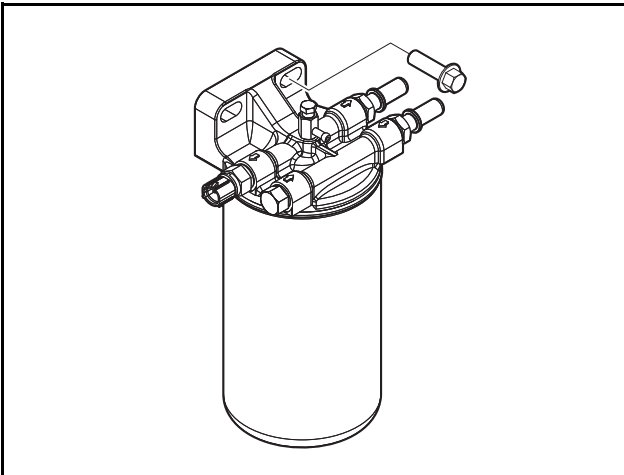
5. General Engine Information

33. Assemble the crankshaft position sensor and camshaft position sensor.



EDX08250071

- 1) Measure the clearance between the crankshaft position sensor assembly and flywheel and use a shim to adjust the clearance to 1.0 mm.
 - 2) Tighten the crankshaft position sensor to a tightening torque of 1.0 kgf.m.
 - 3) Measure the clearance between the camshaft position sensor assembly and timing gear and use a shim to adjust the clearance to 1.0 mm.
 - 4) Tighten the camshaft position sensor to a tightening torque of 1.0 kgf.m.
34. Assemble the fuel filter.



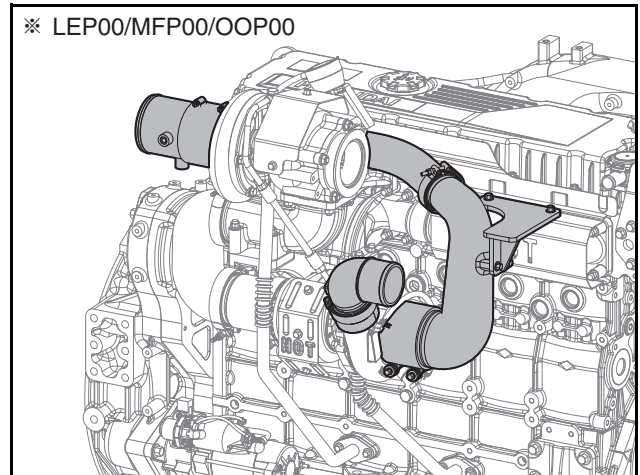
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- 1) Replace the fuel filter cartridge every 1,000 hours.

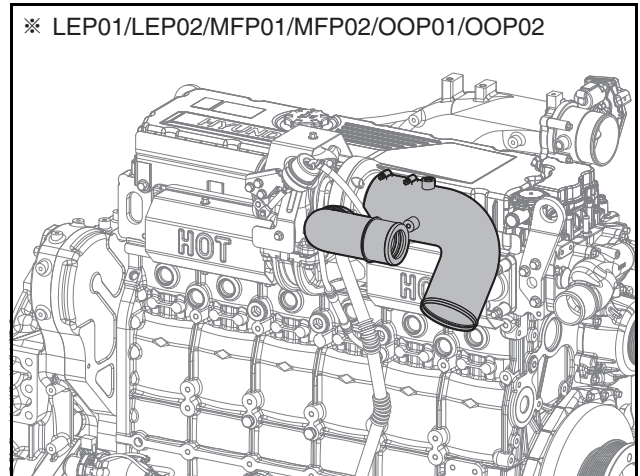
CAUTION

New fuel filters must not contain any fuel when they are installed. Do not fill a new fuel filter with fuel from a replaced fuel filter or fuel in the fuel tank.

35. Assemble the air pipe.



EDX08250113



EDX08250114

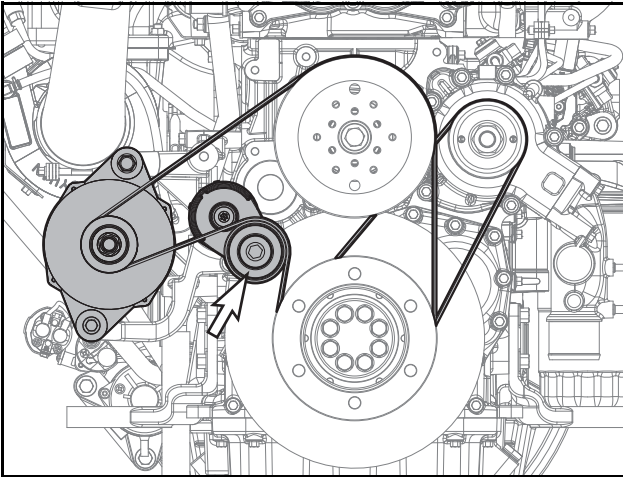
- 1) Assemble the air pipe and throttle valve.
- 2) Air pipe assembly clamp tightening torque is 1.2 kgf.m, and the fixing bolt tightening torque is 2.2 kgf.m.

CAUTION

Be careful not to allow foreign matter to enter the turbo-charger.

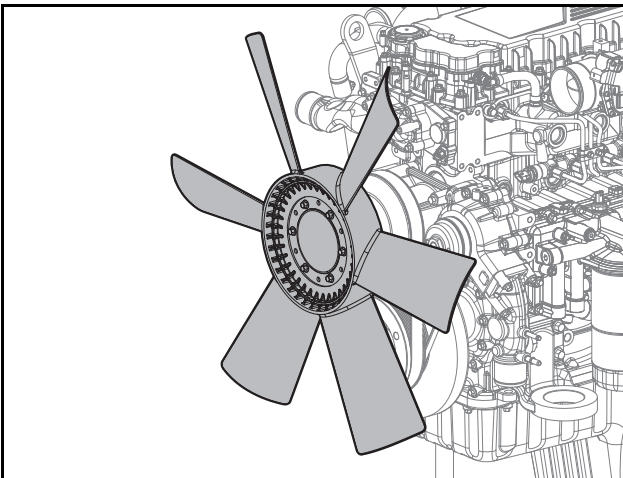
5. General Engine Information

36. Assemble the alternator and belt.



EDX08250046

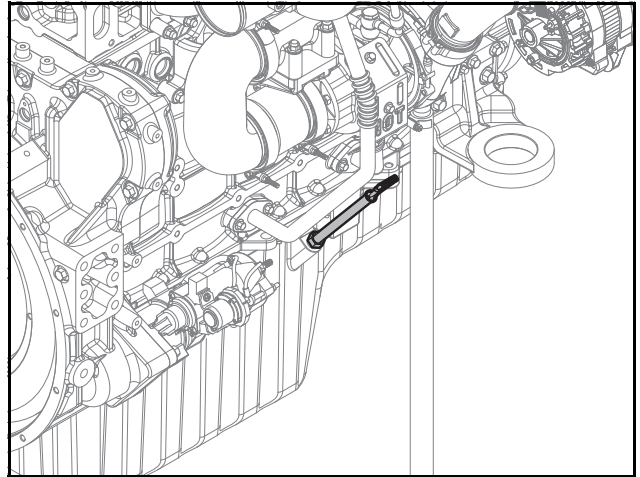
- 1) Assemble the alternator and tighten the bracket fixing bolts.
 - 2) Assemble the alternator and idle pulley.
 - 3) Assemble the alternator bracket fixing bolts to 8.0 kgf.m (M12 × 1.5P), 6.2 kgf.m (M10 × 1.5P)
 - 4) Assemble the belt with the auto tensioner turned clockwise.
37. Assemble the cooling fan.



EDX08250045

- 1) Assemble the cooling fan and flange, then tighten the mounting bolts.

38. Assemble the oil level gauge.



EDX08250042

- 1) Apply an adhesive (Loctite #262) to the guide tube.
 - 2) Install the guide tube and oil level gauge on the oil pan.
39. Connect the cables and harness connected to the various sensors in the engine.
40. Mount the engine in the machine.
41. Add engine oil.
- 1) Open the oil filler cap on the top of the cylinder head cover and add engine oil prepared in advance.

CAUTION

Use the specified genuine oil recommended by HD Construction Equipment.

42. Add coolant.

- 1) Open the radiator cap and add coolant prepared in advance.

CAUTION

Use the specified coolant recommended by HD Construction Equipment.

6. Cooling System

General Information	103
General Information	103
Failure Diagnosis	104
Thermostat	105
General Information	105
Cautions for Replacing and Handling the Thermostat	105
Inspecting the Thermostat	105

General Information

General Information

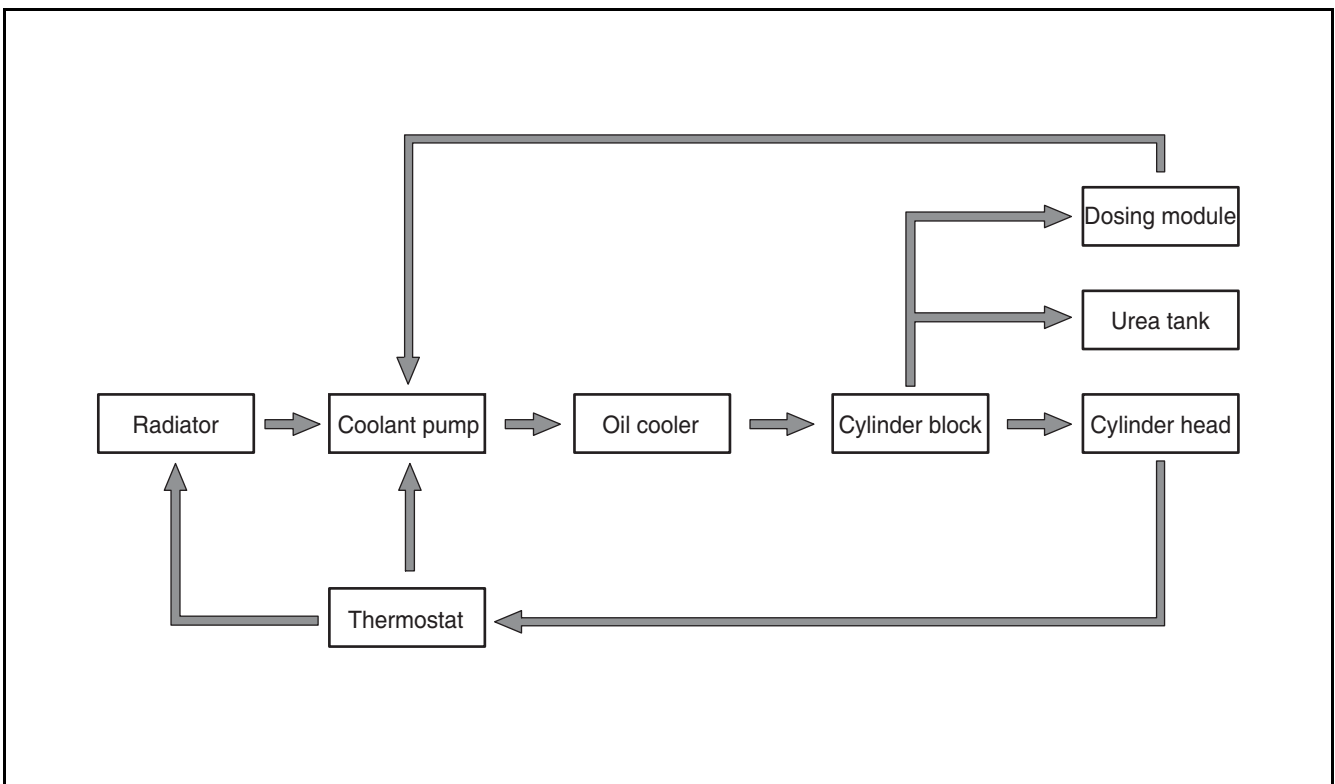
This engine is water-cooled. After coolant absorbs combustion heat from the combustion chamber and heat from engine oil, it releases heat to the outside to ensure normal engine operation.

In the cooling system, coolant supplied from the coolant pump flows to the oil cooler through the coolant pipe to absorb heat from oil. Then, as it passes through the coolant jacket of the cylinder block and the cooling passage of the cylinder head, it absorbs combustion heat.

Having absorbed the heat from oil and combustion, the coolant flows into the thermostat through the coolant pipe. If the coolant temperature is lower than the valve opening temperature of the thermostat, it is returned to the coolant pump.

Otherwise, it flows to the radiator.

In the radiator, coolant releases heat by means of the cooling process and is returned to the coolant pump.



EDX08240235

6. Cooling System

Failure Diagnosis

Symptom	Possible Cause	Troubleshooting
Engine overheating	Insufficient coolant	Add coolant
	Defective radiator cap	Replace
	Contaminated radiator	Clean the outside of the radiator
	Incorrect V-belt play	Adjust or replace
	Contaminated or damaged V-belt	Replace
	Damaged impeller	Replace the coolant pump
	Defective impeller fastener	Replace the coolant pump
	Faulty coolant pump	Replace
	Malfunctioning thermostat	Replace
	Poor coolant flow	Clean the coolant passage
	Incorrect injection timing	Check with a fault diagnostic device
	Damaged cylinder head gasket	Replace
Overcooled engine	Faulty thermostat	Replace
	Excessively low ambient temperature	Heat the cylinder block
Coolant leak	Damaged radiator	Repair or replace
	Loose or damaged radiator connection	Repair or replace the connection
	Defective radiator cap	Replace
	Defective coolant pump fastener	Repair or replace
	Faulty or damaged coolant pump gasket	Replace the gasket
	Defective thermostat fastener	Repair or replace
	Faulty or damaged thermostat gasket	Replace the gasket
	Damaged cylinder head gasket	Replace the gasket
Damaged cylinder head or block	Replace	
Noise	Faulty coolant pump bearing	Replace the coolant pump
	Faulty or damaged cooling fan fastener	Repair or replace
	Poor rotation of the cooling fan	Replace
	Incorrect V-belt play	Adjust or replace

Thermostat

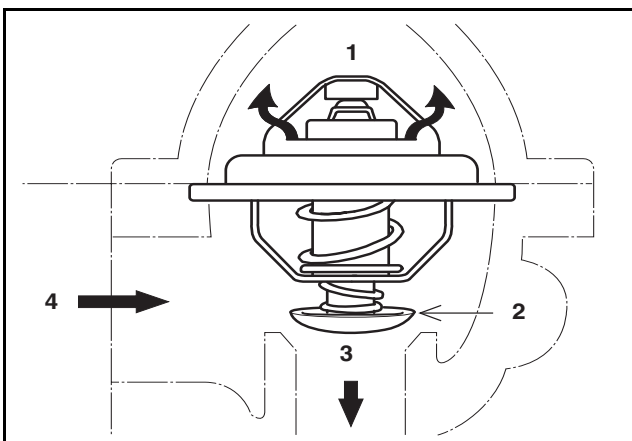
General Information

The thermostat is used to maintain a constant coolant temperature in the engine and prevent heat loss in order to enhance the engine's thermal efficiency.

In the event that the coolant temperature is lower than normal, the thermostat closes and coolant is bypassed directly into the coolant pump. If the coolant temperature is higher than normal, the thermostat valve opens completely and the bypass circuit closes, causing coolant to flow to the radiator.

CAUTION

- **The reaction time of the wax pellet type against changes in the coolant temperature is slower than that of the bellows type. This is because the wax pellet type has higher thermal capacity. Hence, the engine must be idled sufficiently first to prevent a rapid rise in the engine coolant temperature. In cold weather, avoid overloading or overspeeding immediately after starting the engine.**
- **When draining coolant from or adding coolant to the engine cooling system, drain or pour it slowly to allow enough air to escape from the system.**
- **If the thermostat is defective, replace it with a new one.**



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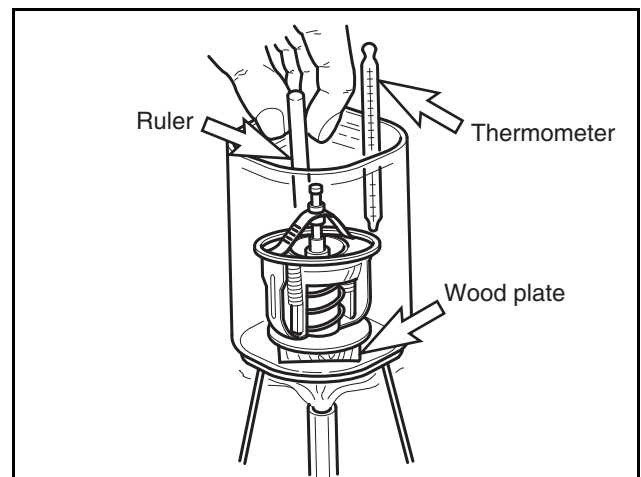
- | | |
|-------------------|-----------------|
| 1. Heat exchanger | 3. Coolant pump |
| 2. Bypass valve | 4. Coolant pipe |

Cautions for Replacing and Handling the Thermostat

1. Cautions for handling
The reaction time of the wax pellet type against changes in the coolant temperature is slower than that of the bellows type.
This is because the wax pellet type has higher thermal capacity.
Hence, the engine must be idled sufficiently first to prevent a rapid rise in the engine coolant temperature. In cold weather, avoid overloading or overspeeding immediately after starting the engine.
2. When draining coolant from or adding coolant to the engine cooling system, drain or pour it slowly to allow enough air to escape from the system.
3. Replace the thermostat
If the thermostat is defective, replace it with a new one.

Inspecting the Thermostat

1. Check the wax pellet and spring for damage.
2. Submerge the thermostat in water and heat the water slowly to check whether the thermostat operates properly.
If the thermostat begins opening at a water temperature of 71°C and opens completely at a water temperature of 85°C, the thermostat is operating normally.



EFM2055I

3. Check the inside of the thermostat for foreign matter.
Note) Use an air gun to clean out the inside of the thermostat.
4. Check the inside and outside of the hose for damage and foreign matter.

6. Cooling System

7. Lubrication System

General Information	109
General Information	109
Failure Diagnosis	110
Oil Pump	111
General Information	111
Gerotor Type Oil Pump Specification.....	111

7. Lubrication System

General Information

General Information

This engine is lubricated with a forced lubrication system. Oil pressure is generated and supplied by the gear rotation of the oil pump driven directly by the crankshaft gear on the back of the cylinder block.

After the oil pump sucks in oil from the oil pan through the suction pipe, the oil is sent to the main gallery of the cylinder block through the oil filter and oil cooler.

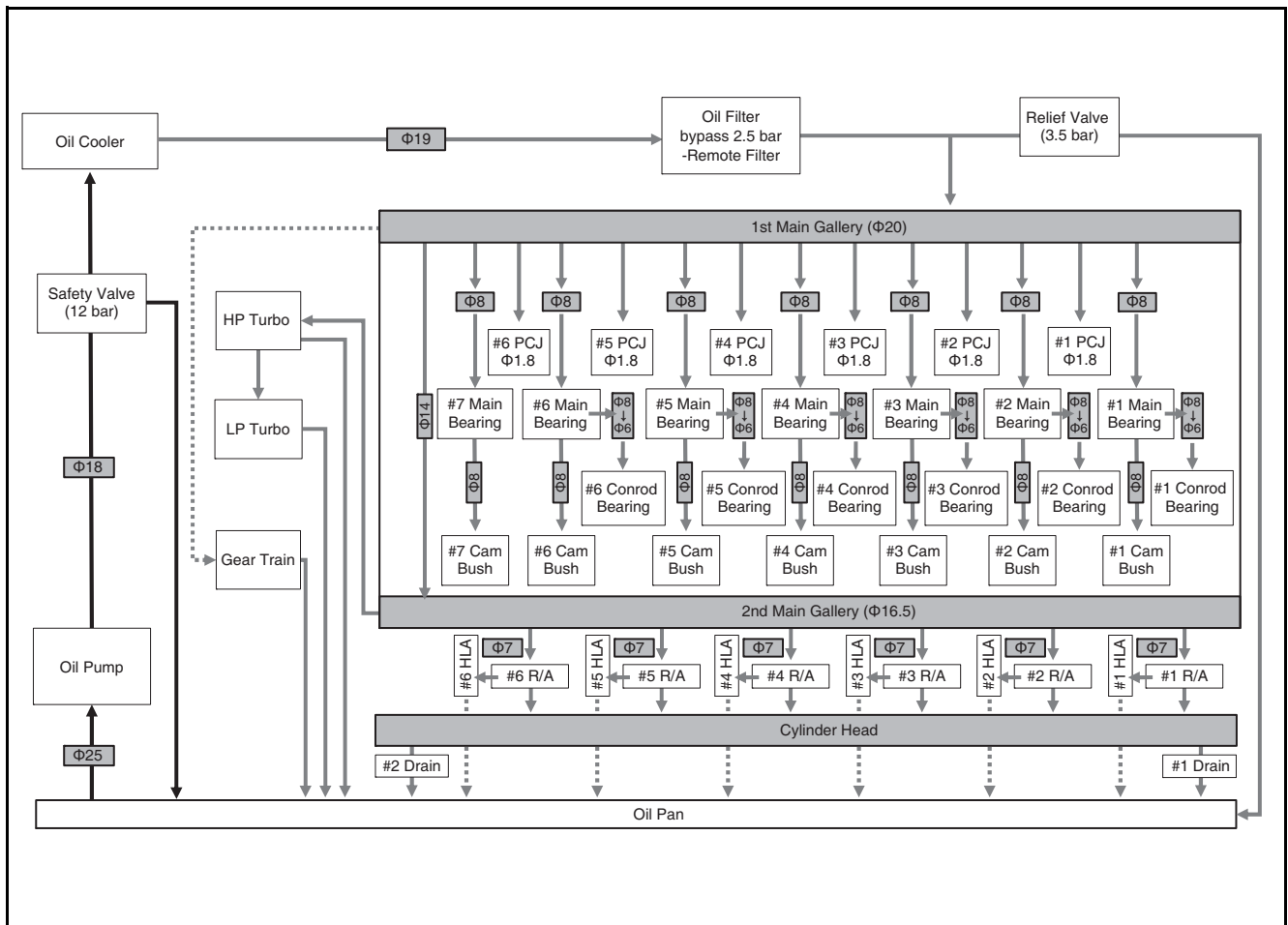
Then, it is distributed to the crankshaft bearings, camshaft bearings and rocker arms to lubricate them.

The engine lubrication circuit is also connected to the turbocharger, and oil is supplied for the operation of the engine brake.

Oil is sprayed around the cylinder block and timing gear for proper lubrication.

Each cylinder is equipped with an oil spray nozzle for cooling the inside of the piston.

Foreign matter is removed from engine oil by the oil filter.



EDX08240236

7. Lubrication System

Failure Diagnosis

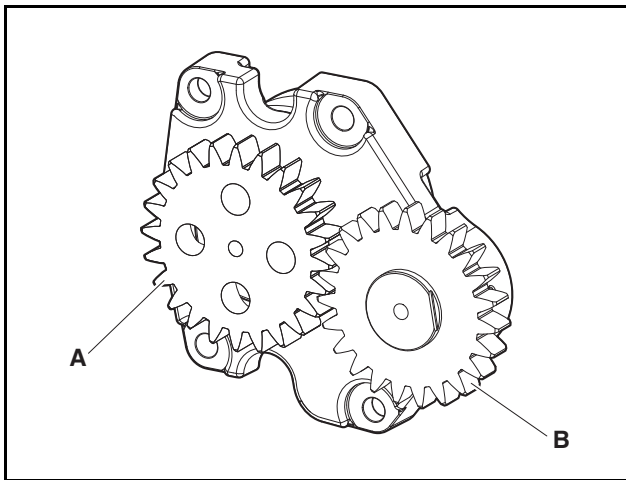
Symptom	Possible Cause	Troubleshooting
Excessive oil consumption	Poor oil	Change to specified oil
	Leaky oil seal ring and packing	Replace
	Worn or damaged piston and piston ring	Replace
	Seized piston ring	Replace
	Worn valve guide oil seal, valve guide, or valve stem	Replace
Oil pressure drop	Poor oil	Change to specified oil
	Seized oil pump relief valve	Replace
	Clogged oil pump strainer	Wash the strainer
	Oil pump gear worn	Replace
	Oil pump feed pipe cracked	Replace
	Defective oil pump	Repair or replace
	Defective hydraulic system	Repair or replace
	Worn bearing	Replace
Contaminated oil	Clogged oil filter	Replace the oil filter
	Gas leak	Replace the piston ring
	Poor oil	Change to specified oil

Oil Pump

General Information

Engine oil is sucked in from the oil pan by the gerotor type oil pump and filtered through the oil cooler and oil filter. The filtered oil passes through the main oil galleries in the cylinder block and lubricates the various bearings in the engine and the turbocharger, thereby maintaining normal engine performance.

Gerotor Type Oil Pump Specification



EDX08240033

Note) Drive gear

- Speed (at engine 1,000 rpm): 1,625 rpm
- Gear ratio: 1.625

Performance specifications

- Discharge volume
 - Minimum 41 L/min, 1.0 bar @ 1,300 rpm
 - Minimum 105 L/min, 4.0 bar @ 3,575 rpm
- Test condition
 - Test oil: SAE 10W40
 - Oil temp: 80°C ±3°C

Drive gear & idle gear circumferential backlash:

0.068 ~ 0.216

• Drive gear (A) specification

Grade (KS)	4	
Normal module	3	
Number of teeth	24	
Base circle DIA.	Ø67.658	
Normal pressure angle	20°	
Addendum modification	1.25	
Span measurement over 4 teeth	32.129 ⁰ _{-0.05}	
Crowning	0.008 ±0.004	
Over ball	Ball DIA.	Ø6
	Distance	81.181 ⁰ _{-0.109}

• Idle gear (B) specification

Grade (KS)	4	
Normal module	3	
Number of teeth	23	
Base circle DIA.	Ø64.839	
Normal pressure angle	20°	
Addendum modification	1.22	
Span measurement over 4 teeth	23.043 ⁰ _{-0.05}	
Crowning	0.008 ±0.004	
Over ball	Ball DIA.	Ø6
	Distance	78.581 ⁰ _{-0.11}

7. Lubrication System

8. Fuel System

- General Information 115
 - General Information 115
- High-Pressure Fuel System Components116
- Injector116
 - General Information 116
 - Injector Operating Principles..... 117
 - Injector protrusion 117
- Common Rail118
 - General Information 118
- Fuel Injection Pump120
 - General Information 120
- Fuel Delivery Pump122
 - General Information 122

General Information

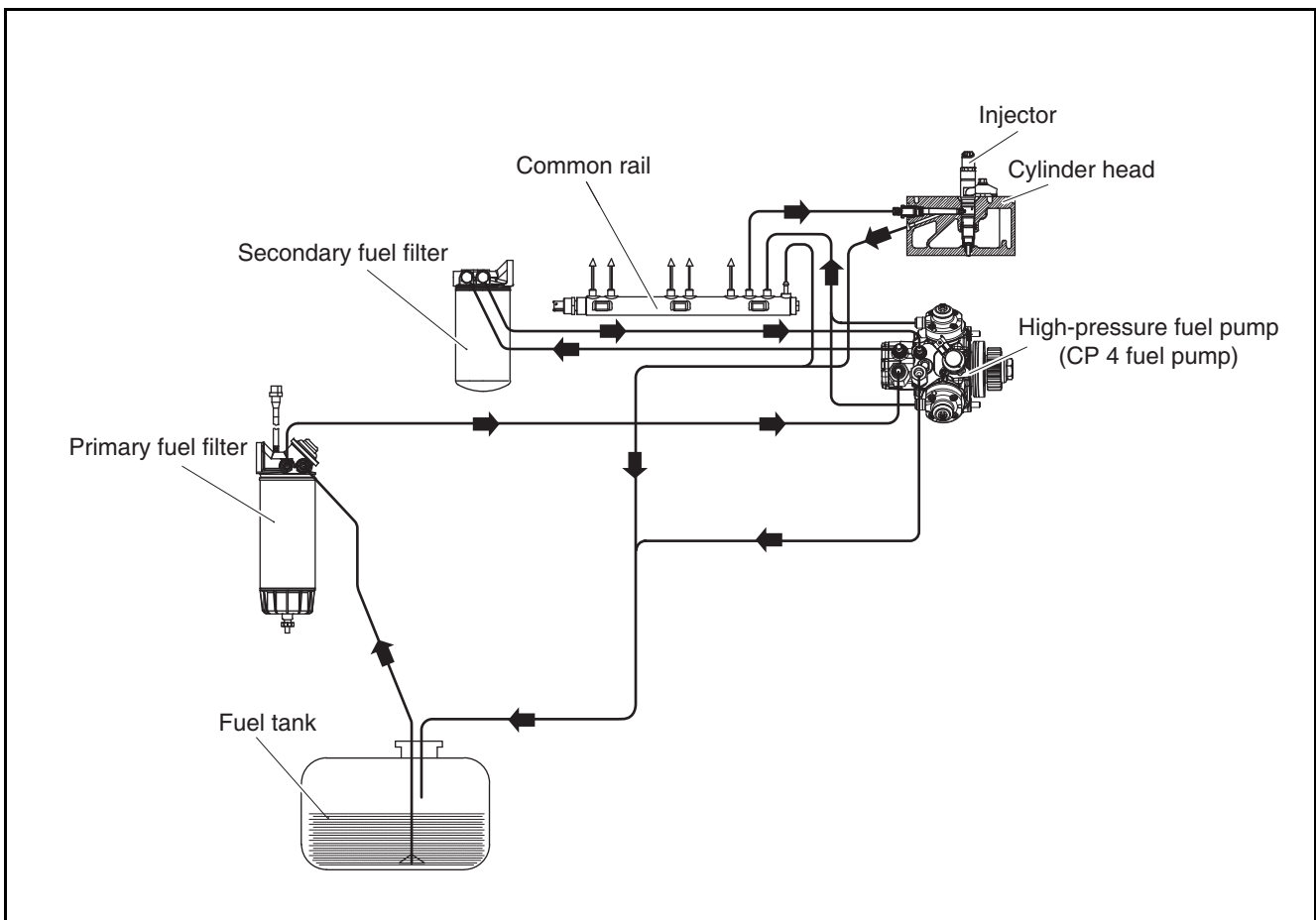
General Information

Diesel engines compress air sucked into the cylinders to produce compression heat; then, spray nozzles inject fuel which is subsequently burnt by the heat of compression. Pressurized fuel generated by the high-pressure pump is stored in the common rail, while the injection timing and injection amount are calculated by the electronic control unit (ECU). The ECU injects fuel by actuating the solenoid valve for the injector installed in each cylinder.

HD Construction Equipment 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.

Pressurized fuel generated by the high-pressure fuel pump is stored in the common rail. When the driver operates the vehicles, the optimal amount of fuel and fuel injection timing are determined based on the data set in the ECU according to the vehicle speed and operating conditions, while the ECU actuates the solenoid valve for the injector installed in each cylinder of the engine to inject fuel into the cylinders.

The fuel tank must be made of non-corrosive material and be able to operate without leaks at twice the operating pressure of the low-pressure fuel pump. The pressure inside the tank must not exceed 0.3 bar.



EDX08240228

8. Fuel System

High-Pressure Fuel System Components

The common rail fuel injection system consists of a low-pressure stage for the low-pressure transfer of fuel, a high-pressure stage for high-pressure transfer, and an ECU.

1. High-pressure fuel pump

The high-pressure fuel pump pressurizes fuel to a pressure of approx. 1,800 bar; then, this pressurized fuel is delivered to the pipe-shaped common rail via a high-pressure line.

2. Common rail

The fuel pressure in the common rail remains constant even after the injectors use fuel from the common rail for fuel injection. The fuel pressure is measured by a common rail pressure sensor and is maintained at the desired level by a pressure adjustment valve. Fuel pressure is controlled by a pressure control valve within the common rail up to a maximum pressure of 1,800 bar.

3. Injector

Solenoid valves allow fuel to flow into the injector nozzles from which the injectors spray fuel directly into the combustion chamber of the engine.

The injector nozzle opens and supplies the required amount of fuel; then, the remaining fuel returns to the tank via a return line. Fuel returned from the fuel pressure adjustment valve and low-pressure stage and fuel used to lubricate the high-pressure pump also return to the fuel tank by means of a return line.

4. High-pressure fuel pipe

The high-pressure fuel pipes deliver high-pressure fuel at a pressure of 1,800 bar.

Hence, the pipes of the fuel lines are made of a special material designed to withstand both the maximum pressure of the system and fluctuations in pressure at the high pressures which occur during fuel injection. The high-pressure pipes have an outside diameter of 8.0 mm and an inside diameter of 3.5 mm. Furthermore, the high-pressure fuel pipes between the common rail and injectors all have an identical length and are designed to be as short as possible.

Injector

General Information

The solenoid valve allows fuel to flow into the injector nozzle from which the injector sprays fuel directly into the combustion chamber of the engine.

The injector nozzle opens and supplies the required amount of fuel; then, the remaining fuel returns to the tank via a return line. Fuel returned from the fuel pressure adjustment valve and low-pressure stage and fuel used to lubricate the high-pressure pump also return to the fuel tank by means of a return line.

The start of fuel injection and amount of injection are adjusted by a solenoid valve installed in each injector, while the injectors replace the functions of nozzles and nozzle holders in previous engines. Fuel is supplied to the injector by means of a high-pressure connector installed in the cylinder head; then, the fuel is supplied to the control valve chamber by means of a delivery hole.

The control valve chamber is opened by a solenoid valve and connected to the fuel return line via a discharge hole.

The force of the hydraulic pressure applied to the valve control plunger while the discharge hole is closed exceeds the pressure of the nozzle needle.

As a result, fuel supply to the combustion chamber is shut off by the force applied to the contact surface of the nozzle needle.

When the solenoid valve of the injector is pulled, the discharge hole is opened.

This lowers the pressure in the control chamber and reduces the hydraulic pressure acting on the plunger. The nozzle needle opens when the force of the hydraulic pressure drops below the force acting on the nozzle needle pressure.

Then, fuel is injected into the combustion chamber through the hole in the spray nozzle.

The nozzle needle is controlled by hydraulic pressure because the force required to open the needle quickly is not generated directly by the solenoid valve. The fuel control rate required to open the nozzle needle is added to the actual amount of fuel injected. Then, the used fuel is discharged into the fuel return line through the hole in the control valve chamber.

Fuel loss occurs not only during the control phase, but also in the nozzle needles and valve plunger guides.

The fuel from the control phase, as well as fuel collected from lines connected to the overflow valve, high-pressure pump, and pressure control valve, return to the fuel tank via the fuel return line.

Injector Operating Principles

Injector operation is divided into four stages involving engine operation and a high-pressure pump which generates pressure.

1. Injector closed (high fuel pressure)
2. Injector open (start of fuel injection)
3. Injector fully open (fuel injection)
4. Injector closed (end of fuel injection)

These operating stages are determined by the distribution of force acting on the injector components.

The injector nozzles do not work when the engine is stopped and there is no pressure in the common rail.

1. Injector closed (paused)

Injectors do not work during the pause stage when power is not supplied to the injector solenoid valves. The valve ball is pressed against the seat surface of the injector discharge hole by a valve spring and magnetic force. High pressure in the common rail is maintained by the fuel control valve and the same pressure is generated in the nozzle chamber of the injector. The common rail fuel pressure acting on the end of the control valve chamber of the injector and the force applied to the injector nozzle spring are greater than the opening force of the nozzle, thereby keeping the nozzle closed.

2. Injector open (start of fuel injection)

When power is supplied with the injector solenoid valve in its closed state, the pulling force of the solenoid valve opens the fuel discharge hole. The high current applied to the solenoid is reduced to a low current almost simultaneously. This is because the air gap in the electromagnetic circuit becomes smaller. The fuel in the control valve chamber flows through a hole in the discharge valve on top of the control valve chamber and into the fuel tank via a fuel return line.

The discharge hole disrupts the pressure balance completely and causes the pressure in the control valve chamber to drop. This, in turn, further reduces the pressure in the nozzle chamber maintaining the pressure in the control valve chamber at the same pressure as in the common rail. The reduced pressure in the control valve chamber causes a reduction in the force applied to the control plunger and, as a result, the nozzle needle opens and fuel injection begins.

3. Injector fully open (fuel injection)

As a result of the fuel buffer created by the discharge rate and the flow of fuel between the delivery holes, the valve control plunger comes to a rest at the top.

At this time, the injector nozzle opens fully and fuel is injected into the combustion chamber at the same pressure as in the common rail.

4. Injector closed (end of injection)

When power to the injector solenoid valve is shut off, the valve spring forces the armature downwards immediately and the valve ball closes the discharge hole. The armature consists of two parts: an armature plate guided downwards by a driving shoulder, and an overspring with a return spring installed to prevent the force acting on the armature and valve ball from being applied in the downward direction. When the discharge hole is closed, fuel enters from the delivery hole and generates pressure in the control chamber. This fuel pressure is equal to the pressure of the common rail and applies pressure to the valve control plunger through the end surface of the valve control plunger. This pressure exceeds both the force of the spring and the pressure built up in the nozzle chamber, thereby closing the nozzle needle. The closing speed of the nozzle needle is determined by the flow rate passing through the delivery hole; as soon as the nozzle needle reaches the stop position, fuel injection is shut off.

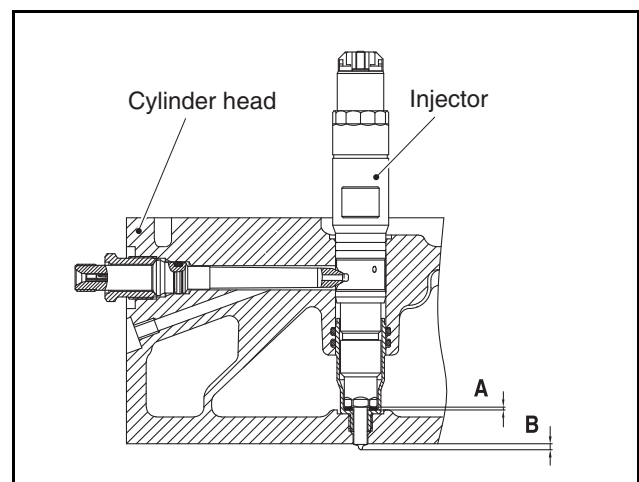
Injector protrusion

1. Insert a seal ring into the cylinder head and assemble the injector.

Note) Refer to the section on engine assembly for the order of assembly.

2. Check the protrusion of the injector from the cylinder head and adjust it if necessary.

A (thickness of seal ring)	2.0 mm
B (injector protrusion)	1.95 mm



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8. Fuel System

Common Rail

General Information

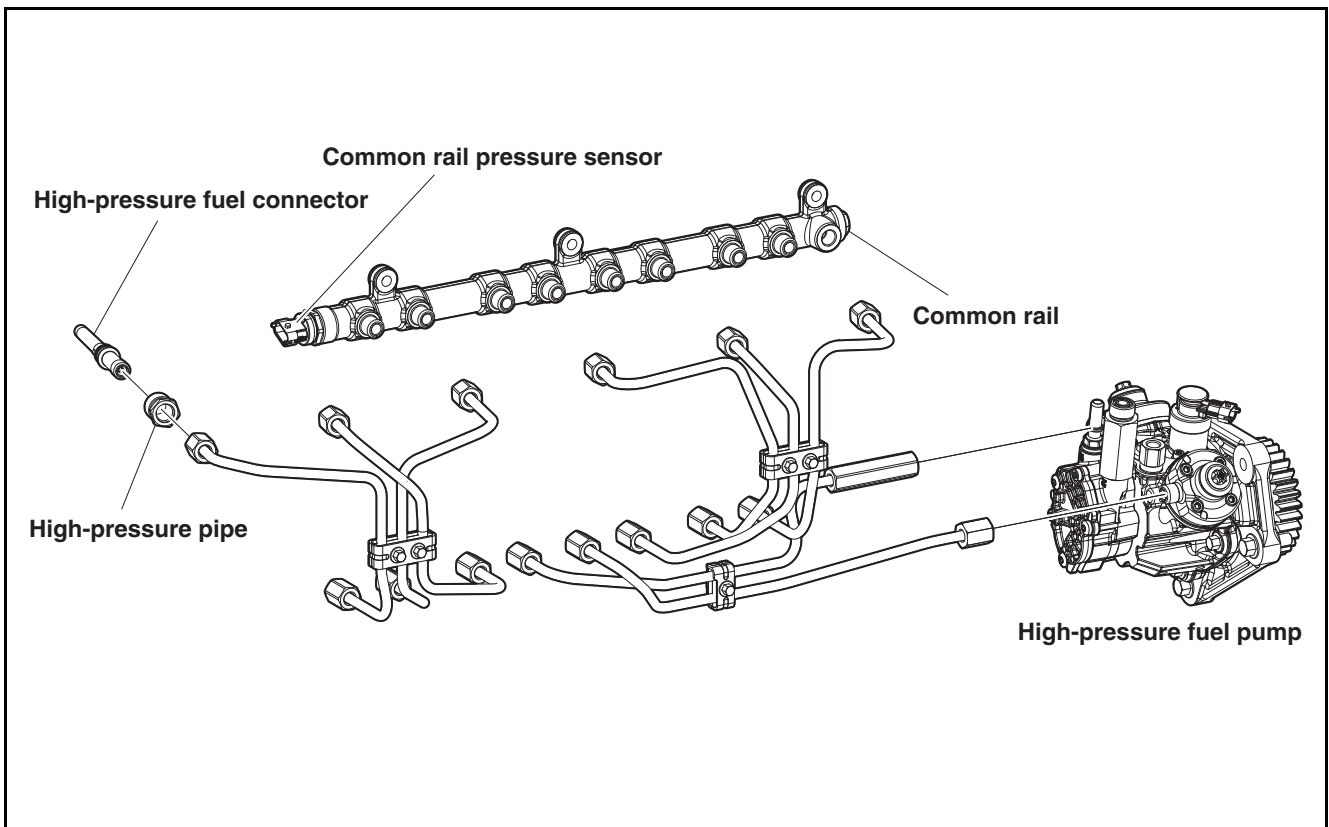
HD Construction Equipment common rail fuel injection system is divided into a high-pressure generation system and a fuel injection system.

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.

The common rail stores fuel pumped from the high-pressure fuel pump at a high pressure.

The fuel pressure in the common rail remains constant due to the volume of the common rail even after the injectors use fuel from the common rail for fuel injection.

The fuel pressure is measured by a common rail pressure sensor and is maintained at the desired level by a pressure adjustment valve. Fuel pressure is controlled by a pressure control valve within the common rail up to a maximum pressure of 1,800 bar.



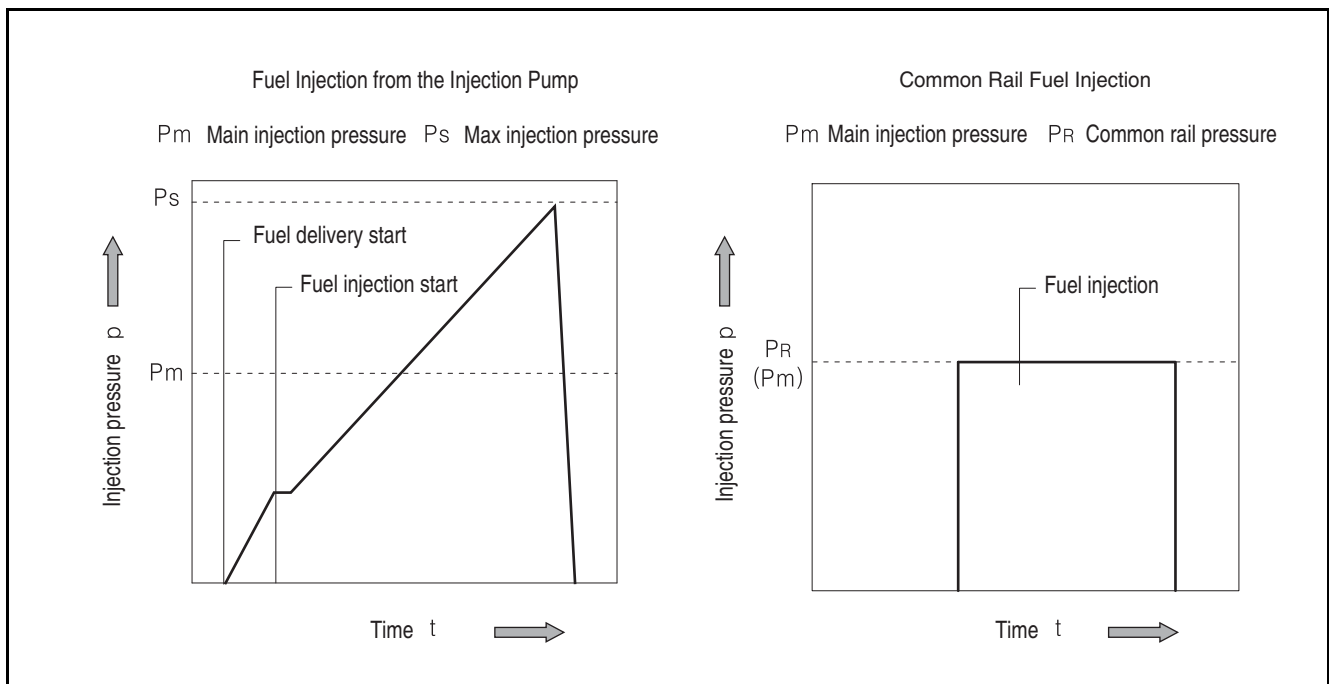
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The main components of the common rail fuel injection system are as follows.

