e-Diesel

Environmentally Friendly Engines Compliant with IMO Secondary Regulations

DAIHATSU

Technology of DAIHATSU DE series Engine

6DE-18 / 6DE-23 / 6DEM-23

DAIHATSU DIESEL MFG.CO.,LTD.

Environmentally Friendly Engines

We have successfully developed an environmentally friendly engine with high potential for meeting future emission regulations that are expected to become increasingly strict, such as those targeting the reduction of CO_2 emissions. We have complied with the IMO emission standards by adding advanced combustion technology to the engine.

e-Diesel

Environmentally Friendly Engines Compliant with IMO Secondary Regulations

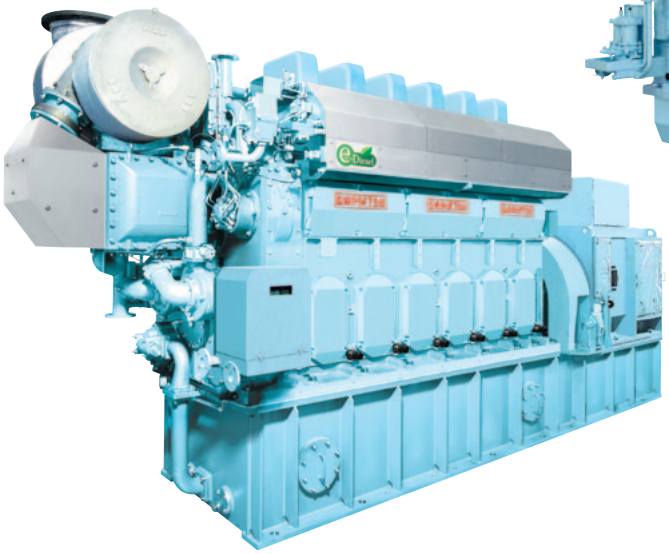
Contents

1 External View Photo of the Engine

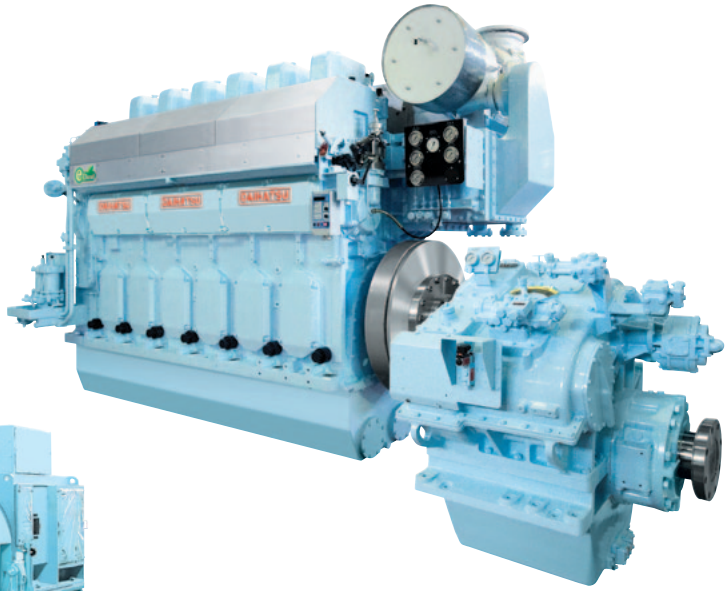
6DE-18

6DE-23 / 6DEM23

Marine Gensets Diesel Engine



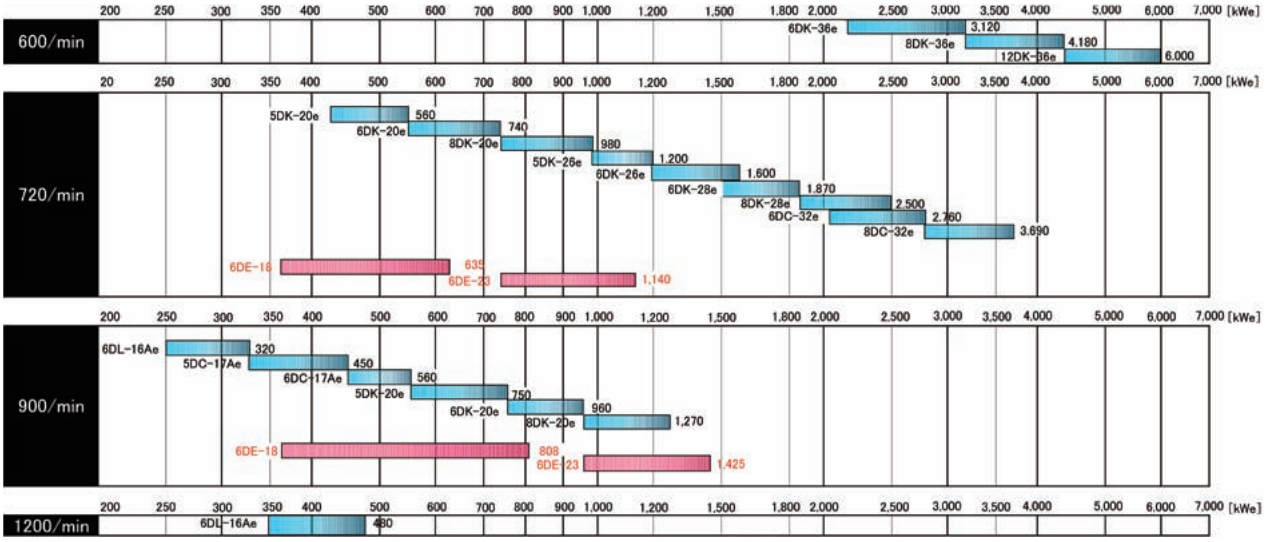
Marine Propulsion Diesel Engine



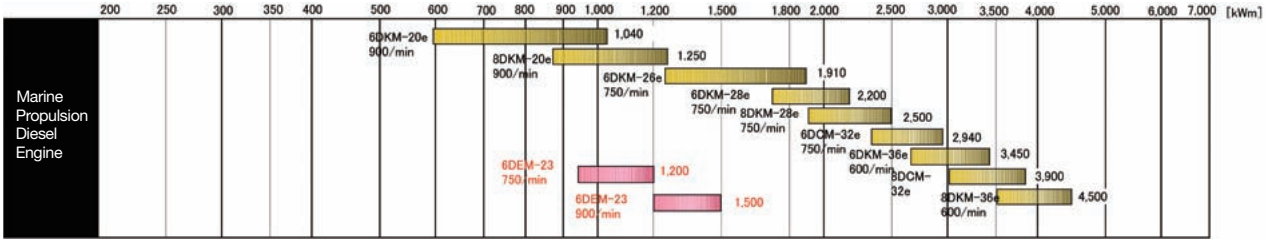
2 Output Range and Principal Particulars