1. Electronic control unit (ECU)
 2. Crankshaft position sensor
 3. Camshaft position sensor
 4. Accelerator pedal sensor
 5. Fuel temperature sensor
 6. Boost pressure & temperature sensor, oil pressure & temperature sensor
 7. Common rail pressure sensor
 8. Coolant temperature sensor
- The ECU receives input signals from the sensors described above in response to the driver pressing the accelerator pedal and operates instantaneously according to the engine, vehicle and operating performance. The ECU also operates the switch circuits and open loop in the vehicle and engine based on this data.

8. Fuel System

- The crankshaft position sensor measures the engine speed, while the camshaft position sensor is used to determine the firing order. Electrical signals produced by the potentiometer in the accelerator pedal sensor notify the ECU of how far the driver pushed the pedal. Furthermore, a turbocharger and intake pressure sensor are installed; the intake pressure sensor measures the intake pressure.
- In cold ambient temperatures or when the engine is cold, the ECU receives data from the coolant temperature sensor and ambient temperature sensor and adjusts the operation of the engine to suit the operating conditions.



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The injection characteristics of the common rail are as follows.

1. In comparison with previous injection characteristics, common rail fuel injection requires the following ideal fuel injection. The amount of fuel injected by the common rail and the injection pressure are both controlled independently of one another, thereby ensuring that all engine conditions are satisfied.
2. The injection amount during the initial stage of the fuel injection process—i.e. the ignition delay time between the start of fuel injection and the start of combustion—must be able to be lowered.
3. The common rail system is a modular system whose components—listed below—play a fundamental role in determining the injection characteristics.
 - 1) Injector solenoid valve installed on the cylinder head
 - 2) Common rail
 - 3) High-pressure fuel pump
 - 4) Electronic control unit (ECU)
 - 5) Crankshaft position sensor

8. Fuel System

Fuel Injection Pump

General Information

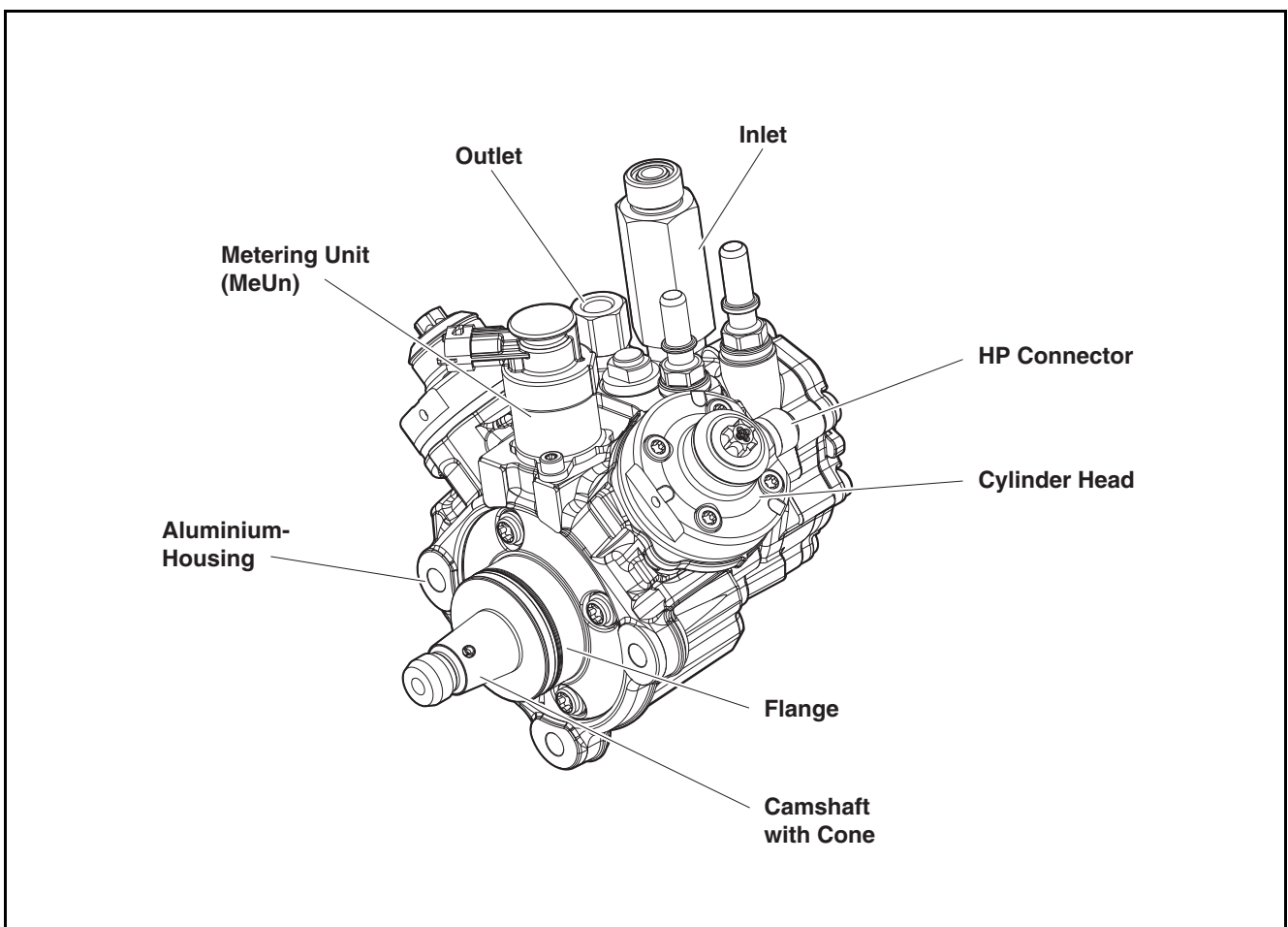
The high-pressure fuel pump uses a radial piston pump to generate high pressure. Pressure is generated independently during the fuel injection process. The rpm of the high-pressure fuel pump is directly linked to the engine rpm, regardless of the transmission gear ratio. In comparison with previous injection systems, the common rail injection system provides a constant amount of fuel.

Consisting of a nozzle and solenoid valve, injectors are connected to the common rail with high-pressure pipes.

When the key switch is turned on, power is supplied to the solenoid valve by the ECU.

The solenoid valve stops injection when the key switch is turned off.

The injector solenoid valves are switched on and off by high voltage and current and operate sequentially according to the ECU settings. The engine rpm sensor uses the crankshaft sensor and camshaft sensor to adjust the start of fuel injection and injection timing.



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1. Functions

1) The high-pressure fuel pump has a low-pressure and high-pressure stage. The pump serves to transfer high-pressure fuel under all operating conditions throughout the service life of the machine. Furthermore, the pump supplies the fuel required for starting the vehicle quickly or sudden changes in the pressure in the common rail. The high-pressure fuel pump continuously generates the system pressure required in the common rail.

2. Configuration of high-pressure fuel pump

1) Inside the high-pressure fuel pump, fuel is compressed circumferentially by two pump pistons installed at 120° to one another. As two compression strokes are performed with every rotation, the pump maintains stress in the pump drive system and requires low driving force. The driving force of the common rail pump requires a load nine times less than the driving force required by previous pump systems.

3. Operating principle

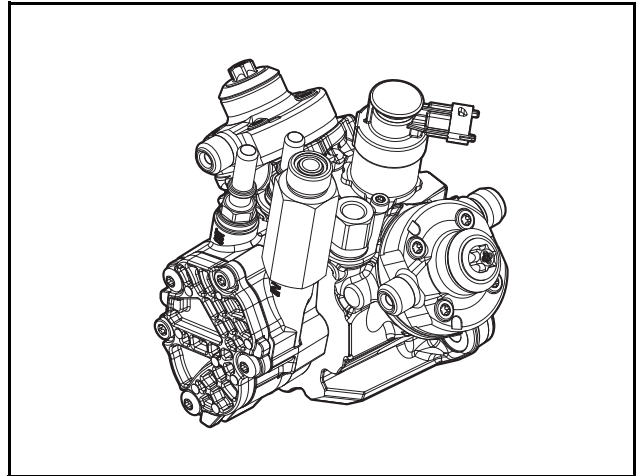
- 1) The fuel delivery pump supplies fuel from the tank to the high-pressure pump via the fuel inlet and safety valve. This delivers fuel from the safety valve to the high-pressure pump and cooling circuit for lubrication. The drive-shaft has an eccentric cam which drives the pump pistons up and down according to the shape of the cam.
- 2) If the transfer pressure of the fuel delivery pump exceeds the full opening pressure of the safety valve, the fuel is delivered via the intake valve of the high-pressure fuel pump to the intake stroke of the pumping chamber in which the pump pistons are moving downwards. Once the pump pistons pass the BDC, the valve inlet closes and fuel is trapped in the pumping chamber; then, the fuel is compressed to a higher pressure than that at which it was delivered.
- 3) As soon as the fuel pressure reaches the pressure of the common rail, it closes the outlet valve. Then, the compressed fuel enters the high-pressure circuit. The pump pistons continue delivering fuel until they reach the TDC, after which the pressure drops and the outlet valve closes. Fuel remaining in the pumping chamber is decompressed and the pump pistons move back downwards. Once the pressure in the pumping chamber drops below the pressure of the fuel delivery pump, the inlet valve opens and the process described above begins again.

4. Returning delivered fuel

- 1) The high-pressure fuel pump is designed to deliver large quantities of fuel. Hence, excess fuel delivered while the engine is idling or running under a partial load returns to the tank via the pressure adjustment valve.

5. High-pressure fuel pump shutoff valve

- 1) When the switch of the high-pressure fuel pump shutoff valve turns off, the amount of fuel delivered to the common rail increases. When the switch is turned off, the intake valve remains open and the fuel pump solenoid valve is pulled, thereby keeping the valve inlet open with the pin on the electromagnet. Thus, fuel supplied to this pumping valve cannot be compressed during the delivery stroke. No pressure is generated while the fuel returns to the low-pressure passage. Since the pump shutoff valve is actuated by a minimal amount of power, fuel delivery and shutoff take place at short intervals.



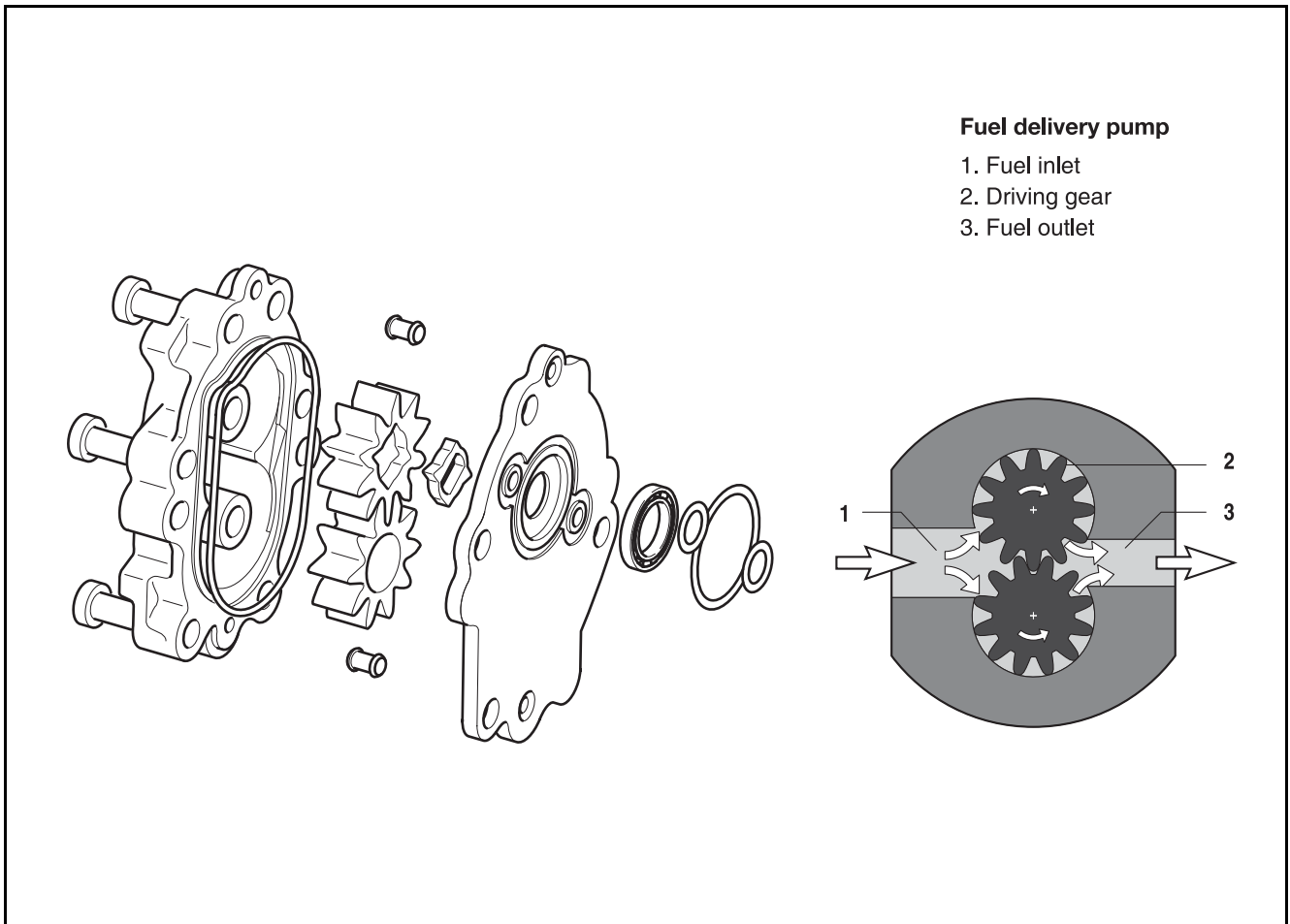
EDX08240198

8. Fuel System

Fuel Delivery Pump

General Information

The gear-driven fuel delivery pump is a fuel pump installed on the back of the high-pressure fuel pump. The fuel delivery pump draws in fuel from the fuel tank and delivers the required amount of fuel continuously to the high-pressure pump.



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9. Intake/Exhaust System

General Information	125
General Information	125
Turbocharger	125
General Information	125
Failure Diagnosis	127
Handling the Turbocharger	129
Check Items During Turbocharger Disassembly and Assembly	131
Inspecting the Turbocharger	132

General Information

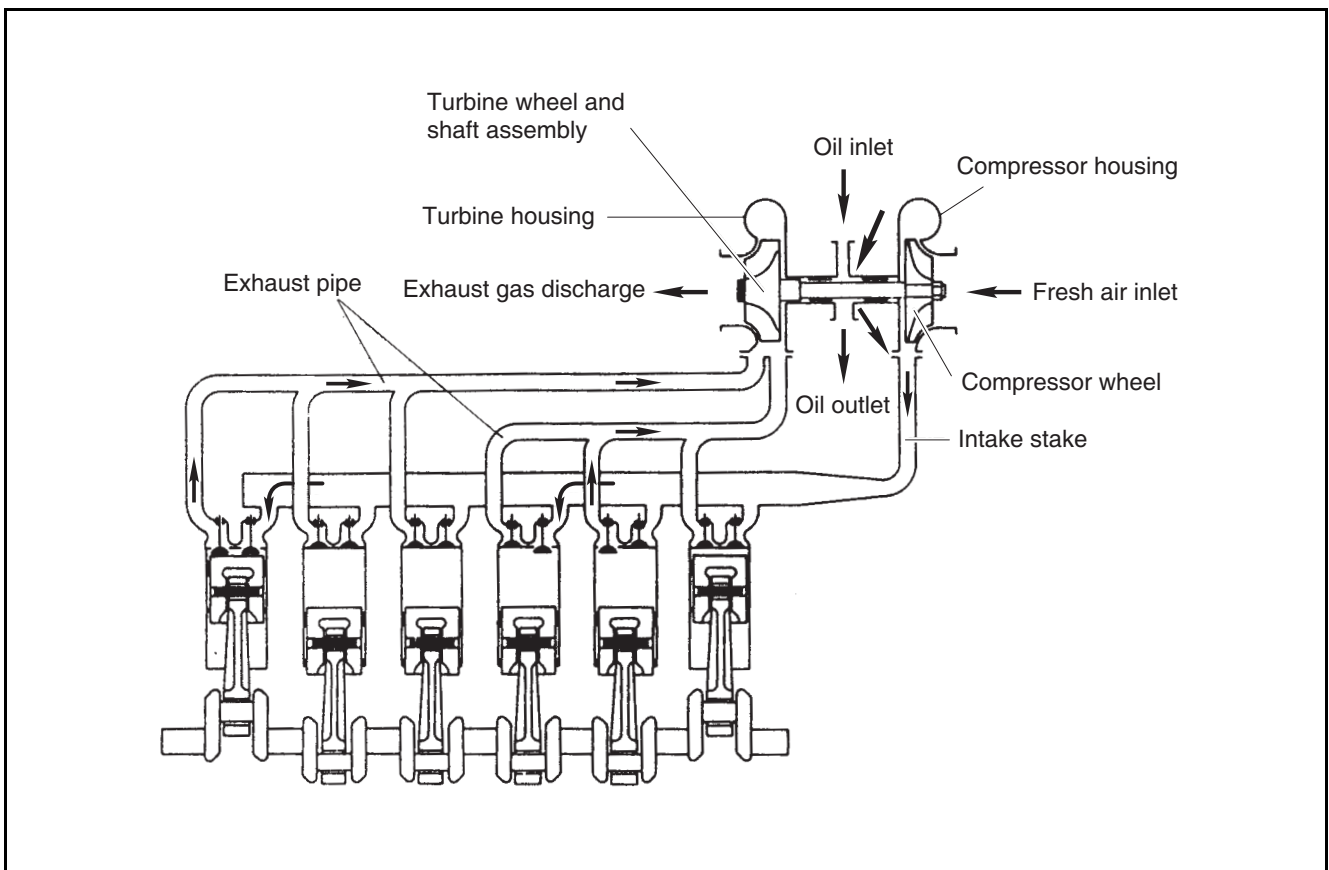
General Information

HD Construction Equipment engines are designed to satisfy stringent emissions regulations and are equipped with the full range of HD Construction Equipment technologies for enhancing fuel economy and reducing emissions.

Turbocharger

General Information

The turbocharger is designed to use the thermal energy of exhaust gas and supply high-density air to the engine cylinders in order to increase the engine power.



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1. Engine power is determined by the amount of fuel delivered and engine efficiency.
2. In order to burn the supplied fuel completely and convert it into effective work for the engine, a sufficient amount of air should be supplied for complete fuel combustion.
3. The engine power is actually determined by the volume of cylinders. If compressed air is delivered to a given volume of cylinders, the amount of air in the cylinders increases, enabling more fuel to be burnt and increasing engine power.
4. Delivering compressed air to cylinders in this way is referred to as "supercharging," while supercharging with exhaust gas discharged from the combustion chamber is known as "Turbocharging."

9. Intake/Exhaust System

5. The main functions of the turbocharger are as follows.
- 1) Turbine: As exhaust gas discharged from the combustion chamber passes through the turbine housing, its energy is transferred to the turbine blades, rotating the turbine shaft. The part where this takes place is known as a turbine. The turbine is equipped with a seal ring and heat shield to prevent exhaust gas from having an adverse effect on the bearing.
 - 2) Compressor: Connected to the same shaft as the turbine and rotating in conjunction with it, the compressor receives rotating force from the turbine shaft to suck in, compress and supply air to the intake stake. This is the basic operating principle of the compressor.
 - 3) Bearings:
 - Thrust bearing: Axial force acts upon the turbine wheel. This is to prevent the shaft from moving due to this axial force.
 - Journal bearing: The floating bearing creates a dual oil film on the inside and outside of the bearing, enabling the bearing to rotate independently. The dual oil film acts as a buffer which keeps the sliding speed of the bearing surface below the rotating speed of the shaft, ensuring stable operation.
 - 4) Compressor shaft seal ring: The seal plate and seal ring form a dual structure to prevent leakage of compressed intake air and lubricant.

9. Intake/Exhaust System

Failure Diagnosis

Symptom	Possible Cause	Troubleshooting
Noise or vibrations	Rotating part in contact with another part	Repair or replace
	Unevenly rotating rotor	Repair or replace
	Seizure	Repair or replace
	Loose connection	Check or replace
	Deformed or damaged intake unit hose	Replace
	Incorrectly tightened clamp	Adjust and tighten
	Contaminated or damaged air filter	Replace and check for damage to the turbocharger impeller
	Turbocharger coolant leak or oil hose leak	Replace the hose and gasket
	Gas leaking from the exhaust manifold	Replace the gasket or tighten the mounting nuts
	Poor turbo actuator operation	Replace the turbocharger
	Leaking engine block and exhaust manifold	Check the engine
	Contaminated blow-by gas and incorrect oil level	Check the turbo impeller and turbo intake outlet
	Excessive free play of turbocharger wheel causing interference with the wall	Check for sand or metallic foreign matter
	Damaged turbocharger wheel	Check for sand or metallic foreign matter
	Damaged turbocharger wheel and shaft	Check for sand or metallic foreign matter
Poor rotating force of the turbocharger wheel	Check for sand or metallic foreign matter	
Output lowered	Gas leaking from the exhaust system	Check or replace
	Clogged air filter element	Clean or replace
	Contaminated or damaged turbocharger	Repair or replace
	Air leaking from outlet on compressor side	Check or replace
	Deformed or damaged intake unit hose	Replace
	Incorrectly tightened clamp	Adjust and tighten
	Contaminated or damaged air filter	Replace and check for damage to the turbocharger impeller
	Poor turbo actuator operation	Replace the turbocharger
	Leaking engine block and exhaust manifold	Check the engine
	Contaminated blow-by gas and incorrect oil level	Check the turbo impeller and turbo intake outlet
	Excessive free play of turbocharger wheel causing interference with the wall	Check for sand or metallic foreign matter
	Damaged turbocharger wheel	Check for sand or metallic foreign matter
	Damaged turbocharger wheel and shaft	Check for sand or metallic foreign matter
Poor rotating force of the turbocharger wheel	Check for sand or metallic foreign matter	
Oil leak	Deformed or damaged intake unit hose	Replace
	Incorrectly tightened clamp	Adjust and tighten
	Contaminated or damaged air filter	Replace and check for damage to the turbocharger impeller
	Turbocharger coolant leak or oil hose leak	Replace the hose and gasket
	Poor turbo actuator operation	Replace the turbocharger
Oil leak	Leaking engine block and exhaust manifold	Check the engine
	Contaminated blow-by gas and incorrect oil level	Check the turbo impeller and turbo intake outlet
	Excessive free play of turbocharger wheel causing interference with the wall	Check for sand or metallic foreign matter
	Damaged turbocharger wheel	Check for sand or metallic foreign matter
	Damaged turbocharger wheel and shaft	Check for sand or metallic foreign matter
	Poor rotating force of the turbocharger wheel	Check for sand or metallic foreign matter

9. Intake/Exhaust System

Symptom	Possible Cause	Troubleshooting
Lubrication oil consumption	Incorrectly tightened clamp	Adjust and tighten
	Turbocharger coolant leak or oil hose leak	Replace the hose and gasket
	Leaking engine block and exhaust manifold	Check the engine
	Contaminated blow-by gas and incorrect oil level	Check the turbo impeller and turbo intake outlet
	Excessive free play of turbocharger wheel causing interference with the wall	Check for sand or metallic foreign matter
	Damaged turbocharger wheel	Check for sand or metallic foreign matter
	Damaged turbocharger wheel and shaft	Check for sand or metallic foreign matter
	Poor rotating force of the turbocharger wheel	Check for sand or metallic foreign matter
Black or white exhaust smoke	Deformed or damaged intake unit hose	Replace
	Contaminated or damaged air filter	Replace and check for damage to the turbocharger impeller
	Turbocharger coolant leak or oil hose leak	Replace the hose and gasket
	Poor turbo actuator operation	Replace the turbocharger
	Contaminated blow-by gas and incorrect oil level	Check the turbo impeller and turbo intake outlet
	Excessive free play of turbocharger wheel causing interference with the wall	Check for sand or metallic foreign matter
	Damaged turbocharger wheel	Check for sand or metallic foreign matter
	Damaged turbocharger wheel and shaft	Check for sand or metallic foreign matter
	Poor rotating force of the turbocharger wheel	Check for sand or metallic foreign matter
Blue exhaust smoke	Leaking engine block and exhaust manifold	Check the engine
Excessive white smoke	Oil leaking into turbine or compressor	Repair or replace
	Worn or damaged seal ring due to excessively worn bearing	Repair or replace
Excessive emissions	Clogged air filter element	Clean or replace
	Clogged air duct	Check or replace
	Air leaking from the intake system	Check or replace
	Seized turbocharger (impossible to rotate)	Repair or replace
	One turbine blade or compression blade is in contact with another or is damaged	Repair or replace
	Deformed or clogged exhaust system pipe	Check or replace

Handling the Turbocharger

1. Cautions for engine operation

- 1) Follow the instructions below when starting, running and stopping the engine:

Item	Caution	Reason
When starting the engine	Check the oil level	
	Before starting the engine, make sure to run it with the starter motor to check for a rise in hydraulic pressure (until the needle on the hydraulic pressure gauge moves or the pressure indicator turns on).	If the engine is started abruptly, oil cannot reach the turbocharger or the various parts of the engine; this lack of lubrication can lead to abnormal wear or seizure of the bearings.
	After changing the oil, replacing the oil filter cartridge or lubrication system component or leaving the engine stopped for an extended period of time or in cold weather, undo the oil pipe connection at the inlet of the turbocharger and run the starter motor until oil flows out of it. Once this step is complete, make sure to retighten the pipe connection and start the engine.	Oil flow in pipes worsens after the engine has been stopped for a prolonged period of time or in cold weather.
Right after starting	Idle the engine for 5 minutes after starting it.	If the engine is overloaded abruptly right after it is started, the turbocharger is still not rotating freely and the lack of lubrication can lead to seizure of parts.
	Check each part for oil leaks, gas leaks and air leaks, and take any necessary measures to resolve the issues.	Oil leaks, gas leaks and air leaks (especially oil leaks) can drop hydraulic pressure and oil loss can cause bearings to seize up.
During operation	Check the following:	
	Hydraulic pressure During idling : 1.5 ~ 3.0 kg/cm ² Under a full load : 3.0 ~ 5.5 kg/cm ²	Excessively low oil pressure can lead to abnormal wear or seizure of bearings. If it is excessively high, it can cause oil leaks.
	If abnormal noise or vibrations occur, lower the speed slowly and stop the engine to locate the cause.	Continuing to drive with abnormal noise or vibrations can severely damage the engine beyond repair.
When stopping	Before stopping the engine, idle the engine for 5 minutes first.	Stopping the engine abruptly after overloaded operation causes heat to be transferred from the hot turbine blades to the bearings. Since this heat burns the oil on the bearings, the metal bearings and rotating shaft may seize up.

2. Cautions for handing

- 1) If the engine rpm is increased abruptly after starting the engine, the crankshaft rotates at an excessive speed before the crankshaft journal bearing has been lubricated sufficiently. If the turbocharger rotates in this state, bearings may seize up due to the lack of cooling and lubrication, leading to damage in related parts.
- 2) After replacing the engine oil or oil filter, make sure to idle the engine for at least two minutes before driving to ensure that enough lubricant circulates throughout the turbocharger.
- 3) After operating the engine at a high speed for a prolonged period of time, idle the engine sufficiently before stopping it. Otherwise, the turbine wheel continues rotating without any hydraulic pressure in the turbocharger and an oil layer is not formed on the turbocharger center bearing and journal bearing, leading to wear and shortening of the turbocharger life.
- 4) In extremely cold temperatures or after a prolonged period of inactivity of the engine, idle the engine for a sufficient amount of time after starting it until the hydraulic pressure in the engine reaches a normal level.

9. Intake/Exhaust System

- 5) The turbocharger turbine spins at extremely high speeds of 50,000 ~ 200,000 rpm. Hence, the oil supply of bearings has a significant impact on the turbocharger life, so make sure to use genuine engine oil recommended by HD Construction Equipment and check and replace the engine oil periodically.
- 6) Using a contaminated air cleaner for a prolonged period of time can cause critical damage to the turbocharger, so make sure to check and replace the air cleaner regularly.
- 7) The turbocharger is a highly complex unit of precision machinery which should only be handled by certified technicians.
- 8) Operating the turbocharger without the intake or exhaust manifold installed may severely damage the engine or cause physical injuries to workers. The turbocharger must only be operated with all of the parts installed properly in their designated positions.
- 9) Do not lift the turbocharger by the actuator. It may be damaged by the weight of the turbocharger.
- 10) The turbocharger is a heavy unit. When lifting the turbocharger to remove or mount it, workers should lower their center of gravity or hold the turbocharger closely. Otherwise, the turbocharger may fall, damaging the parts and causing physical injuries to workers.

9. Intake/Exhaust System

Check Items During Turbocharger Disassembly and Assembly

No.	Check Items	Reason						Troubleshooting
		Noise	Power Drop	Oil Leak	Oil Cons.	Black/White Exhaust Smoke	Blue Exhaust Smoke	
Before removal								
1	Are any hoses in the intake system torn or deformed?	o	o	o		o		Replace the hose
2	Are clamps tightened properly?	o	o	o	o			Retighten the bolts and nuts
3	Is the air filter in good condition?	o	o	o		o		Replace the air filter Check the turbocharger impeller for damage
4	Are there any leaks in the turbocharger coolant or oil hoses?	o		o	o	o		Replace the hose and gasket
5	Is gas leaking from the exhaust manifold gasket?	o						Replace the nuts and gasket
6	Is the turbocharger actuator operating normally?	o	o	o		o		Replace the turbocharger
During removal								
1	Are there any traces of leaks between the engine block and exhaust manifold?	o	o	o	o		o	Check the engine
2	Is there any foreign matter in the blow-by gas? Is the oil level normal?	o	o	o	o	o		Check the turbo impeller and turbo intake outlet
3	Are there any traces of interference with the wall due to excessive free play of the wheel?	o	o	o	o	o		Check for foreign matter (Sand, metallic matter)
4	Is the wheel damaged?	o	o	o	o	o		Check for foreign matter (Sand, metallic matter)
After removal								
1	Is the wheel damaged or is the shaft split?	o	o	o	o	o		Check for foreign matter (Sand, metallic matter)
2	Is the wheel rotating properly?	o	o	o	o	o		

9. Intake/Exhaust System

Inspecting the Turbocharger

1. Daily inspection and service

Turbocharger performance depends largely on the state of engine maintenance.

Hence, it is important to maintain the engine as instructed.

1) Intake system

In the intake system, pay attention to the maintenance of the air filter. For a wet-type air filter, if the oil level is below the specified level, its filtering performance is degraded. On the other hand, if the oil level is too high, it sucks in oil, contaminating its case. In particular, if the rotor is contaminated, the finely tuned balance is lost, causing vibrations. In addition, a massive load is applied to the bearing, causing seizure and abnormal wear. Thus, use of the air filter is essential for full use of the machine. For a dry-type air filter, intake air resistance should be as low as possible.

2) Exhaust system

In the exhaust system, if exhaust gas leaks from the exhaust manifold or turbocharger connection, the turbocharger performance is degraded. Hence, particular care should be taken to prevent gas leaks and seizure.

Since heat-resistant steel nuts are used for components that become hot during operation, such as the turbine chamber, these nuts should not be confused with other general nuts.

In addition, mounting nuts should be coated with an anti-sticking agent if specified.

3) Lubrication system

In the lubrication system, pay attention to the oil quality and oil filter cartridge replacement interval. Degraded engine oil can affect the turbocharger as well as the engine itself adversely.

2. Periodic inspection and service

The condition and contamination of the turbocharger should be checked regularly.

1) Inspecting the rotation of the rotor

To check the rotating state of the rotor, listen for any abnormal noise during rotation.

If a sound rod is used, touch the tip of the rod to the turbocharger housing and rev up the engine slowly.

If a high-pitched noise persists, there is a problem with the part.

In this case, the bearing or rotor may be operating abnormally, so the turbocharger must either be replaced or repaired.

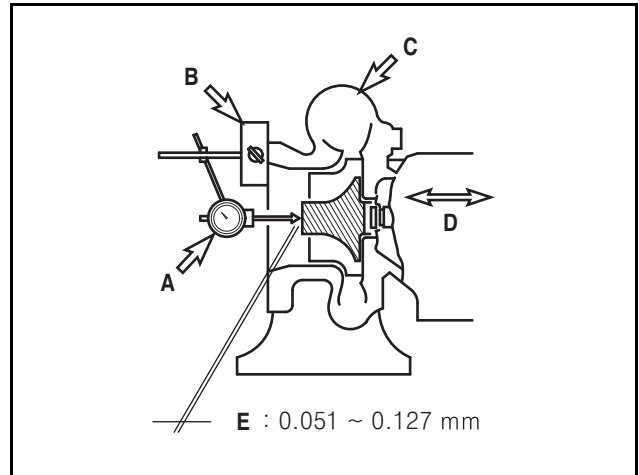
2) Checking the free play of the rotor

Remove the turbocharger from the engine and check both the axial and radial play of the rotor.

When removing the turbocharger, make sure to seal the oil inlet and outlet with tape, etc.

During rotation, the wheel must rotate smoothly without any interference.

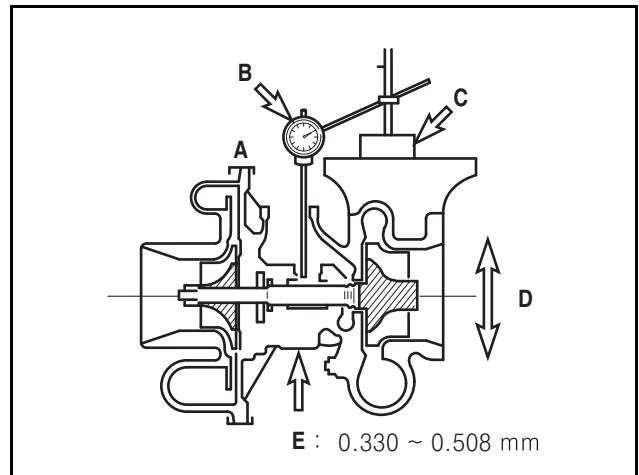
• Rotor axial play



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- | | |
|--------------------|---|
| A. Dial gauge | D. Move the turbine shaft in the axial direction. |
| B. Magnetic vice | E. Maintenance standard (0.051 ~ 0.127 mm) |
| C. Turbine chamber | |

• Rotor radial play



EDX08240230

- | | |
|------------------|--|
| A. Oil outlet | D. Move the turbine shaft side to side in the radial direction simultaneously. |
| B. Dial gauge | E. Maintenance standard for radial play (0.330 ~ 0.508 mm) |
| C. Magnetic vice | |

- If the axial or radial play exceeds the wear limit, either replace the turbocharger or remove and repair it.
- 3) Removing and inspecting the turbocharger
- Remove the turbocharger from the engine to clean or inspect it.
- When doing so, make sure to seal the oil inlet and outlet with tape, etc.

4) Cautions for turbocharger assembly

When mounting the turbocharger on the engine or handling it after assembly, follow the instructions below. Take particular care to ensure that foreign matter does not enter the turbocharger.

- Lubrication system
 - Before mounting it on the engine, add fresh oil through its oil filler port and turn the turbine shaft by hand to lubricate the journal bearing and thrust bearing.
 - Wash the pipe between the engine and oil inlet and the pipe from the oil outlet; then, check them for damage or foreign matter.
 - Tighten each oil pipe connection firmly to prevent oil leaks.
- Intake system
 - Check the intake system for foreign matter.
 - Install it securely so that there are no air leaks from the various connections in the intake system and air filter.
- Exhaust system
 - Check that there is no foreign matter in the exhaust system.
 - Use heat-resistant steel bolts and nuts and keep them separate from general bolts and nuts during assembly. Apply an anti-sticking agent to bolts and nuts.
 - Install it securely to prevent gas leaks from the exhaust system connections.

9. Intake/Exhaust System

10. Cylinder Block/Head

General Information	137
General Information	137
Cylinder Block	138
General Inspection of the Cylinder Block.....	138
Cylinder Head	139
Assembling the Cylinder Head.....	139
Inspecting the Cylinder Head	140
Valves	141
General Information	141
Inspecting Valves.....	141
Inspecting the Valve Guide.....	141
Inspecting the Valve Seat	142
Inspecting the Valve Spring	143
Rocker Arms	144
Removing Rocker Arms.....	144
Assembling Rocker Arms.....	144
Inspecting Rocker Arms.....	144
Inspecting the Rocker Arm Shaft	144
Roller Tappets and Pushrods	145
Inspecting the Roller Tappets	145
Checking the Warpage of Pushrods	145
Camshaft	146
Camshaft Free Play	146
Inspecting the Camshaft	146

General Information

General Information

Equipped with an overhead valve and turbocharger, HD Construction Equipment diesel engines are electronically controlled engine air-cooled by a cooling fan. Pressurized fuel generated by the high-pressure fuel pump is stored in the common rail. When the driver operates the vehicles, the optimal amount of fuel and fuel injection timing are determined based on the data set in the ECU according to the vehicle speed and operating conditions, while the ECU actuates the solenoid valve for the injector installed in each cylinder of the engine to inject fuel into the cylinders.

The crankshaft is a single forged unit. The oil seals on the crankshaft and flywheel are designed to prevent oil from entering the inside of the flywheel.

The connecting rod is a single forged unit. Its big end can be disconnected in the vertical direction, enabling it to be removed with the piston through the top of the cylinder. The moving parts of the crankshaft and connecting rod are equipped with alloy bearings.

10. Cylinder Block/Head

Cylinder Block

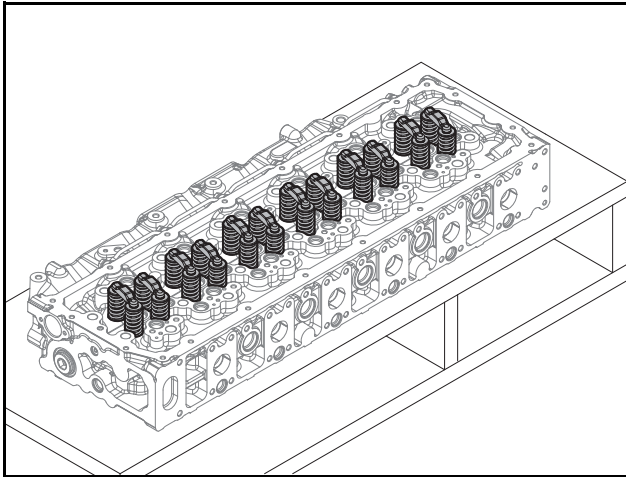
General Inspection of the Cylinder Block

1. Clean the cylinder block thoroughly and check it visually for damage.
2. If it is severely cracked or damaged, replace it with a new one; repair any minor damage.
3. Check the oil passage and coolant passage for clogging and corrosion.
4. Perform a hydrostatic test to check for cracks or air leaks.
5. Plug the coolant and oil outlets of the cylinder block and supply approx. 4 kg/cm² of pressure through the inlet. Then, soak the cylinder block in 70 °C water for approx. one minute and check for air leaks.

10. Cylinder Block/Head

Cylinder Head

1. Disassemble the cylinder and keep the components on a shelf for later assembly.
2. Be careful not to damage the cylinder head gasket mating surface.
3. Remove the valve cotter, spring and spring seat using a valve spring compressor.



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4. Pull out the intake and exhaust valves.
5. Keep the removed parts in order.
6. Remove the valve stem seal.

Assembling the Cylinder Head

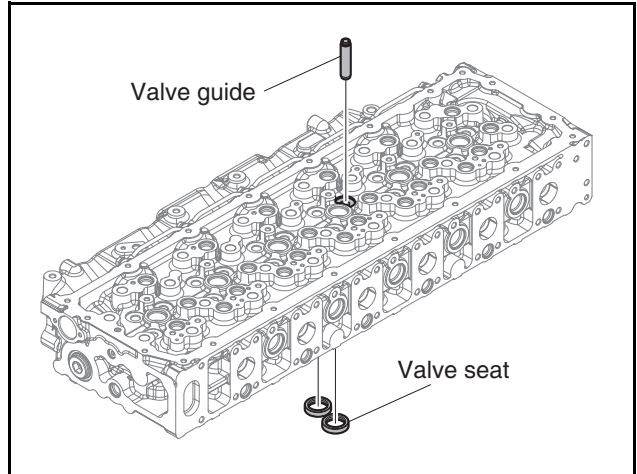
1. Clean the cylinder head thoroughly.
2. Replace the valve stem seal with a new one.
3. Use a special service tool to insert the stem seal into the valve guide of the cylinder head.
4. Apply engine oil to the valve stem and valve guide. Then, install the valve.

CAUTION

Be careful not to damage the valve stem seal.

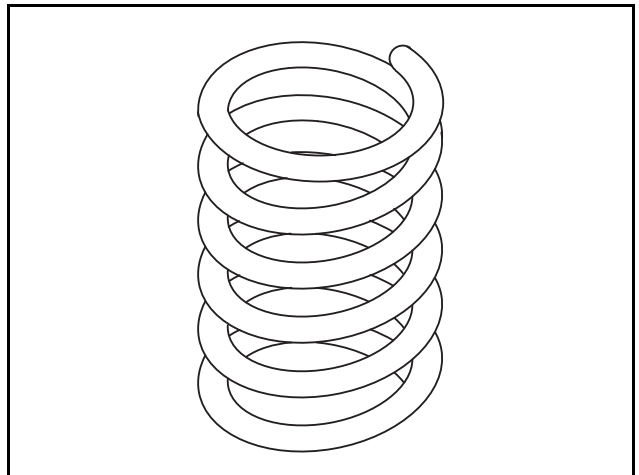
Make sure to keep bolts free of oil.

Wipe any oil off bolts before using them.



EDX08240039

5. Install the valve spring seat on the valve guide on the top side of the cylinder head.
6. Assemble the inner/outer valve springs. Then, place the spring seat on top.



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7. Use a valve spring compressor to press the valve spring. Then, insert the valve cotter to install the valve.
8. After installing the valve, tap it with a urethane hammer gently to check that it has been installed correctly.