Output Range

Lineup: Marine Gensets Diesel Engine



Lineup: Marine Propulsion Diesel Engine

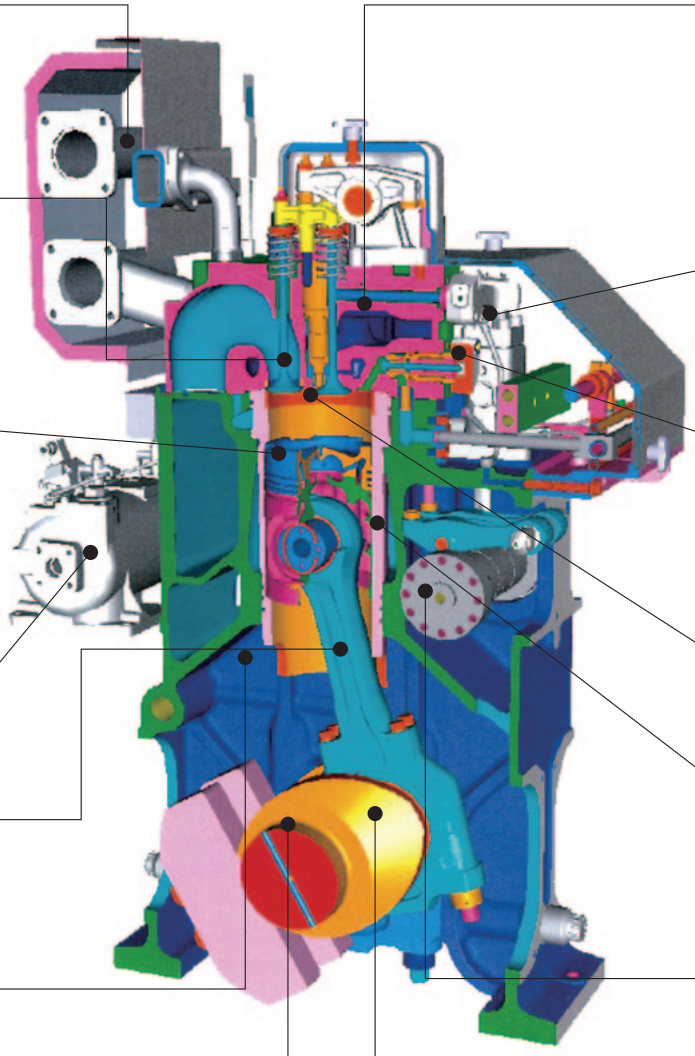


Principal Particulars

		Marine Gensets Diesel Engine				Marine Propulsion Diesel Engine	
Engine Model		6DE-18		6DE-23		6DEM-23	
Cylinder Diameter	mm	185		230		230	
Stroke	mm	280		320		320	
No. of Cylinders		6		6		6	
Engine Revolutions	min-1	720	900	720	900	750	900
Engine Output	kWm	400～680	440～850	800～1,200	1,040～1,500	950～1,200	1,200～1,500
Generator Output	kWe	360～635	400～808	760～1,140	988～1,425	—	
Brake Mean Effective Pressure	MPa	1.5～2.5	1.3～2.5	1.7～2.5	1.7～2.5	1.8～2.4	2.0～2.5
Average Piston Speed	m/s	6.72	8.4	7.68	9.6	8	9.6
Combustion Pressure	MPa	Max.20		Max.20		Max.20	
Starting Method		Compressed Air Start		Compressed Air Start		Compressed Air Start	
Turbocharging System		Dynamic Pressure		Dynamic Pressure		Dynamic Pressure	
Overall Length※1	mm	4,850		6,100		3,160	
Overall Width※2	mm	1,070		1,110		1,050	
Overall Height※3	mm	2,400		2,840		1,870	
Piston Overhaul Height※4	mm	2,300		2,860		1,710	
Generator Set Dry Mass※5	kg	12,000		23,000		14,000	

※1 Varies depending on the generator. Main engine specification dimensions extend from the crankshaft end.
※2 The maximum width of the common baseplate mounting surface. Main engine specifications indicate the maximum width of the engine mount.
※3 The height of the exhaust port from the common baseplate mounting surface. Main engine specifications indicate the height from the center of the crankshaft.
※4 The height from the common baseplate mounting surface. Main engine specifications indicate the height from the center of the crankshaft.
※5 Varies depending on the generator. Main engine specifications indicate only the engine body.

3 6DE-18：Engine Cross Sectional View



Exhaust pipe
- With a fire prevention type cover
- Dynamic pressure exhaust pipe

Intake and exhaust valves
- Heat resisting steel type with a valve rotator
- Exhaust valve seat ring: Water-cooling type

Piston
- Composite type
  Crown: Alloyed steel
  Skirt: Ductile cast iron
- Chrome plated ring grooves
- Three compression rings and one oil ring

Automatic backwash filter
- Nominal: 30μm

Connecting rod
- Marine type
- Crankpin bolt: Hydraulically tightened

Engine frame
- Monoblock structure of high stiffness
- Main bearing bolt, side bolt: Hydraulically tightened

Main metal, crankpin metal
- Corrosion and wear resistance: Aluminum alloy metal

Cylinder head
- Stiffness enhancement by a thick wall structure
- Combustion face cooling by a bore cooling method
- Hydraulically tightened four studs

Fuel injection device
- Block type high pressure pipes

Fuel injection pump
- High-pressure injection type, optimized injection
- Anti-cavitation
- Plungers for low sulfur fuel

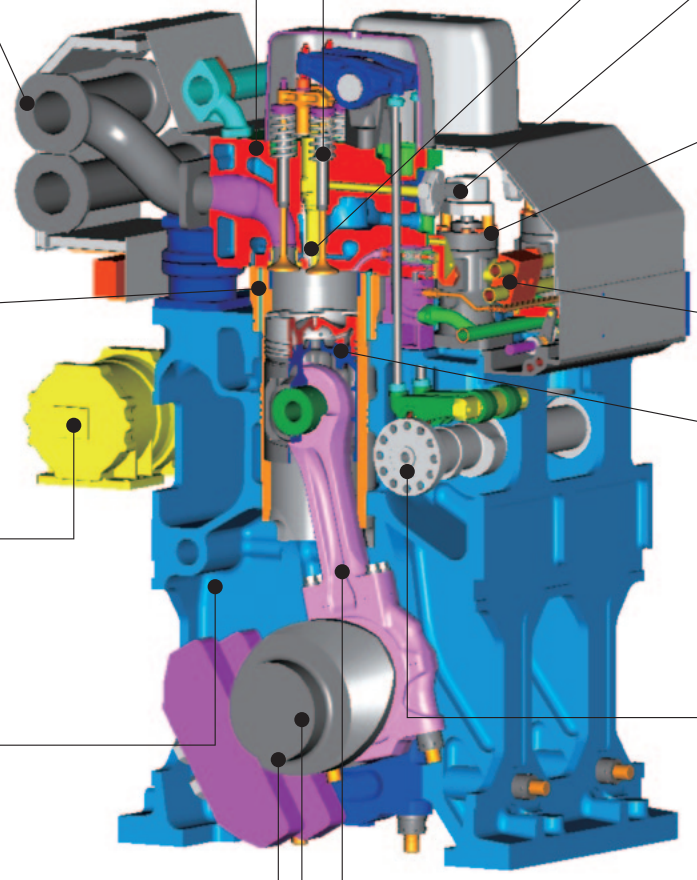
Fuel nozzle
- Uncooled nozzle

Cylinder liner
- Thick wall high stiffness performance
- Wear resistance special cast iron

Camshaft
- Large diameter two-split unit camshaft

Crankshaft
- High stiffness performance: Large diameter pins, journals
- Die forged material
- Securing sufficient oil film thickness, reducing oil film pressure

4 6DE-23：Engine Cross Sectional View



Cylinder head
- The heat-resistant high strength special cast iron
- The double shelf structure of high stiffness
- Cooling enhancement around the exhaust valve seat by effective cooling water passage
- Hydraulically tightened four studs

Exhaust pipe
- Excellent load correspondence enabled by the pulse turbo charging method
- Optimized matching with the intake/exhaust timing
- The passage shape maximizing the turbocharger efficiency

Cylinder liner
- Bore cooling type: Effective cooling
- The special cast iron excellent in wear resistance
- With the protect ring
- Optimized cooling area

Automatic backwash filter
- Enhancement of the filtering performance and simplified maintenance work

Engine frame
- Monoblock structure of high stiffness
- The main bearing bolts and side bolts tightened with oil pressure
- Good accessibility for inspection and maintenance
- Integration of the passages for the cooling water, air intake, and lubrication oil

Main metal, crankpin metal
- Special aluminum alloy metal excellent in wear resistance performance, corrosion resistance performance, and load capacity performance

Intake and exhaust valves
- With a valve rotator
- Exhaust valve seat ring: Water-cooling type

Fuel nozzle
- Uncooled nozzle

Fuel injection device
- Block type high pressure pipes

Fuel injection pump
- High-pressure injection type, optimized injection
- Plungers for low sulfur fuel

Fuel system
- Main pipe with damper

Piston
- Composite type
  Crown: Alloyed steel
  Skirt: Ductile cast iron
- Hardened top and second ring grooves
- Three compression piston rings and one oil ring

Camshaft
- The large diameter unit camshaft of a two-cylinder integrated type
- The valve drive mechanism of a simple swing arm type

Connecting rod
- Marine type
- Hydraulically tightened big end bolts

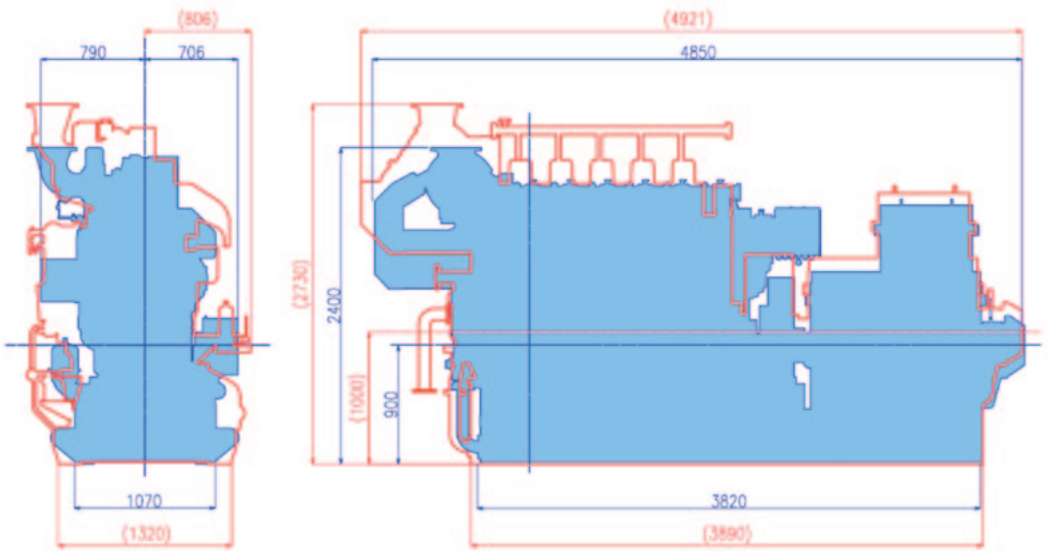
Crankshaft
- CGF RR forging
- Optimized shape by FEM analysis
- Optimized shaft diameter to secure bearing oil film thickness, reducing oil film pressure

5 Comparison of the Outside Dimensions with Conventional Models

6DE-18

Comparison of the Outside Dimensions with Conventional Models (5DK-20)

Blue:6DE-18 Red:5DK-20e

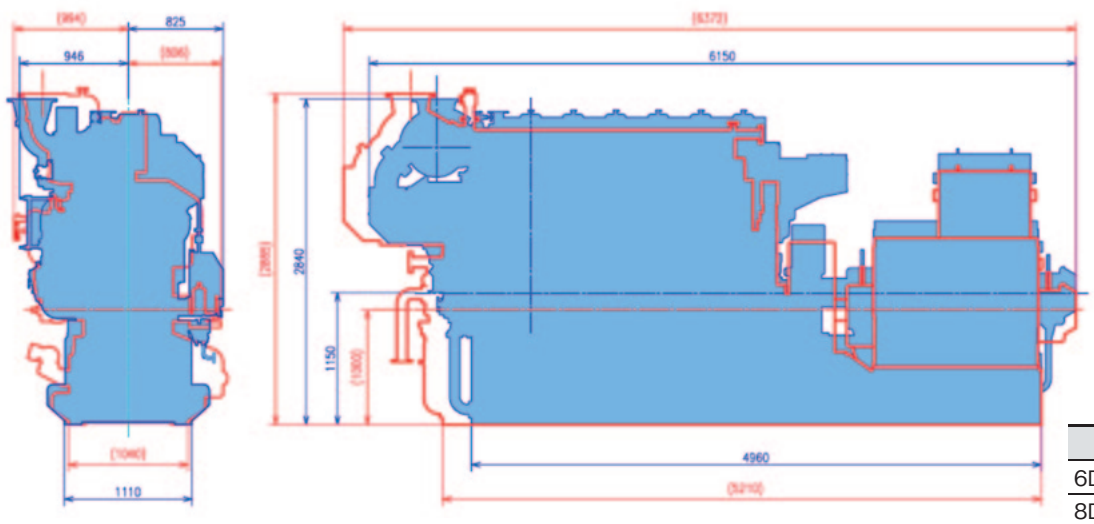


Weight	
6DE-18	12.0t
5DK-20e	13.5t

6DE-23

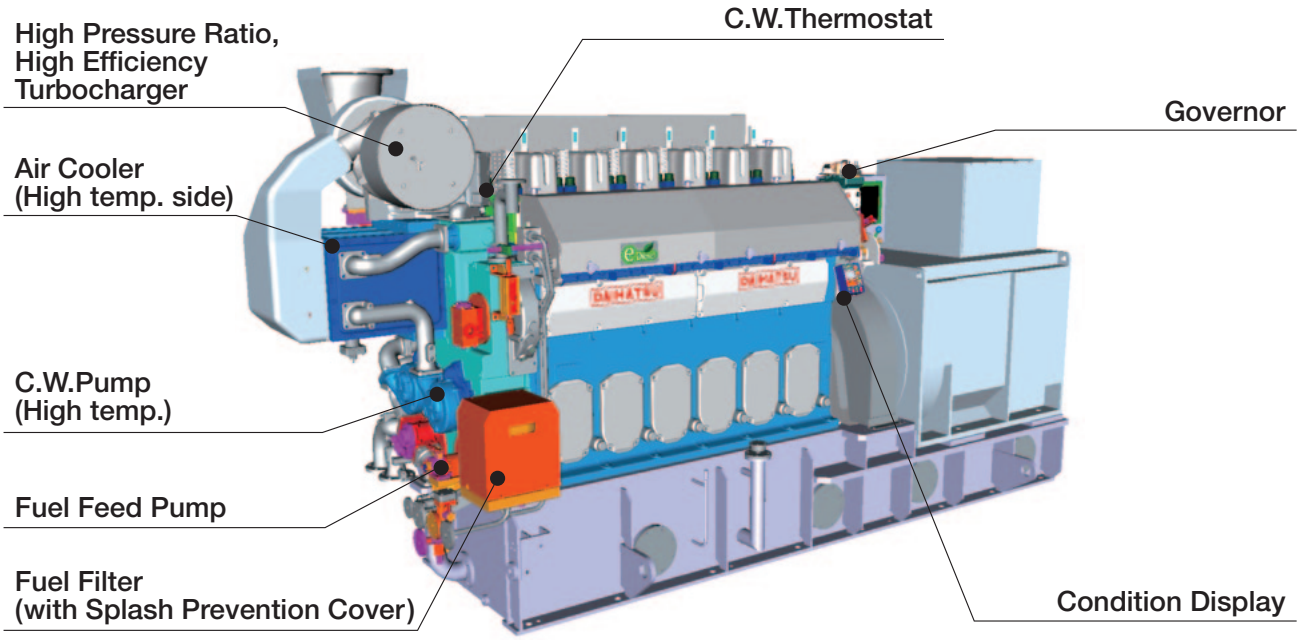
Comparison of the Outside Dimensions with Conventional Models (8DK-20)