10. Cylinder Block/Head

Inspecting the Cylinder Head

1. Inspecting the cylinder head
 - 1) Remove carbon residue from the bottom of the cylinder head.

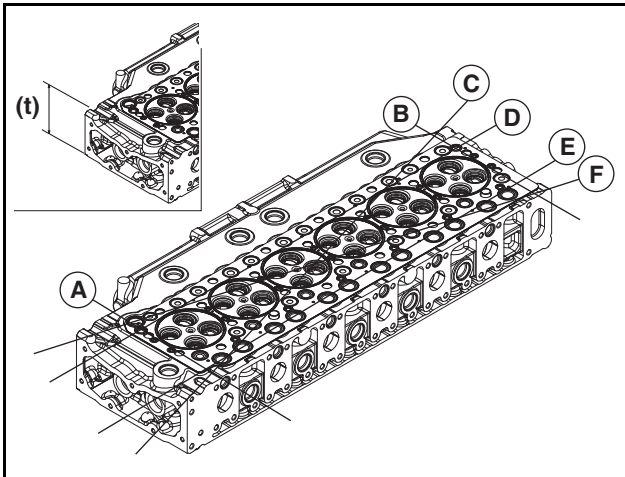
⚠ CAUTION

Be careful not to scratch the valve seat surface.

Make sure to keep bolts free of oil.

Wipe any oil off bolts before using them.

- 2) Check the cylinder head visually for damage.
 - 3) Perform the hydrostatic test or magnetic particle test to check for small cracks or damage that cannot be identified with the naked eye.
2. Bottom distortion
- 1) Measure the distortion of the cylinder head in the 6 directions with a feeler gauge.



EDX08240040

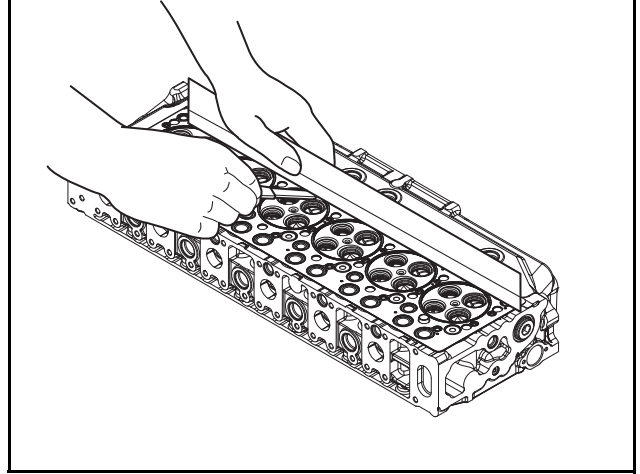
- 2) If the measurement exceeds the allowable service limit, grind it down using fine sandpaper or a grinder.
- 3) If the measurement exceeds the allowable limit, replace the cylinder head.

- Cylinder head distortion and height

	Reference value	Allowable limit
Flatness of bottom surface of cylinder head	0.08 mm or less	0.15 mm
Head height: t	119.7 ~ 120.3 mm	119.4 mm

3. Flatness

- 1) Measure the flatness of the intake/exhaust manifold mounting surface of the cylinder head with a straightedge and feeler gauge.



EDX08240041

Reference value	Allowable limit
0.15 mm	0.3 mm

4. Flatness

- 1) The hydrostatic test for the cylinder head is performed in the same way as the test for the cylinder block.

Valves

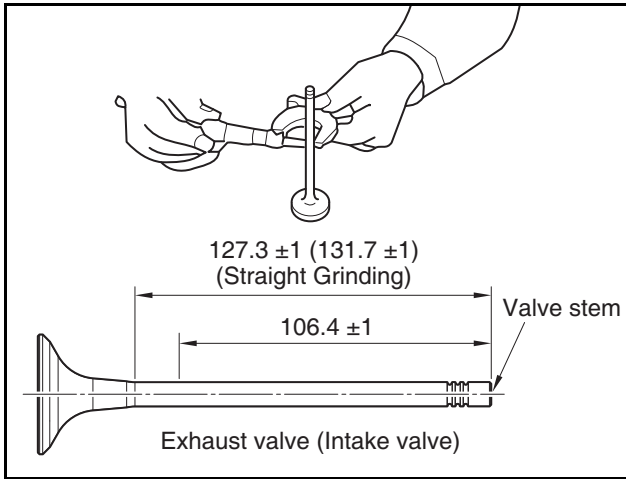
General Information

The overhead valve is operated by the cast iron tappet, pushrod and rocker arm on the camshaft.

Inspecting Valves

Wash the valve with clean engine oil and inspect it as follows.

1. Valve stem outside diameter



EDX08250102

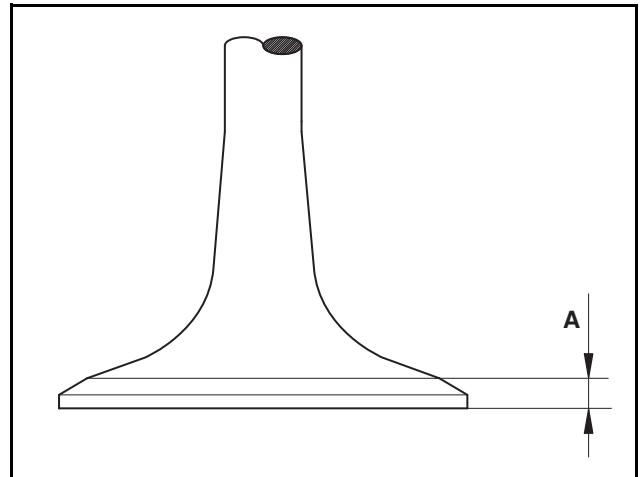
- 1) Measure the valve stem outside diameter in three places (top, middle, bottom).
- 2) If the amount of wear exceeds the allowable limit, replace the valve.

	Reference value	Allowable limit
Intake valve stem	Ø7.963 ~ Ø7.977 mm	Ø7.933 mm
Exhaust valve stem	Ø7.950 ~ Ø7.964 mm	Ø7.91 mm

2. Valve seat mating surface

- 1) Check the valve seat mating surface for scratches or damage.
- 2) If necessary, grind the surface with sandpaper. However, if the damage is severe, replace the part.

3. Valve head thickness



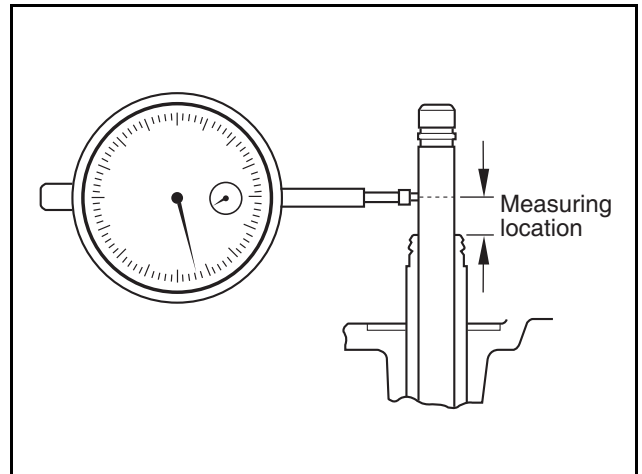
EE10M066

- 1) Measure the thickness of the valve head.
- 2) If the measurement is below the allowable limit, replace the valve.

	Reference value	Allowable limit
Intake valve (A)	3.7 ~ 4.1 mm	3.2 mm or less
Exhaust valve (A)	4.2 ~ 4.6 mm	3.7 mm or less

Inspecting the Valve Guide

1. Install the valve on the cylinder head.
2. Measure the clearance between the valve guide and valve arising from the movement of the valve.



EA0M4052

3. If the clearance is excessively large, measure the valve size. Then, replace the valve or valve guide, whichever part is more worn.

10. Cylinder Block/Head

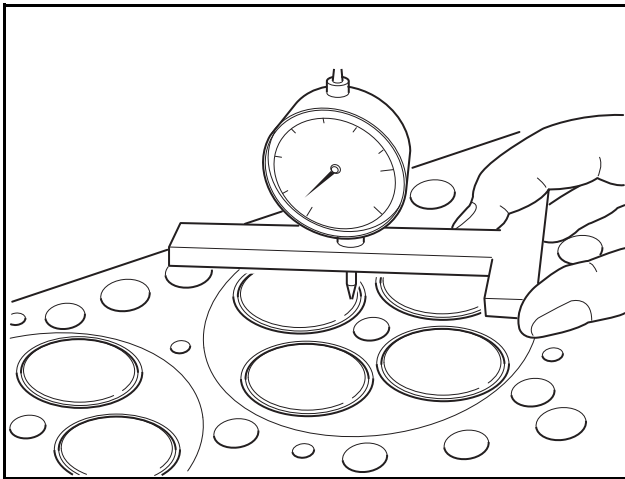
- Valve stem play

	Reference value	Allowable limit
Intake valve	0.023 ~ 0.052 mm	0.1 mm
Exhaust valve	0.036 ~ 0.065 mm	0.15 mm

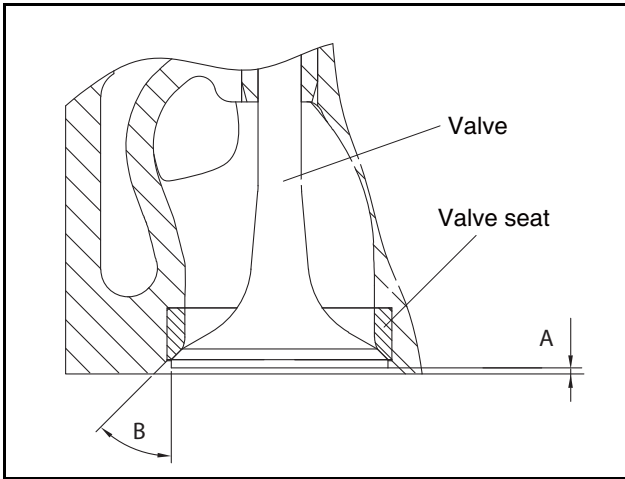
4. Install the valve on the cylinder head valve guide.
5. Use a special service tool to check whether the valve seat is aligned with the center.

Inspecting the Valve Seat

1. Amount of contact with mating surface



EE10M067



EE10M068

- 1) To check the amount of wear on the valve seat, measure the height of the mating surface between the intake and exhaust valve.
- 2) If the measurement exceeds the allowable limit, replace the part.
- 3) Install the valve on the cylinder head valve seat.
- 4) Use a dial gauge to measure the insertion length of the valve from the bottom of the cylinder head.

- Valve step height

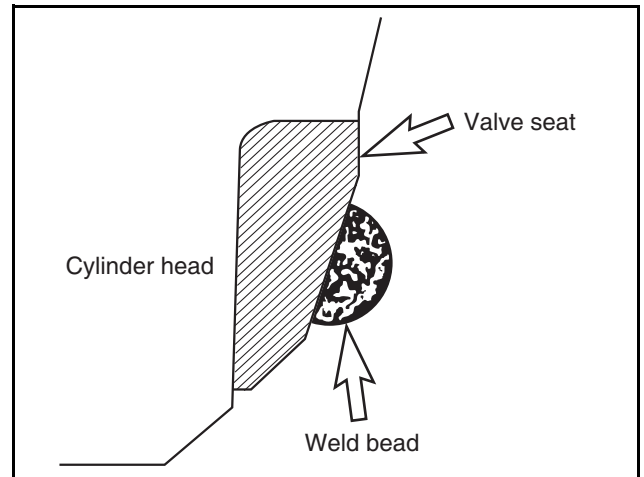
	Reference value	Allowable limit
Intake valve (A)	0.05 ~ 0.35 mm	0.80 mm
Exhaust valve (A)	0.19 ~ 0.49 mm	0.84 mm

- Valve angle

Intake valve (B)	Exhaust valve (B)
70°	60°

- 5) If the insertion length of the valve exceeds the allowable limit, replace the valve seat.
- 6) To remove the valve seat, perform arc welding in two places on the valve seat; then, use a special service tool to pull out the valve seat.

Note) The inside diameter needs to be bored during the removal of the valve seat.

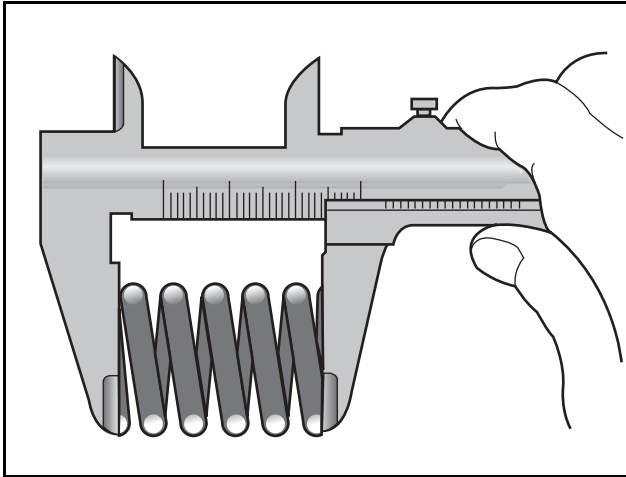


EA3M2032

- 7) Before assembling the valve seat, cool it in dry ice for approx. two hours.
- 8) Use a bench press to press-fit the valve seat into the cylinder head.
- 9) Apply abrasive to the valve head mating surface of the valve seat.
- 10) Turn the valve to polish the valve seat surface until the valve is properly seated. Then, remove the abrasive completely.

Inspecting the Valve Spring

1. Perform a visual inspection of the exterior of the valve spring.
- 1) Visually inspect the valve spring for external damage and replace it if necessary.
2. Check the free length of the valve spring.

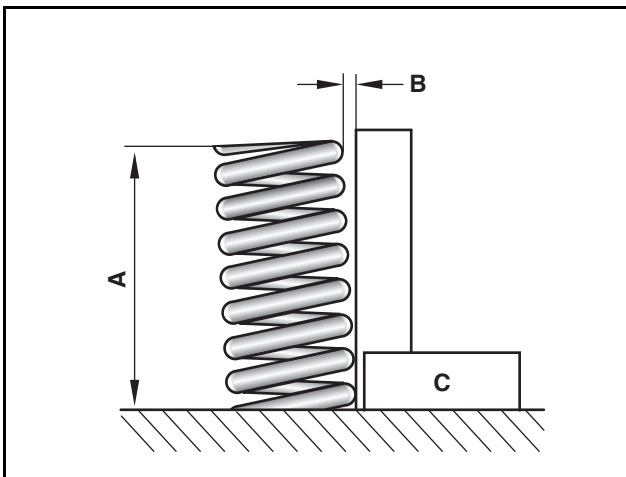


EA3M2033

- 1) Measure the free length of the valve spring with vernier calipers.
- 2) If the measurement is below the specification, replace the valve spring.

Free length of spring	Reference value
Intake valve	64.39 mm
Exhaust valve	

3. Check the squareness of the valve spring.



EDL022097A

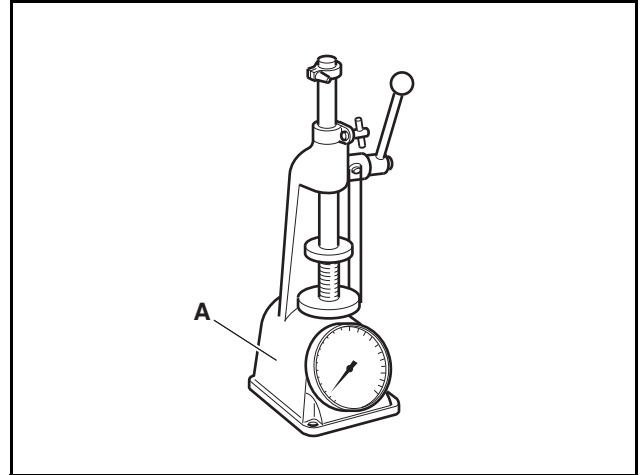
A. Free length B. Squareness C. Straightedge

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

- 2) If the measurement exceeds the allowable limit, replace the valve spring.

	Specified value	Allowable limit
Valve spring squareness	1.5 mm or less	2.0 mm

4. Check the tension of the valve spring.



EDL022098B

- 1) Measure the tension of the valve spring with a spring tester (A).
- 2) If the measurement is below the allowable limit, replace the valve spring.

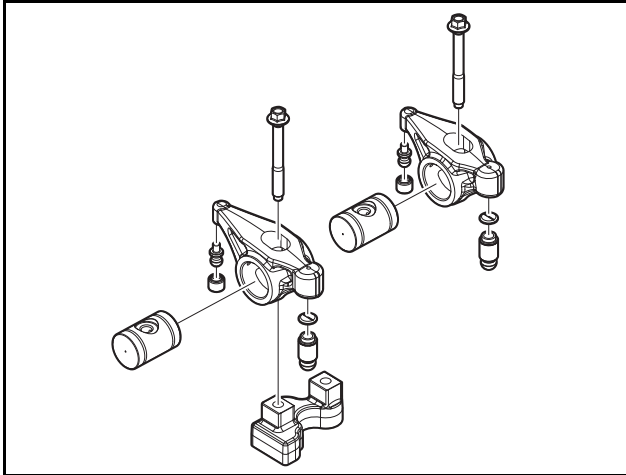
Set length	Spring tension	Allowable limit
49 mm	33 kgf	±2 kgf
38 mm	56.57 kgf	±2 kgf

10. Cylinder Block/Head

Rocker Arms

Removing Rocker Arms

1. Remove the rocker arm bolts.
2. Separate the rocker arm and rocker arm shaft from the bracket in that order.



EDX08250101

Assembling Rocker Arms

1. Assemble rocker arms in the reverse order of disassembly.

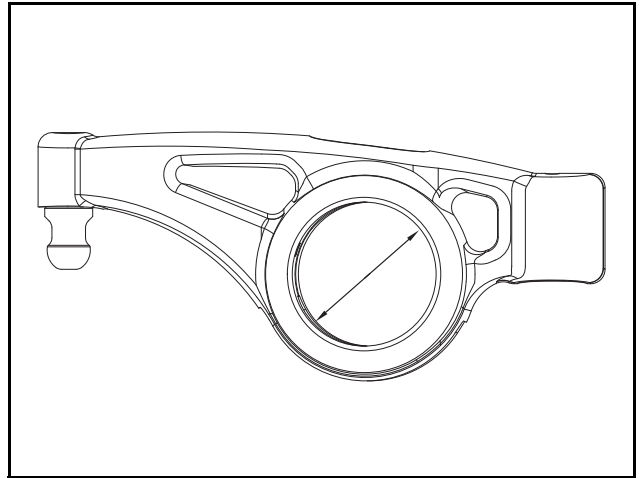
CAUTION

- Check the oil delivery hole of the rocker arm shaft for foreign matter and clean it thoroughly.
- Make sure to install the rocker arm in the correct location and correct order.

Inspecting Rocker Arms

1. Visual check
 - 1) Check the adjusting screw cap assembly surface—which slides in contact with the valve stem—visually for scratches or layered wear.
 - 2) For minor wear, use an oily grindstone or fine sandpaper to polish the surface. In the case of severe layered wear, replace the rocker arm.

2. Rocker arm bushing I.D.



EDX08240042

- 1) Measure the inside diameter of the rocker arm bushing with a micrometer or vernier calipers.
- 2) Compare the measurement with the outside diameter of the rocker arm shaft. If the clearance exceeds the allowable limit, replace either the bushing or shaft, whichever part is more worn.

Reference value	Allowable limit
Ø30.025 ~ Ø30.044 mm	Ø30.089 mm

	Specified value	Allowable limit
Clearance between rocker arm and shaft	0.025 ~ 0.057 mm	0.14 mm or less

Inspecting the Rocker Arm Shaft

1. Rocker arm shaft O.D.
 - 1) Use an O.D. micrometer to measure the outside diameter of the rocker arm shaft at its mounting position.
 - 2) If the measurement exceeds the allowable limit, replace the rocker arm shaft.

Reference value	Allowable limit
Ø29.987 ~ Ø30.000 mm	Ø29.940 mm

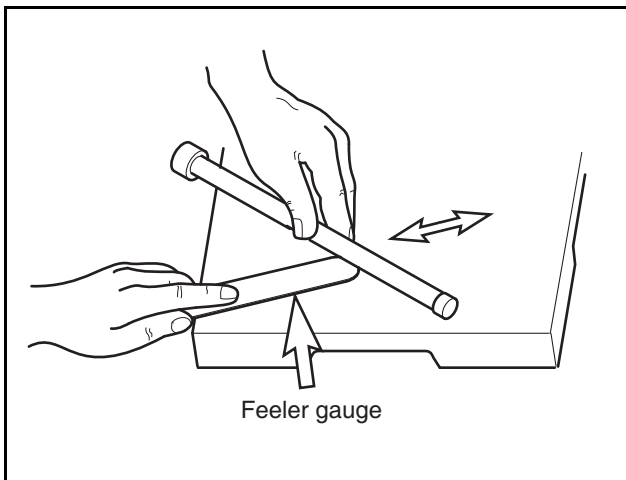
Roller Tappets and Pushrods

Inspecting the Roller Tappets

1. If abnormal noise occurs in the valve train system, disassemble and inspect the roller tappet from the engine.
2. If damage is found during visual inspection of the disassembled roller tappet assembly, replace it.

Checking the Warpage of Pushrods

1. Place the pushrod on a surface plate.
2. Rotate the pushrod while measuring the amount of warpage with a feeler gauge.



EA0M4073

3. If the measurement exceeds the allowable limit, replace the part.

Allowable limit	0.3 mm or less
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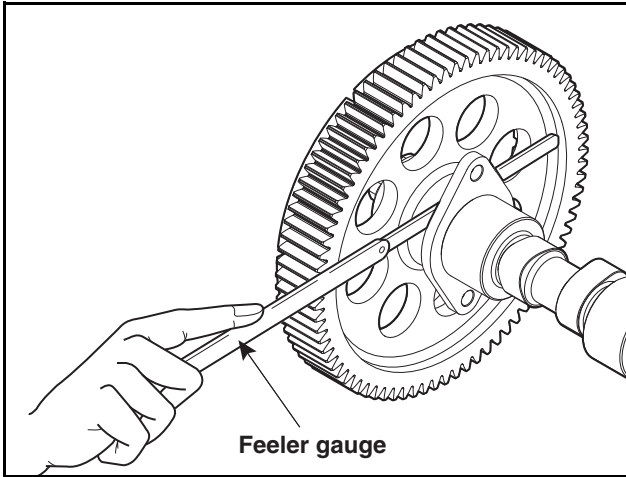
Pushrod length	284.1 mm
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10. Cylinder Block/Head

Camshaft

Camshaft Free Play

1. Move the camshaft gear to the opposite side of the cylinder block.
2. Measure the clearance between the thrust plate and camshaft gear with a feeler gauge.



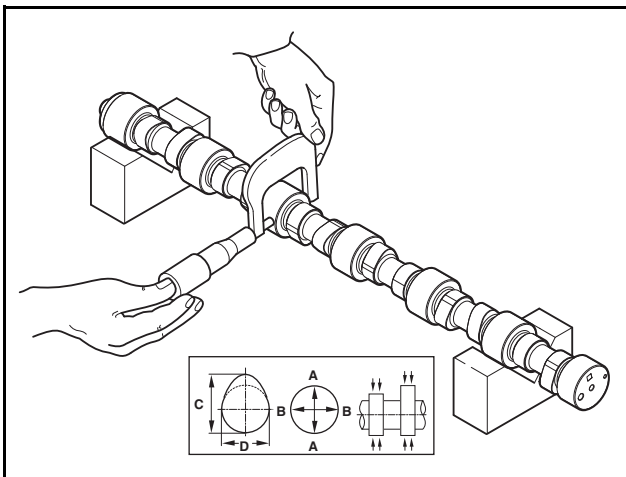
EDX08240043

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

Reference value	Allowable limit
0.26 ~ 0.43 mm	0.5 mm

Inspecting the Camshaft

1. Measure the height of the cam lobe.



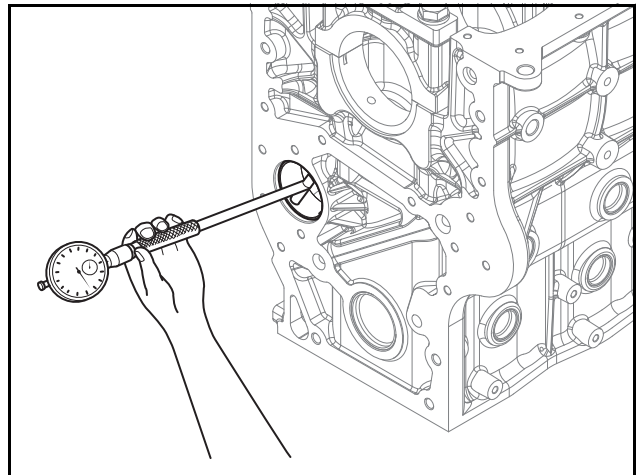
EDX08240044

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

- 2) If the measurement is below the allowable limit, replace the camshaft.

		Reference value	Allowable limit
Cam lobe height (C)	Intake	48.872 mm	48.58 mm
	Exhaust	49.957 mm	49.66 mm
Cam journal diameter (A, B)		Ø57.86 ~ Ø57.88 mm	Ø57.57 mm

2. Inspect the surface of the camshaft.
 - 1) Check the cam surface for scratches or damage.
 - 2) For minor layered wear or damage, use an oily grindstone or fine sandpaper to polish the surface. For severe damage, replace the cam.
3. Clearance between camshaft and bearing

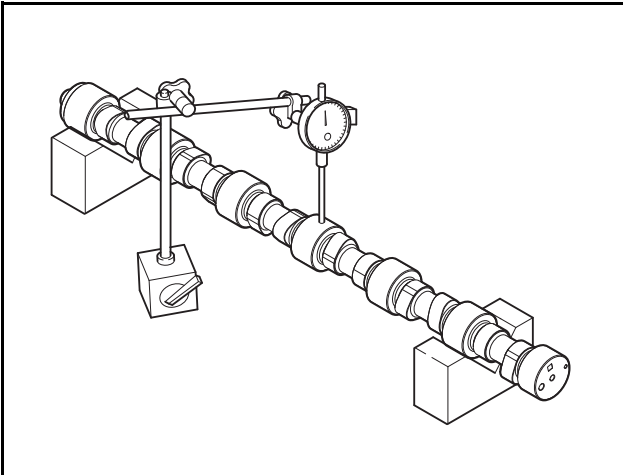


EDX08240086

- 1) Use an O.D. micrometer to measure the outside diameter of the camshaft bearing.
- 2) Use a cylinder I.D. gauge to measure the inside diameter of the camshaft bearing. Then, compare the measurement with the camshaft O.D. to determine the clearance.
- 3) If the measurement exceeds the allowable limit, replace the camshaft bearing.

Reference value	Allowable limit
0.060 ~ 0.115 mm	Within 0.2 mm

4. Camshaft deflection



EDX08240045

- 1) Place the camshaft on two V-blocks.
- 2) Use a dial gauge to check the deflection of the camshaft; correct the deflection if necessary.
- 3) If the deflection is too severe to be repaired, replace the camshaft.

Reference value	Allowable limit
0.05 mm	0.15 mm

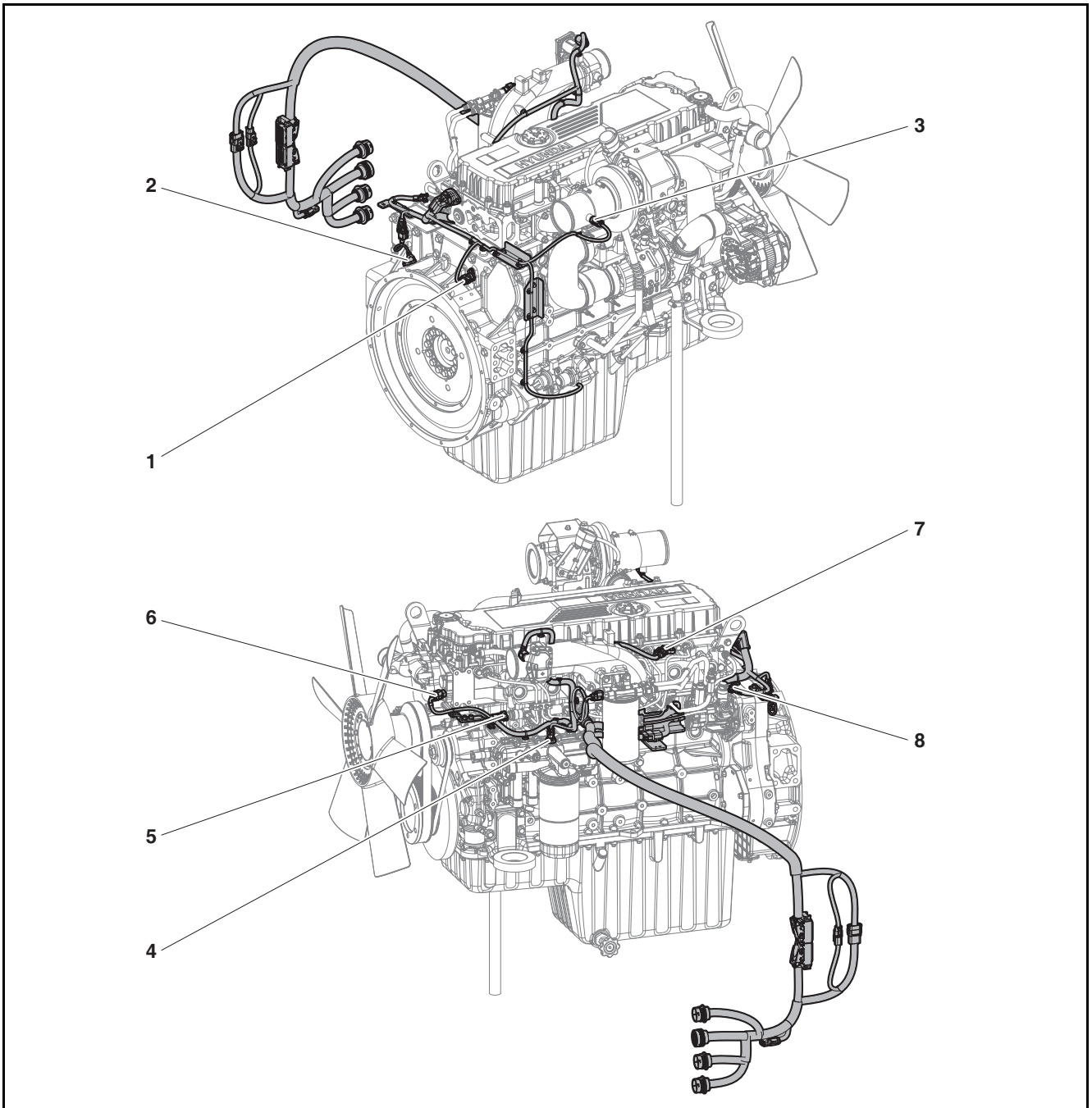
10. Cylinder Block/Head

11. Electrical System

Electronic Components	151
Electronic Components (LEP00/MFP00)	151
Electronic Components (LEP01/LEP02/MFP01/MFP02).....	152
Electronic Components (OOP00)	153
Electronic Components (OOP01/OOP02)	154
Circuit Diagram	155
General Information	155
Engine Connectors	156
Engine Control Unit (ECU) Engine Connectors	158
Switches and sensors	169
Electronic Control Unit	169
Boost Pressure and Temperature Sensor	183
Engine Oil Pressure Sensor.....	183
Coolant Temperature Sensor.....	183
Common Rail Pressure Sensor	183
Crankshaft Position Sensor	183
Camshaft Position Sensor	183
Exhaust Gas Temperature Sensor	184
NOx Sensor	184
DEF Quality Sensor	184
DPF Delta P Sensor, DPF Pressure Sensor.....	184
Ambient Temperature Sensor.....	184
Engine Control Unit (ECU)	185
Engine Control Unit (ECU) Connectors	185
Engine Control Unit (ECU) Input/Output	186
Engine Control Unit (ECU) Operating Conditions.....	187
Starter Motor	188
General Information	188
Circuit Diagram	189
Alternator	190
General Information	190
Wiring diagram.....	191

Electronic Components

Electronic Components (LEP00/MFP00)

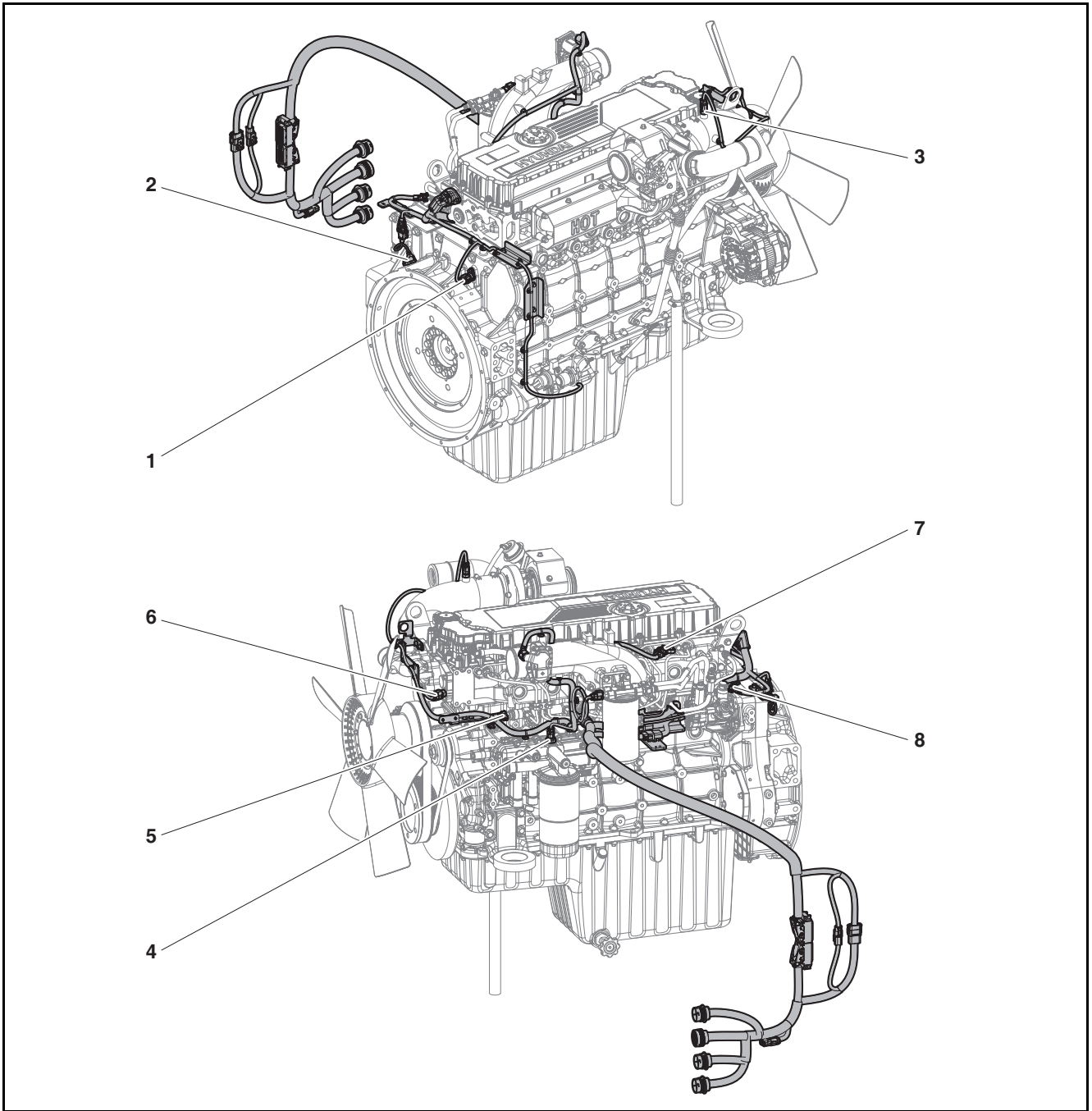


EDX08250069

- | | | |
|-------------------------|-------------------------|-------------------------|
| 1. CAM sensor | 4. Oil pressure sensor | 7. TMAP sensor |
| 2. Crank sensor | 5. Rail pressure sensor | 8. Inlet metering valve |
| 3. Ambient temp. sensor | 6. Coolant temp. sensor | |

11. Electrical System

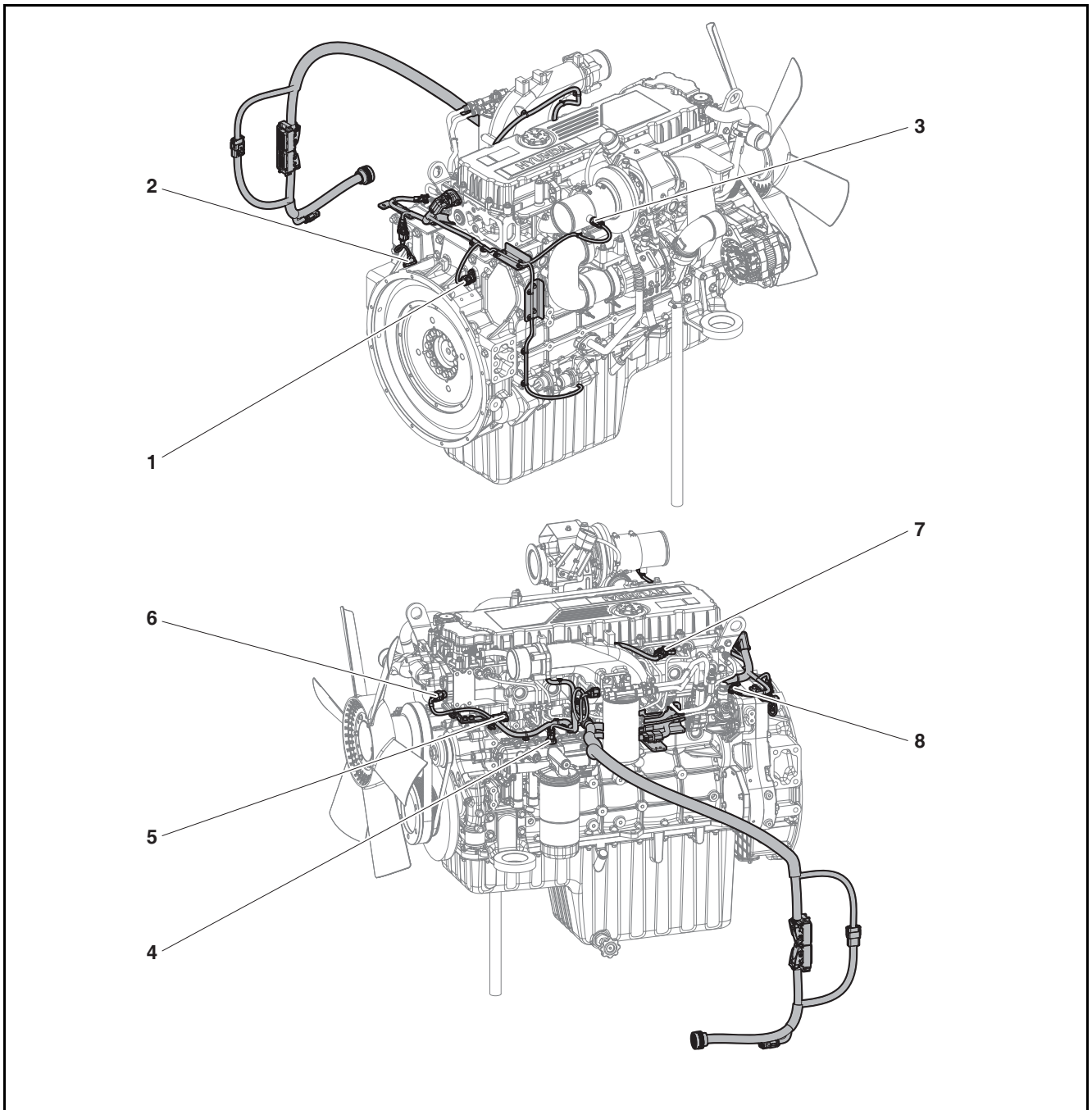
Electronic Components (LEP01/LEP02/MFP01/MFP02)



EDX08250070

- | | | |
|-------------------------|-------------------------|-------------------------|
| 1. CAM sensor | 4. Oil pressure sensor | 7. TMAP sensor |
| 2. Crank sensor | 5. Rail pressure sensor | 8. Inlet metering valve |
| 3. Ambient temp. sensor | 6. Coolant temp. sensor | |

Electronic Components (OOP00)

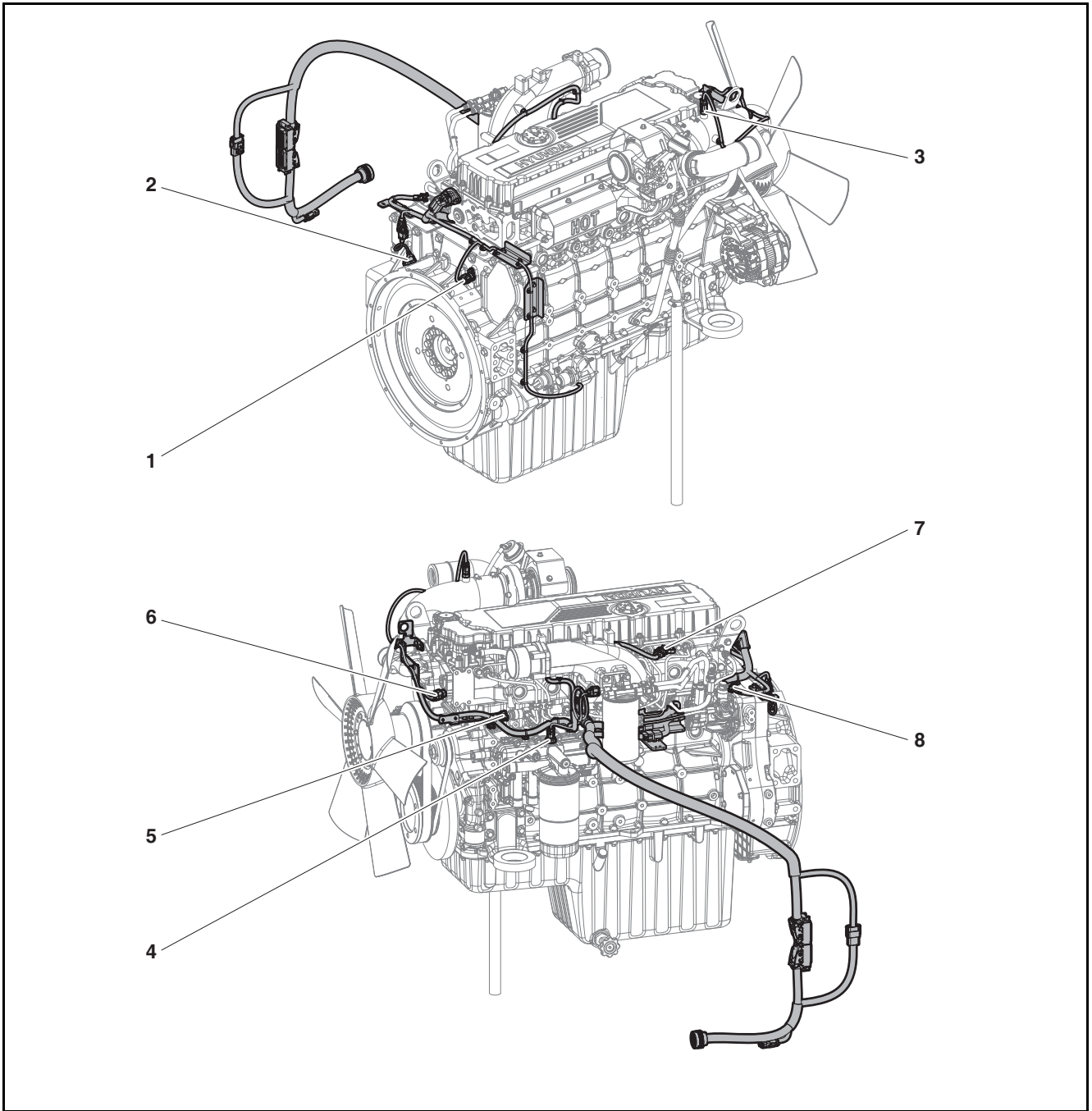


EDX08250125

- | | | |
|-------------------------|-------------------------|-------------------------|
| 1. CAM sensor | 4. Oil pressure sensor | 7. TMAP sensor |
| 2. Crank sensor | 5. Rail pressure sensor | 8. Inlet metering valve |
| 3. Ambient temp. sensor | 6. Coolant temp. sensor | |