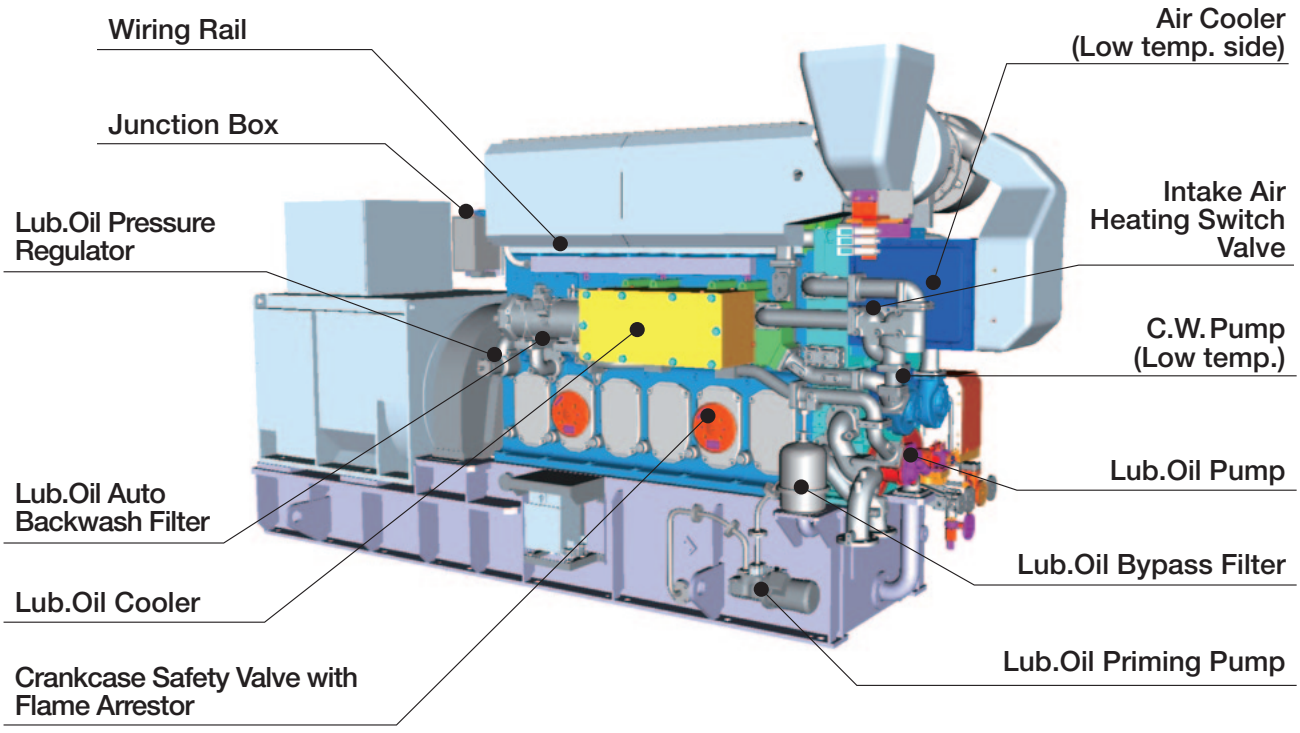
Blue:6DE-23 Red:8DK-20e



Weight	
6DE-23	25t
8DK-20e	22t

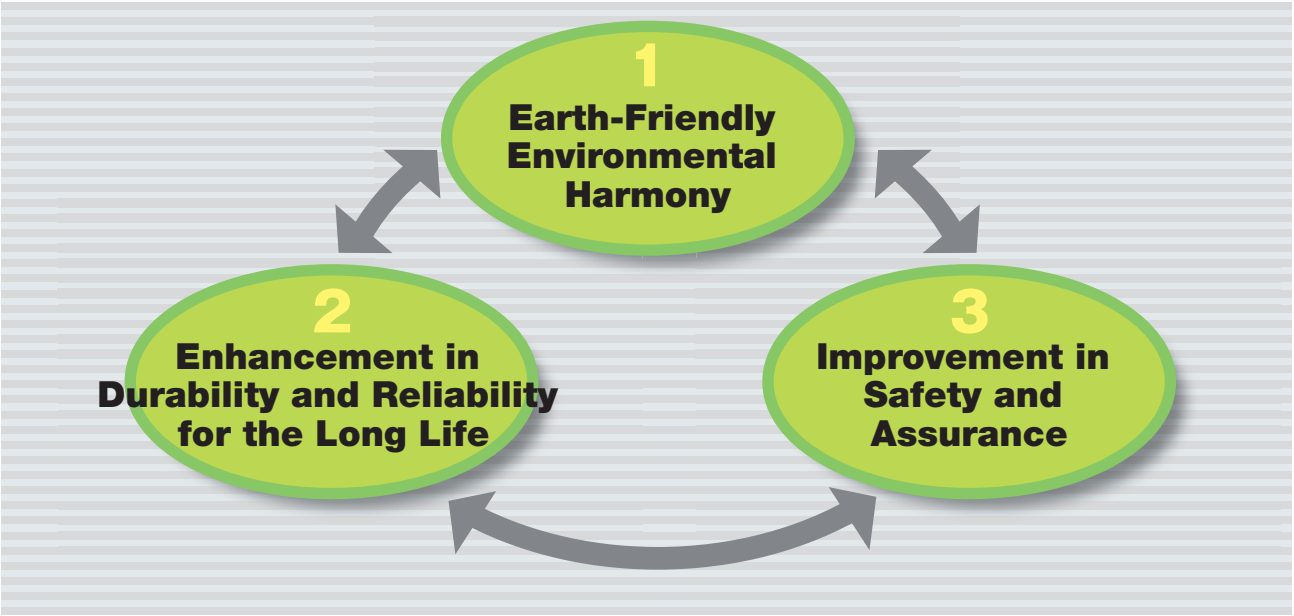
6 External View (Equipment Layout)





7 Development Concept and Scheme

Concept



Scheme

1. Earth-Friendly Environmental Harmony

Decreasing Exhaust Gas Emissions

- Conformity with IMO NOx regulations Tier 2 and Tier 3
- Compatibility to low sulfur fuel oil
- Reduction of CO_2 emissions with low fuel consumption and smokeless

Reduction and Management of Hazardous Materials

- Compliance with the “Ship Recycling Convention”
- Reduction of the hazardous materials within the scope

2. Enhancement in Durability and Reliability for the Long Life

Reduction of Navigation Costs

- Enhancing the reliability and the durability of parts and securing the longevity
- Achieving the low lubricating oil consumption and the fuel consumption
- Simple maintenance finished in a short time

Stable and Certain Engine Start

- Adoption of the compressed air start system, not influenced by air quality

Securing the Lub.Oil Performance in the Long Life

- Adoption of a large centrifugal filter and an automatic backwash filter

3. Improvement in Safety and Assurance

Perfect Fire Prevention Measures

- Perfect protection of high temperature parts
- Perfect splash prevention of fuel oil and lubricating oil