11. Electrical System

Electronic Components (OOP01/OOP02)



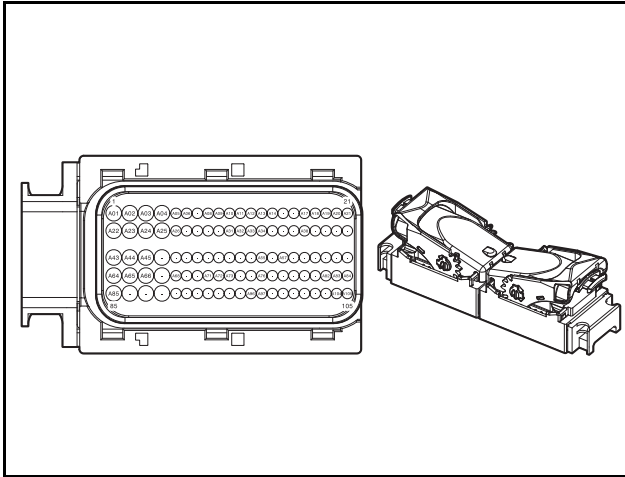
EDX08250126

- | | | |
|-------------------------|-------------------------|-------------------------|
| 1. CAM sensor | 4. Oil pressure sensor | 7. TMAP sensor |
| 2. Crank sensor | 5. Rail pressure sensor | 8. Inlet metering valve |
| 3. Ambient temp. sensor | 6. Coolant temp. sensor | |

Circuit Diagram

General Information

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

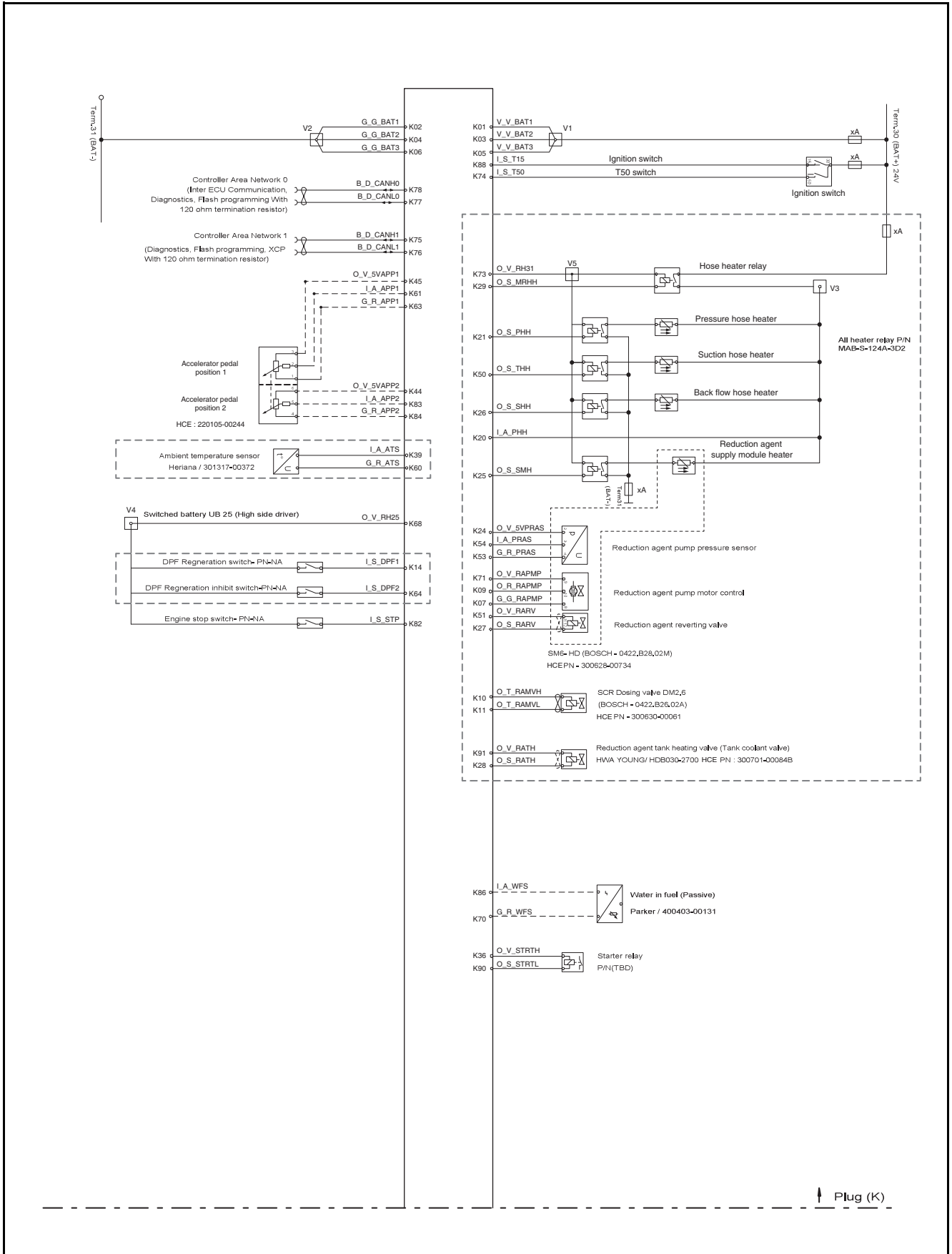


EDX08240144

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

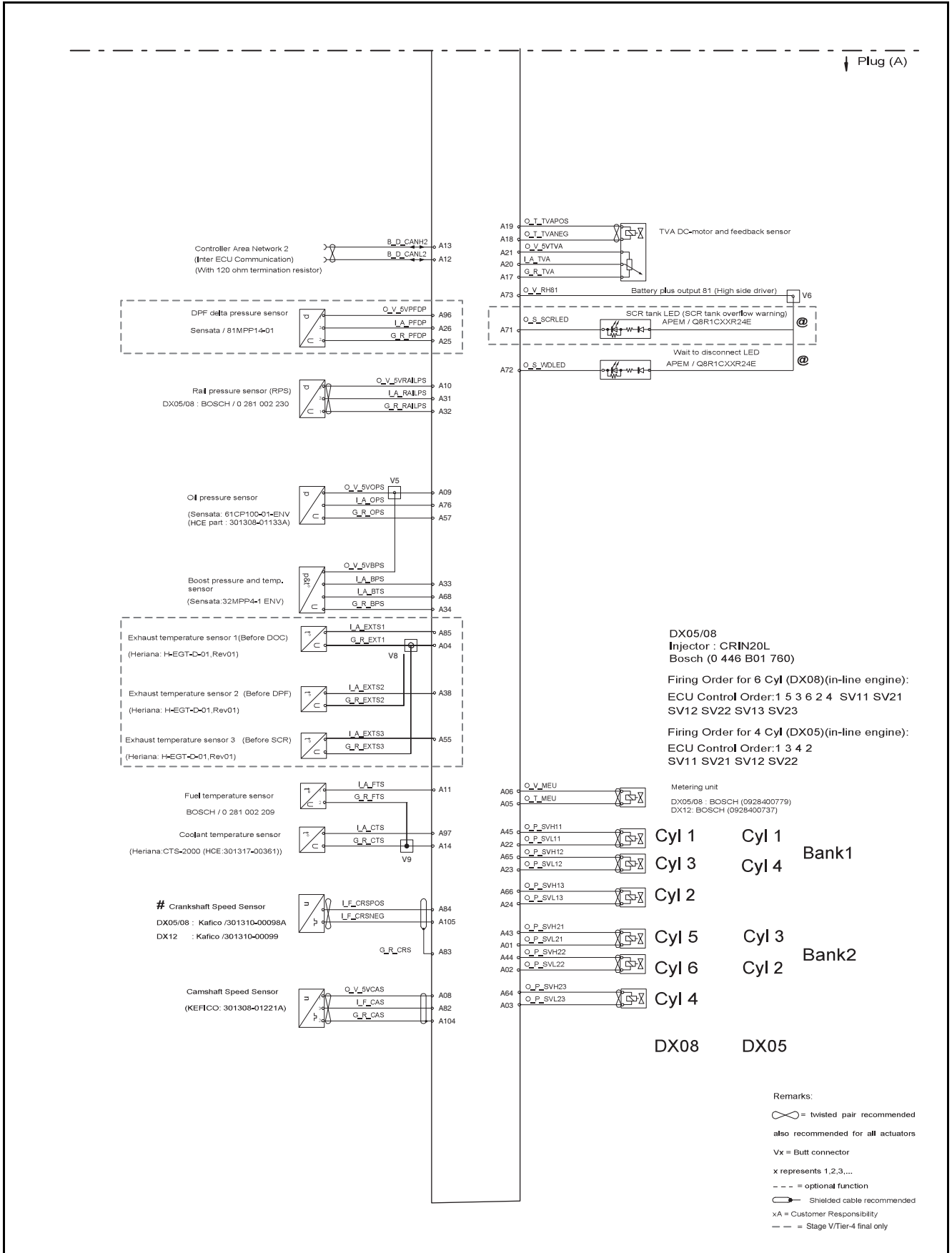
11. Electrical System

Engine Connectors



EDX05250171

11. Electrical System



EDX05250172

11. Electrical System

Engine Control Unit (ECU) Engine Connectors

ECU Connector Main

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
1	K02	1.5	B	ECU GND	ECU K (ECU K)	2	SP_01	-	Splice 01
2	K02A	1.5	B	ECU GND	SP_01	-	Inter panel (INT panel)	9	Splice 01
3	K02B	1.5	B	ECU GND	SP_01	-	Check conn (CHECK)	3	Splice 01
4	K04	1.5	B	ECU GND	ECU K (ECU K)	4	SP_01	-	Splice 01
5	K06	1.5	B	ECU GND	ECU K (ECU K)	6	SP_01	-	Splice 01
6	K01	1.5	R	ECU PWR	ECU K (ECU K)	1	SP_02	-	Splice 02
7	K01A	1.5	R	ECU PWR	SP_02	-	Inter junction box (INT JBOX)	28	Splice 02
8	K01B	1.5	R	ECU PWR	SP_02	-	Check conn (CHECK)	4	Splice 02
9	K03	1.5	R	ECU PWR	ECU K (ECU K)	3	SP_02	-	Splice 02
10	K05	1.5	R	ECU PWR	ECU K (ECU K)	5	SP_02	-	Splice 02
11	K36	0.75	Y	Start relay high	ECU K (ECU K)	36	Inter junction box (INT JBOX)	2	
12	K90	0.75	Brn	Start relay low	ECU K (ECU K)	90	Inter junction box (INT JBOX)	3	
13	G01	0.75	B	NOx sensor GND	Inter SCR (INT SCR)	12	SP_10	-	Splice 10 Stage-V/ Tier-4 final only
14	G01A	0.75	B	Urea tank ground	SP_10	-	Inter panel (INT panel)	10	Splice 10 Stage-V/ Tier-4 final only
15	G01B	0.75	B	Urea tank ground	SP_10	-	Inter urea (INT urea)	14	Splice 10 Stage-V/ Tier-4 final only
16	P01	0.75	R	NOx sensor PWR	Inter SCR (INT SCR)	11	SP_11	-	Splice 11 Stage-V/ Tier-4 final only
17	P01A	0.75	R	Urea tank supply	SP_11	-	Inter junction box (INT JBOX)	13	Splice 11 Stage-V/ Tier-4 final only
18	P01B	0.75	R	Urea tank supply	SP_11	-	Inter urea (INT urea)	13	Splice 11 Stage-V/ Tier-4 final only
19	A73	0.75	R	Battery plus output	SP_12	-	Inter 4 (INT 4)	7	Splice 12
20	A73A	0.75	R	Battery plus output	Inter panel (INT panel)	19	SP_12	-	Splice 12

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
21	A73B	0.75	R	Battery plus output	Inter urea (INT urea)	21	SP_12	-	Splice 12
22	A71	0.75	W	SCR tank led low	Inter urea (INT urea)	20	Inter 4 (INT 4)	8	Stage-V/ Tier-4 final only
23	A72	0.75	Y	Wait to disconnect led low	Inter panel (INT panel)	20	Inter 4 (INT 4)	9	
24	K88	0.75	Brn	Key-on (T15)	ECU K (ECU K)	88	SP_03	-	Splice 03
25	K88A	0.75	Brn	Key-on (T15)	SP_03	-	Inter junction box (INT JBOX)	18	Splice 03
26	K88B	0.75	Brn	Key-on (T15)	SP_03	-	Check conn (CHECK)	6	Splice 03
27	K74	0.75	B	Key switch start (T50)	ECU K (ECU K)	74	Inter junction box (INT JBOX)	16	
28	K77	0.75	Y	Can 0 low	ECU K (ECU K)	77	SP_04	-	Splice 04/ Twist pair (K78/K77)
29	K77A	0.75	Y	Can 0 low	SP_04	-	Inter panel (INT panel)	15	Splice 04/ Twist pair (K78A/K77A)
30	K77B	0.75	Y	Can 0 low	SP_04	-	Check conn (CHECK)	7	Splice 04/ Twist pair (K78B/K77B)
31	K78	0.75	W	Can 0 high	ECU K (ECU K)	78	SP_0S	-	Splice 05/ Twist pair (K78/K77)
32	K78A	0.75	W	Can 0 high	SP_0S	-	Inter panel (INT panel)	16	Splice 05/ Twist pair (K78A/K77A)
33	K78B	0.75	W	Can 0 high	SP_0S	-	Check conn (CHECK)	8	Splice 05/ Twist pair (K78B/K77B)
34	K76	0.75	O	Can 1 low	ECU K (ECU K)	76	SP_06	-	Splice 06/ Twist pair (K75/K76)
35	K76A	0.75	O	Can 1 low	SP_06	-	Inter panel (INT panel)	17	Splice 06/ Twist pair (K75A/K76A)
36	K76B	0.75	O	Can 1 low	SP_06	-	Check conn (CHECK)	1	Splice 06/ Twist pair (K75B/K76B)
37	K75	0.75	R	Can 1 high	ECU K (ECU K)	75	SP_07	-	Splice 07/ Twist pair (K75/K76)
38	K75A	0.75	R	Can 1 high	SP_07	-	Inter panel (INT panel)	18	Splice 07/ Twist pair (K75A/K76A)

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
39	K75B	0.75	R	Can 1 high	SP_07	-	Check conn (CHECK)	2	Splice 07/ Twist pair (K75B/K76B)
40	A12	0.75	Brn	Can 2 low	Inter 4 (INT 4)	1	SP_08	-	Splice 08/ Twist pair (A12/A13)
41	A13	0.75	O	Can 2 high	Inter 4 (INT 4)	2	SP_09	-	Splice 09/ Twist pair (A12/A13)
42	A12A	0.75	Brn	Can 2 low	SP_08	-	Inter SCR (INT SCR)	13	Splice 08/ Twist pair (A12A/A13A)
43	A13A	0.75	O	Can 2 high	SP_09	-	Inter SCR (INT SCR)	14	Splice 09/ Twist pair (A12A/A13A)
44	A12B	0.75	Brn	Can 2 low	SP_08	-	Inter urea (INT urea)	16	Splice 08/ Twist pair (A12B/A13B)
45	A13B	0.75	O	Can 2 high	SP_09	-	Inter urea (INT urea)	15	Splice 09/ Twist pair (A12B/A13B)
46	K10	0.75	L	Dosing valve high side	ECU K (ECU K)	10	Inter SCR (INT SCR)	2	Twist pair (K10/K11) Stage-V/ Tier-4 final only
47	K11	0.75	B	Dosing valve low side	ECU K (ECU K)	11	Inter SCR (INT SCR)	3	Twist pair (K10/K11) Stage-V/ Tier-4 final only
48	K39	0.75	Y	Ambient temp sensor signal	ECU K (ECU K)	39	Inter 4 (INT 4)	10	
49	K60	0.75	B	Ambient temp sensor GND	ECU K (ECU K)	60	Inter 4 (INT 4)	11	
50	K29	0.75	Y	Hose heater RLY SIG	ECU K (ECU K)	29	Inter junction box (INT JBOX)	4	Stage-V/ Tier-4 final only
51	K73	0.75	G	Heater RLY PWR	ECU K (ECU K)	73	Inter junction box (INT JBOX)	5	Stage-V/ Tier-4 final only
52	A26	0.75	Brn	DPF DP sensor flex 1/O 18	Inter 4 (INT 4)	3	Inter SCR (INT SCR)	17	Stage-V/ Tier-4 final only
53	A25	0.75	B	DPF DP sensor GND	Inter 4 (INT 4)	4	Inter SCR (INT SCR)	16	Stage-V/ Tier-4 final only
54	A96	0.75	R	DPF DP sensor 5V sensor supply 1B	Inter 4 (INT 4)	5	Inter SCR (INT SCR)	15	Stage-V/ Tier-4 final only
55	A85	0.75	Y	DOC upstream signal	Inter 3 (INT 3)	1	Inter SCR (INT SCR)	4	Stage-V/ Tier-4 final only
56	A04	0.75	B	DOC upstream GND	Inter 3 (INT 3)	2	Inter SCR (INT SCR)	5	Stage-V/ Tier-4 final only

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
57	A38	0.75	W	DPF upstream signal	Inter 3 (INT 3)	3	Inter SCR (INT SCR)	9	Stage-V/ Tier-4 final only
58	A55	0.75	O	SCR upstream signal	Inter 3 (INT 3)	4	Inter SCR (INT SCR)	10	Stage-V/ Tier-4 final only
59	K21	0.75	L	Pressure heater RLY SIG	ECU K (ECU K)	21	Inter junction box (INT JBOX)	6	Stage-V/ Tier-4 final only
60	K50	0.75	O	Suction heater RLY SIG	ECU K (ECU K)	-	Inter junction box (INT JBOX)	7	Stage-V/ Tier-4 final only
61	K26	0.75	Y	Back flow heater RLY SIG	ECU K (ECU K)	26	Inter junction box (INT JBOX)	8	Stage-V/ Tier-4 final only
62	K25	0.75	W	Supply module heater RLY SIG	ECU K (ECU K)	25	Inter junction box (INT JBOX)	9	Stage-V/ Tier-4 final only
63	K86	0.75	L	WIF sensor	ECU K (ECU K)	86	Inter junction box (INT JBOX)	29	
64	K70	0.75	Y	WIF sensor	ECU K (ECU K)	70	Inter junction box (INT JBOX)	30	
65	S01	2	W	Starter SIG	Inter 4 (INT 4)	6	Inter junction box (INT JBOX)	1	
66	17A	2	B	T50 (START)	Inter panel (INT panel)	14	Inter junction box (INT JBOX)	17	
67	19A	1.5	W	T15_Ignition	Inter panel (INT panel)	12	Inter junction box (INT JBOX)	19	
68	20A	2	B	Fuel heater #1 GND	Inter panel (INT panel)	8	Inter junction box (INT JBOX)	20	
69	21A	2	B	Fuel heater #2 GND	Inter panel (INT panel)	7	Inter junction box (INT JBOX)	21	
70	K20	0.75	R	Hose heater feedback	ECU K (ECU K)	20	SP_13	-	Splice 13 Stage-V/ Tier-4 final only
71	K20A	2	R	Hose heater BAT +	SP_13	-	Inter junction box (INT JBOX)	15	Splice 13 Stage-V/ Tier-4 final only
72	K20B	2	R	Hose heater BAT +	SP_13	-	Inter urea (INT urea)	4	Splice 13 Stage-V/ Tier-4 final only
73	22A	2	B	Hose heater GND	Inter panel (INT panel)	6	Inter junction box (INT JBOX)	22	Stage-V/ Tier-4 final only
74	23A	2	R	Fuel heater supply	Inter panel (INT panel)	5	Inter junction box (INT JBOX)	23	
75	23B	2	R	Fuel heater supply	Inter panel (INT panel)	4	Inter junction box (INT JBOX)	24	
76	25A	1.5	Y	Urea tank supply	Inter panel (INT panel)	3	Inter junction box (INT JBOX)	25	Stage-V/ Tier-4 final only
77	26A	2	P	Hose heater supply	Inter panel (INT panel)	2	Inter junction box (INT JBOX)	26	Stage-V/ Tier-4 final only

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
78	27A	2	R	ECU PWR	Inter panel (INT panel)	1	Inter junction box (INT JBOX)	27	
79	10A	1.5	R	Pressure heater	Inter urea (INT urea)	19	Inter junction box (INT JBOX)	10	Stage-V/ Tier-4 final only
80	11A	1.5	Brn	Suction heater	Inter urea (INT urea)	18	Inter junction box (INT JBOX)	11	Stage-V/ Tier-4 final only
81	12A	1.5	L	Back flow heater	Inter urea (INT urea)	18	Inter junction box (INT JBOX)	12	Stage-V/ Tier-4 final only
82	14A	1.5	Y	SCR supply module heater GND	Inter urea (INT urea)	5	Inter junction box (INT JBOX)	14	Stage-V/ Tier-4 final only
83	K45	0.75	R	Pedal position 1 PWR (5V)	ECU K (ECU K)	45	Inter panel (INT panel)	21	
84	K61	0.75	Y	Pedal position 1 SIG	ECU K (ECU K)	61	Inter panel (INT panel)	22	
85	K63	0.75	B	Pedal position 1 GND	ECU K (ECU K)	63	Inter panel (INT panel)	23	
86	K44	0.75	R	Pedal position 2 PWR (5V)	ECU K (ECU K)	44	Inter panel (INT panel)	24	
87	K83	0.75	G	Pedal position 2 SIG	ECU K (ECU K)	83	Inter panel (INT panel)	25	
88	K84	0.75	B	Pedal position 2 GND	ECU K (ECU K)	84	Inter panel (INT panel)	26	
89	K68	0.75	R	Switched battery UB25	ECU K (ECU K)	68	Inter panel (INT panel)	28	
90	K14	0.75	O	DPF regeneration switch	ECU K (ECU K)	14	Inter panel (INT panel)	29	Stage-V/ Tier-4 final only
91	K64	0.75	Y	DPF regeneration inhibit switch	ECU K (ECU K)	64	Inter panel (INT panel)	30	Stage-V/ Tier-4 final only
92	K82	0.75	G	Engine stop switch	ECU K (ECU K)	82	Inter panel (INT panel)	31	
93	K24	0.75	R	SCR pressure sensor (5V)	ECU K (ECU K)	24	Inter urea (INT urea)	1	Stage-V/ Tier-4 final only
94	K54	0.75	W	SCR pressure sensor (I)	ECU K (ECU K)	54	Inter urea (INT urea)	2	Stage-V/ Tier-4 final only
95	K53	0.75	B	SCR pressure sensor (G)	ECU K (ECU K)	53	Inter urea (INT urea)	3	Stage-V/ Tier-4 final only
96	K07	0.75	B	SCR agent pump motor control (GROUND)	ECU K (ECU K)	7	Inter urea (INT urea)	6	Stage-V/ Tier-4 final only
97	K71	0.75	R	SCR agent pump motor control (24V)	ECU K (ECU K)	71	Inter urea (INT urea)	7	Stage-V/ Tier-4 final only
98	K09	0.75	O	SCR agent pump motor control (B_P)	ECU K (ECU K)	9	Inter urea (INT urea)	B	Stage-V/ Tier-4 final only
99	K51	0.75	R	SCR reverting valve (24)	ECU K (ECU K)	51	Inter urea (INT urea)	9	Stage-V/ Tier-4 final only
100	K27	0.75	L	SCR reverting valve (P)	ECU K (ECU K)	27	Inter urea (INT urea)	10	Stage-V/ Tier-4 final only

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
101	K91	1.5	R	SCR tank heating valve (24V)	ECU K (ECU K)	91	Inter urea (INT urea)	11	Stage-V/ Tier-4 final only
102	K28	0.75	Y	SCR tank heating valve (S)	ECU K (ECU K)	28	Inter urea (INT urea)	12	Stage-V/ Tier-4 final only

11. Electrical System

ECU Connector RH

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
1	A45	1.5	L	Injector 1 bank 1 high	Inter 1 (INT 1)	1	Injector (INJ)	1	Twist pair (A22/A45)
2	A22	1.5	B	Injector 1 bank 1 low	Inter 1 (INT 1)	2	Injector (INJ)	2	Twist pair (A22/A45)
3	A65	1.5	L	Injector 2 bank 1 high	Inter 1 (INT 1)	3	Injector (INJ)	5	Twist pair (A23/A65)
4	A23	1.5	B	Injector 2 bank 1 low	Inter 1 (INT 1)	4	Injector (INJ)	6	Twist pair (A23/A65)
5	A66	1.5	L	Injector 3 bank 1 high	Inter 1 (INT 1)	5	Injector (INJ)	3	Twist pair (A24/A66)
6	A24	1.5	B	Injector 3 bank 1 low	Inter 1 (INT 1)	6	Injector (INJ)	4	Twist pair (A24/A66)
7	A43	1.5	L	Injector 1 bank 2 high	Inter 1 (INT 1)	7	Injector (INJ)	9	Twist pair (A01/A43)
8	A01	1.5	B	Injector 1 bank 2 low	Inter 1 (INT 1)	8	Injector (INJ)	10	Twist pair (A01/A43)
9	A44	1.5	L	Injector 2 bank 2 high	Inter 1 (INT 1)	9	Injector (INJ)	11	Twist pair (A02/A44)
10	A02	1.5	B	Injector 2 bank 2 low	Inter 1 (INT 1)	10	Injector (INJ)	12	Twist pair (A02/A44)
11	A64	1.5	L	Injector 3 bank 2 high	Inter 1 (INT 1)	11	Injector (INJ)	7	Twist pair (A03/A64)
12	A03	1.5	B	Injector 3 bank 2 low	Inter 1 (INT 1)	12	Injector (INJ)	8	Twist pair (A03/A64)
13	A06	0.75	R	Fuel metering unit PWR	Inter 2 (INT 2)	1	Fuel metering unit (FMU)	1	Twist pair (A05/A06)
14	A05	0.75	O	Fuel metering unit signal	Inter 2 (INT 2)	2	Fuel metering unit (FMU)	2	Twist pair (A05/A06)
15	A105	0.75	P	Crank shaft speed sensor NEG	Inter 2 (INT 2)	3	Crank shaft speed sensor (CRS)	1	Shield (A84/A105)/ Twist pair (A84/A105)
16	A84	0.75	O	Crank shaft speed sensor POS	Inter 2 (INT 2)	4	Crank shaft speed sensor (CRS)	2	Shield (A84/A105)/ Twist pair (A84/A105)
17	A83	0.75	B	Crank shaft speed sensor GND	Inter 2 (INT 2)	5	Crank shaft speed sensor (CRS)	3	Shield drain (A84/A105)
18	A104	0.75	B	Cam shaft speed sensor GND	Inter 2 (INT 2)	6	Cam shaft speed sensor (CAS)	1	Shield drain (A82/A08)
19	A82	0.75	L	Cam shaft speed sensor signal	Inter 2 (INT 2)	7	Cam shaft speed sensor (CAS)	2	Shield (A82/A08)/ Twist pair (A82/A08)

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
20	A08	0.75	P	Cam shaft speed sensor PWR	Inter 2 (INT 2)	8	Cam shaft speed sensor (CAS)	3	Shield (A82/A08)/ Twist pair (A82/A08)
21	K39	0.75	Y	Ambient temp sensor signal	Inter 2 (INT 2)	11	Ambient temp sensor (ATS)	2	
22	K60	0.75	B	Ambient temp sensor GND	Inter 2 (INT 2)	12	Ambient temp sensor (ATS)	1	
23	S01	2	W	Starter SIG	Inter 2 (INT 2)	10	Start S (STS)	1	

11. Electrical System

ECU Connector LH

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
1	A97	0.75	W	Coolant temp sensor signal	ECU A (ECU A)	97	Coolant temp sensor (CTS)	1	
2	A14	0.75	B	GND	ECU A (ECU A)	14	SP_01	-	Splice 01
3	A14A	0.75	B	Coolant temp sensor GND	SP_01	-	Coolant temp sensor (CTS)	2	Splice 01
4	A10	0.75	R	Rail press sensor PWR	ECU A (ECU A)	10	Rail press sensor (RPS)	3	Twist pair (A10/A31/A32)
5	A31	0.75	W	Rail press sensor signal	ECU A (ECU A)	31	Rail press sensor (RPS)	2	Twist pair (A10/A31/A32)
6	A32	0.75	B	Rail press sensor GND	ECU A (ECU A)	32	Rail press sensor (RPS)	1	Twist pair (A10/A31/A32)
7	A09	0.75	R	PWR	ECU A (ECU A)	9	SP_02	-	Splice 02
8	A09A	0.75	R	Oil press sensor PWR	SP_02	-	Oil press sensor (OPS)	3	Splice 02
9	A57	0.75	B	Oil press sensor GND	ECU A (ECU A)	57	Oil press sensor (OPS)	2	
10	A76	0.75	Y	Oil press sensor signal	ECU A (ECU A)	76	Oil press sensor (OPS)	1	
11	A34	0.75	B	TMAP sensor GND	ECU A (ECU A)	34	TMAP sensor (TMAP)	1	
12	A68	0.75	Y	TMAP sensor temp signal	ECU A (ECU A)	68	TMAP sensor (TMAP)	2	
13	A09B	0.75	R	TMAP sensor PWR	SP_02	-	TMAP sensor (TMAP)	3	Splice 02
14	A33	0.75	W	TMAP sensor press signal	ECU A (ECU A)	33	TMAP sensor (TMAP)	4	
15	A20	0.75	Y	Throttle valve actuator signal	ECU A (ECU A)	20	Throttle valve actuator (TVA)	1	Stage-V/ Tier-4 final only
16	A21	0.75	R	Throttle valve actuator PWR	ECU A (ECU A)	21	Throttle valve actuator (TVA)	2	Stage-V/ Tier-4 final only
17	A19	0.75	W	Throttle valve actuator motor +	ECU A (ECU A)	19	Throttle valve actuator (TVA)	3	Twist pair (A18/A19) Stage-V/ Tier-4 final only
18	A18	0.75	Brn	Throttle valve actuator motor	ECU A (ECU A)	18	Throttle valve actuator (TVA)	5	Twist pair (A18/A19) Stage-V/ Tier-4 final only
19	A17	0.75	B	Throttle valve actuator GND	ECU A (ECU A)	17	Throttle valve actuator (TVA)	6	Stage-V/ Tier-4 final only
20	A11	0.75	Y	Fuel temp sensor signal	ECU A (ECU A)	11	Fuel temp sensor (FTS)	1	
21	A14B	0.75	B	Fuel temp sensor GND	SP_01	-	Fuel temp sensor (FTS)	2	Splice 01
22	A45	1.5	L	Injector 1 bank 1 high	ECU A (ECU A)	45	Inter 1 (INT 1)	1	Twist pair (A22/A45)

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
23	A22	1.5	B	Injector 1 bank 1 low	ECU A (ECU A)	22	Inter 1 (INT 1)	2	Twist pair (A22/A45)
24	A65	1.5	L	Injector 2 bank 1 high	ECU A (ECU A)	65	Inter 1 (INT 1)	3	Twist pair (A23/A65)
25	A23	1.5	B	Injector 2 bank 1 low	ECU A (ECU A)	23	Inter 1 (INT 1)	4	Twist pair (A23/A65)
26	A66	1.5	L	Injector 3 bank 1 high	ECU A (ECU A)	66	Inter 1 (INT 1)	5	Twist pair (A24/A66)
27	A24	1.5	B	Injector 3 bank 1 low	ECU A (ECU A)	24	Inter 1 (INT 1)	6	Twist pair (A24/A66)
28	A43	1.5	L	Injector 1 bank 2 high	ECU A (ECU A)	43	Inter 1 (INT 1)	7	Twist pair (A01/A43)
29	A01	1.5	B	Injector 1 bank 2 low	ECU A (ECU A)	1	Inter 1 (INT 1)	8	Twist pair (A01/A43)
30	A44	1.5	L	Injector 2 bank 2 high	ECU A (ECU A)	44	Inter 1 (INT 1)	9	Twist pair (A02/A44)
31	A02	1.5	B	Injector 2 bank 2 low	ECU A (ECU A)	2	Inter 1 (INT 1)	10	Twist pair (A02/A44)
32	A64	1.5	L	Injector 3 bank 2 high	ECU A (ECU A)	64	Inter 1 (INT 1)	11	Twist pair (A03/A64)
33	A03	1.5	B	Injector 3 bank 2 low	ECU A (ECU A)	3	Inter 1 (INT 1)	12	Twist pair (A03/A64)
34	A06	0.75	R	Fuel metering unit PWR	ECU A (ECU A)	6	Inter 2 (INT 2)	1	Twist pair (A05/A06)
35	A05	0.75	O	Fuel metering unit signal	ECU A (ECU A)	5	Inter 2 (INT 2)	2	Twist pair (A05/A06)
36	A105	0.75	P	Crank shaft speed sensor NEG	ECU A (ECU A)	105	Inter 2 (INT 2)	3	Shield (A84/A105)/ Twist pair (A84/A105)
37	A84	0.75	O	Crank shaft speed sensor POS	ECU A (ECU A)	84	Inter 2 (INT 2)	4	Shield (A84/A105)/ Twist pair (A84/A105)
38	A83	0.75	B	Crank shaft speed sensor GND	ECU A (ECU A)	83	Inter 2 (INT 2)	5	Shield drain (A84/A105)
39	A104	0.75	B	Cam shaft speed sensor GND	ECU A (ECU A)	104	Inter 2 (INT 2)	6	Twist pair (A08/A82/A104)
40	A82	0.75	Y	Cam shaft speed sensor signal	ECU A (ECU A)	82	Inter 2 (INT 2)	7	Twist pair (A08/A82/A104)
41	A08	0.75	R	Cam shaft speed sensor PWR	ECU A (ECU A)	8	Inter 2 (INT 2)	8	Twist pair (A08/A82/A104)
42	A12	0.75	Brn	Can 2 low	ECU A (ECU A)	12	Inter 4 (INT 4)	1	Twist pair (A12/A13)
43	A13	0.75	O	Can 2 high	ECU A (ECU A)	13	Inter 4 (INT 4)	2	Twist pair (A12/A13)

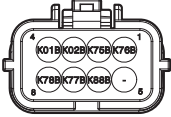
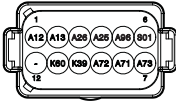

11. Electrical System

No.	Wire label	Size (mm ²)	Color	Circuit Description	From	No.	To	No.	Remark
44	A26	0.75	Brn	DPF DP sensor flex 1/O 18	ECU A (ECU A)	26	Inter 4 (INT 4)	3	Stage-V/ Tier-4 final only
45	A25	0.75	B	DPF DP sensor GND	ECU A (ECU A)	25	Inter 4 (INT 4)	4	Stage-V/ Tier-4 final only
46	A96	0.75	R	DPF DP sensor 5V sensor supply 1B	ECU A (ECU A)	96	Inter 4 (INT 4)	5	Stage-V/ Tier-4 final only
47	A85	0.75	Y	DOC upstream signal	ECU A (ECU A)	85	Inter 3 (INT 3)	1	Stage-V/ Tier-4 final only
48	A04	0.75	B	DOC upstream GND	ECU A (ECU A)	4	Inter 3 (INT 3)	2	Stage-V/ Tier-4 final only
49	A38	0.75	W	DPF upstream signal	ECU A (ECU A)	38	Inter 3 (INT 3)	3	Stage-V/ Tier-4 final only
50	A55	0.75	O	SCR upstream signal	ECU A (ECU A)	55	Inter 3 (INT 3)	4	Stage-V/ Tier-4 final only
51	A73	0.75	R	Battery plus output	ECU A (ECU A)	73	Inter 4 (INT 4)	7	
52	A71	0.75	W	SCR tank led low	ECU A (ECU A)	71	Inter 4 (INT 4)	8	Stage-V/ Tier-4 final only
53	A72	0.75	Y	Wait to disconnect led low	ECU A (ECU A)	72	Inter 4 (INT 4)	9	
54	K39	0.75	Y	Ambient temp sensor signal	Inter 2 (INT 2)	2	Inter 4 (INT 4)	10	
55	K60	0.75	B	Ambient temp sensor GND	Inter 2 (INT 2)	1	Inter 4 (INT 4)	11	
56	S01	2	W	Starter SIG	Inter 2 (INT 2)	6	Inter 2 (INT 2)	10	

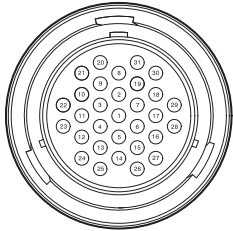
Switches and sensors

Electronic Control Unit

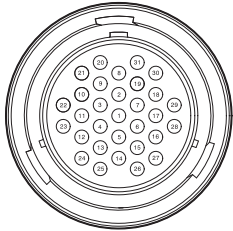
ECU Connector Main

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
<p>Check conn</p> 	K76B	0.75	O	FLR91X-A_T10	Can 1 low	SP_06	-	1
	K75B	0.75	R	FLR91X-A_T10	Can 1 high	SP_07	-	2
	K02B	1.5	B	FLR91X-A	ECU GND	SP_01	-	3
	K01B	1.5	R	FLR91X-A	ECU PWR	SP_02	-	4
	K88B	0.75	Brn	FLR91X-A	Key-on (T15)	SP_03	-	6
	K77B	0.75	Y	FLR91X-A_T07	Can 0 low	SP_04	-	7
	K78B	0.75	W	FLR91X-A_T07	Can 0 high	SP_05	-	8
<p>Inter 4 (INT 4)</p>  <p>(Stage-V/Tier-4 final only)</p>	A12	0.75	Brn	FLR91X-A_T01	Can 2 low	Inter 4 (INT 4)	1	-
	A13	0.75	O	FLR91X-A_T01	Can 2 high	Inter 4 (INT 4)	2	-
	A26	0.75	Brn	FLR91X-A	DPF DP sensor flex 1/O 18	Inter 4 (INT 4)	3	17
	A25	0.75	B	FLR91X-A	DPF DP sensor GND	Inter 4 (INT 4)	4	16
	A96	0.75	R	FLR91X-A	DPF DP sensor 5V sensor supply 1B	Inter 4 (INT 4)	5	15
	S01	2	W	FLR91X-A	Starter SIG	Inter 4 (INT 4)	6	1
	A73	0.75	R	FLR91X-A	Battery plus output	SP_12	-	7
	A71	0.75	W	FLR91X-A	SCR tank led low	Inter urea (INT urea)	20	8
	A72	0.75	Y	FLR91X-A	Wait to disconnect led low	Inter panel (INT panel)	20	9
	K39	0.75	Y	FLR91X-A	Ambient temp sensor signal	ECU K (ECU K)	39	10
	K60	0.75	B	FLR91X-A	Ambient temp sensor GND	ECU K (ECU K)	60	11
<p>Inter 3 (INT 3)</p>  <p>(Stage-V/Tier-4 final only)</p>	A85	0.75	Y	FLR91X-A	DOC upstream signal	Inter 3 (INT 3)	1	4
	A04	0.75	B	FLR91X-A	DOC upstream GND	Inter 3 (INT 3)	2	5
	A38	0.75	W	FLR91X-A	DPF upstream signal	Inter 3 (INT 3)	3	9
	A55	0.75	O	FLR91X-A	SCR upstream signal	Inter 3 (INT 3)	4	10

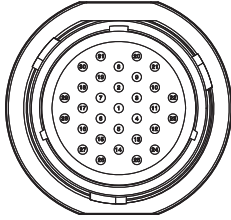
11. Electrical System

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin																																																																						
<p>Inter junction box</p>  <table border="1" data-bbox="145 748 432 1263"> <tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr> <tr><td>S01</td><td>K36</td><td>K90</td><td>K29</td><td>K73</td></tr> <tr><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr> <tr><td>K21</td><td>K50</td><td>K26</td><td>K25</td><td>10A</td></tr> <tr><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td></tr> <tr><td>11A</td><td>12A</td><td>P01A</td><td>14A</td><td>K20A</td></tr> <tr><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td></tr> <tr><td>K74</td><td>17A</td><td>K88A</td><td>19A</td><td>20A</td></tr> <tr><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td></tr> <tr><td>21A</td><td>22A</td><td>23A</td><td>23B</td><td>25A</td></tr> <tr><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr> <tr><td>26A</td><td>27A</td><td>K01A</td><td>K86</td><td>K70</td></tr> <tr><td>31</td><td></td><td></td><td></td><td></td></tr> <tr><td>-</td><td></td><td></td><td></td><td></td></tr> </table> <p>(Stage-V/Tier-4 final only)</p>	1	2	3	4	5	S01	K36	K90	K29	K73	6	7	8	9	10	K21	K50	K26	K25	10A	11	12	13	14	15	11A	12A	P01A	14A	K20A	16	17	18	19	20	K74	17A	K88A	19A	20A	21	22	23	24	25	21A	22A	23A	23B	25A	26	27	28	29	30	26A	27A	K01A	K86	K70	31					-					S01	2	W	FLR91X-A	Starter SIG	Inter 4 (INT 4)	6	1
	1	2	3	4	5																																																																									
	S01	K36	K90	K29	K73																																																																									
	6	7	8	9	10																																																																									
	K21	K50	K26	K25	10A																																																																									
	11	12	13	14	15																																																																									
	11A	12A	P01A	14A	K20A																																																																									
	16	17	18	19	20																																																																									
	K74	17A	K88A	19A	20A																																																																									
	21	22	23	24	25																																																																									
	21A	22A	23A	23B	25A																																																																									
	26	27	28	29	30																																																																									
	26A	27A	K01A	K86	K70																																																																									
	31																																																																													
	-																																																																													
K36	0.75	Y	FLR91X-A	Start relay high	ECU K (ECU K)	36	2																																																																							
K90	0.75	Brn	FLR91X-A	Start relay low	ECU K (ECU K)	90	3																																																																							
K29	0.75	Y	FLR91X-A	Hose heater RLY SIG	ECU K (ECU K)	29	4																																																																							
K73	0.75	G	FLR91X-A	Heater RLY PWR	ECU K (ECU K)	73	5																																																																							
K21	0.75	L	FLR91X-A	Pressure heater RLY SIG	ECU K (ECU K)	21	6																																																																							
K50	0.75	O	FLR91X-A	Suction heater RLY SIG	ECU K (ECU K)	-	7																																																																							
K26	0.75	Y	FLR91X-A	Back flow heater RLY SIG	ECU K (ECU K)	26	8																																																																							
K25	0.75	W	FLR91X-A	Supply module heater RLY SIG	ECU K (ECU K)	25	9																																																																							
10A	1.5	R	FLR91X-A	Pressure heater	Inter urea (INT urea)	19	10																																																																							
11A	1.5	Brn	FLR91X-A	Suction heater	Inter urea (INT urea)	18	11																																																																							
12A	1.5	L	FLR91X-A	Back flow heater	Inter urea (INT urea)	18	12																																																																							
P01A	0.75	R	FLR91X-A	Urea tank supply	SP_11	-	13																																																																							
14A	1.5	Y	FLR91X-A	SCR supply module heater GND	Inter urea (INT urea)	5	14																																																																							
K20A	2	R	FLR94X-A	Hose heater BAT +	SP_13	-	15																																																																							