Simplified Connection Points for Easier Installation

- Converged arrangement of external connection points at the front-end part
- Simplification in workability by unitization

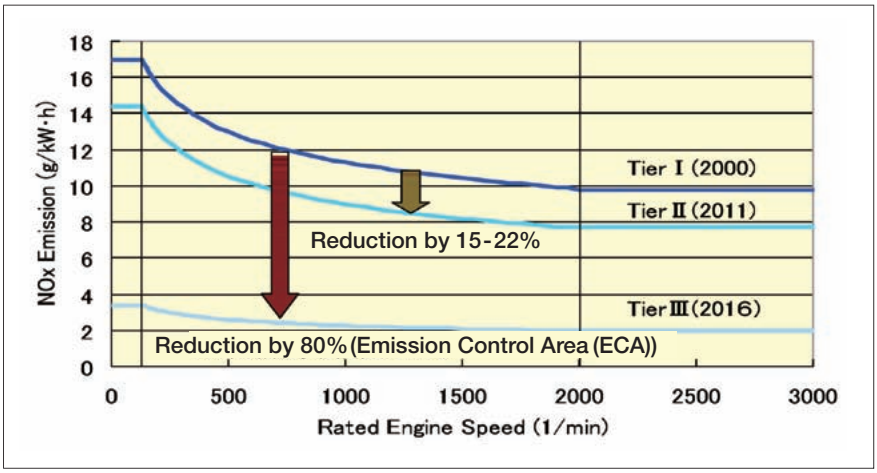
Engine Controller with Easy Handling

- Integration of engine ignition, start, stop, and protection devices and installation on the engine
- Simplification of communications by the sea-land communication system

7-1 Earth-Friendly Environmental Harmony

Decreasing Exhaust Gas Emissions

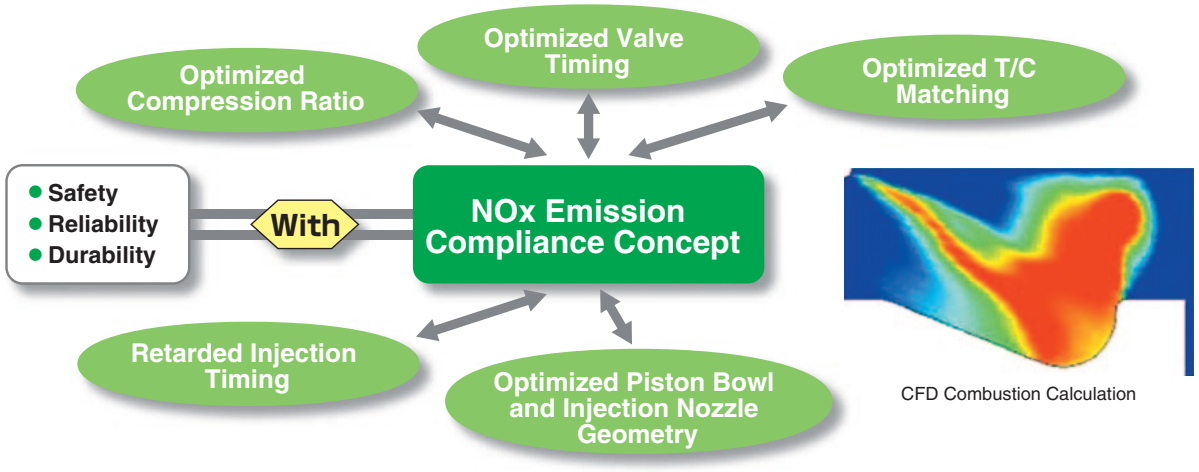
Environmental consciousness
Technology for the conformity with IMO NOx regulations Tier 2



Combustion technology for the conformity with IMO NOx regulations Tier 2

- Optimized fuel injection timing
- High-pressure fuel injection
- Specifications for the optimized combustion chamber configuration and fuel nozzle spray holes
- Optimized valve timing with consideration to the start performance and the transient response characteristics
- Optimized matching of the high pressure ratio and the high efficiency turbocharger

NOx Emission Compliance Concept

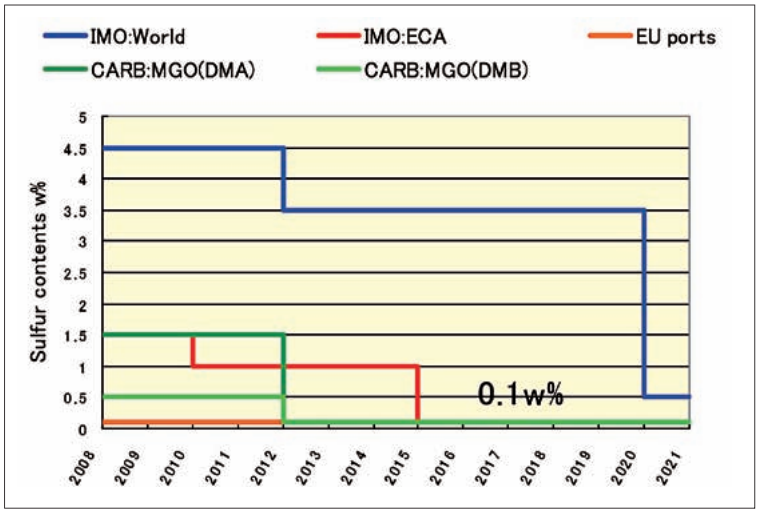


7 Development Concept and Scheme

7-1 Earth-Friendly Environmental Harmony

Decreasing Exhaust Gas Emissions

Compatibility to low sulfur fuel oil

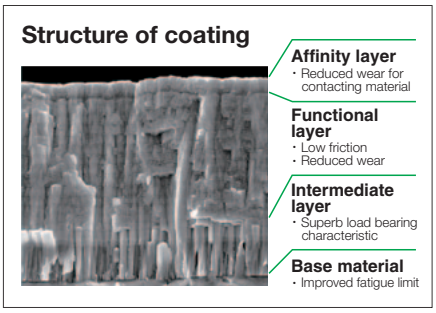


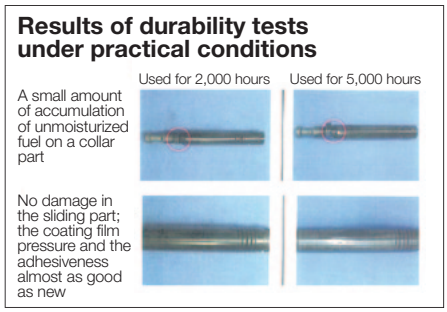
Countermeasures for low viscosity

- Carbon coated plunger
- Plunger oiling
- Addition of lubricity improvers
- Fuel feed pump for low viscosity
- Engine inlet viscosity: 2mm²/s or higher

1. Adoption of the carbon coated plunger

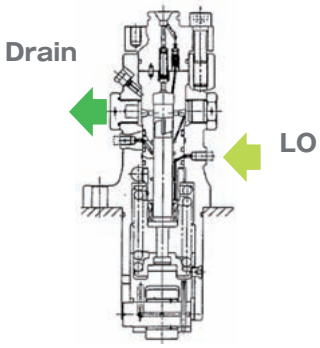
- Improvement in the slide performance and the wear resistance