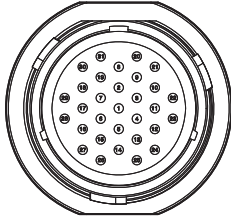
11. Electrical System

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin																																																																						
<p style="text-align: center;">Inter junction box</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr> <tr><td>S01</td><td>K36</td><td>K90</td><td>K29</td><td>K73</td></tr> <tr><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr> <tr><td>K21</td><td>K50</td><td>K26</td><td>K25</td><td>10A</td></tr> <tr><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td></tr> <tr><td>11A</td><td>12A</td><td>P01A</td><td>14A</td><td>K20A</td></tr> <tr><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td></tr> <tr><td>K74</td><td>17A</td><td>K88A</td><td>19A</td><td>20A</td></tr> <tr><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td></tr> <tr><td>21A</td><td>22A</td><td>23A</td><td>23B</td><td>25A</td></tr> <tr><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr> <tr><td>26A</td><td>27A</td><td>K01A</td><td>K86</td><td>K70</td></tr> <tr><td>31</td><td></td><td></td><td></td><td></td></tr> <tr><td>-</td><td></td><td></td><td></td><td></td></tr> </table> <p>(Stage-V/Tier-4 final only)</p>	1	2	3	4	5	S01	K36	K90	K29	K73	6	7	8	9	10	K21	K50	K26	K25	10A	11	12	13	14	15	11A	12A	P01A	14A	K20A	16	17	18	19	20	K74	17A	K88A	19A	20A	21	22	23	24	25	21A	22A	23A	23B	25A	26	27	28	29	30	26A	27A	K01A	K86	K70	31					-					K74	0.75	B	FLR91X-A	Key switch start (T50)	ECU K (ECU K)	74	16
	1	2	3	4	5																																																																									
	S01	K36	K90	K29	K73																																																																									
	6	7	8	9	10																																																																									
	K21	K50	K26	K25	10A																																																																									
	11	12	13	14	15																																																																									
	11A	12A	P01A	14A	K20A																																																																									
	16	17	18	19	20																																																																									
	K74	17A	K88A	19A	20A																																																																									
	21	22	23	24	25																																																																									
	21A	22A	23A	23B	25A																																																																									
	26	27	28	29	30																																																																									
	26A	27A	K01A	K86	K70																																																																									
	31																																																																													
	-																																																																													
	17A	2	B	FLR91X-A	T50 (Start)	Inter panel (INT panel)	14	17																																																																						
K88A	0.75	Brn	FLR91X-A	Key-on (T15)	SP_03	-	18																																																																							
19A	1.5	W	FLR91X-A	T15_Ignition	Inter panel (INT panel)	12	19																																																																							
20A	2	B	FLR91X-A	Fuel heater #1 GND	Inter panel (INT panel)	8	20																																																																							
21A	2	B	FLR92X-A	Fuel heater #2 GND	Inter panel (INT panel)	7	21																																																																							
22A	2	B	FLR95X-A	Hose heater GND	Inter panel (INT panel)	6	22																																																																							
23A	2	R	FLR95X-A	Fuel heater supply	Inter panel (INT panel)	5	23																																																																							
23B	2	R	FLR95X-A	Fuel heater supply	Inter panel (INT panel)	4	24																																																																							
25A	1.5	Y	FLR91X-A	Urea tank supply	Inter panel (INT panel)	3	25																																																																							
26A	2	P	FLR91X-A	Hose heater supply	Inter panel (INT panel)	2	26																																																																							
27A	2	R	FLR91X-A	ECU PWR	Inter panel (INT panel)	1	27																																																																							
K01A	1.5	R	FLR91X-A	ECU PWR	SP_02	-	28																																																																							
K86	0.75	L	FLR91X-A	WIF sensor	ECU K (ECU K)	86	29																																																																							
K70	0.75	Y	FLR91X-A	WIF sensor	ECU K (ECU K)	70	30																																																																							

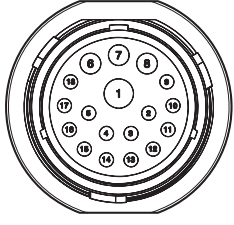
11. Electrical System

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin																																																																						
<p>Inter panel</p>  <table border="1" data-bbox="145 685 432 1205"> <tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr> <tr><td>27A</td><td>26A</td><td>25A</td><td>23B</td><td>23A</td></tr> <tr><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr> <tr><td>22A</td><td>21A</td><td>20A</td><td>K02A</td><td>G01A</td></tr> <tr><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td></tr> <tr><td>-</td><td>19A</td><td>-</td><td>17A</td><td>K77A</td></tr> <tr><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td></tr> <tr><td>K78A</td><td>K76A</td><td>K75A</td><td>A73A</td><td>A72</td></tr> <tr><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td></tr> <tr><td>K45</td><td>K61</td><td>K63</td><td>K44</td><td>K83</td></tr> <tr><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr> <tr><td>K84</td><td>-</td><td>K68</td><td>K14</td><td>K64</td></tr> <tr><td>31</td><td></td><td></td><td></td><td></td></tr> <tr><td>K82</td><td></td><td></td><td></td><td></td></tr> </table> <p>(Stage-V/Tier-4 final only)</p>	1	2	3	4	5	27A	26A	25A	23B	23A	6	7	8	9	10	22A	21A	20A	K02A	G01A	11	12	13	14	15	-	19A	-	17A	K77A	16	17	18	19	20	K78A	K76A	K75A	A73A	A72	21	22	23	24	25	K45	K61	K63	K44	K83	26	27	28	29	30	K84	-	K68	K14	K64	31					K82					27A	2	R	FLR91X-A	ECU PWR	Inter panel (INT panel)	1	27
	1	2	3	4	5																																																																									
	27A	26A	25A	23B	23A																																																																									
	6	7	8	9	10																																																																									
	22A	21A	20A	K02A	G01A																																																																									
	11	12	13	14	15																																																																									
	-	19A	-	17A	K77A																																																																									
	16	17	18	19	20																																																																									
	K78A	K76A	K75A	A73A	A72																																																																									
	21	22	23	24	25																																																																									
	K45	K61	K63	K44	K83																																																																									
	26	27	28	29	30																																																																									
	K84	-	K68	K14	K64																																																																									
	31																																																																													
	K82																																																																													
26A	2	P	FLR91X-A	Hose heater supply	Inter panel (INT panel)	2	26																																																																							
25A	1.5	Y	FLR91X-A	Urea tank supply	Inter panel (INT panel)	3	25																																																																							
23B	2	R	FLR95X-A	Fuel heater supply	Inter panel (INT panel)	4	24																																																																							
23A	2	R	FLR95X-A	Fuel heater supply	Inter panel (INT panel)	5	23																																																																							
22A	2	B	FLR95X-A	Hose heater GND	Inter panel (INT panel)	6	22																																																																							
21A	2	B	FLR92X-A	Fuel heater #2 GND	Inter panel (INT panel)	7	21																																																																							
20A	2	B	FLR91X-A	Fuel heater #1 GND	Inter panel (INT panel)	8	20																																																																							
K02A	1.5	B	FLR91X-A	ECU GND	SP_01	-	9																																																																							
G01A	0.75	B	FLR91X-A	Urea tank ground	SP_10	-	10																																																																							
19A	1.5	W	FLR91X-A	T15_Ignition	Inter panel (INT panel)	12	19																																																																							
17A	2	B	FLR91X-A	T50 (START)	Inter panel (INT panel)	14	17																																																																							
K77A	0.75	Y	FLR91X-A_T06	Can 0 low	SP_04	-	15																																																																							
K78A	0.75	W	FLR91X-A_T06	Can 0 high	SP_05	-	16																																																																							

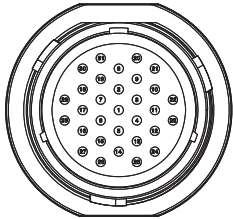
11. Electrical System

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin																																																																						
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	1	2	3	4	5																																																																									
	27A	26A	25A	23B	23A																																																																									
	6	7	8	9	10																																																																									
	22A	21A	20A	K02A	G01A																																																																									
	11	12	13	14	15																																																																									
	-	19A	-	17A	K77A																																																																									
	16	17	18	19	20																																																																									
	K78A	K76A	K75A	A73A	A72																																																																									
	21	22	23	24	25																																																																									
	K45	K61	K63	K44	K83																																																																									
	26	27	28	29	30																																																																									
	K84	-	K68	K14	K64																																																																									
	31																																																																													
K82																																																																														
K75A	0.75	R	FLR91X-A_T09	Can 1 high	SP_07	-	18																																																																							
A73A	0.75	R	FLR91X-A	Battery plus output	Inter panel (INT panel)	19	-																																																																							
A72	0.75	Y	FLR91X-A	Wait to disconnect led low	Inter panel (INT panel)	20	9																																																																							
K45	0.75	R	FLR91X-A	Pedal position 1 PWR (5V)	ECU K (ECU K)	45	21																																																																							
K61	0.75	Y	FLR91X-A	Pedal position 1 SIG	ECU K (ECU K)	61	22																																																																							
K63	0.75	B	FLR91X-A	Pedal position 1 GND	ECU K (ECU K)	63	23																																																																							
K44	0.75	R	FLR91X-A	Pedal position 2 PWR (5V)	ECU K (ECU K)	44	24																																																																							
K83	0.75	G	FLR91X-A	Pedal position 2 SIG	ECU K (ECU K)	83	25																																																																							
K84	0.75	B	FLR91X-A	Pedal position 2 GND	ECU K (ECU K)	84	26																																																																							
K68	0.75	R	FLR91X-A	Switched battery UB25	ECU K (ECU K)	68	28																																																																							
K14	0.75	O	FLR91X-A	DPF regeneration switch	ECU K (ECU K)	14	29																																																																							
K64	0.75	Y	FLR91X-A	DPF regeneration inhibit switch	ECU K (ECU K)	64	30																																																																							
K82	0.75	G	FLR91X-A	Engine stop switch	ECU K (ECU K)	82	31																																																																							

11. Electrical System

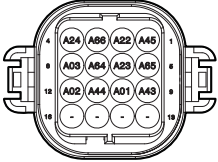
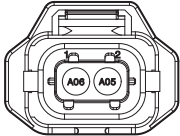
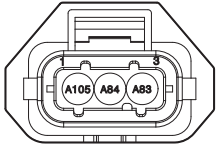
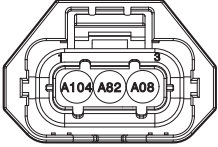
Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin																																								
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	1	2	3	4	5																																											
	-	K10	K11	A85	A04																																											
	6	7	8	9	10																																											
	-	-	-	A38	A55																																											
	11	12	13	14	15																																											
	P01	G01	A12A	A13A	A96																																											
	16	17	18																																													
	A25	A26	-																																													
	K11	0.75	B	FLR91X-A_T04	Dosing valve low side	ECU K (ECU K)	11	3																																								
	A85	0.75	Y	FLR91X-A	DOC upstream signal	Inter 3 (INT 3)	1	4																																								
	A04	0.75	B	FLR91X-A	DOC upstream GND	Inter 3 (INT 3)	2	5																																								
	A38	0.75	W	FLR91X-A	DPF upstream signal	Inter 3 (INT 3)	3	9																																								
	A55	0.75	O	FLR91X-A	SCR upstream signal	Inter 3 (INT 3)	4	10																																								
	P01	0.75	R	FLR91X-A	NOx sensor PWR	Inter SCR (INT SCR)	11	-																																								
G01	0.75	B	FLR91X-A	NOx sensor GND	Inter SCR (INT SCR)	12	-																																									
A12A	0.75	Brn	FLR91X-A_T02	Can 2 low	SP_08	-	13																																									
A13A	0.75	O	FLR91X-A_T02	Can 2 high	SP_09	-	14																																									
A96	0.75	R	FLR91X-A	DPF DP sensor 5V sensor supply 1B	Inter 4 (INT 4)	5	15																																									
A25	0.75	B	FLR91X-A	DPF DP sensor GND	Inter 4 (INT 4)	4	16																																									
A26	0.75	Brn	FLR91X-A	DPF DP sensor flex 1/O 18	Inter 4 (INT 4)	3	17																																									

11. Electrical System

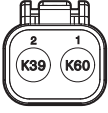
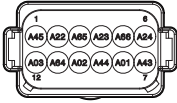
Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin																																																																						
<p>Inter urea</p>  <table border="1" data-bbox="145 1048 432 1563"> <tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr> <tr><td>K24</td><td>K54</td><td>K53</td><td>K20B</td><td>14A</td></tr> <tr><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td></tr> <tr><td>K07</td><td>K71</td><td>K09</td><td>K51</td><td>K27</td></tr> <tr><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td></tr> <tr><td>K91</td><td>K28</td><td>P01B</td><td>G01B</td><td>A13B</td></tr> <tr><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td></tr> <tr><td>A12B</td><td>12A</td><td>11A</td><td>10A</td><td>A71</td></tr> <tr><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td></tr> <tr><td>A73B</td><td>-</td><td>-</td><td>-</td><td>-</td></tr> <tr><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td></tr> <tr><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr> <tr><td>31</td><td colspan="4"></td></tr> <tr><td>-</td><td colspan="4"></td></tr> </table> <p>(Stage-V/Tier-4 final only)</p>	1	2	3	4	5	K24	K54	K53	K20B	14A	6	7	8	9	10	K07	K71	K09	K51	K27	11	12	13	14	15	K91	K28	P01B	G01B	A13B	16	17	18	19	20	A12B	12A	11A	10A	A71	21	22	23	24	25	A73B	-	-	-	-	26	27	28	29	30	-	-	-	-	-	31					-					K24	0.75	R	FLR91X-A	SCR pressure sensor (5V)	ECU K (ECU K)	24	1
	1	2	3	4	5																																																																									
	K24	K54	K53	K20B	14A																																																																									
	6	7	8	9	10																																																																									
	K07	K71	K09	K51	K27																																																																									
	11	12	13	14	15																																																																									
	K91	K28	P01B	G01B	A13B																																																																									
	16	17	18	19	20																																																																									
	A12B	12A	11A	10A	A71																																																																									
	21	22	23	24	25																																																																									
	A73B	-	-	-	-																																																																									
	26	27	28	29	30																																																																									
	-	-	-	-	-																																																																									
	31																																																																													
	-																																																																													
	K54	0.75	W	FLR91X-A	SCR pressure sensor (I)	ECU K (ECU K)	54	2																																																																						
	K53	0.75	B	FLR91X-A	SCR pressure sensor (G)	ECU K (ECU K)	53	3																																																																						
	K20B	2	R	FLR95X-A	Hose heater BAT +	SP_13	-	4																																																																						
	14A	1.5	Y	FLR91X-A	SCR supply module heater GND	Inter urea (INT urea)	5	14																																																																						
	K07	0.75	B	FLR91X-A	SCR agent pump motor control (GROUND)	ECU K (ECU K)	7	6																																																																						
K71	0.75	R	FLR91X-A	SCR agent pump motor control (24V)	ECU K (ECU K)	71	7																																																																							
K09	0.75	O	FLR91X-A	SCR agent pump motor control (B_P)	ECU K (ECU K)	9	B																																																																							
K51	0.75	R	FLR91X-A	SCR reverting valve (24)	ECU K (ECU K)	51	9																																																																							
K27	0.75	L	FLR91X-A	SCR reverting valve (P)	ECU K (ECU K)	27	10																																																																							
K91	1.5	R	FLR91X-A	SCR tank heating valve (24V)	ECU K (ECU K)	91	11																																																																							
K28	0.75	Y	FLR91X-A	SCR tank heating valve (S)	ECU K (ECU K)	28	12																																																																							
P01B	0.75	R	FLR91X-A	Urea tank supply	SP_11	-	13																																																																							
G01B	0.75	B	FLR91X-A	Urea tank ground	SP_10	-	14																																																																							
A13B	0.75	O	FLR91X-A_T03	Can 2 high	SP_09	-	15																																																																							
A12B	0.75	Brn	FLR91X-A_T03	Can 2 low	SP_08	-	16																																																																							
12A	1.5	L	FLR91X-A	Back flow heater	Inter urea (INT urea)	18	12																																																																							
11A	1.5	Brn	FLR91X-A	Suction heater	Inter urea (INT urea)	18	11																																																																							
10A	1.5	R	FLR91X-A	Pressure heater	Inter urea (INT urea)	19	10																																																																							
A71	0.75	W	FLR91X-A	SCR tank led low	Inter urea (INT urea)	20	8																																																																							
A73B	0.75	R	FLR91X-A	Battery plus output	Inter urea (INT urea)	21	-																																																																							

11. Electrical System

ECU Connector RH

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
<p>Injector (INJ)</p> 	A45	1.5	L	FLR91X-A T01	Injector 1 bank 1 high	Inter 1 (INT 1)	1	1
	A22	1.5	B	FLR91X-A T01	Injector 1 bank 1 low	Inter 1 (INT 1)	2	2
	A66	1.5	L	FLR91X-A T03	Injector 3 bank 1 high	Inter 1 (INT 1)	5	3
	A24	1.5	B	FLR91X-A T03	Injector 3 bank 1 low	Inter 1 (INT 1)	6	4
	A65	1.5	L	FLR91X-A T02	Injector 2 bank 1 high	Inter 1 (INT 1)	3	5
	A23	1.5	B	FLR91X-A T02	Injector 2 bank 1 low	Inter 1 (INT 1)	4	6
	A64	1.5	L	FLR91X-A T06	Injector 3 bank 2 high	Inter 1 (INT 1)	11	7
	A03	1.5	B	FLR91X-A T06	Injector 3 bank 2 low	Inter 1 (INT 1)	12	8
	A43	1.5	L	FLR91X-A T04	Injector 1 bank 2 high	Inter 1 (INT 1)	7	9
	A01	1.5	B	FLR91X-A T04	Injector 1 bank 2 low	Inter 1 (INT 1)	8	10
	A44	1.5	L	FLR91X-A T05	Injector 2 bank 2 high	Inter 1 (INT 1)	9	11
	A02	1.5	B	FLR91X-A T05	Injector 2 bank 2 low	Inter 1 (INT 1)	10	12
<p>Fuel metering unit (FMU)</p> 	A06	0.75	R	FLR91X-A T07	Fuel metering unit PWR	Inter 2 (INT 2)	1	1
	A05	0.75	O	FLR91X-A T07	Fuel metering unit signal	Inter 2 (INT 2)	2	2
<p>Crank shaft speed sensor (CRS)</p> 	A105	0.75	P	FLR91X-A BS01	Crank shaft speed sensor NEG	Inter 2 (INT 2)	3	1
	A84	0.75	O	FLR91X-A BS01	Crank shaft speed sensor POS	Inter 2 (INT 2)	4	2
	A83	0.75	B	FLR91X-A	Crank shaft speed sensor GND	Inter 2 (INT 2)	5	3
<p>Cam shaft speed sensor (CAS)</p> 	A104	0.75	B	FLR91X-A	Cam shaft speed sensor GND	Inter 2 (INT 2)	6	1
	A82	0.75	L	FLR91X-A BS02	Cam shaft speed sensor signal	Inter 2 (INT 2)	7	2
	A08	0.75	P	FLR91X-A BS02	Cam shaft speed sensor PWR	Inter 2 (INT 2)	8	3

11. Electrical System

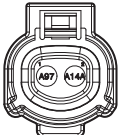
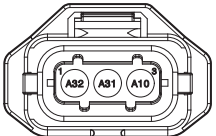

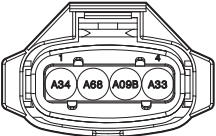
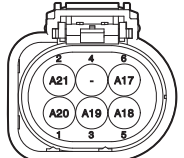
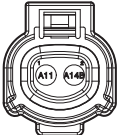
Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
Ambient temp sensor (ATS)  (LEP00/MFP00 only)	K39	0.75	Y	FLR91X-A	Ambient temp sensor signal	Inter 2 (INT 2)	11	2
	K60	0.75	B	FLR91X-A	Ambient temp sensor GND	Inter 2 (INT 2)	12	1
Inter 1 (INT 1) 	A45	1.5	L	FLR91X-A T01	Injector 1 bank 1 high	Inter 1 (INT 1)	1	1
	A22	1.5	B	FLR91X-A T01	Injector 1 bank 1 low	Inter 1 (INT 1)	2	2
	A65	1.5	L	FLR91X-A T02	Injector 2 bank 1 high	Inter 1 (INT 1)	3	5
	A23	1.5	B	FLR91X-A T02	Injector 2 bank 1 low	Inter 1 (INT 1)	4	6
	A66	1.5	L	FLR91X-A T03	Injector 3 bank 1 high	Inter 1 (INT 1)	5	3
	A24	1.5	B	FLR91X-A T03	Injector 3 bank 1 low	Inter 1 (INT 1)	6	4
	A43	1.5	L	FLR91X-A T04	Injector 1 bank 2 high	Inter 1 (INT 1)	7	9
	A01	1.5	B	FLR91X-A T04	Injector 1 bank 2 low	Inter 1 (INT 1)	8	10
	A44	1.5	L	FLR91X-A T05	Injector 2 bank 2 high	Inter 1 (INT 1)	9	11
	A02	1.5	B	FLR91X-A T05	Injector 2 bank 2 low	Inter 1 (INT 1)	10	12
	A64	1.5	L	FLR91X-A T06	Injector 3 bank 2 high	Inter 1 (INT 1)	11	7
	A03	1.5	B	FLR91X-A T06	Injector 3 bank 2 low	Inter 1 (INT 1)	12	8

11. Electrical System

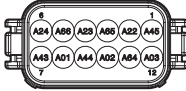
Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
<p>Inter 2 (INT 2)</p>	A06	0.75	R	FLR91X-A T07	Fuel metering unit PWR	Inter 2 (INT 2)	1	1
	A05	0.75	O	FLR91X-A T07	Fuel metering unit signal	Inter 2 (INT 2)	2	2
	A105	0.75	P	FLR91X-A BS01	Crank shaft speed sensor NEG	Inter 2 (INT 2)	3	1
	A84	0.75	O	FLR91X-A BS01	Crank shaft speed sensor POS	Inter 2 (INT 2)	4	2
	A83	0.75	B	FLR91X-A	Crank shaft speed sensor GND	Inter 2 (INT 2)	5	3
	A104	0.75	B	FLR91X-A	Cam shaft speed sensor GND	Inter 2 (INT 2)	6	1
	A82	0.75	L	FLR91X-A BS02	Cam shaft speed sensor signal	Inter 2 (INT 2)	7	2
	A08	0.75	P	FLR91X-A BS02	Cam shaft speed sensor PWR	Inter 2 (INT 2)	8	3
	S01	2	W	FLR91X-A	Starter SIG	Inter 2 (INT 2)	10	1
	K39	0.75	Y	FLR91X-A	Ambient temp sensor signal	Inter 2 (INT 2)	11	2
	K60	0.75	B	FLR91X-A	Ambient temp sensor GND	Inter 2 (INT 2)	12	1
<p>Start S (STS)</p>	S01	2	W	FLR91X-A	Starter SIG	Inter 2 (INT 2)	10	1

11. Electrical System

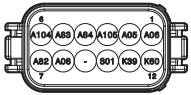

ECU Connector LH

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
Coolant temp sensor (CTS) 	A97	0.75	W	FLR91X-A	Coolant temp sensor signal	ECU A (ECU A)	97	1
	A14A	0.75	B	FLR91X-A	Coolant temp sensor GND	SP_01	-	2
Rail press sensor (RPS) 	A32	0.75	B	FLR91X-A T01	Rail press sensor GND	ECU A (ECU A)	32	1
	A31	0.75	W	FLR91X-A T01	Rail press sensor signal	ECU A (ECU A)	31	2
	A10	0.75	R	FLR91X-A T01	Rail press sensor PWR	ECU A (ECU A)	10	3
Oil press sensor (OPS) 	A76	0.75	Y	FLR91X-A	Oil press sensor signal	ECU A (ECU A)	76	1
	A57	0.75	B	FLR91X-A	Oil press sensor GND	ECU A (ECU A)	57	2
	A09A	0.75	R	FLR91X-A	Oil press sensor PWR	SP_02	-	3
TMAP sensor (TMAP) 	A34	0.75	B	FLR91X-A	TMAP sensor GND	ECU A (ECU A)	34	1
	A68	0.75	Y	FLR91X-A	TMAP sensor temp signal	ECU A (ECU A)	68	2
	A09B	0.75	R	FLR91X-A	TMAP sensor PWR	SP_02	-	3
	A33	0.75	W	FLR91X-A	TMAP sensor press signal	ECU A (ECU A)	33	4
Throttle valve actuator (TVA)  (Stage-V/Tier-4 final only)	A20	0.75	Y	FLR91X-A	Throttle valve actuator signal	ECU A (ECU A)	20	1
	A21	0.75	R	FLR91X-A	Throttle valve actuator PWR	ECU A (ECU A)	21	2
	A19	0.75	W	FLR91X-A T03	Throttle valve actuator motor+	ECU A (ECU A)	19	3
	A18	0.75	Brn	FLR91X-A T03	Throttle valve actuator motor	ECU A (ECU A)	18	5
	A17	0.75	B	FLR91X-A	Throttle valve actuator GND	ECU A (ECU A)	17	6
Fuel temp sensor (FTS) 	A11	0.75	Y	FLR91X-A	Fuel temp sensor signal	ECU A (ECU A)	11	1
	A14B	0.75	B	FLR91X-A	Fuel temp sensor GND	SP_01	-	2



11. Electrical System

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
<p>Inter 1 (INT 1)</p> 	A45	1.5	L	FLR91X-A T04	Injector 1 bank 1 high	ECU A (ECU A)	45	1
	A22	1.5	B	FLR91X-A T04	Injector 1 bank 1 low	ECU A (ECU A)	22	2
	A65	1.5	L	FLR91X-A T05	Injector 2 bank 1 high	ECU A (ECU A)	65	3
	A23	1.5	B	FLR91X-A T05	Injector 2 bank 1 low	ECU A (ECU A)	23	4
	A66	1.5	L	FLR91X-A T06	Injector 3 bank 1 high	ECU A (ECU A)	66	5
	A24	1.5	B	FLR91X-A T06	Injector 3 bank 1 low	ECU A (ECU A)	24	6
	A43	1.5	L	FLR91X-A T07	Injector 1 bank 2 high	ECU A (ECU A)	43	7
	A01	1.5	B	FLR91X-A T07	Injector 1 bank 2 low	ECU A (ECU A)	1	8
	A44	1.5	L	FLR91X-A T08	Injector 2 bank 2 high	ECU A (ECU A)	44	9
	A02	1.5	B	FLR91X-A T08	Injector 2 bank 2 low	ECU A (ECU A)	2	10
	A64	1.5	L	FLR91X-A T09	Injector 3 bank 2 high	ECU A (ECU A)	64	11
	A03	1.5	B	FLR91X-A T09	Injector 3 bank 2 low	ECU A (ECU A)	3	12

11. Electrical System

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
<p>Inter 2 (INT 2)</p> 	A06	0.75	R	FLR91X-A T10	Fuel metering unit PWR	ECU A (ECU A)	6	1
	A05	0.75	O	FLR91X-A T10	Fuel metering unit signal	ECU A (ECU A)	5	2
	A105	0.75	P	FLR91X-A BS01	Crank shaft speed sensor NEG	ECU A (ECU A)	105	3
	A84	0.75	O	FLR91X-A BS01	Crank shaft speed sensor POS	ECU A (ECU A)	84	4
	A83	0.75	B	FLR91X-A	Crank shaft speed sensor GND	ECU A (ECU A)	83	5
	A104	0.75	B	FLR91X-A T11	Cam shaft speed sensor GND	ECU A (ECU A)	104	6
	A82	0.75	Y	FLR91X-A T11	Cam shaft speed sensor signal	ECU A (ECU A)	82	7
	A08	0.75	R	FLR91X-A T11	Cam shaft speed sensor PWR	ECU A (ECU A)	8	8
	S01	2	W	FLR91X-A	Starter SIG	Inter 4 (INT 4)	6	10
	K39	0.75	Y	FLR91X-A	Ambient temp sensor signal	Inter 2 (INT 2)	2	10
	K60	0.75	B	FLR91X-A	Ambient temp sensor GND	Inter 2 (INT 2)	1	11
	<p>Inter 3 (INT 3)</p>  <p>(Stage-V/Tier-4 final only)</p>	A85	0.75	Y	FLR91X-A	DOC upstream signal	ECU A (ECU A)	85
A04		0.75	B	FLR91X-A	DOC upstream GND	ECU A (ECU A)	4	2
A38		0.75	W	FLR91X-A	DPF upstream signal	ECU A (ECU A)	38	3
A55		0.75	O	FLR91X-A	SCR upstream signal	ECU A (ECU A)	55	4

11. Electrical System

Figure	Circuit	Wire size	Color	Insulation	Circuit Description	From	Pin	Connector Pin
<p>Inter 4 (INT 4)</p>  <p>(Stage-V/Tier-4 final only)</p>	A12	0.75	Brn	FLR91X-A T12	Can 2 low	ECU A (ECU A)	12	1
	A13	0.75	O	FLR91X-A T12	Can 2 high	ECU A (ECU A)	13	2
	A26	0.75	Brn	FLR91X-A	DPF DP sensor flex 1/O 18	ECU A (ECU A)	26	3
	A25	0.75	B	FLR91X-A	DPF DP sensor GND	ECU A (ECU A)	25	4
	A96	0.75	R	FLR91X-A	DPF DP sensor 5V sensor supply 1B	ECU A (ECU A)	96	5
	S01	2	W	FLR91X-A	Starter SIG	Inter 4 (INT 4)	6	10
	A73	0.75	R	FLR91X-A	Battery plus output	ECU A (ECU A)	73	7
	A71	0.75	W	FLR91X-A	SCR tank led low	ECU A (ECU A)	71	8
	A72	0.75	Y	FLR91X-A	Wait to disconnect led low	ECU A (ECU A)	72	9
	K39	0.75	Y	FLR91X-A	Ambient temp sensor signal	Inter 2 (INT 2)	2	10
	K60	0.75	B	FLR91X-A	Ambient temp sensor GND	Inter 2 (INT 2)	1	11
<p>Ambient temp sensor (ATS)</p>  <p>(LEP01/LEP02/ MFP01/MFP02 only)</p>	K39	0.75	Y	FLR91X-A	Ambient temp sensor signal	Inter 2 (INT 2)	2	10
	K60	0.75	B	FLR91X-A	Ambient temp sensor GND	Inter 2 (INT 2)	1	11

Boost Pressure and Temperature Sensor

1. The boost pressure and temperature sensor is connected to the exhaust manifold with an O-ring and measures the absolute pressure and temperature in the exhaust manifold.
2. The output signal is transmitted to the ECU which calculates the boost pressure based on the programmed characteristics curve.

Engine Oil Pressure Sensor

The engine oil pressure sensor detects the oil pressure and transmits data to engine control unit (ECU)

Coolant Temperature Sensor

The engine coolant temperature sensor detects the engine coolant temperature and relays the data to the engine control unit (ECU).

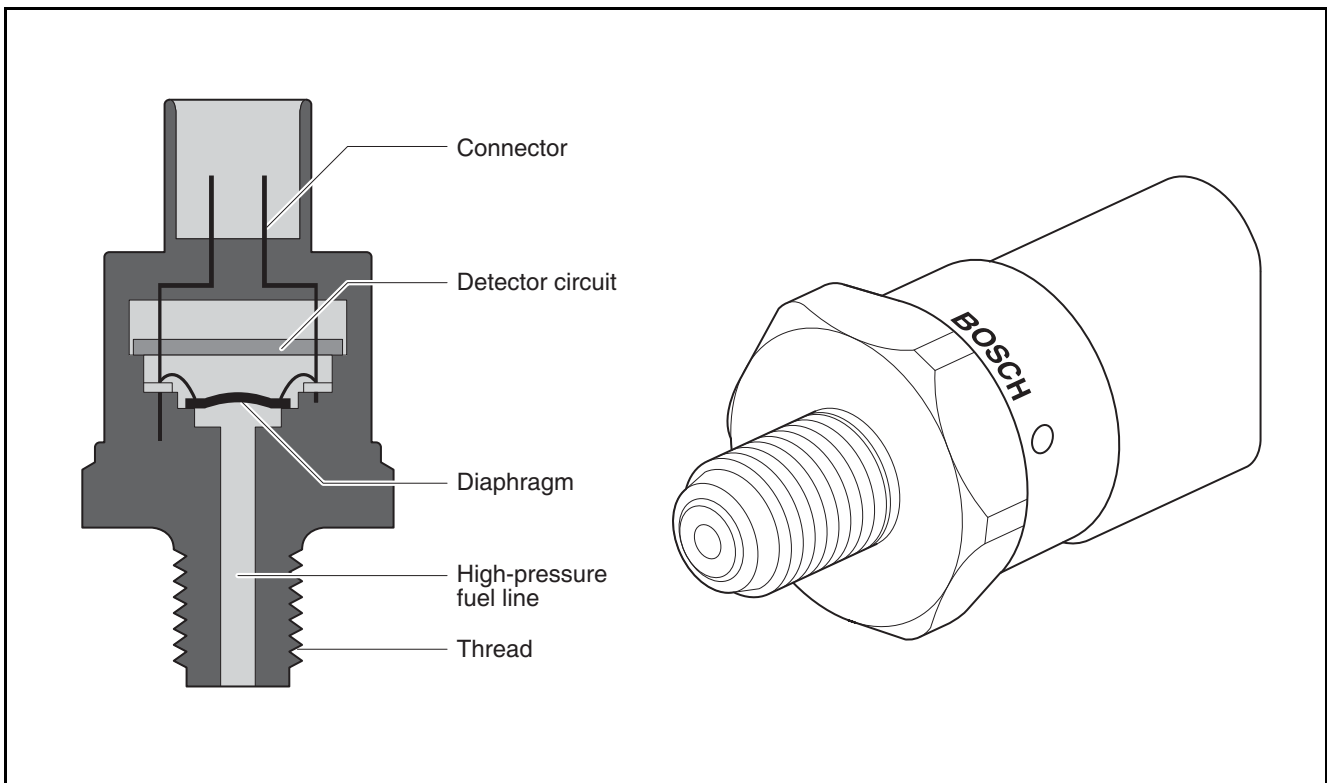
Common Rail Pressure Sensor

Fuel flows into the common rail pressure sensor via a passage running from the common rail.

The tip of the sensor is sealed with a diaphragm, and pressurized fuel

reaches the sensor diaphragm through a hole.

Connected to this diaphragm, the sensor converts fuel pressure into an electrical signal; then, the signal generated by the sensor amplifies the measurement signal and transmits it to the ECU where it enters the evaluation circuit.



EE10M099

Crankshaft Position Sensor

The position of pistons in the combustion chambers plays a very important role in fuel injection.

In every engine, pistons are connected to the crankshaft with connecting rods.

The crankshaft position sensor installed in the flywheel housing provides information on the position of every piston. The rotation speed is defined as the number of crankshaft rotations per minute.

The main input variables are calculated in the ECU using the signals received from the crankshaft position sensor.

Camshaft Position Sensor

The camshaft position sensor controls the engine intake and exhaust valves.

Rotating at half the speed of the crankshaft, this sensor determines whether the camshaft is on the compression stroke or exhaust stroke as the pistons move towards the TDC.

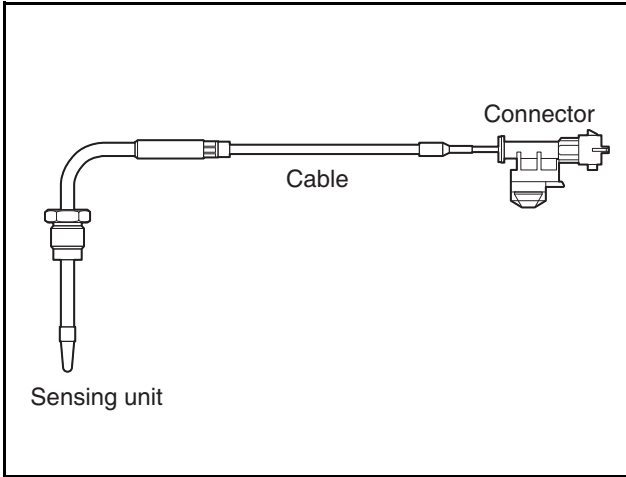
This data cannot be detected by the crankshaft position sensor. However, as long as the engine is operating normally, the data generated by the crankshaft position sensor is sufficient for determining the state of the engine.

This means that the ECU receives information on the state of the engine from the crankshaft position sensor if the camshaft position sensor malfunctions while the vehicle is in operation.

11. Electrical System

Exhaust Gas Temperature Sensor

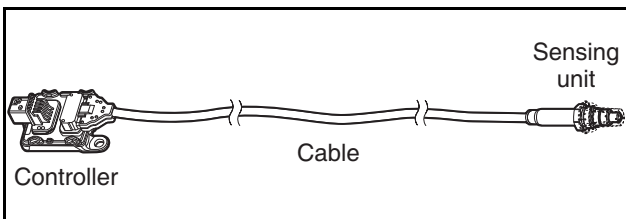
1. This sensor measures the exhaust gas temperature in each part of the aftertreatment system and relays the data to the engine control unit (ECU).
2. The sensor measures upstream of the exhaust reduction system (DPF) and upstream/downstream of the selective catalytic reduction (SCR) system.



EDL08190074

NOx Sensor

1. This sensor measures the amount of NOx using the amount of oxygen in the exhaust gas and relays the data to the engine control unit (ECU).
2. The sensor measures upstream of the diesel oxidation catalyst (DOC) and downstream of the selective catalytic reduction (SCR) system.



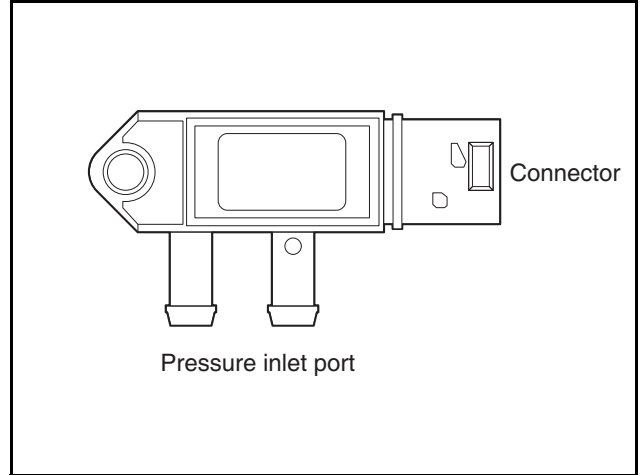
EDL08190075

DEF Quality Sensor

1. This sensor measures the DEF concentration, temperature, and DEF level in the tank and relays the data to the engine control unit (ECU).
2. Installed on the top of the DEF tank, the sensor is connected to the coolant line to thaw the DEF in cold weather.

DPF Delta P Sensor, DPF Pressure Sensor

1. This sensor measures the upstream/downstream pressure of the exhaust gas reduction system (DPF) and relays the calculated differential pressure to the engine control unit (ECU).



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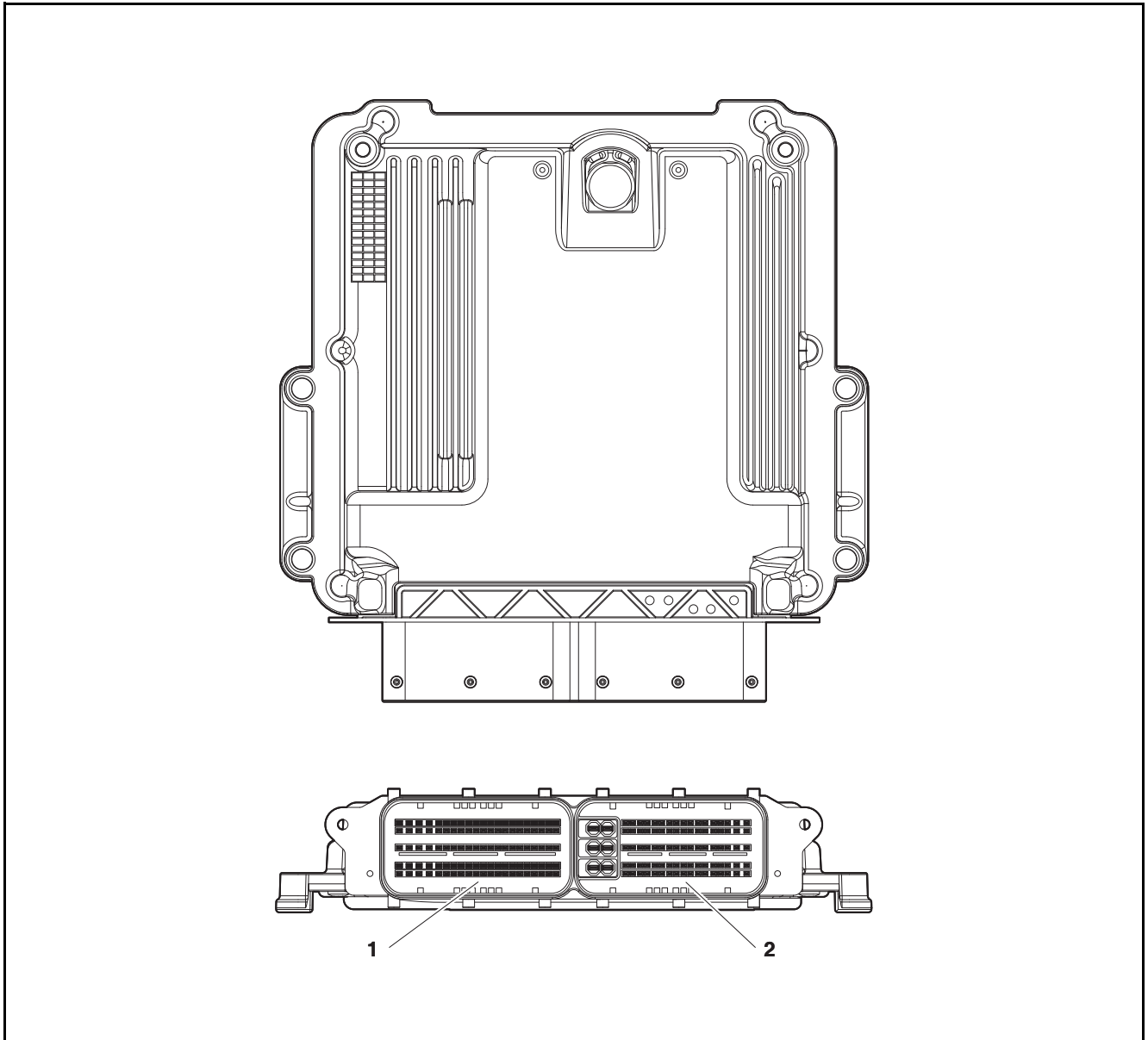
Ambient Temperature Sensor

1. Ambient temperature sensor detects the temperature passed air filter and transmits data to engine control unit (ECU).

Engine Control Unit (ECU)

Engine Control Unit (ECU) Connectors

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

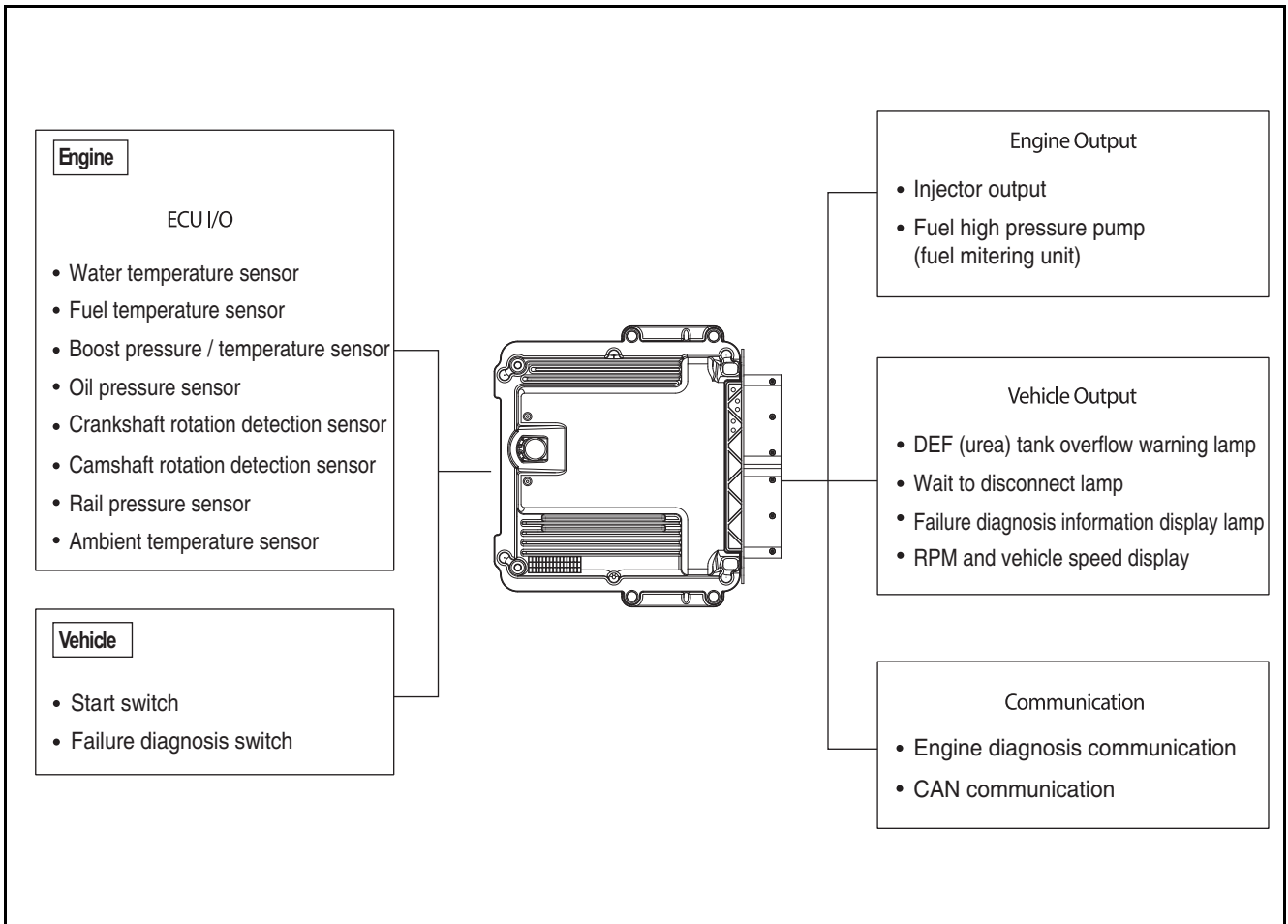


EDM03190095

1. Connectors for connections on the engine
2. Connectors for connections on the vehicle

11. Electrical System

Engine Control Unit (ECU) Input/Output



EDX08240135

Engine Control Unit (ECU) Operating Conditions

1. Starting the engine

- 1) 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.
- 2) To set the reference temperature for determining the amount of fuel, the ECU sets the engine coolant temperature as the reference temperature.
- 3) After determining a suitable amount of fuel for starting the engine, the ECU supplies the fuel to the engine and uses the crankshaft position sensor to measure the engine rpm signal.