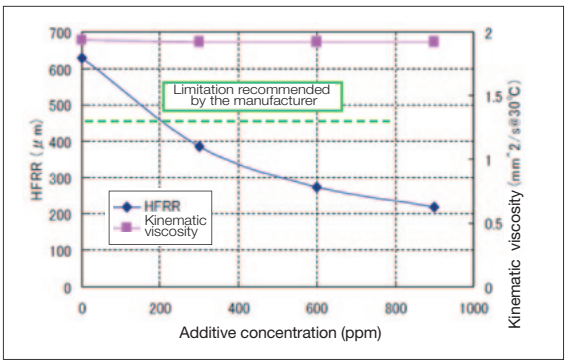
2. Adoption of plunger oiling

- Able to enhance the sealing performance and the lubricity



3. Adoption of lubricity improvers

- An example of the addition rate of the additives and a high-frequency reciprocating rig (HFRR)



4. Wear protection measures for the fuel feed pump

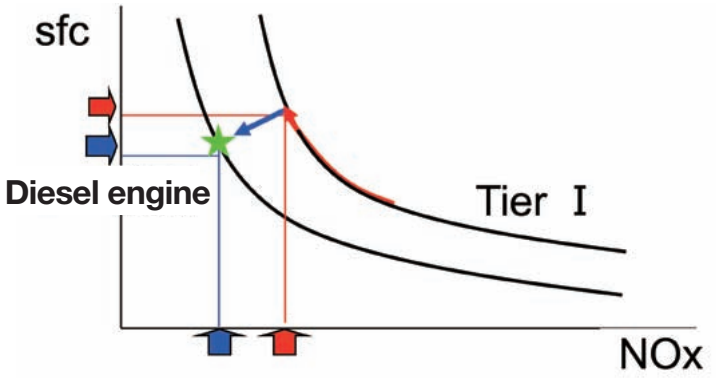
- Special treatment is applied to both of the inner rotor and the outer rotor to prevent abnormal abrasion of the diesel oil pump.

5. A plan (option) includes a fuel cooler (cooler or chiller).

➡ Securing the viscosity at the inlet to the engine

Low fuel consumption and smokeless for the reduction of CO_2 emissions

Low fuel consumption

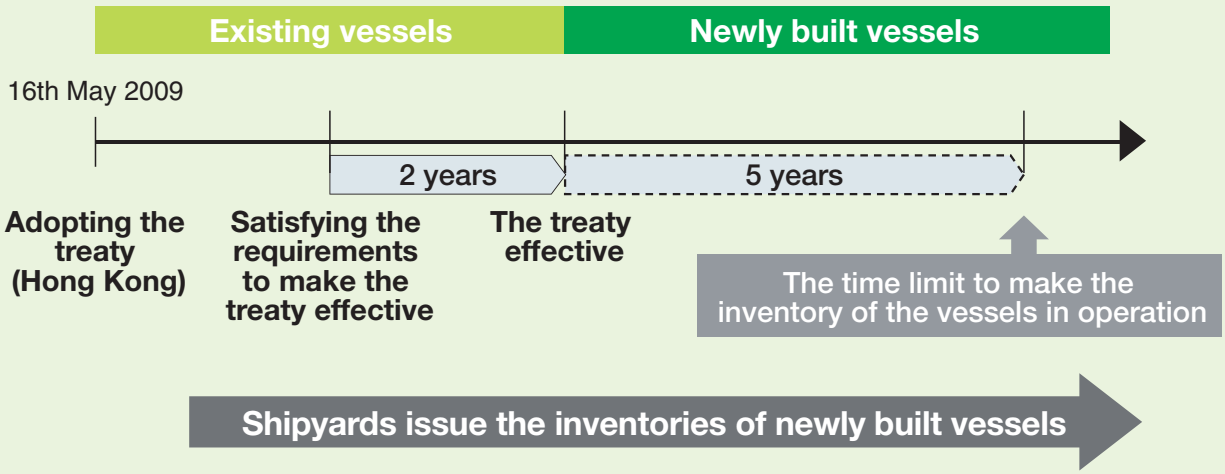


- High Pmax
- High-pressure fuel injection pump
- High efficiency, high-pressure ratio turbocharger
- Combustion system matching
- Reduction of mechanical loss

Smokeless

- Optimized fuel control at transient response by an electronic governor
- Improvement in turbocharger response by pulse turbo charging

Reduction and Management of Hazardous Materials



1. Compliance with the “Ship Recycling Convention”
2. Reduction of designated hazardous materials

7 Development Concept and Scheme

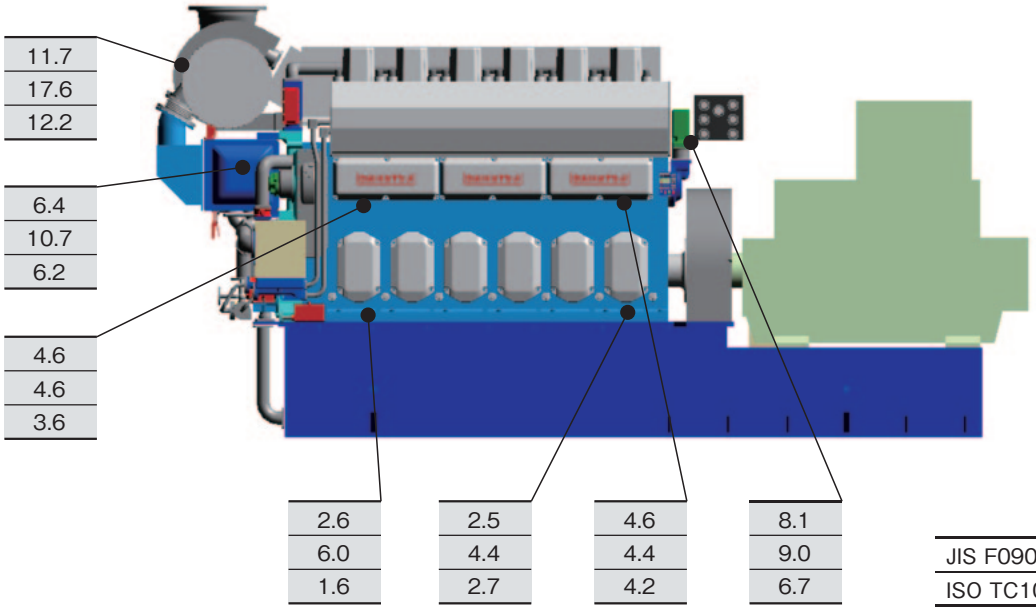
7-1 Earth-Friendly Environmental Harmony