2. Driving the vehicle

- 1) The ECU calculates essential data required for driving the vehicle, such as CAN data received from the vehicle control unit and the engine rpm.
3. Adjusting the engine rpm to the needs of the driver
 - 1) 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 vehicle control unit.

4. Limp Home function

- 1) This function enables the vehicle to be driven to a service center under the minimum but safest conditions required for vehicle operation in the event that an error code occurs.
- 2) The Limp Home function activates under the following conditions.
 - Accelerator pedal malfunction: The engine rpm remains constant even when the accelerator pedal is pressed.
 - Sensor malfunction: Certain alternate values are used in the event of a malfunction in any of the sensors.
 - Limited output: The amount of fuel delivered to the engine is limited depending on the type of fault. There are a total of four levels depending on the severity of the fault. The more severe the fault, the more the amount of fuel is limited.
 - Diagnostic information lamp: Data regarding faults which have occurred is provided to the driver to ensure safe operation of the vehicle.

5. Failure diagnosis

- 1) The fault diagnosis information lamp on the gauge panel activates in the event of a fault.
- 2) The fault diagnosis information lamp can be used to check the fault code.

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

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

11. Electrical System

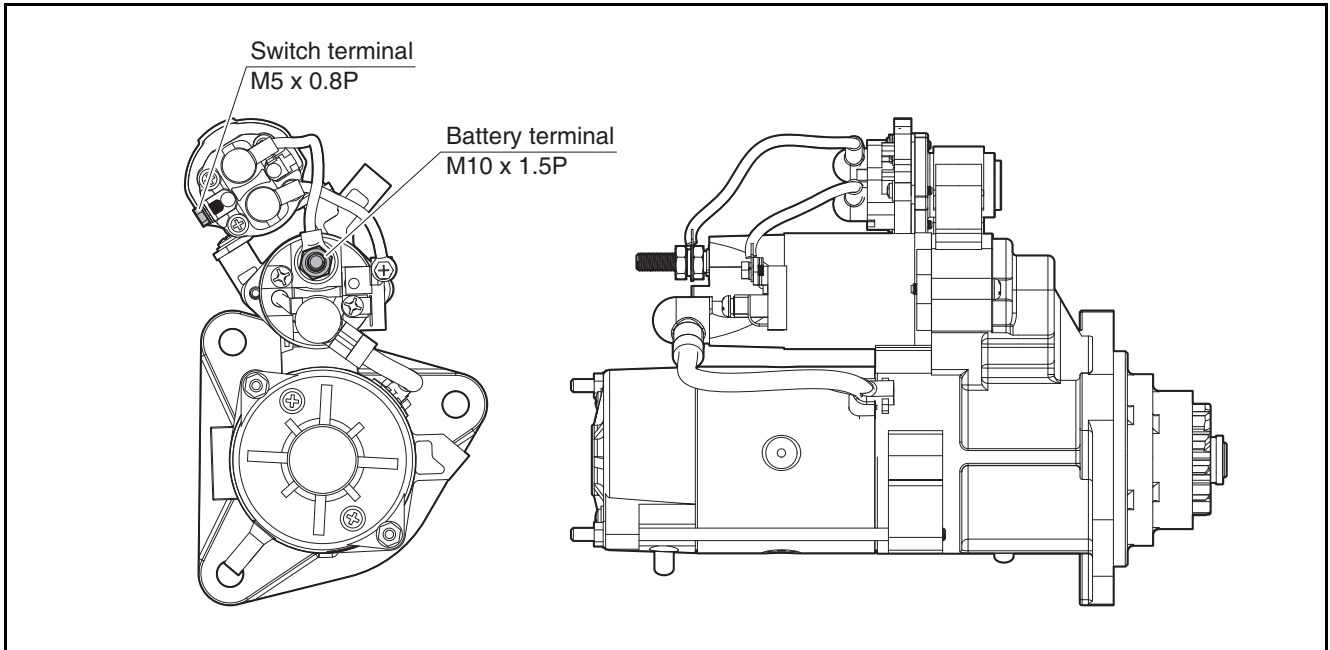
Starter Motor

General Information

The starter motor is mounted on the back of the flywheel housing.

When disassembling the engine, soak the starter motor pinion gear and ring gear in fuel and clean them thoroughly with a brush. Then, apply grease to them to prevent rust.

24 V x 6.0 kW

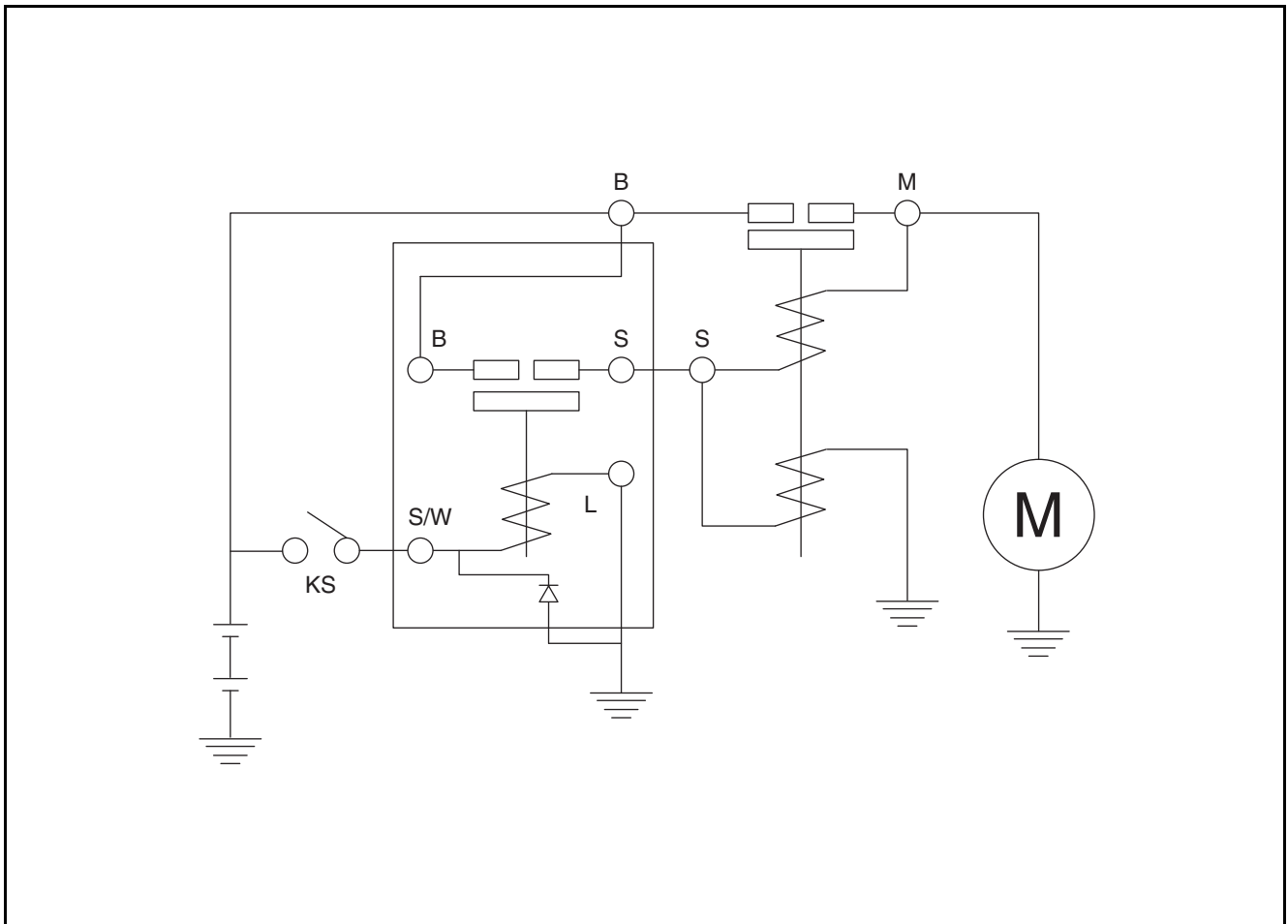


EDX08240073

CAUTION

The starter motor should always be protected from moisture.

Circuit Diagram



EDX08240087

⚠ CAUTION

Before working on any electrical system, disconnect the negative ('-') battery cable (ground cable). To prevent a short circuit, connect the ground cable only after work is complete.

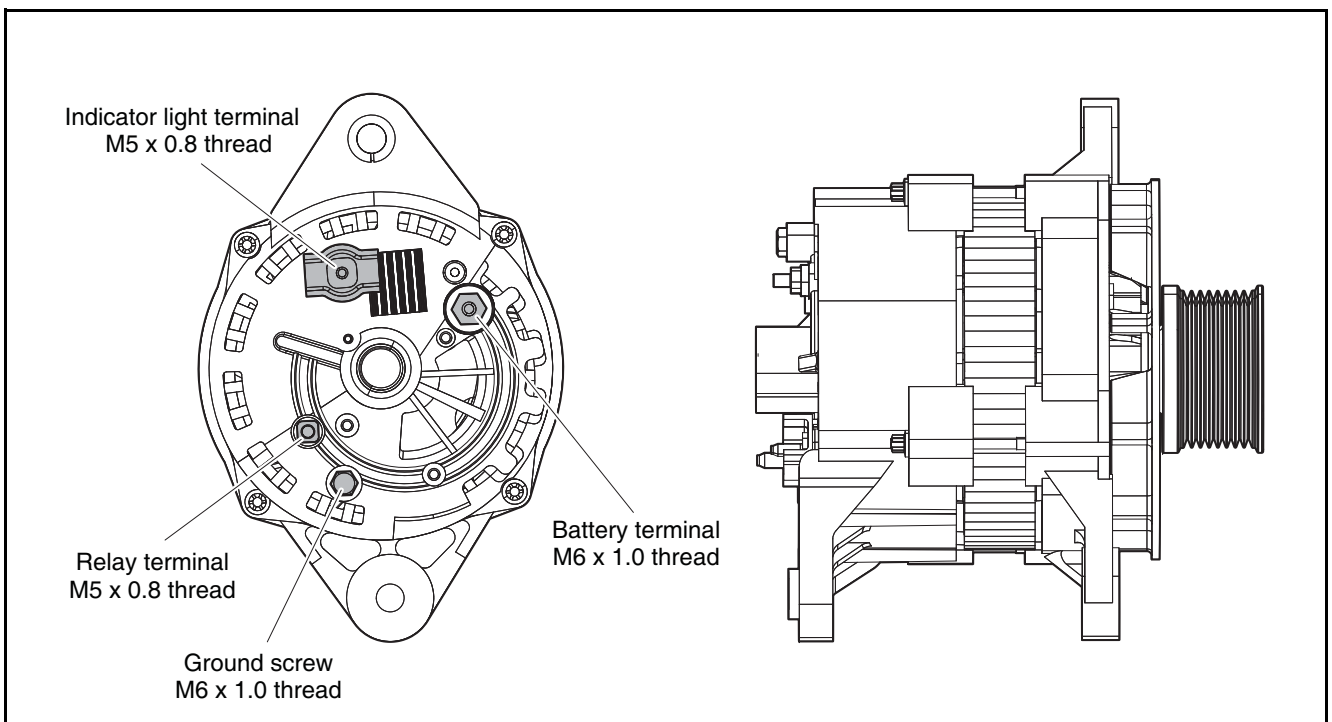
11. Electrical System

Alternator

General Information

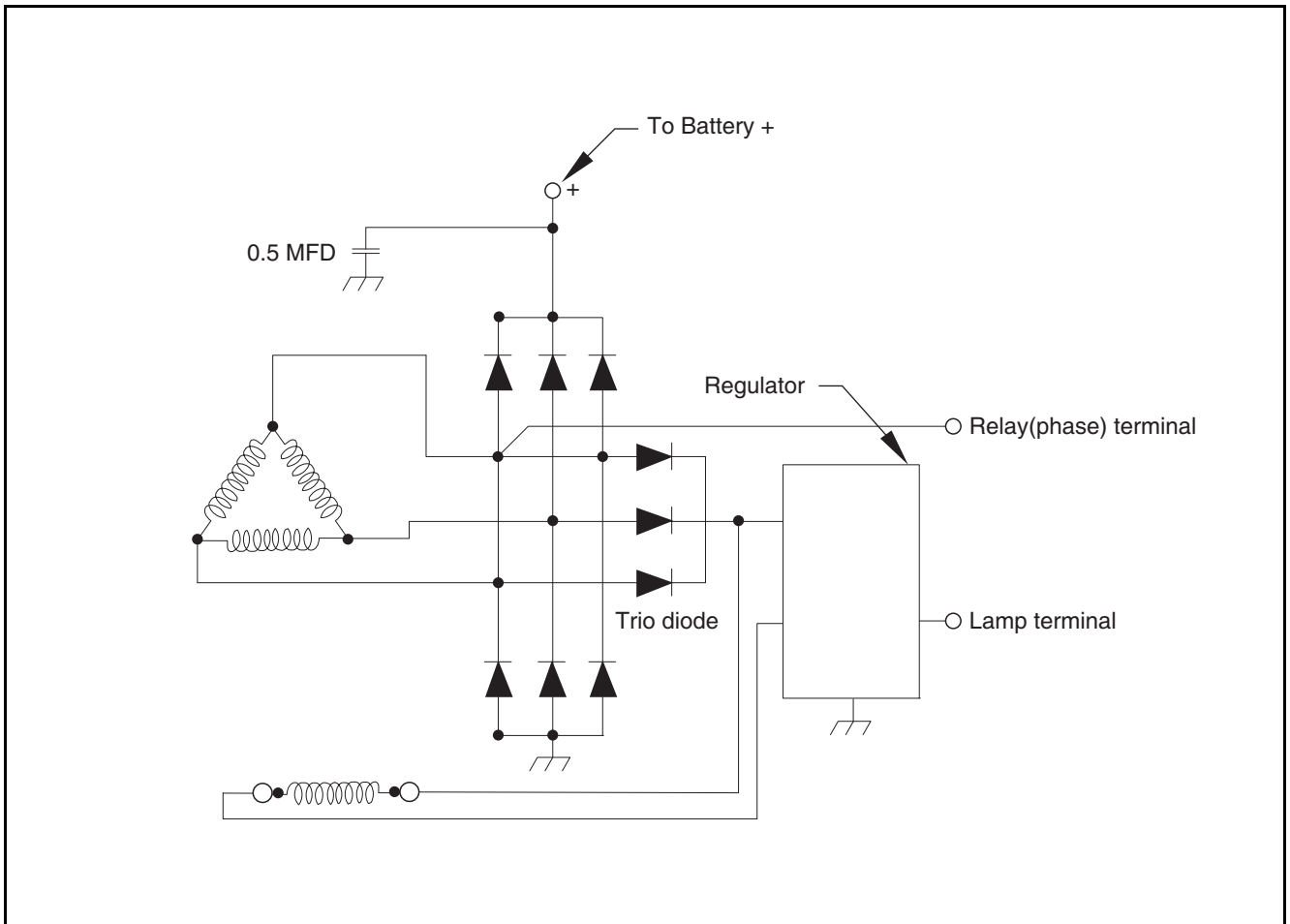
The alternator is fitted with integral silicon rectifiers. A transistorized regulator mounted on the alternator body interior limits the alternator voltage. The alternator should not be operated except with the regulator and battery connected in circuit to avoid damage to the rectifier and regulator.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

24 V x 80 A



EDX05250037

Wiring diagram



EDX05250038

11. Electrical System

12. Other/Driving System

General Information	195
General Information	195
Crankshaft	196
Inspecting the Crankshaft	196
Inspecting the Crankshaft Bearings and Connecting Rods	197
Pistons	199
Disassembling Pistons.....	199
Assembling Pistons.....	199
Inspecting Pistons.....	199
Inspecting the Piston Rings	200
Inspecting the Pistons and Piston Pins.....	200
Connecting Rods	201
Inspecting Connecting Rods.....	201
Miscellaneous	202
Engine Timing.....	202

General Information

General Information

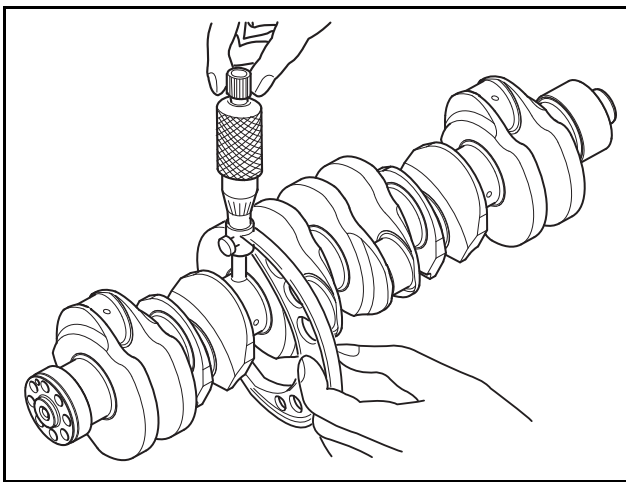
1. Engine pistons are cooled by an oil gallery. The shape of the gallery, the shape and position of the nozzles, and the oil flow rate are all very important factors in lowering the temperature of the piston oil gallery. The cross sectional shape of the piston gallery is designed to achieve maximum cooling effectiveness with efficient oil flow.
2. The crankshaft is a forged single unit. The crankshaft and rear oil seals are designed to prevent oil from entering the inside of the flywheel housing.
3. The connecting rod is a single unit. Its big end can be disconnected diagonally, allowing it to be removed along with the piston through the top of the cylinder. Prefabricated alloy bearings are used in the moving parts of the crankshaft and connecting rods.
4. The camshaft, oil pump, and high-pressure injection pump are driven by gear connections in the timing gear case.
5. The overhead valve is operated by the valve tappets, pushrods and rocker arms on the camshaft.

12. Other/Driving System

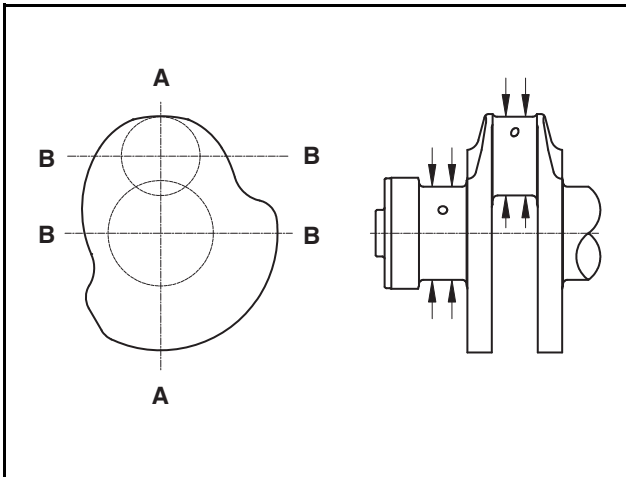
Crankshaft

Inspecting the Crankshaft

1. Inspecting for defects
 - 1) Check the journals and crank pins on the crankshaft visually for scratches or cracks.
 - 2) Perform the magnetic particle test or dye penetrant test (color check) to check the crankshaft for cracks. If any cracks are found, replace the crankshaft.
2. Measuring wear
 - 1) Use an O.D. micrometer to measure the journals and pins on the crankshaft in the direction shown in the figure in order to check the amount of wear.



EH6OM026



EH6OM033

- 2) If the amount of wear exceeds the allowable limit, polish the crankshaft and install an undersize bearing on it.
- 3) However, if the amount of wear is within the allowable limit, use an oily grindstone or fine sandpaper to polish the surface.

Note) Use sandpaper soaked in oil.

	Reference value	Allowable limit
Journal O.D.	Ø91.966 ~ Ø91.988 mm	Ø91.466 mm
Outside diameter of pin	Ø76.971 ~ Ø76.990 mm	Ø76.471 mm

- 4) If the pin wear exceeds the allowable limit, polish the crank journal and crank pin and use an undersize bearing.

Note) To polish the crankshaft, use sandpaper soaked into oil.

- 5) There are two types of undersize bearings which can be chosen according to the crankshaft and ground for use.

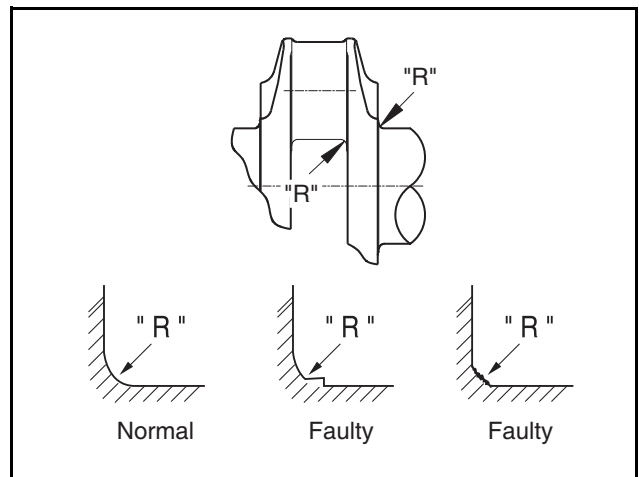
- Standard
- 0.25 (0.25 mm smaller than standard I.D.)
- 0.50 (0.50 mm smaller than standard I.D.)

- 6) Reference value for "R"

- "R" on the crank pin: $4.5^{+0}_{-0.2}$
- "R" on the crank journal: $4^{+0}_{-0.2}$

⚠ CAUTION

When grinding the crankshaft, make sure to grind part "R" on the end of the bearing precisely. There should not be any steps or burrs.



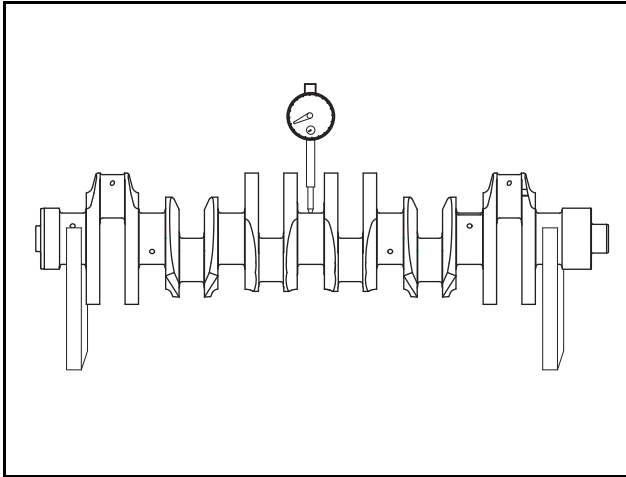
EH6OM034

12. Other/Driving System

3. Crankshaft deflection

- 1) Place the crankshaft on a V-block.
- 2) Set a dial gauge on a surface plate and roll the crankshaft to measure its deflection.

Reference value	Allowable limit
0.1 mm	0.15 mm or less

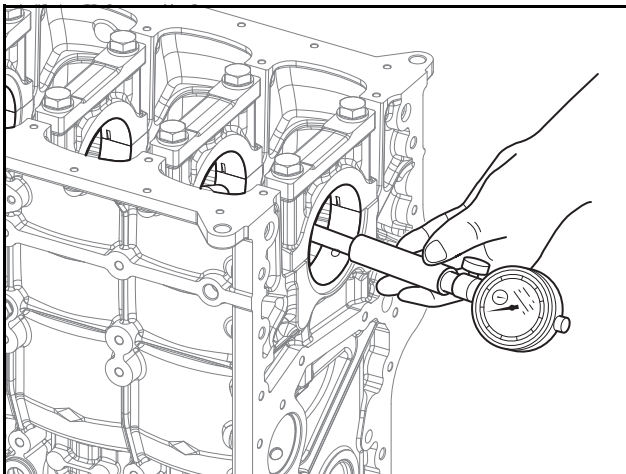


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Inspecting the Crankshaft Bearings and Connecting Rods

1. Visual check
 - 1) Check the crankshaft bearings and connecting rod bearings visually for scratches, abnormal wear or damage.
2. Oil clearance between the crankshaft and bearings (method no.1 : dial gauge)
 - 1) Main bearing clearance
 - a) Install the main bearings on the cylinder block and measure the inside diameter after tightening the bearing caps to the specified torque.

Torque	30 kgf.m
--------	----------



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- b) Compare the main bearing inside diameter with the crankshaft journal outside diameter to determine the oil clearance.

Main bearing oil clearance	
Reference value	Allowable limit
0.062 ~ 0.132 mm	0.16 mm

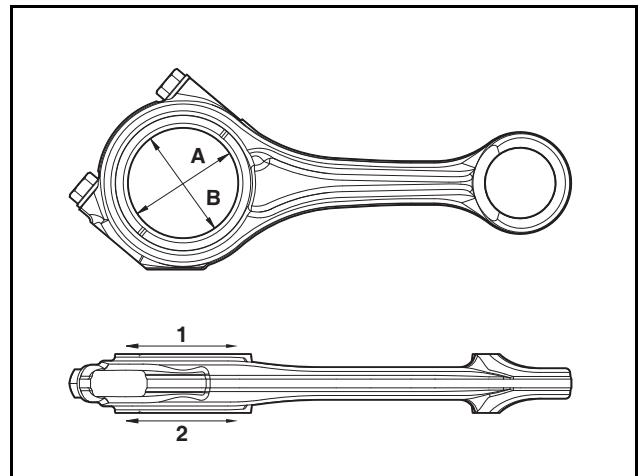
2) Connecting rod bearing clearance

- a) Install the connecting rod bearings in the connecting rod bearing caps, tighten the bolts to the specified tightening torque, and measure the inside diameter.

Torque	8.16 kgf.m + 120°
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CAUTION

Assemble the connecting rod bolts manually in the correct order until the connection on the bolt heads comes into contact with the bolt seat surfaces on both sides of the connecting rods. Then, use a torque wrench to perform a final tightening.

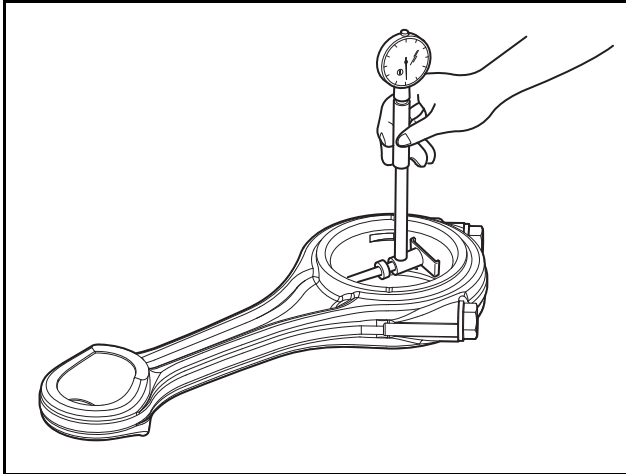


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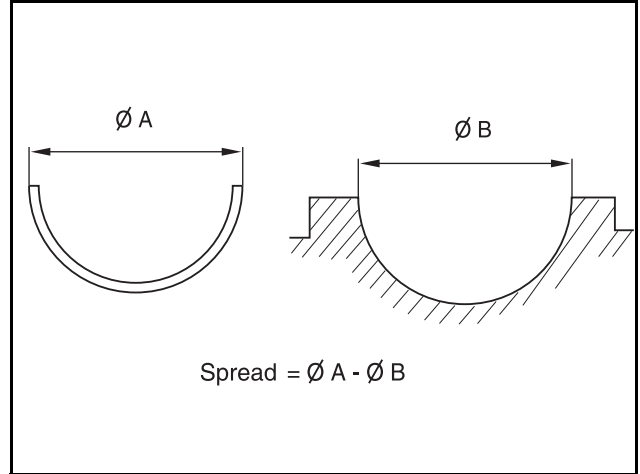
- b) Compare the two measured values of the connecting rod bearing inside diameter with the outside diameter of the crankshaft pin to determine the oil clearance.

Reference value	Allowable limit
0.04 ~ 0.107 mm	0.14 mm

12. Other/Driving System



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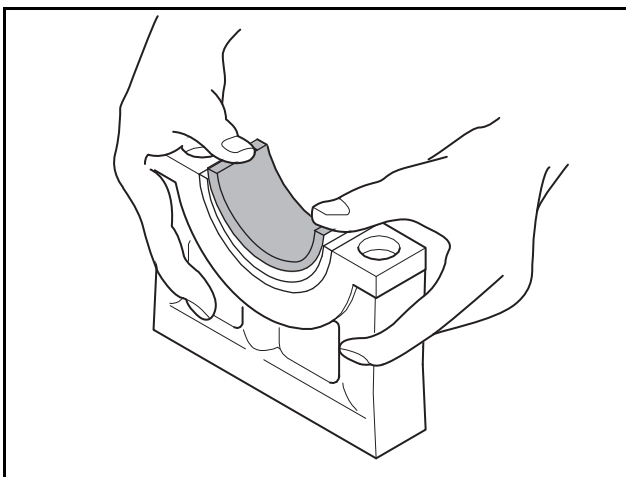


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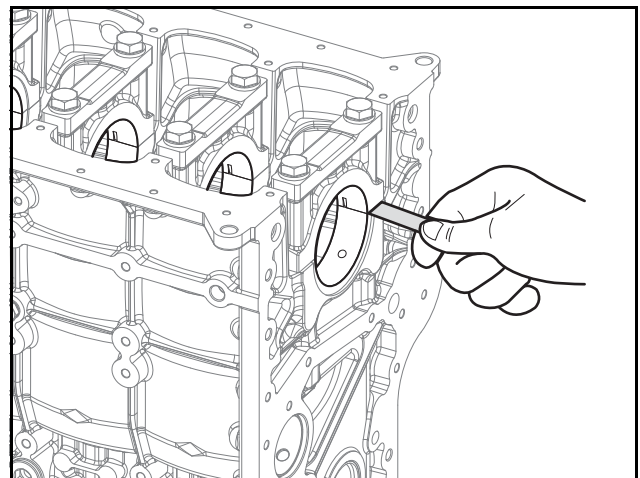
- c) If the clearance exceeds the allowable limit, grind the crankshaft journal and pin and use an undersize bearing.
3. Oil clearance between the crankshaft and bearings (method no.2 : plastigauge)
 - 1) Install the crankshaft on the cylinder block.
 - 2) Place a plastigauge on the crankshaft journal and pin.
 - 3) Install the bearing caps and tighten the bolts to the specified torque.
 - 4) Loosen the bolts and remove the bearing caps.
 - 5) Measure the thickness of the flat section of the plastigauge with a plastigauge measuring rule.
 - 6) This is the oil clearance.
4. Bearing spread and crush
 - 1) Checks
 - a) Check whether a considerable amount of pressure is felt with your finger when installing the bearing.

- 2) Bearing cap crush
 - a) Install the bearings and caps on the cylinder block.
 - b) Tighten the bolts to the specified tightening torque.
 - c) Loosen one of the bolts completely and use a feeler gauge to measure the clearance between the bearing caps and cylinder block.

Reference value	0.100 ~ 0.140 mm
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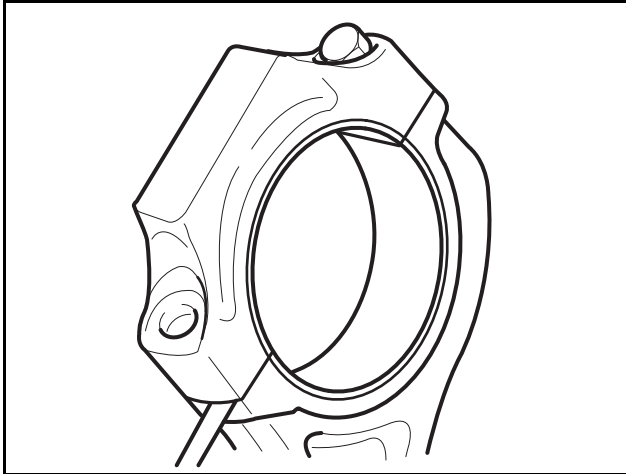
EH60M039



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- 3) Connecting rod bearing crush
 - a) Install the bearings and caps on the big ends of the connecting rods.
 - b) Tighten the bolts to the specified tightening torque.
 - c) Loosen one of the bolts completely and use a feeler gauge to measure the clearance between the bearing caps and connecting rod big ends.

Reference value	0.105 ~ 0.145 mm
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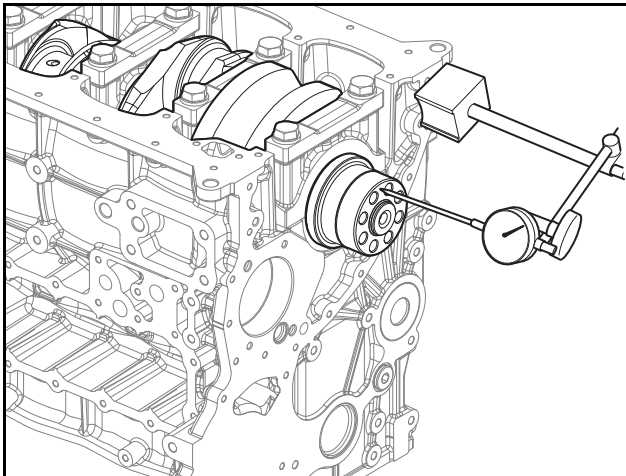


EA6M064I

4) Axial play of crankshaft

- a) Install the crankshaft on the cylinder block.
- b) Use a dial gauge to measure the axial play of the crankshaft.

Reference value	Allowable limit
0.100 ~ 0.300 mm	0.5 mm



EDX08240075

Pistons

Disassembling Pistons

1. Follow the piston disassembly procedure to disassemble the pistons.

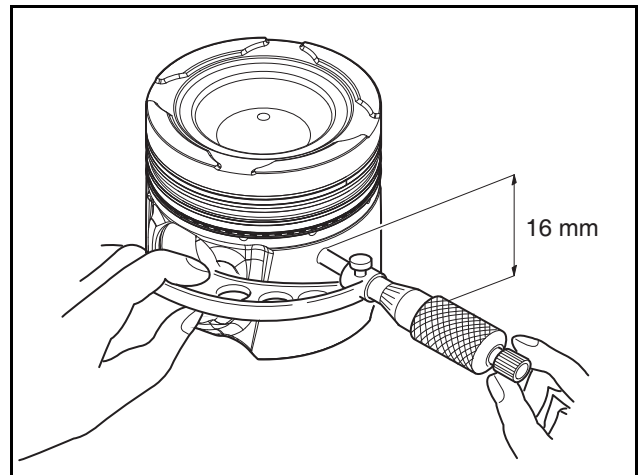
Assembling Pistons

1. Follow the piston assembly procedure to assemble the pistons.

Inspecting Pistons

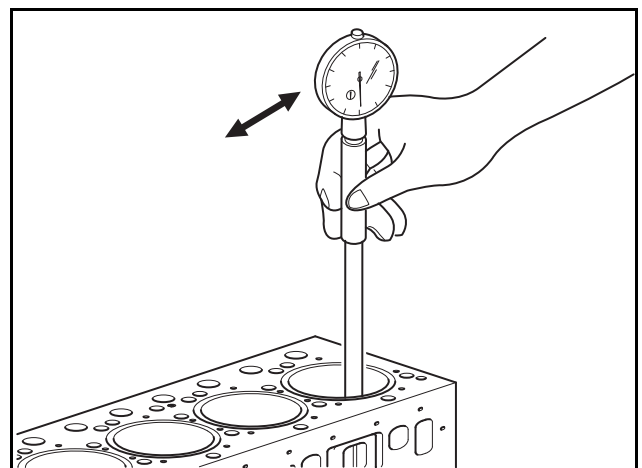
1. Visual check
 - 1) Check the pistons visually for cracks, scratches and wear.
 - 2) In particular, check whether the ring groove is worn.
2. Clearance between the piston and cylinder bore
 - 1) Use an O.D. micrometer to measure the outside diameter of the piston at the position 16 mm from the bottom of the piston at a right angle to the piston pin hole.

Reference value	$\varnothing 109.870 \pm 0.010$ mm
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EDX08240143

- 2) Use a cylinder I.D. gauge to measure the inside diameter of the cylinder bore.



EH6OM043

12. Other/Driving System

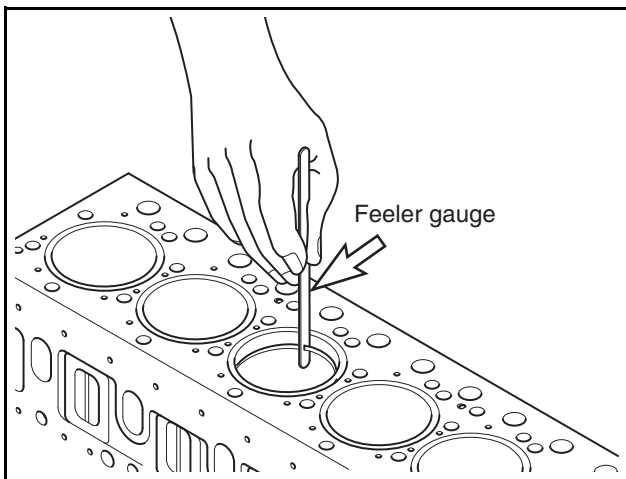
- 3) Measure the inside diameter at three locations of the cylinder bore in the 45° direction: the top ring contact section, middle section and oil ring contact section near the BDC.
- 4) Then, calculate the average value, excluding the minimum and maximum values.
- 5) The clearance is the piston O.D. subtracted from the cylinder bore I.D.
- 6) If this value exceeds the allowable limit, replace either the piston or cylinder bore, whichever is more worn.

Clearance between the piston and bore	
Reference value	0.120 ~ 0.140 mm

Inspecting the Piston Rings

1. Visual check
 - 1) If damage or wear on the piston ring is found while disassembling the engine, replace the ring with a new one.
2. Piston ring gap
 - 1) Insert the piston ring into the top of the cylinder bore so that it is set at the right angle to the cylinder bore wall.
 - 2) Measure the gap of the piston ring with a feeler gauge.

	Reference value	Allowable limit
Top ring	0.30 ~ 0.35 mm	0.7 mm
Second ring	1.0 ~ 1.15 mm	1.5 mm
Oil ring	0.25 ~ 0.45 mm	0.8 mm



EH6OM044

- 3) If the piston ring gap exceeds the allowable limit, replace the piston ring with a new one.

3. Piston ring side gap

- 1) Fit the compression ring and oil ring into the piston ring groove.
- 2) Use a feeler gauge to measure the side clearance of the ring.

	Reference value	Allowable limit
Top ring	0.072 ~ 0.122 mm	0.17 mm
Second ring	0.07 ~ 0.11 mm	0.16 mm
Oil ring	0.04 ~ 0.08 mm	0.13 mm

- 3) If the measured value exceeds the allowable limit, replace either the ring or the piston.

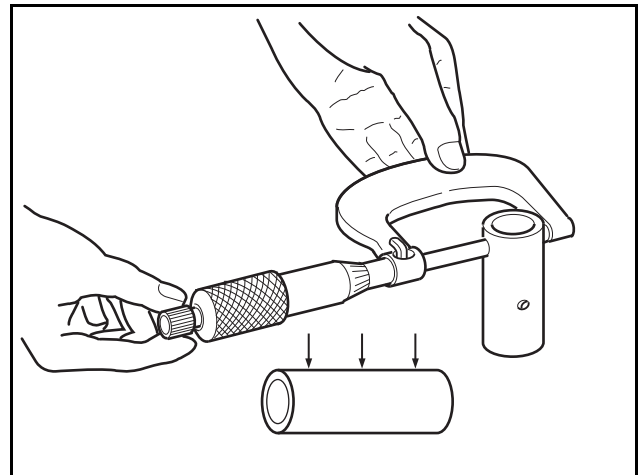
4. Piston ring tension

- 1) Measure the tension of the piston ring with a tension gauge.
- 2) If the measured value exceeds the allowable limit, replace the piston ring.

Item	Specified value
Top ring	15 ±3 N
Second ring	15 ±3 N
Oil ring	41.3 ±8.3 N

Inspecting the Pistons and Piston Pins

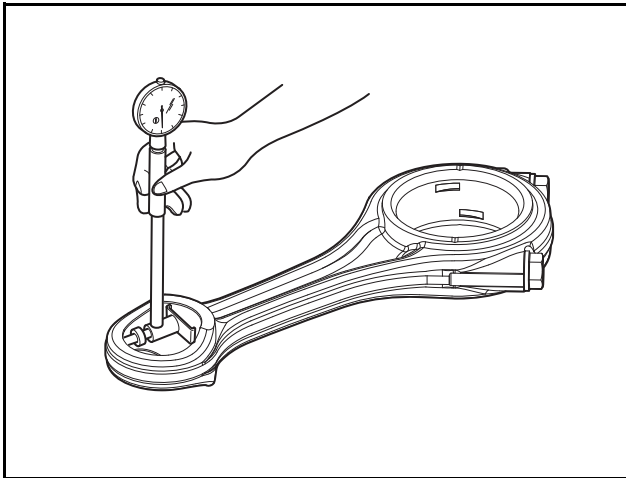
1. Measure the amount of wear on the piston pins; if the measured value exceeds the allowable limit, replace the pin.



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Piston pin reference value	Allowable limit
Ø47.994 ~ Ø48.000 mm	Ø47.94 mm

2. Measure the clearance between the piston pins and the connecting rod bushings.



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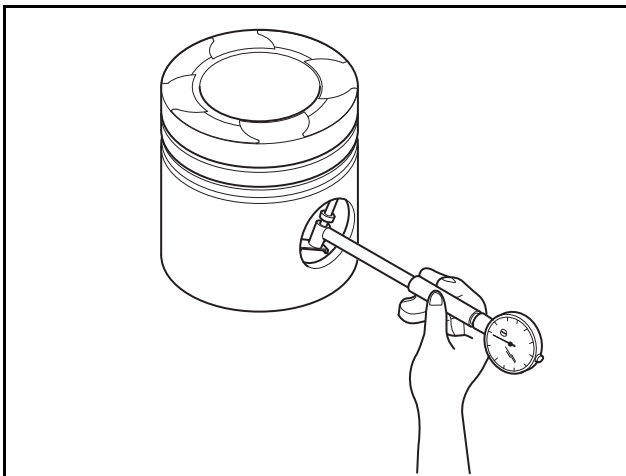
3. If the measured value exceeds the allowable limit, replace whichever part is more worn.