Low Frequency and Low Noise

Result of vibration measurements

6DE-23 VIBRATION MEASUREMENT

900/min x 1500kWm



X	Axis
Y	Horizontal
Z	Vertical

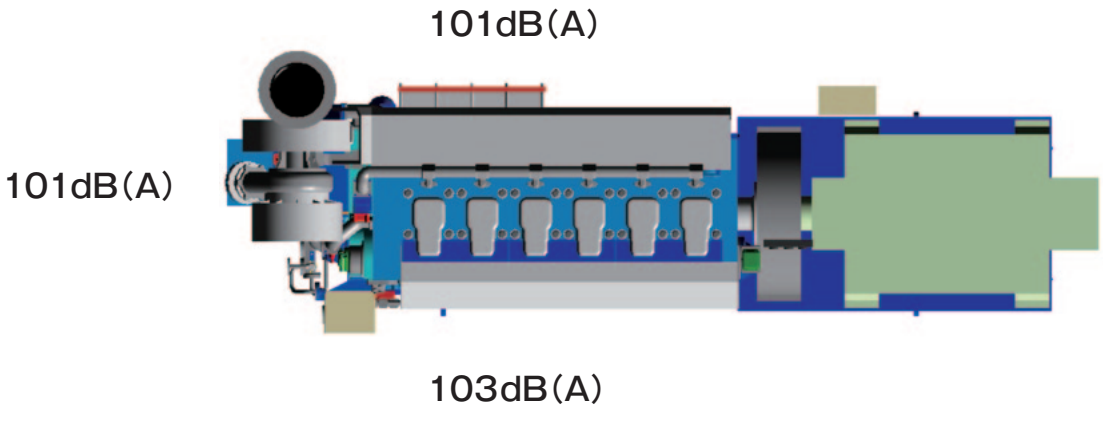
Unit:mm/sec.
RMS 200Hz

JIS F0906	30mm/s
ISO TC108 CLASS	28mm/s

Result of noise measurements

6DE-23 SOUND LEVEL

900/min x 1500kWm Distance:1m

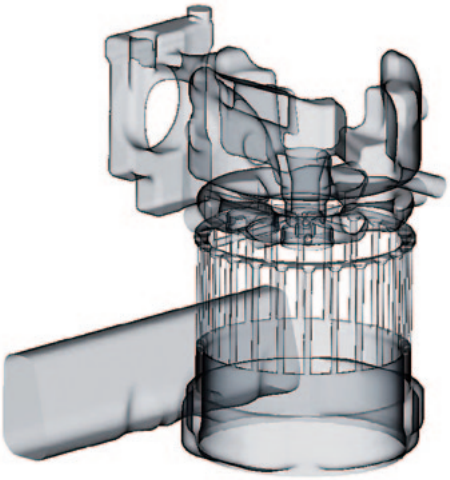


7-2 Enhancement in durability and reliability for the long life

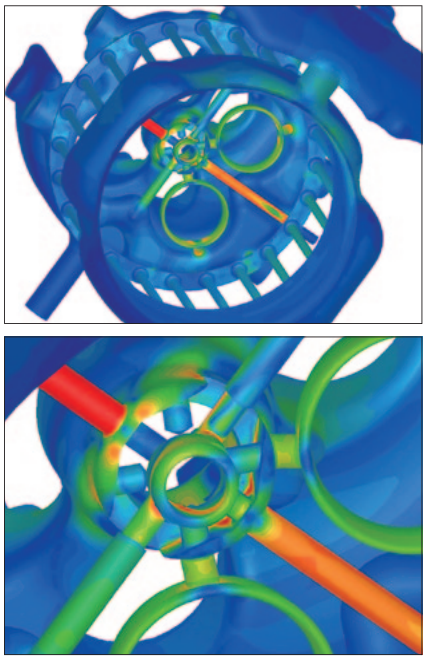
Reduction of Operation Costs

Cooling enhancement of the high stiffness cylinder head

The stiffness of the cylinder head is increased, and an effective cool down is achieved to mitigate heat load, too. The cool down is augmented around the fuel valves in particular.



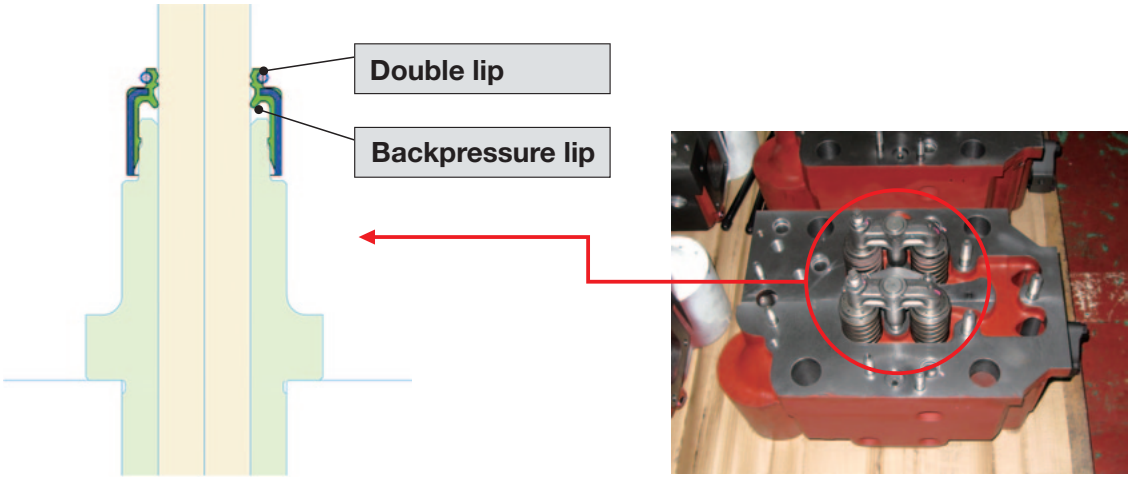
Cylinder head cooling water model



Result of computational fluid dynamics analysis of the cylinder head cooling water

Adoption of valve stem oil seals with a backpressure lip

The stem oil seal with the double lip and the backpressure lip is adopted for the intake and exhaust valve stems, which intensifies the gas seal performance. The proper lub.oil control enhances durability.



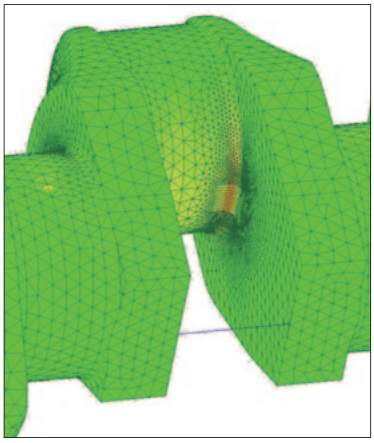
7 Development Concept and Scheme

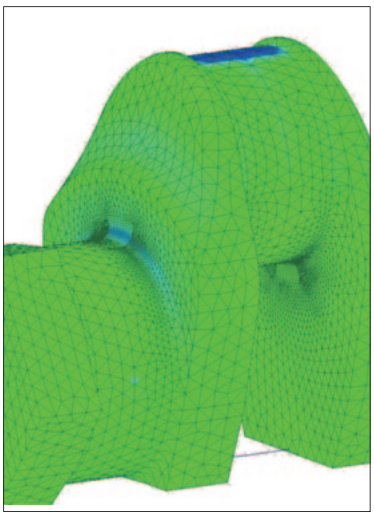
7-2 Enhancement in durability and reliability for the long life

Reduction of Operation Costs

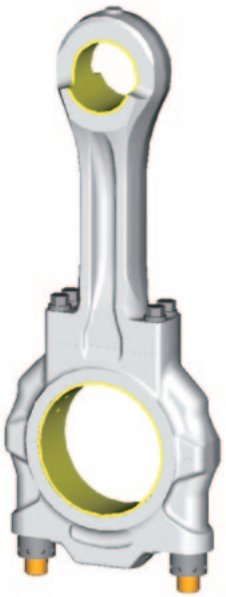
High stiffness crankshaft

- Optimal shape for stress reduction
- Continuous grain flow forging of the low alloy steel
- Large shaft diameter to secure bearing oil films