Reference value	Allowable limit
0.045 ~ 0.071 mm	0.12 mm

4. Check the mounting conditions of the piston and piston pin.

⚠ CAUTION

When replacing pistons, replace the piston pin as well.

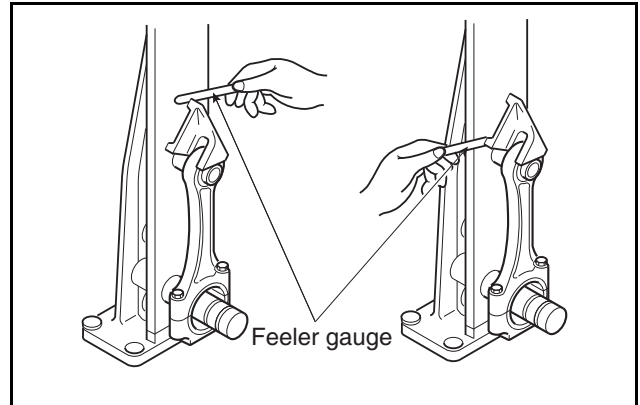


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Connecting Rods

Inspecting Connecting Rods

1. Warpage
 - 1) Check the connecting rod for distortion.
 - 2) Install the connecting rod on a connecting rod measuring device and use a feeler gauge to check for distortion.



EA0M4034

- 3) If the connecting rod is distorted, replace it with a new one.
2. Hole parallelism
 - 1) Measure the parallelism of the bushing groove at the small end and the bearing groove at the big end of the connecting rod.

Note) Use both a connecting rod measuring device and feeler gauge for this task.

Reference value	Allowable limit
0.02 mm	0.1 mm or less

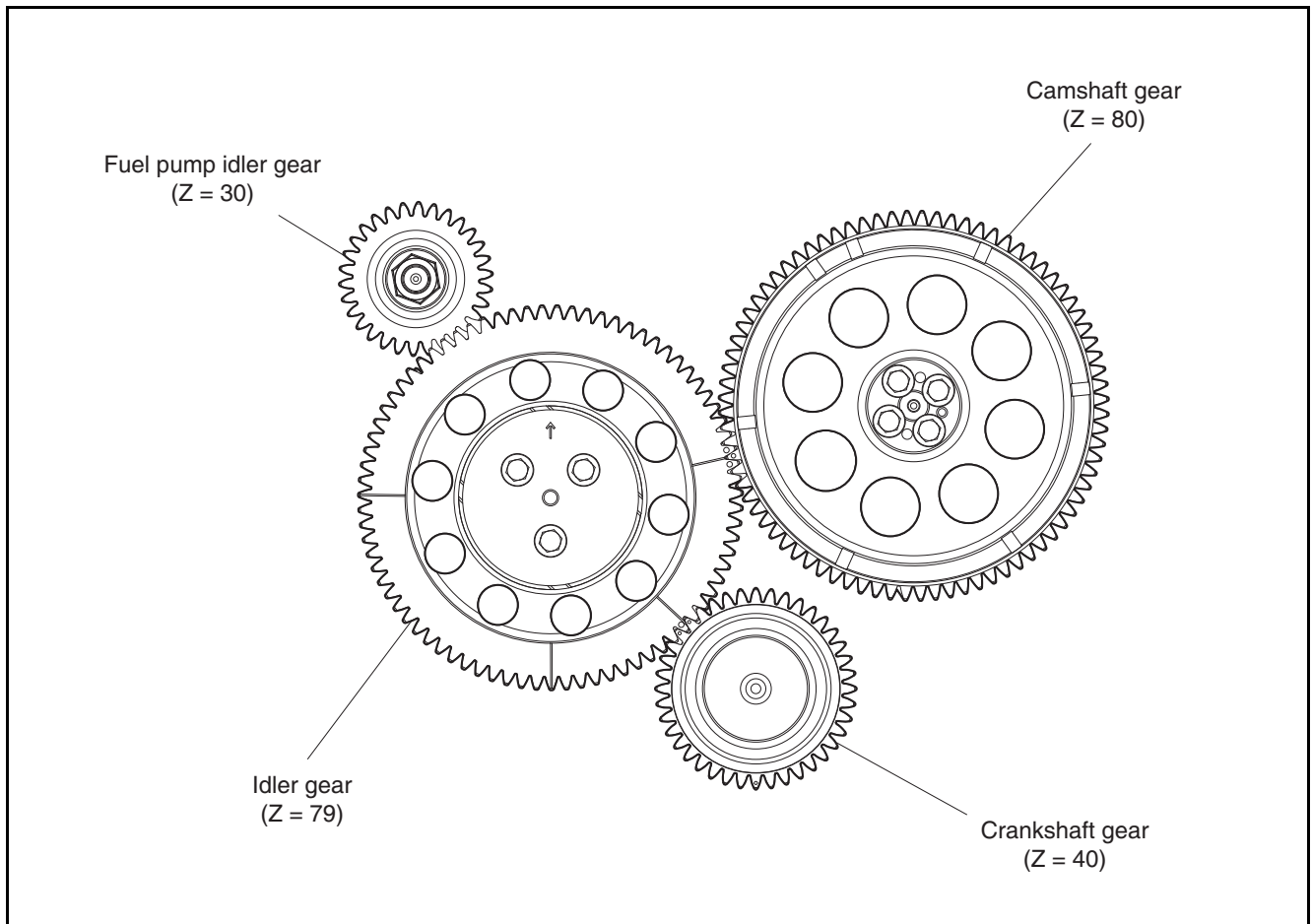
3. Wear
 - 1) Install the connecting rods on the crankshaft.
 - 2) Use a feeler gauge to measure the side clearance of the big end of the connecting rods.
 - 3) Install the connecting rods on the pistons.
 - 4) Measure the side clearance of the small end of the connecting rods.
 - 5) If the measurement exceeds the allowable limit, replace the connecting rod.

Specified value	Allowable limit
0.17 ~ 0.28 mm	0.50 mm

12. Other/Driving System

Miscellaneous

Engine Timing



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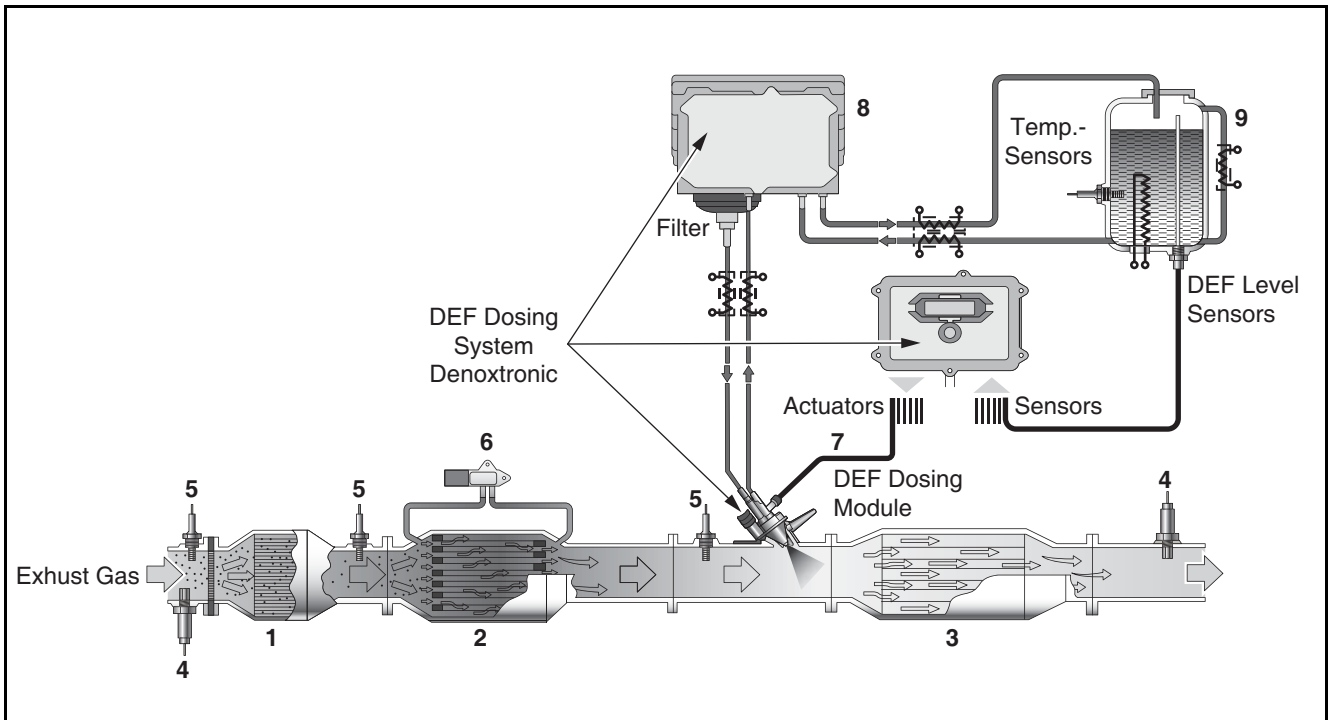
13. Aftertreatment System

Exhaust Gas Reduction System (LEP00/LEP01/LEP02/MFP00/MFP01/MFP02)	205
General instructions	205
Aftertreatment Muffler And Catalyst.....	206
DNOX System.....	207
DEF Tank.....	208
Supply Module	209
Dosing Module	210
Replacing the DEF Filter.....	211
Components of the DNOX System	213
Inspecting the DNOX System for Faults	213
DEF (Diesel Exhaust Fluid, Urea).....	215
Diesel Oxidation Catalyst (DOC)	216
Diesel Particulate Filter (DPF)	217
Removing, Assembling and Disassembling the DPF Muffler Assembly	222
Emission Sensors	222
Cautions for Handling the DPF Assembly.....	223

Exhaust Gas Reduction System (LEP00/LEP01/LEP02/MFP00/MFP01/MFP02)

General instructions

HD Construction Equipment engines are designed to satisfy Stage V emissions regulations using DOC (Diesel Oxidation Catalyst), DPF (Diesel Particulate Filter), and SCR (Selective Catalytic Reduction) systems. HD Construction Equipment SCR system consists of a dosing module, supply module, ECU (Engine Control Unit), and various other components. In the SCR system, DEF (Diesel Exhaust Fluid, urea) is stored in the DEF tank before being pressurized by the supply module and supplied to the dosing module at a constant pressure. The dosing module is installed on the muffler in the aftertreatment system and injects DEF into a mixer located upstream of the SCR.



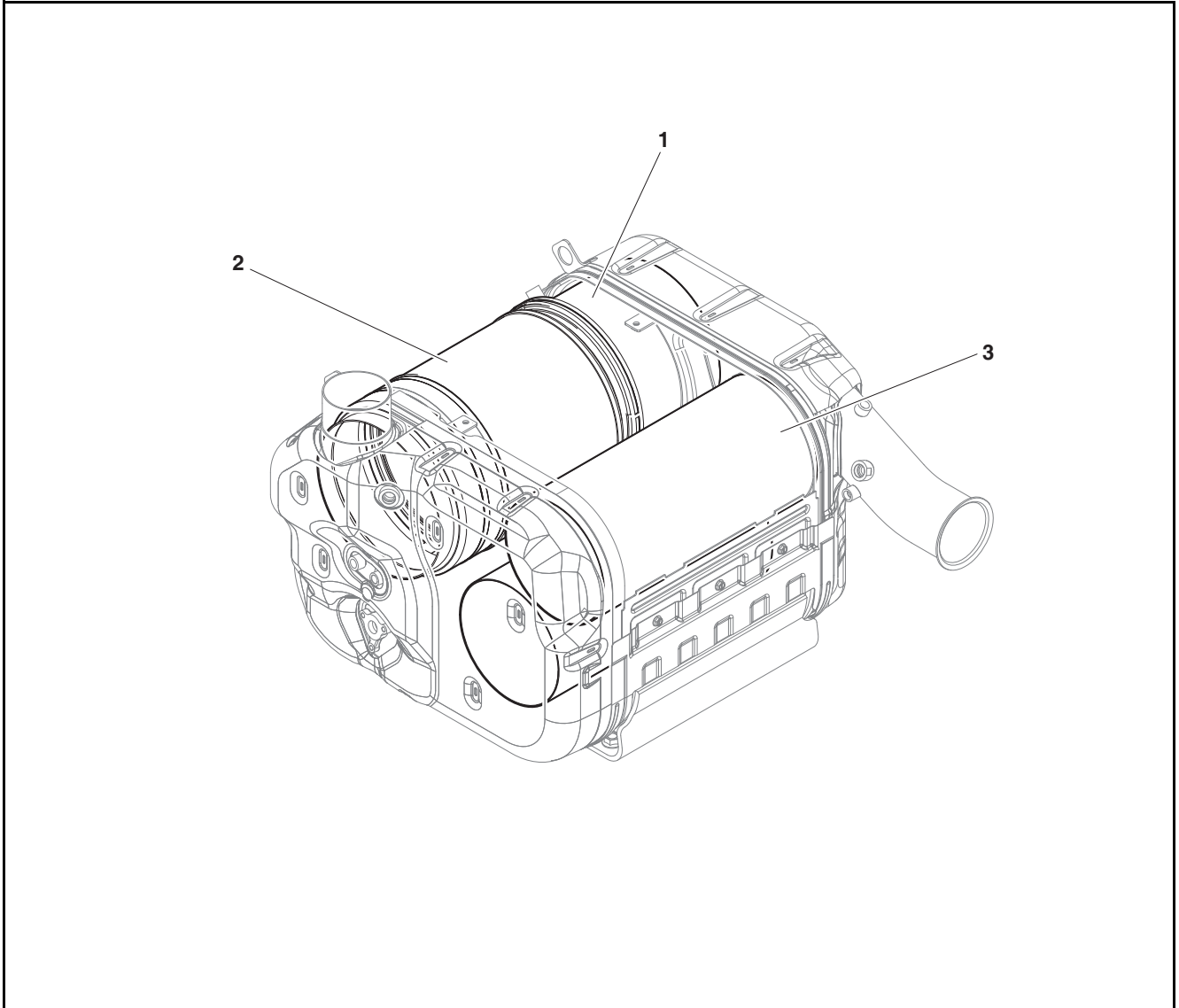
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No.	Part Name	Quantity
1	Diesel Oxidation Catalyst	1
2	Diesel Particulate Filter	1
3	SCR/AOC	1
4	NOx Sensor	2
5	Temp. Sensor	3
6	DPF Delta P Sensor	1
7	Dosing Module	1
8	Supply Module	1
9	DEF Tank	1

13. Aftertreatment System

Aftertreatment Muffler And Catalyst

The aftertreatment muffler consists of a DOC muffler, DPF muffler, mixer, and SCR muffler. The DOC muffler contains a diesel oxidation catalyst (DOC), while the DPF muffler contains a diesel particulate filter (DPF) and the SCR muffler contains a selective catalytic reduction (SCR) device.



EDX08240077

1. DOC

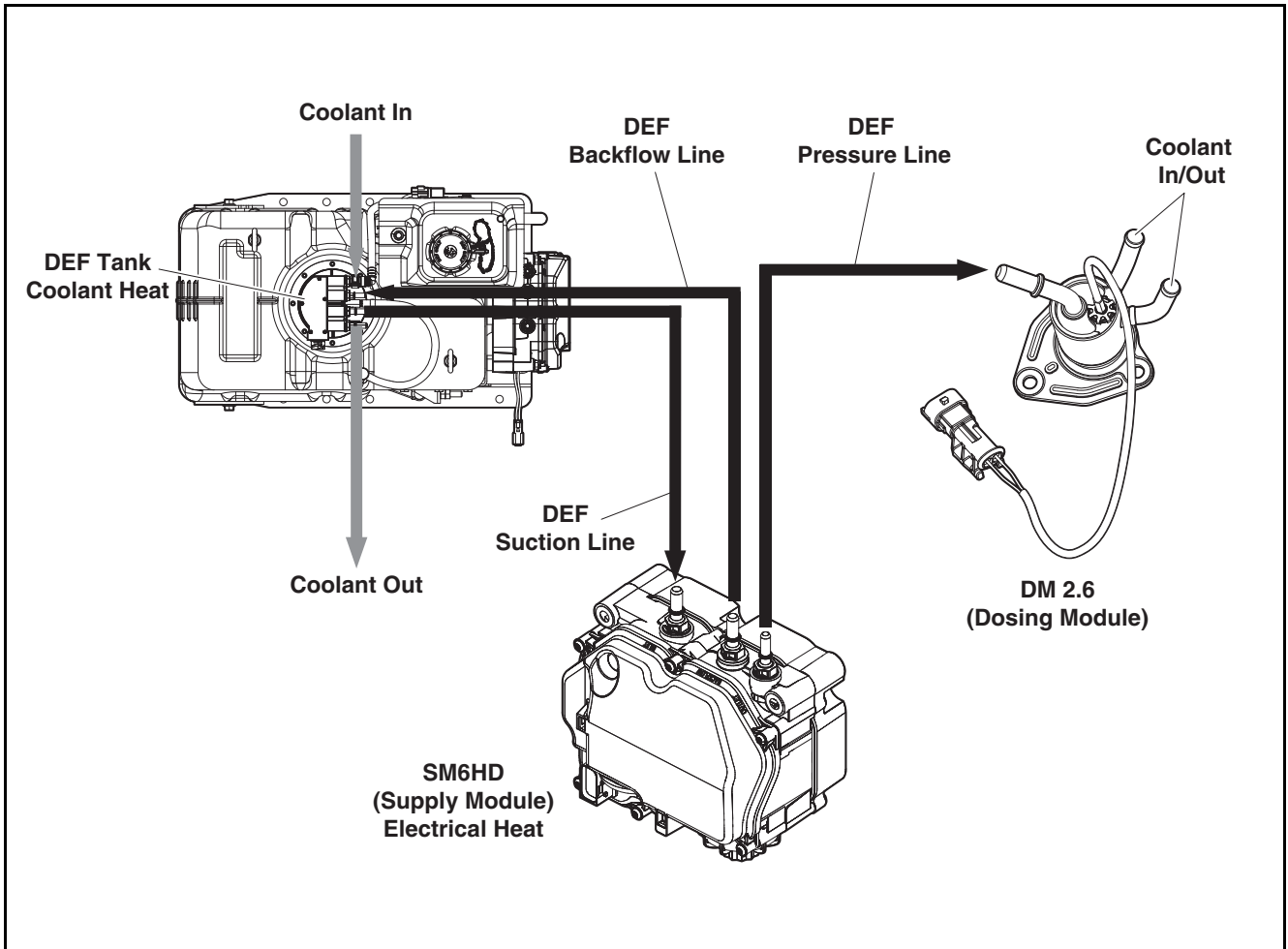
2. DPF

3. SCR

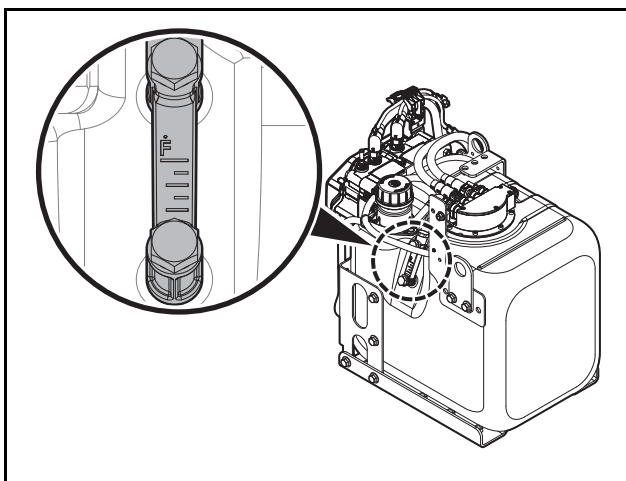
13. Aftertreatment System

DNOX System

The DNOX System injects DEF (Diesel Exhaust Fluid, urea) into the SCR catalyst to reduce NOx (nitrogen oxide) emissions. The system consists of a supply module acting as a pump, a dosing module which injects DEF, an ECU which controls the entire system, a DEF tank for storing DEF, and DEF/coolant lines.



EDX08240078



EDM03210136

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

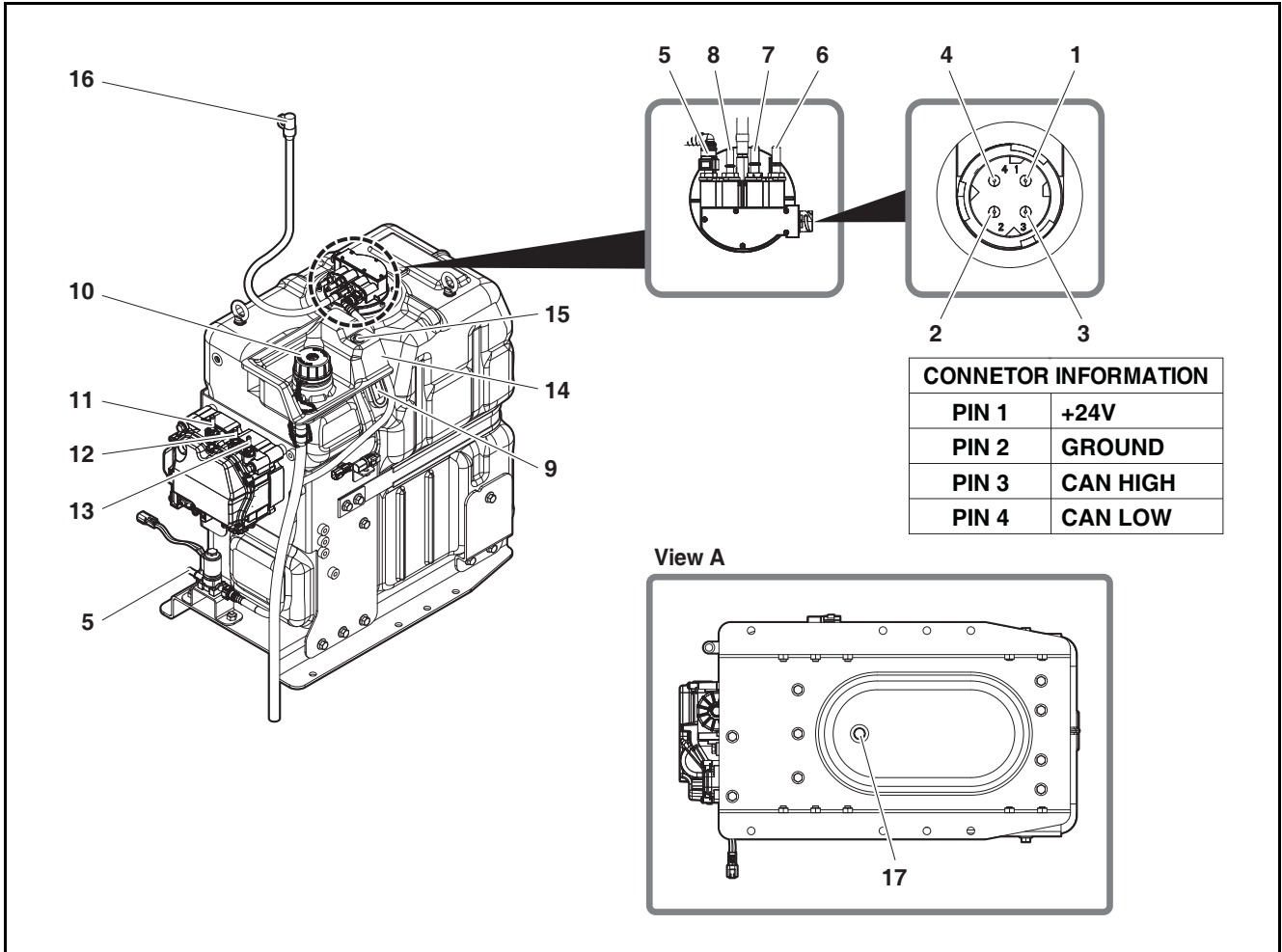
⚠ CAUTION

DEF (Urea) should not exceed the "F" line of the level indicator attached to the DEF TANK.
(Reference for models that HD Construction Equipment supplies DEF TANK.)

13. Aftertreatment System

DEF Tank

The DEF tank is used to store DEF (urea). Be sure to install connecting lines in their designated positions. Take care not to apply any excessive force or shocks to the DEF tank.

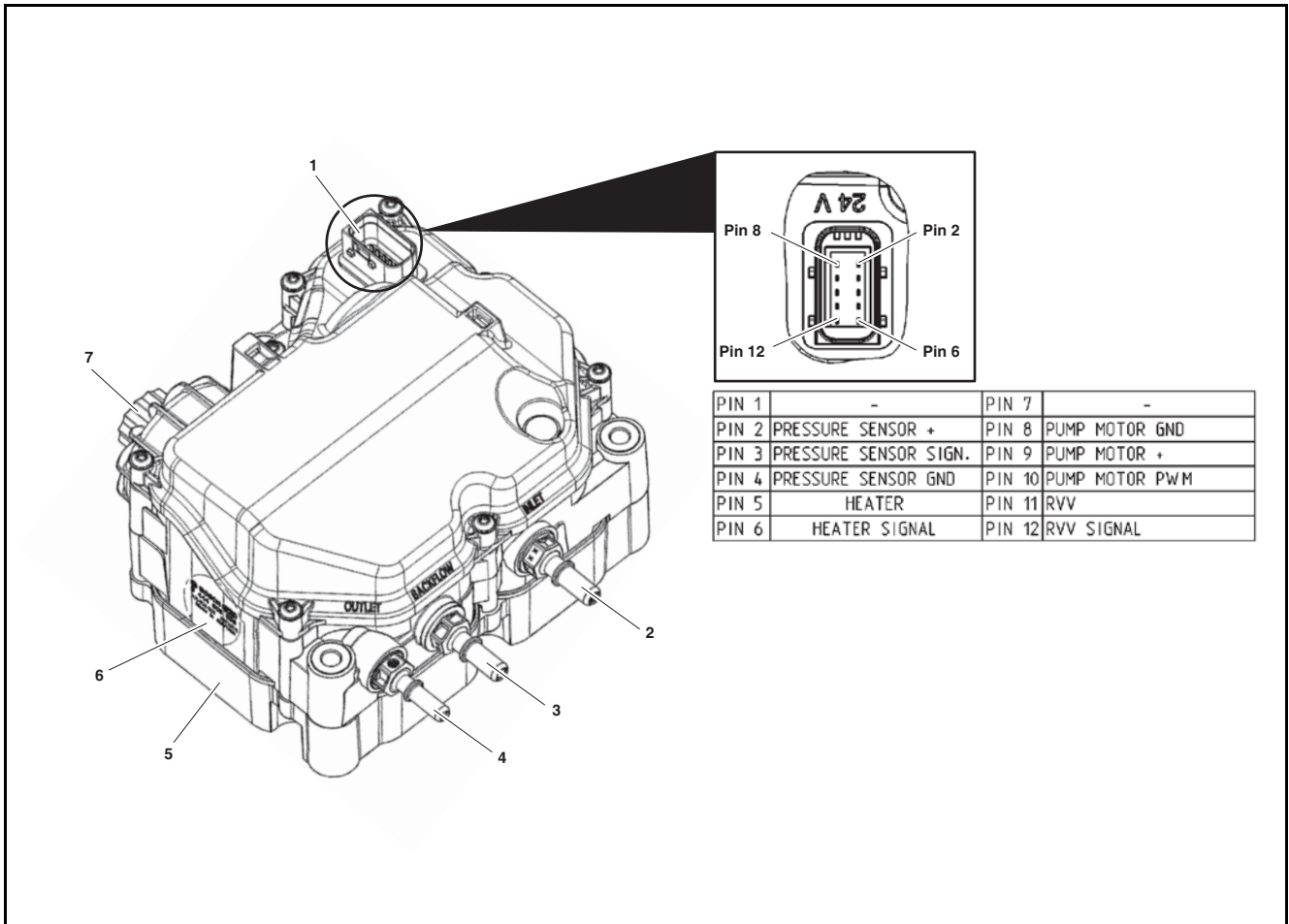


EDX08240079

- | | | |
|------------------------|--------------------|--|
| 1. +24V (Pin No.1) | 7. DEF outlet | 13. Pressure line |
| 2. Ground (Pin No.2) | 8. DEF inlet | 14. Cap gutter (support for preventing overflow) |
| 3. CAN HIGH (Pin No.3) | 9. Level indicator | 15. LED lamp (indicates full tank) |
| 4. CAN LOW (Pin No.4) | 10. DEF tank cap | 16. Breather filter |
| 5. Coolant inlet | 11. Suction line | 17. Drain plug |
| 6. Coolant outlet | 12. Back flow | |

Supply Module

The supply module is a device which pressurizes DEF in the DEF tank to a constant pressure and delivers it to the dosing module.



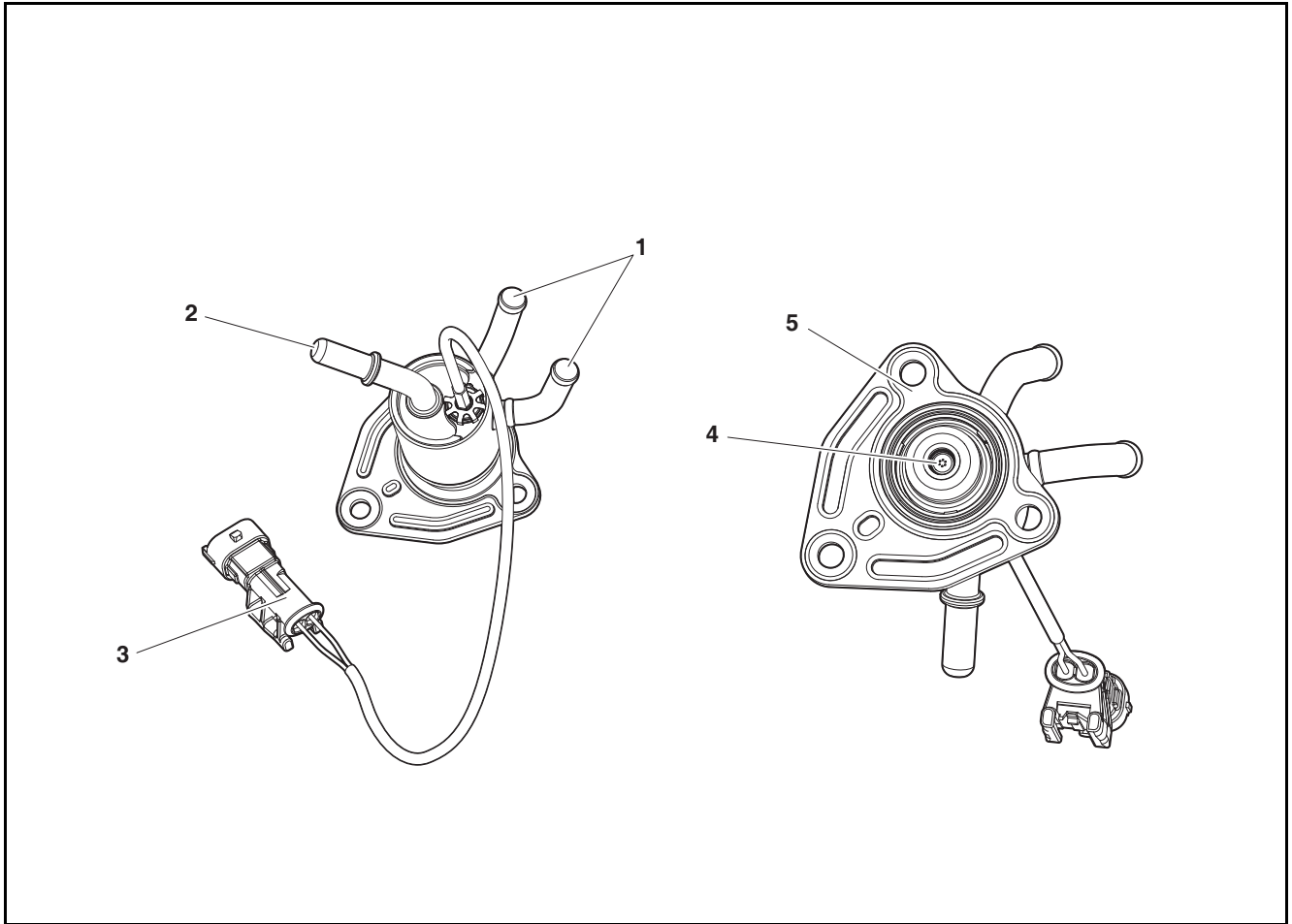
EK00303A

- | | |
|-------------------------|---------------------|
| 1. Connector | 5. Cover plate |
| 2. DEF inlet | 6. Detailed display |
| 3. DEF back flow outlet | 7. Filter cover |
| 4. DEF outlet | |

13. Aftertreatment System

Dosing Module

Installed on the mixer located upstream of the SCR, the dosing module is a device which injects DEF supplied by the supply module into the mixer.



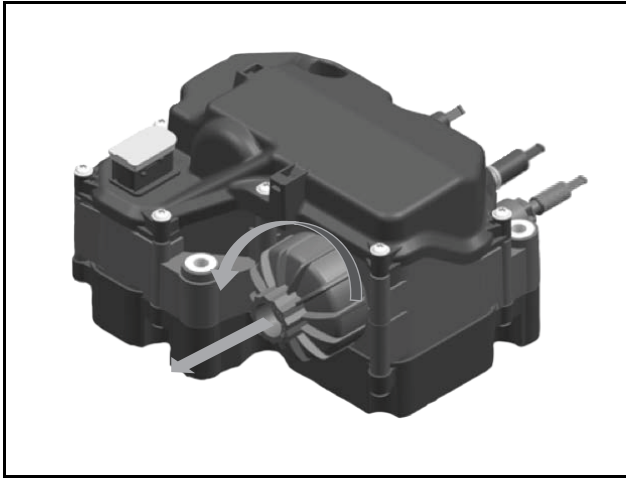
EDL08190057

- | | |
|-------------------------|---------------|
| 1. Coolant inlet/outlet | 4. DEF outlet |
| 2. DEF inlet | 5. Flange |
| 3. Connector | |

13. Aftertreatment System

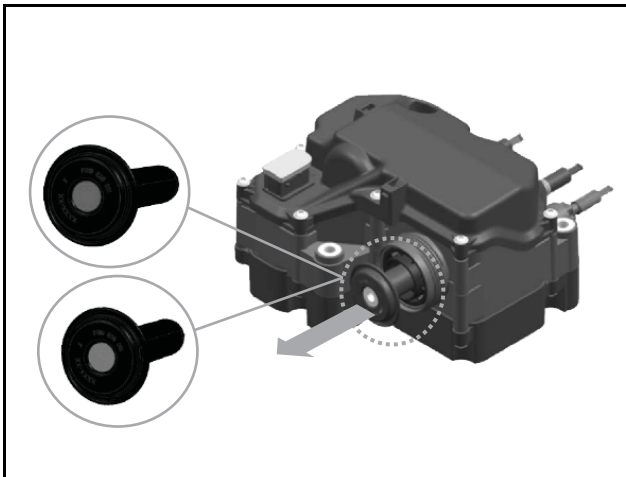
Replacing the DEF Filter

1. Unscrew the filter cover.



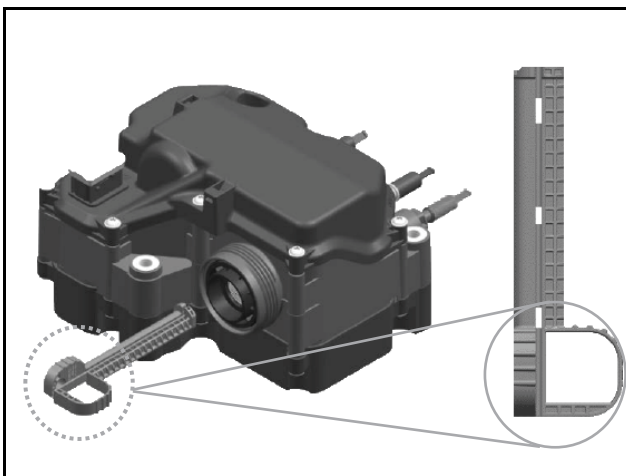
EDX08240146

2. Remove of the equalizing element. If its central part is black, the correct spare kit is 1457436088. However, if it is red, the correct number is 1457436057.



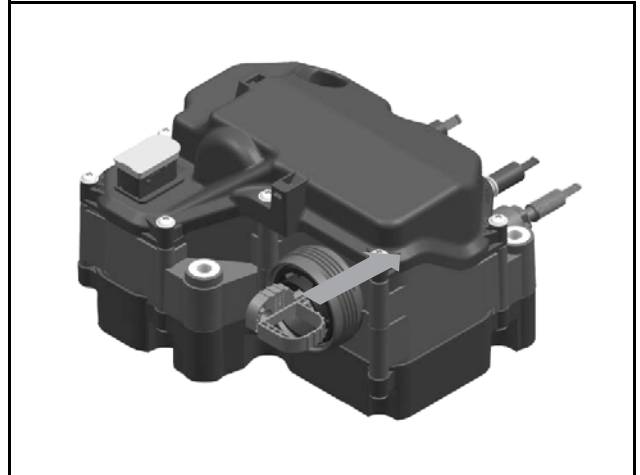
EDX08240147

3. Place the extraction tool into the insertion position. For correct operation, bend the hinge before tool insertion until its inner sides get in touch.



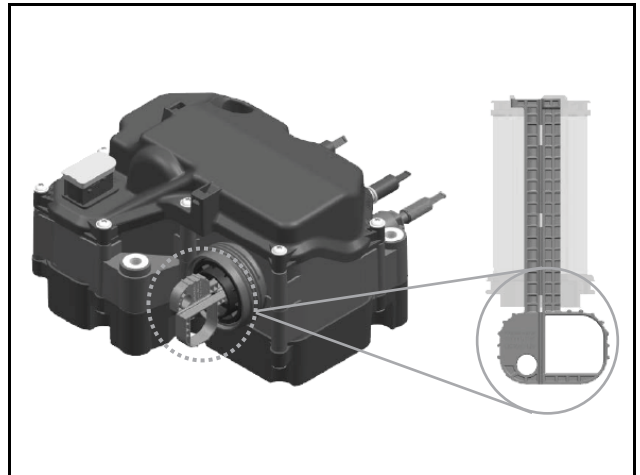
EDX08240148

4. Introduce the extraction tool until it is completely inserted.



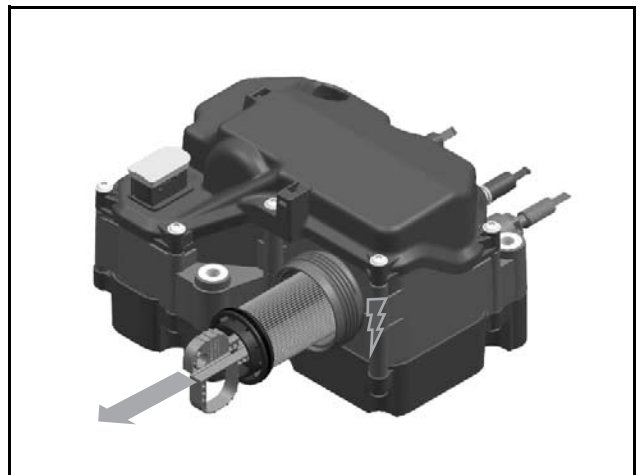
EDX08240149

5. Press one side of the extraction tool to place it into the extraction position.



EDX08240150

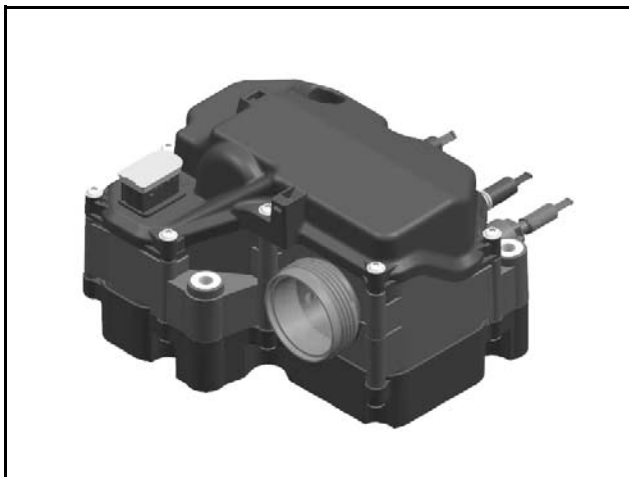
6. Pull out the filter with the tool. To avoid damages do not use the housing surface as supporting.



EDX08240151

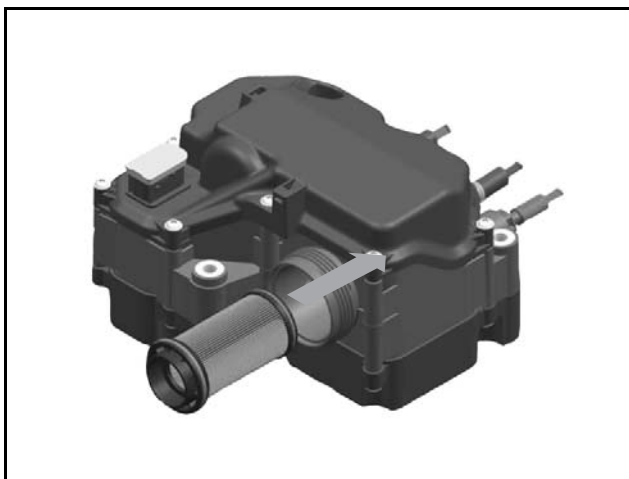
13. Aftertreatment System

7. Functional surfaces must be cleaned only with water.



EDX08240152

8. Oil the O-Rings and assembly new filter.

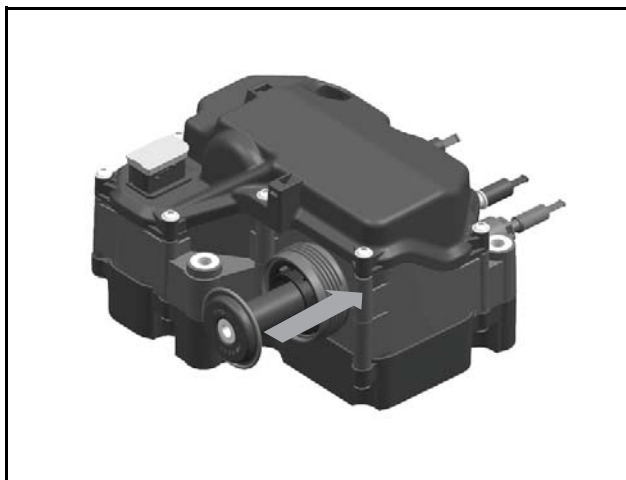


EDX08240153

CAUTION

RB recommended oil is Mobil Velocite No.6. Other lubricants may be used but at the customers' own risk.

9. Oil the sealing profile and assembly the new equalizing element.

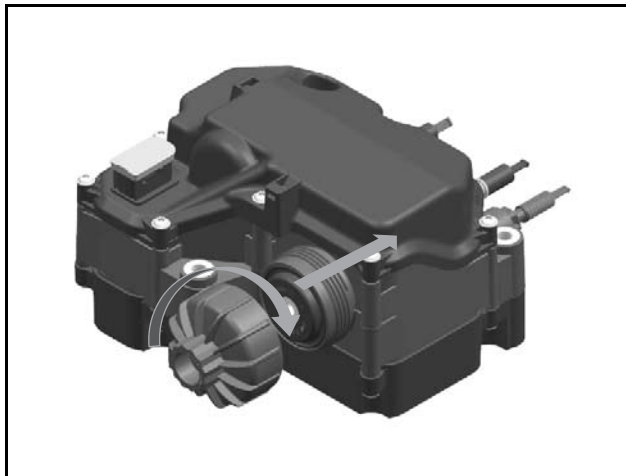


EDX08240154

CAUTION

RB recommended oil is Mobil Velocite No.6. Other lubricants may be used but at the customers' own risk.

10. Assembly of the filter cover with 20 N.m + 5 N.m.
Functional surfaces in filter cover must be cleaned previously only with water.

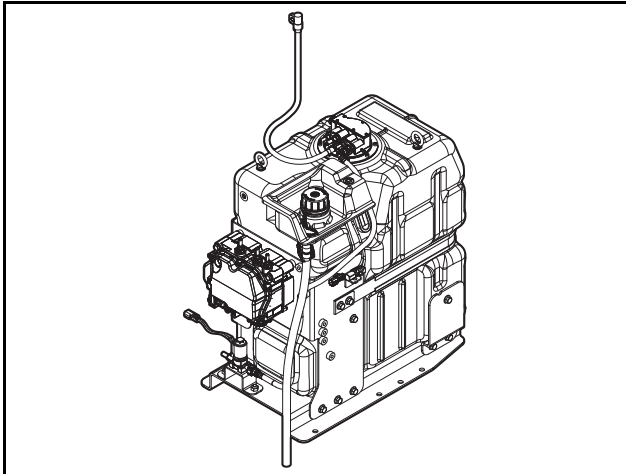


EDX08240155

Components of the DNOX System

1. The components of the DNOX system are installed throughout the vehicle where they are most essential. Each part is designed to be protected from damage due to the surroundings.

Note) The DEF tank and supply module are both installed in the same cabin.

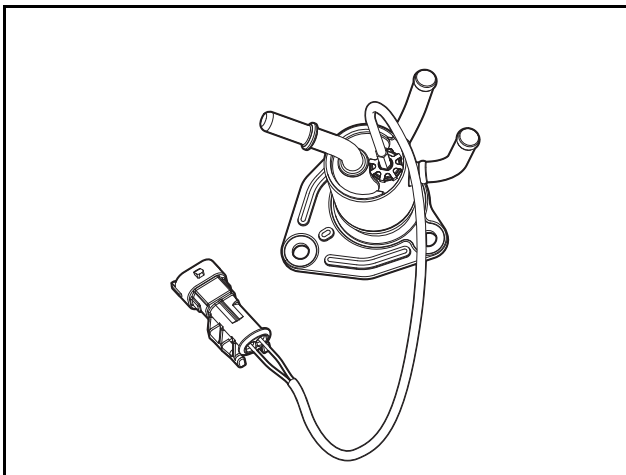


EDX08240080

2. The dosing module (DM) is mounted on the mixer between the DPF and SCR. It is connected both to a DEF line passing through the SM and an engine coolant line, as well as to the connector of pin no.2 which controls the DEF dosing valve.

Inspecting the DNOX System for Faults

1. Dosing Module
Dosing module malfunctions may be caused by the tip of the DEF injection nozzle being exposed to high temperatures, a faulty connection in the electrical harness, or a damaged or improperly connected DEF hose line.
The following DM fault inspection items can be checked visually.



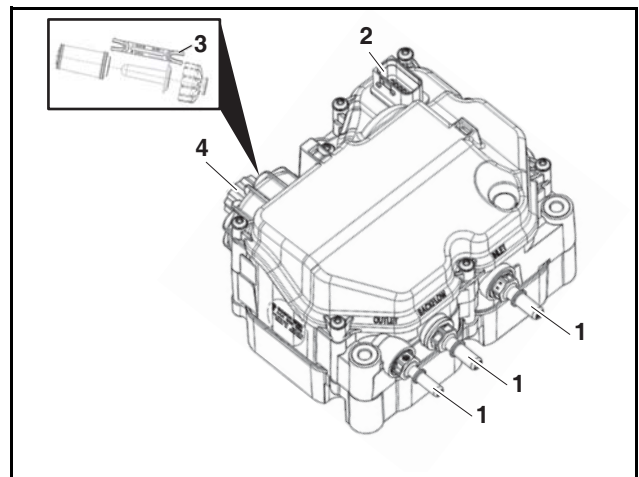
EDL08190052

- 1) Air leak due to insufficiently tightened bolt or DM and bolt damaged due to overtightened bolt during replacement or installation of DM.
- 2) Improperly installed electrical connector or connector contaminated by foreign matter.
- 3) DEF leak due to improperly connected DEF line.
- 4) Coolant leak due to improperly connected coolant line or DM exposed to high temperatures due to disconnected coolant line.
- 5) DM exposed to high temperatures due to improperly installed gasket.
- 6) DEF leak due to reuse of gasket.

2. Supply Module

Supply module (SM) fault modes may be caused by damaged or improperly connected DEF lines and electrical connectors.

Faults may occur due to incorrect installation during regular replacements of the main urea filter.



EK00344A

⚠ CAUTION

When replacing a filter, remove the packaging on the new filter immediately before performing the replacement.

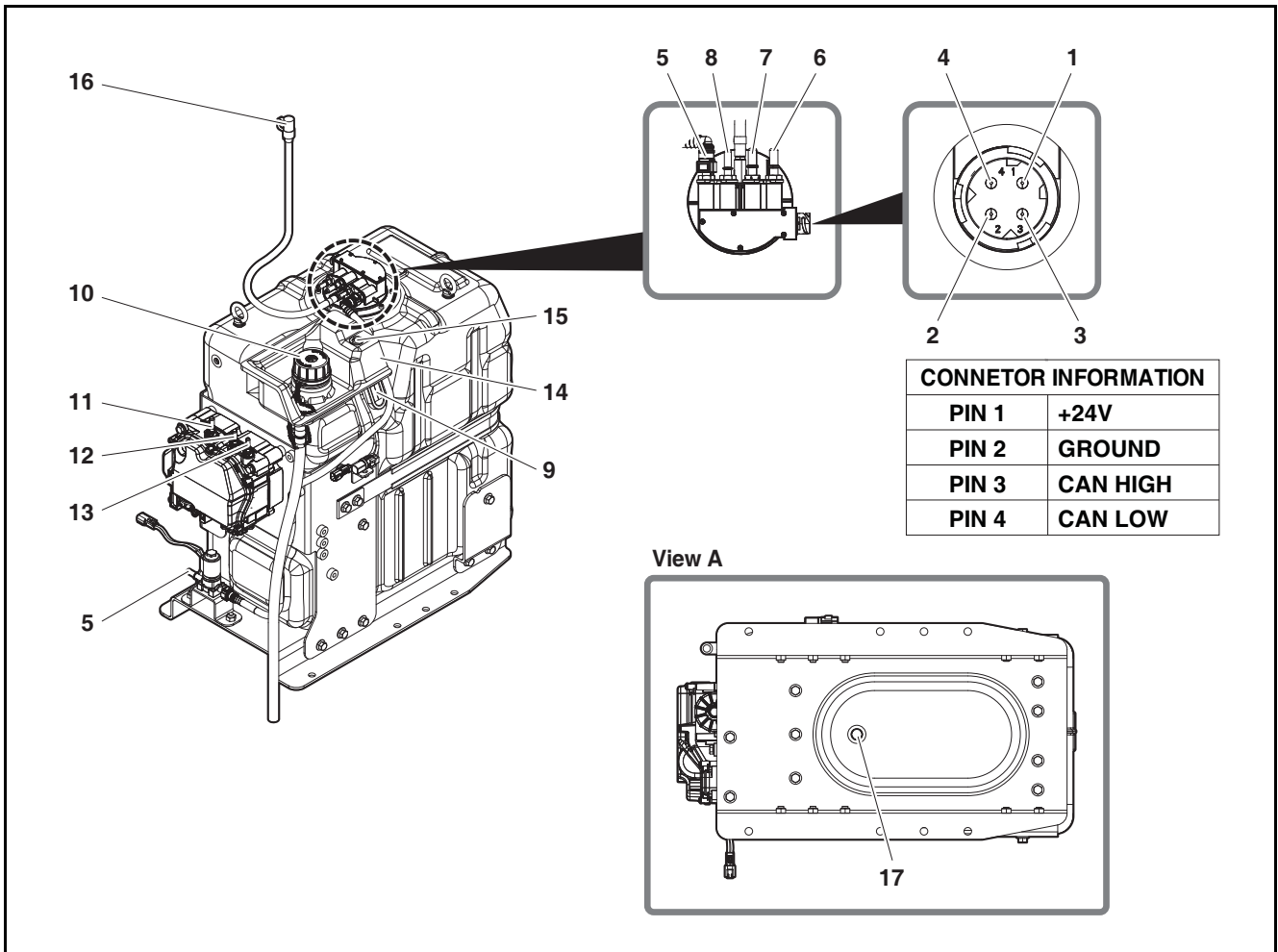
- 1) Fault due to improper assembly or improperly connected line while connecting DEF lines.
- 2) Improperly installed electrical connector or connector contaminated by foreign matter.
- 3) Filter damaged due to use of improper tools during replacement of SM filter or residue build-up in SM filter.
- 4) Cap damaged by overtightening of DEF cap during replacement of filter or filter loose due to incorrect installation.

13. Aftertreatment System

3. DEF Tank

The DEF tank is used to store DEF (urea).

Be sure to install connecting lines in their designated positions. Take care not to apply any excessive force or shocks to the DEF tank.



EDX08240079

1) Do not mix up the DEF inlet hose and back flow hose. To install connectors, insert them until a click is heard, taking care not to damage the connectors.

CAUTION

The DEF inlet hose is shown in red, whereas the back flow hose is shown in yellow.

- 2) Check whether the DEF tank mounting bracket has been tightened. Failing to tighten it may lead to damage due to vibrations.
- 3) Check the tank temperature and the connection of the level sensor connector, taking care to avoid damaging or contaminating the connector with foreign matter.
- 4) Coolant lines must be installed in their proper positions. Failing to tighten coolant lines may cause coolant leakage.

5) Check the connection of the DEF line heater (2-PIN). There is a risk of freezing and bursting in winter if the heater is not working.

4. Muffler and other pipes
There is no need to replace, remove, or change the position of the installed muffler and various pipes except in the event of a fault or problem due to external factors. When replacing or removing them due to a fault or problem, be sure to tighten each part to its specified tightening torque in order to prevent air leaks.

13. Aftertreatment System

DEF (Diesel Exhaust Fluid, Urea)

Component	Unit	Range		Test Method
		Minimum	max	
Urea concentration ^a	% (m/m) ^b	31.8	33.2	ISO 22241-2 Annex B ^c ISO 22241-2 Annex C ^c
Density (at 20°C ^d)	kg/m ³	-	1,093	ISO 3675 or ISO 12185
Deflection (at 20°C ^e)	-	-	1.3843	ISO 22241 2 Annex C
Ammonia alkaline	% (m/m) ^b	-	0.2	ISO 22241 2 Annex D
Biuret	% (m/m) ^b	-	0.3	ISO 22241 2 Annex E
Aldehydes	mg/kg	-	5	ISO 22241 2 Annex F
Insoluble matter	mg/kg	-	20	ISO 22241 2 Annex G
Phosphate (PO ₄)	mg/kg	-	0.5	ISO 22241 2 Annex H
Calcium	mg/kg	-	0.5	ISO 22241 2 Annex I
Iron	mg/kg	-	0.5	
Copper	mg/kg	-	0.2	
Zinc	mg/kg	-	0.2	
Chrome	mg/kg	-	0.2	
Nickel	mg/kg	-	0.2	
Aluminium	mg/kg	-	0.5	
Magnesium	mg/kg	-	0.5	
Sodium	mg/kg	-	0.5	
Potassium	mg/kg	-	0.5	
Identity	-	Identical		

a) Reference value: 32.5% (m/m).

b) The unit "%(m/m)" is used to express the mass of matter as a fraction according to international standards.

c) Calculated without subtracting nitrogen from ammonia.

d) Reference value: 1,090 kg/m³

e) Reference value: 1.3829

AUS 32 requires the addition of a tracer element. Take care to ensure that the quality of AUS 32 indicated in the table and the tracer element do not damage the SCR system.

Note) The conditions of ISO 4259 must be applied between the maximum and minimum values within the specified range. Be sure to take the minimum difference of $4 \times R$ (R is the reproducibility of the test method) into account. However, for the sake of maintaining high quality, $4 \times R$ is not factored into the urea concentration.

Note) The urea concentration, density and deflection are the actual values. (For the actual values, please refer to ISO 4259)

Note) The values defined in notes a, d and e are standard among AUS 32 manufacturers.

Note) Be sure to check whether the DEF (Diesel Exhaust Fluid, urea) satisfies the required specifications. Be sure to apply the conditions of ISO 4259.

13. Aftertreatment System

Diesel Oxidation Catalyst (DOC)

Outline

The diesel oxidation catalyst (DOC) is a device which oxidizes and eliminates HC (hydrocarbon) and CO (carbon monoxide) emissions. It also serves to increase the temperature of the DPF to help with the oxidation of diesel fuel injected into the engine combustion chamber during DPF regeneration. In addition, the DOC accelerates the passive regeneration of particulate matter (PM) collected in the DPF by converting NO (nitrogen monoxide) into NO₂ (nitrogen dioxide).

Replacement and Assembly

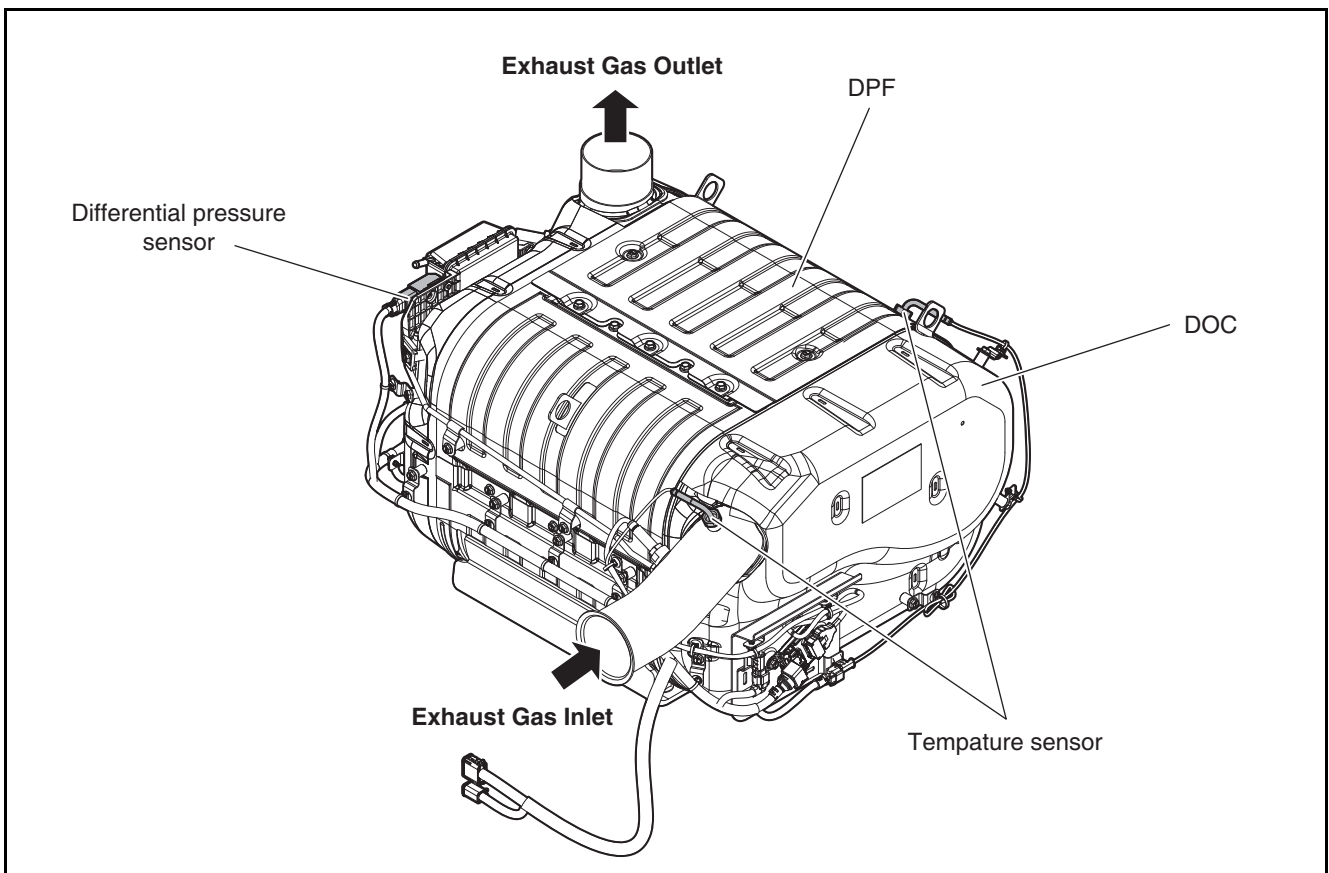
As shown in the figure below, a temperature sensor is installed on the front of the DPF (Diesel Particulate Filter) to control the DOC temperature during regeneration.

Removal

Remove the temperature sensor installed on the DOC and perform a visual inspection downstream of the DOC to check for any damage or melting.

Take care not to damage the DOC during removal.

(For more information on removal, assembly and disassembly, please refer to "Removing, Assembling and Disassembling the DOC/DPF Muffler Assembly.")



EDX08240081

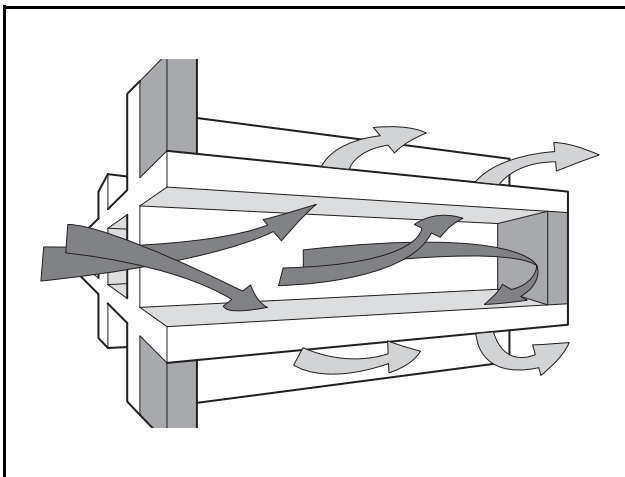
Diesel Particulate Filter (DPF)

Overview

The DPF (Diesel Particulate Filter) system serves to prevent particulate matter (PM) in emissions from being discharged into the air and consists of the DPF body, three exhaust gas temperature sensors, and one differential pressure sensor. The DPF is composed of a porous wall capable of filtering out particulate matter. As exhaust gas passes through the DPF, particulate matter accumulates in the DPF, while the rest of the exhaust gas travels through the DPF to the SCR system. Following this, PM collected in the DPF is eliminated using a suitable regeneration method.

DPF Regeneration

The DPF serves to filter out soot, a contaminant found in the emissions of diesel engines. An excessive build-up of soot in the DPF leads to issues such as a drop in engine power due to increased back pressure in the engine, making it crucial to perform regeneration in order to eliminate PM in the DPF. The ECU (Engine Control Unit) calculates the amount of exhaust smoke using the signal from the DPF differential sensor, the vehicle operating time, the vehicle fuel consumption, and engine simulation data. Once this amount reaches a certain level, the ECU performs DPF regeneration. Regeneration—a process which involves burning accumulated PM—increases the temperature upstream of the DOC by means of adjustment of the engine throttle and post injection, as well as raising the DPF temperature higher than the soot combustion temperature (580° or higher) to burn soot. After DPF regeneration, only ash remains in the DPF. DPF regeneration comprises forced regeneration while driving (Active Regeneration) and manual regeneration performed by the driver (Forced Regeneration).



EJ9OM060

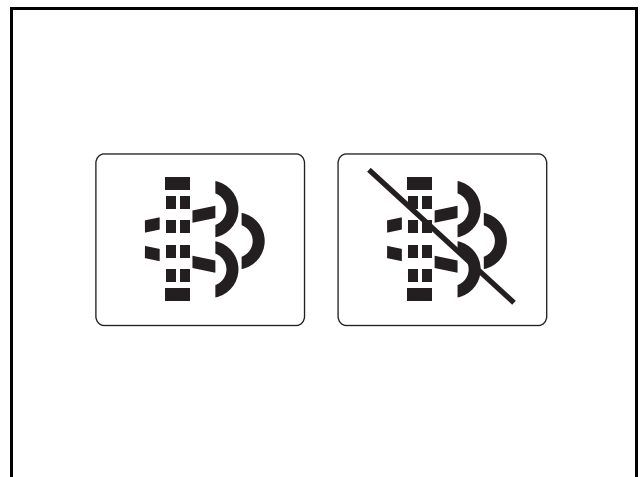
DPF Regeneration Lamp and Switch

1. HEST (High Exhaust System Temperature) Lamp
This lamp notifies the driver when hot exhaust gas is being discharged from the engine during DPF regeneration. Be sure to keep the area around the exhaust manifold free of flammable materials.



EJ9OM061

2. DPF Regeneration Lamp
This lamp turns on either during regeneration or when regeneration is needed and turns off during active regeneration while driving if the soot level is less than 100%. The lamp appears as shown on the right when the driver disables regeneration.

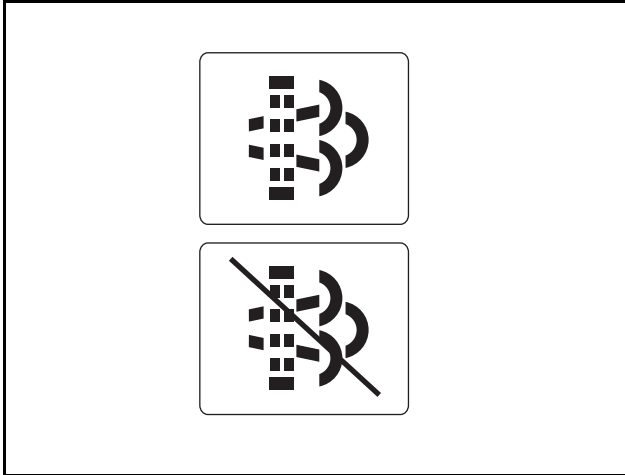


EJ9OM062

13. Aftertreatment System

3. Manual Regeneration

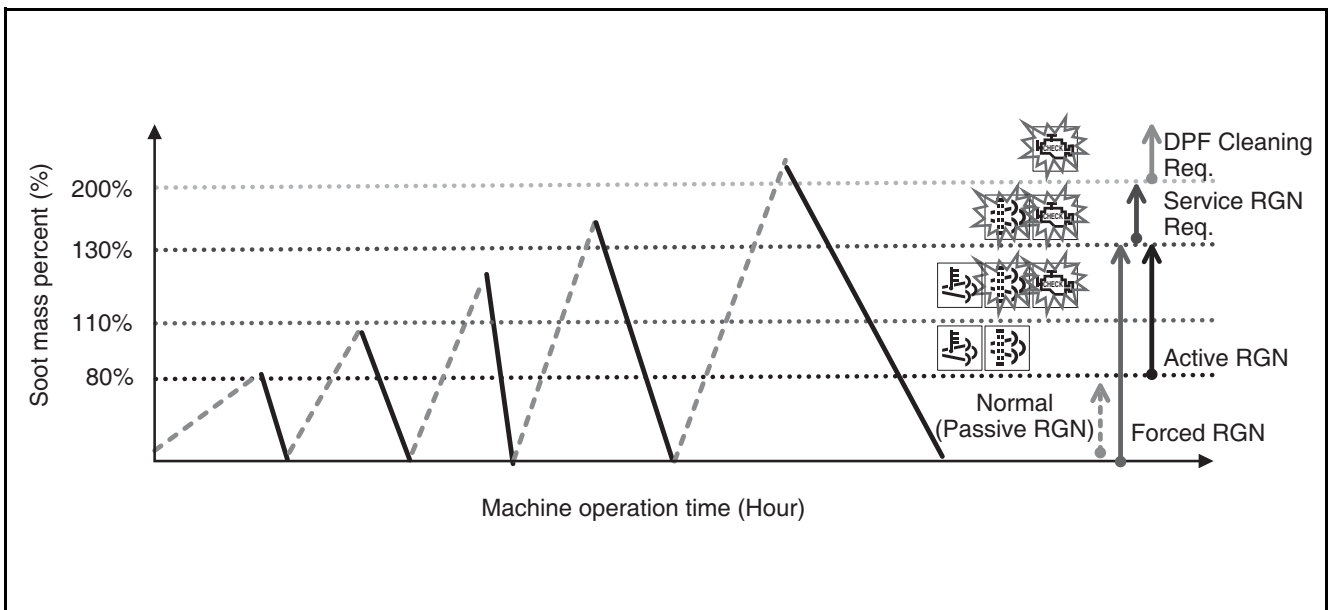
The driver can use these switches to initiate or disable forced regeneration. The switch above is the switch for forced regeneration and the switch below is the switch for disabling regeneration.






EJ9OM063

13. Aftertreatment System

Active Regeneration Strategy by Exceeding of Soot Mass

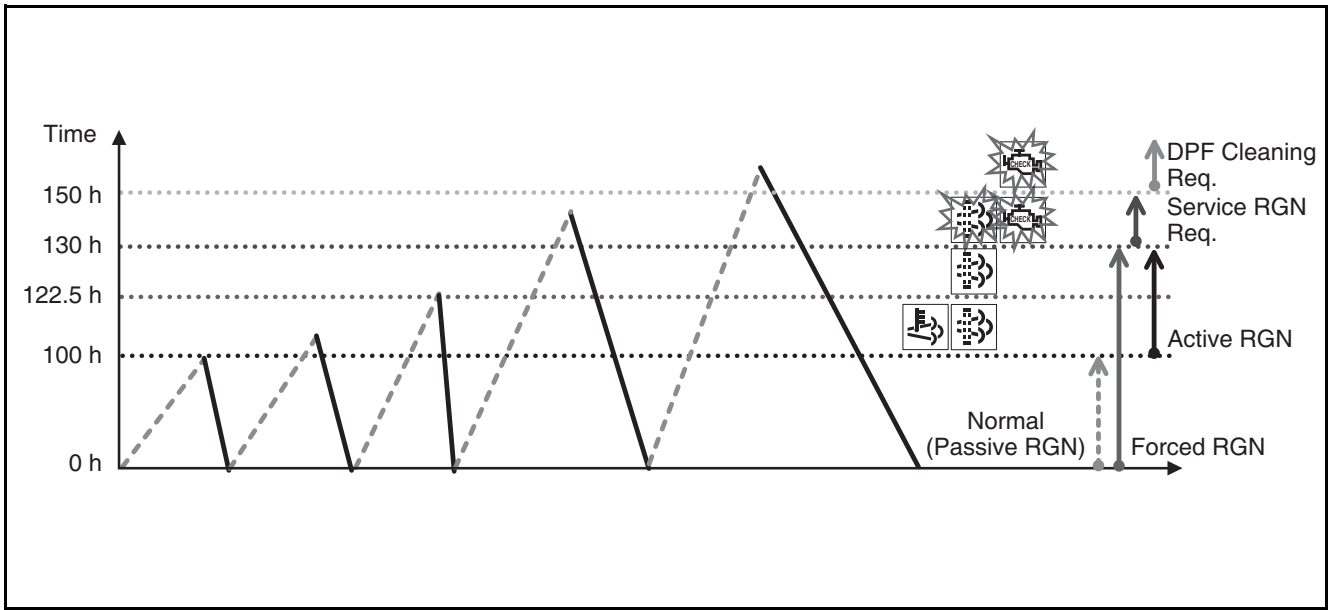


EDX08250103




No.	Soot Quantity	Active RGN Lamp 	DPF Lamp 	Check Engine Lamp 	Torque de-rate	Remark
1	Under 80%	Off	Off	Off	No	<ul style="list-style-type: none"> No action (Passive regeneration dependent on machine CUP)
2	80% ~ 110%	On	On (If active RGN is failed)	Off	No	<ul style="list-style-type: none"> Start active RGN. with high temp. (480 ~ 640°C) during running. (Active RGN lamp on.) If active RGN is failed, then DPF lamp will be on.
3	111% ~ 130%	On	Slow Blinka	Blink	Mild Torque de-rate	<ul style="list-style-type: none"> Soot percent is over 110%, then soot max level 1 fault is detected and DPF lamp will be slow blinking. Engine power is limited to 75%.
4	131% ~ 200%	Off	Fast Blink	Blinka	Severe Torque de-rate	<ul style="list-style-type: none"> If soot percent is over 130%, then soot max level 2 fault is detected and active/forced RGN is inhibited. Service call is needed and perform the service RGN by diagnostic tool. Start service RGN with low ~ high temp. (400 ~ 640°C) during running by diagnostic tool. Engine power is limited to 50%.
5	Over 200%	Off	Off	Blink	Severe Torque de-rate	<ul style="list-style-type: none"> If soot percent is over 200%, then active/forced/service RGN is inhibited. Service call is needed and perform the DPF cleaning in center. Engine power is limited to 50%.

13. Aftertreatment System

Active Regeneration Strategy by a Time Cycle



EDX08250104

No.	Time Since Last RGN Success	Active RGN Lamp 	DPF Lamp 	Check Engine Lamp 	Torque de-rate	Remark
1	Below 100 h	Off	Off	Off	No	<ul style="list-style-type: none"> No action (Passive regeneration dependent on machine CUP)
2	100 h ~ 122.5 h	On	On (If active RGN is failed)	Off	No	<ul style="list-style-type: none"> Start active RGN. With high temp. (540 ~ 640°C) during running. (Active RGN lamp on.) If active RGN is failed, then DPF lamp will be on.
3	122.5 h ~ 130 h	Off	On	Off	No	<ul style="list-style-type: none"> Active RGN is inhibited and forced RGN is needed.
4	130 h ~ 150 h	Off	Blink	Blink	Mild Torque de-rate	<ul style="list-style-type: none"> If time is over 130 h, then time limit level 1 fault is detected and active/forced RGN is inhibited. Service call is needed and perform the service RGN by diagnostic tool. Start service RGN with low ~ high temp. (400 ~ 640°C) during running by diagnostic tool. Engine power is limited to 75%.
5	Over 150 h	Off	Off	Blink	Severe Torque de-rate	<ul style="list-style-type: none"> If time is over 150 h, then time limit level 2 fault is detected and active/forced/service RGN is inhibited. Service call is needed and perform the DPF cleaning in center. Engine power is limited to 50%.

DPF Regeneration Methods

Stage V engines are designed to perform passive regeneration of soot accumulated in the DPF even under normal exhaust conditions without needing to be initiated by the driver. The DPF regeneration modes are divided into the following four stages depending on the level of soot build-up in the DPF.

- 1) Soot level 80% or less : Normal operating conditions.
- 2) Soot level 80 ~ 110% : Automatic regeneration during operation. (Active Regeneration)
- 3) Soot level 111 ~ 130% : Regeneration initiated by driver. (Manual Regeneration)
- 4) Soot level 131 ~ 200% : Service call is needed and perform the service regeneration by diagnostic tool. (Service regeneration)
- 5) Over 200% : Service call is needed and perform the DPF cleaning in center.

1. Regeneration mode during operation (Active Regeneration)

This regeneration mode is performed automatically by the ECU in order to regenerate the DPF when any of the following regeneration mode conditions are met. During regeneration, the regeneration lamp and HEST lamp turn on to warn the driver of the hot exhaust gas.

At this time, normal operation is possible, although with caution for safety. Once regeneration is complete after 20 ~ 30 minutes, the regeneration lamp and HEST lamp turn off.

CAUTION

Turning the engine off during regeneration (i.e. while the HEST lamp is turned on) may have a severe impact on the DPF. Hence, do not turn the engine off while the regeneration lamp and HEST lamp are turned on except in emergencies.

- **Vehicle (or equipment) operating time : > 10 hours**
 - **Vehicle (or equipment) fuel consumption : > 190 liters**
 - **When the soot level reaches the specified level in the simulation**
 - **If service regeneration performed three or more consecutive times, the vehicle (or equipment) user must replace the engine oil in accordance with maintenance procedure. this is because engine oil viscosity may fall below the specified threshold, potentially compromising engine durability.**
-

2. Manual regeneration mode (Forced Regeneration)

This regeneration mode is performed by the driver with the vehicle stopped in the event that DPF regeneration is not performed while the vehicle is in operation. Forced regeneration (Active Regeneration) may not be performed under the following operating conditions, so the driver must perform manual regeneration according to vehicle warnings as befits the circumstances.

- Working repeatedly under a low load or driving at low speeds over short distances
- Frequent idling

Forced/Service regeneration release condition.

- 1) Coolant temperature is over 40°C.
- 2) Parking brake is engaged. and safety lever is in the safe position.
- 3) Soot load mass percent is between 0% and 130% for forced RGN.
- 4) Soot load mass percent is between Step 0% and 200% for service RGN.
- 5) Battery voltage is over than 20 V.

Order of manual regeneration

- 1) Stop the vehicle. (Be sure to stop the vehicle in a safe place as the exhaust temperature will increase.)
- 6) Set the engine to an idling rpm.
- 7) Lower the safety lever.
- 8) Place the manual regeneration switch in the ON position.
- 9) The engine rpm increases from idling to 1,400 rpm (varies depending on the model) and regeneration begins.
- 10) Manual regeneration is performed for 20 ~ 30 minutes. (May take longer depending on the above-mentioned manual regeneration conditions). The regeneration lamp and HEST lamp turn on.
- 11) The engine rpm drops to an idling rpm.
- 12) The regeneration lamp and HEST lamp turn off.
- 13) Place the manual regeneration switch in the OFF position.

- * In the event that manual regeneration must be stopped due to an emergency, raise the safety lever. However, doing so has a severely adverse effect on **DPF** regeneration, so be sure to perform manual regeneration in a safe place with enough time to complete the process.

Removal

Remove the temperature sensor and differential pressure sensor installed in the DPF, perform a visual inspection upstream and downstream of the DPF to check for any damage or melting, and take care not to damage the DPF.

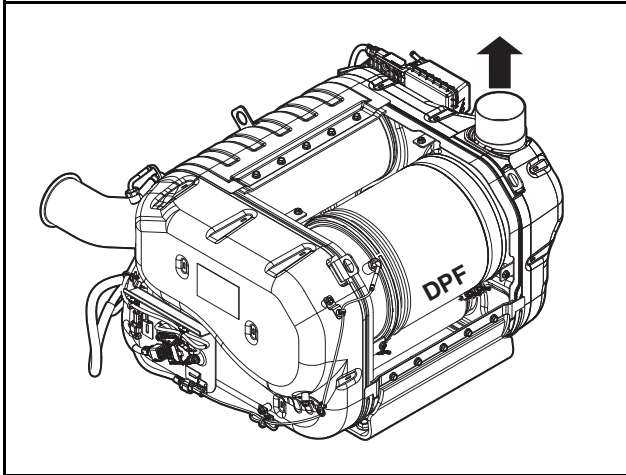
1. Inspect upstream and downstream of the DPF to check for any damage or melting on the DPF.
2. Check downstream of the DPF for soot : If any soot (black) is found during the visual inspection and cannot be removed even after being wiped with a cloth or paper towel, there is a problem with the DPF.

Replacement and Assembly

13. Aftertreatment System

Removing, Assembling and Disassembling the DPF Muffler Assembly

1. After removing the aftertreatment muffler from the machine, face the inlet pipe upwards in order to remove the DPF.

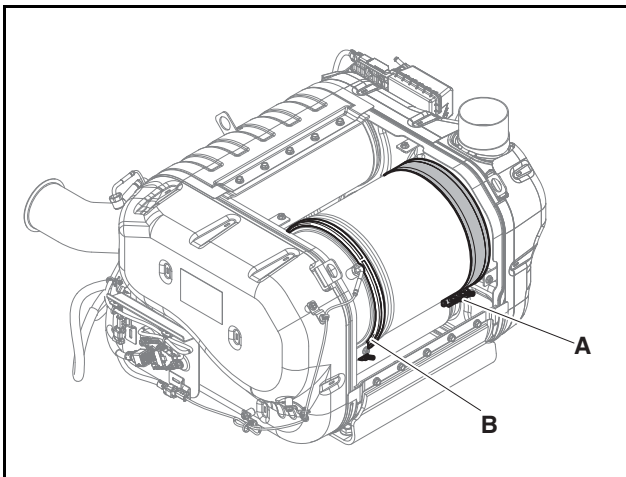


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2. Remove the band clamp (A) and V clamp (B).

⚠ CAUTION

Gaskets and clamps are intended for single use only; do not reuse them.



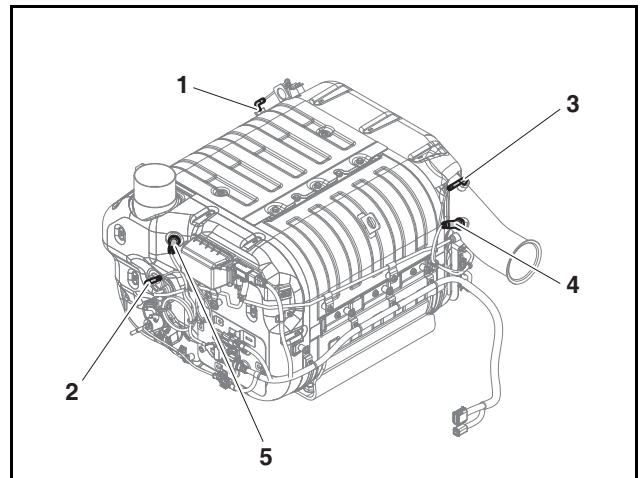
EDX08240094

3. Remove the DPF/SCR.
4. Perform reassembly in the reverse order of disassembly, tightening parts to their specified tightening torque.

Name	Tightening Torque
V Clamp	15 ~ 17 Nm
Pressure Pipe	40 ~ 50 Nm
NOx Sensor	45 ~ 55 Nm
Temp. Sensor	40 ~ 50 Nm
M6 Bolt (DP Sensor & Dosing Module)	6 ~ 10 Nm
M8 Bolt	22 ~ 32 Nm
Band Clamp	40 ~ 50 Nm

Emission Sensors

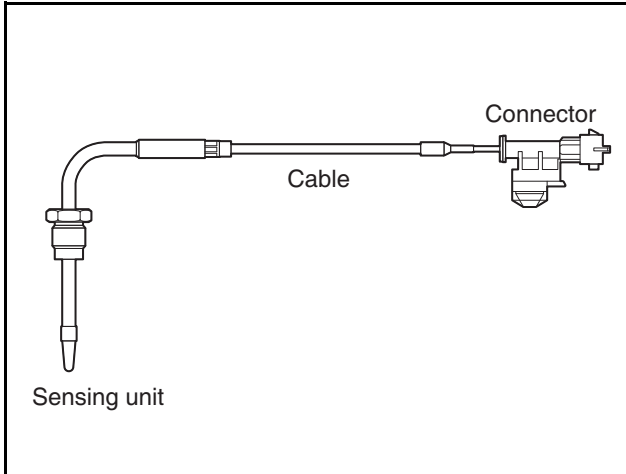
- DPF temperature sensor & NOx sensor



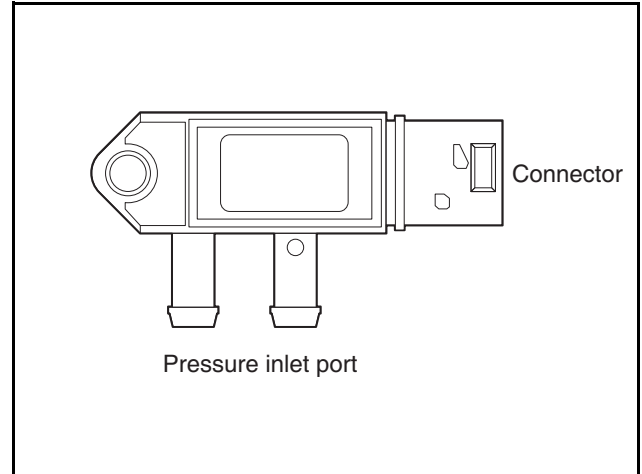
EDX08240095

Number	Name
1	DPF upstream temperature sensor
2	SCR upstream temperature sensor
3	DOC upstream temperature sensor
4	Upstream NOx sensor
5	Downstream NOx sensor

- The following temperature sensors were installed in the DOC upstream, DPF upstream, and DPF downstream positions in order to measure the temperature of the DOC and DPF aftertreatment systems.

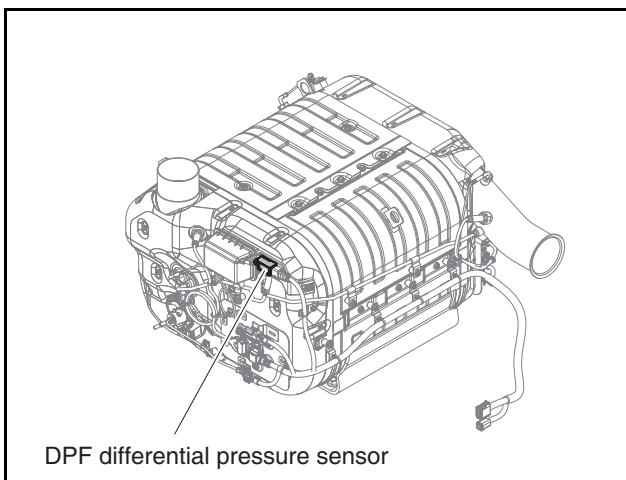


EDL08190074



EDL08190073

- DPF differential pressure sensor



EDX08240096

A differential pressure sensor was installed to measure the pressure difference between upstream and downstream of the DPF.

Number	Name
1	Supply voltage (VCC)
2	Ground
3	Output signal

Cautions for Handling the DPF Assembly

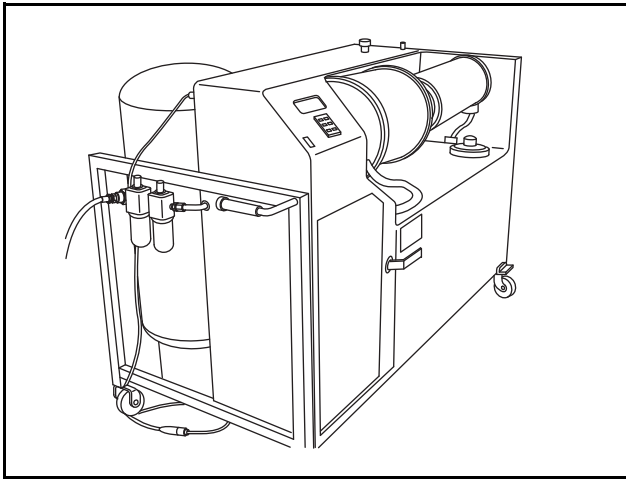
Please note the following while handling the DPF assembly.

1. The assembly weighs approx. 11 kg and the DPF are sensitive to impacts. Hence, be careful not to damage them during removal.
2. When replacing the differential pressure sensor, take care to ensure that foreign matter does not enter the differential pressure sensor pipe. If foreign matter enters the pipe, a fault may occur due to a misreading of the differential pressure.
3. Take care to ensure that foreign matter does not enter the inlet/outlet after removing the DPF assembly. If foreign matter enters the system, it may damage the DPF.
4. The differential pressure sensor and temperature sensor are installed on the outside of the DPF assembly, so take care not to damage them during removal and installation.
5. Reusing gaskets removed during the removal of the assembly may cause air leaks, so be sure to use new gaskets.
6. Air leaks in the exhaust system can lead to violation of emissions regulations, increased noise, and increased exhaust smoke, so be sure to tighten parts to their specified tightening torque.

13. Aftertreatment System

Removing DPF Ash and Cleaning the DPF

During the regeneration of soot in the DPF, ash accumulates in the DPF. Once a certain amount of ash accumulates, engine performance and fuel efficiency are affected due to a build-up of back pressure in the exhaust system, so ash cleaning must be performed regularly to prevent any worsening of engine performance and fuel efficiency. The DPF part of the DPF assembly must be disassembled in order to clean out ash. Ash cleaning cycle may vary depending on operating conditions, operating environment, and type of engine oil used, and should be performed every 8,000 engine hours under normal conditions.



EJ9OM071

CAUTION

1. Be sure to use ultra-low-sulfur diesel (ULSD) to ensure normal performance of the DPF.
 2. Be sure to use low ash engine lubricant oil (CJ4 grade or higher) to establish suitable DPF cleaning intervals.
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