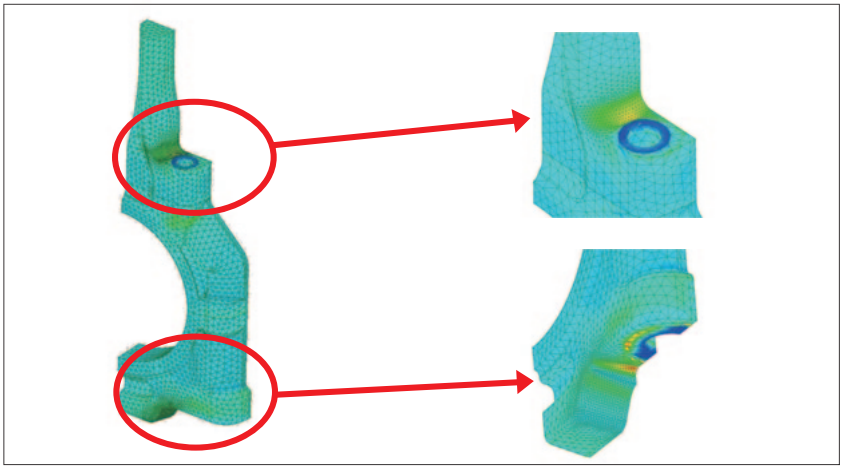




Horizontal three split connecting rod (Marine type)

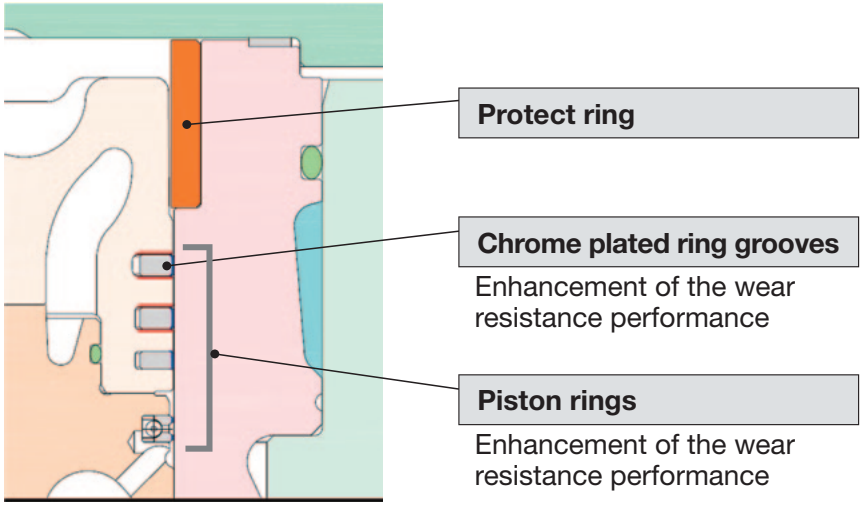


- Stress reduction in the crankpin bolt thread under the combustion load
- Stress reduction in the serration
- Reduction of the piston overhaul height
- No need to disassemble the big end part to remove the piston



Piston

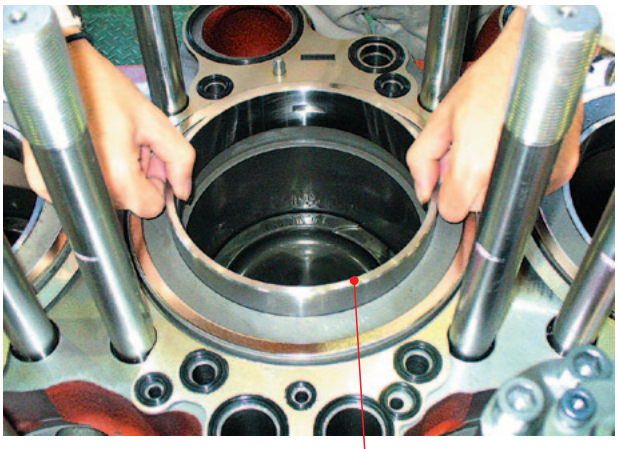
The two-split structure is adopted for the piston, which comprises the alloyed steel crown and the ductile iron body.
An effective cooling is achieved to mitigate the heat load brought by the combustion pressure of 20 MPa.



Achievement of low fuel consumption proper lubricating oil consumption

Low lubricating oil consumption

Reduction and stabilization of lubricating oil consumption



Low fuel consumption

- High Pmax
- High-pressure fuel injection pump
- High efficiency, high-pressure ratio turbocharger
- Combustion system matching
- Reduction of mechanical loss

7 Development Concept and Scheme

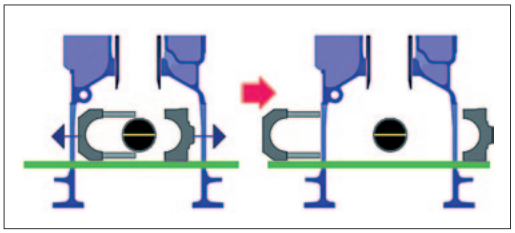
7-2 Enhancement in durability and reliability for the long life

Reduction of Operation Costs

Simple maintenance finished in a short time

Cylinder head

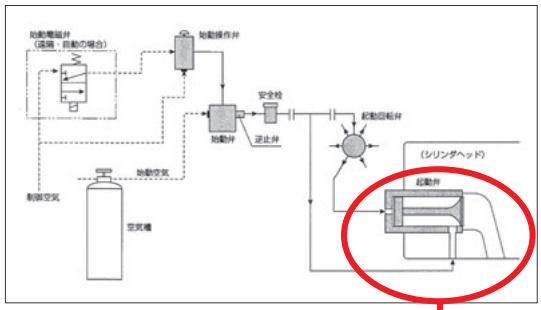
Main bearing

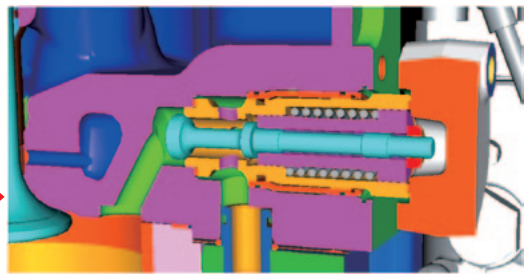


Connecting rod

Stable and Certain Engine Start

The direct air injection system is adopted, which is not influenced by air quality.



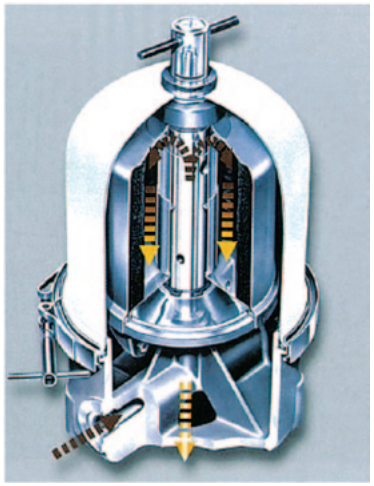


Pilot air

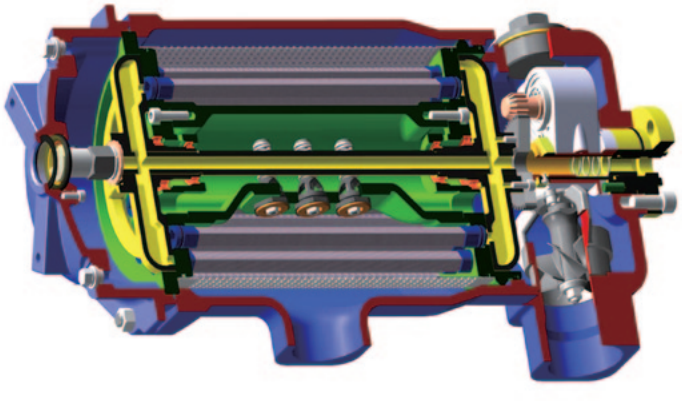
Starting air main pipe

Securing the Lub.Oil Performance in the Long Life

Large centrifugal filter

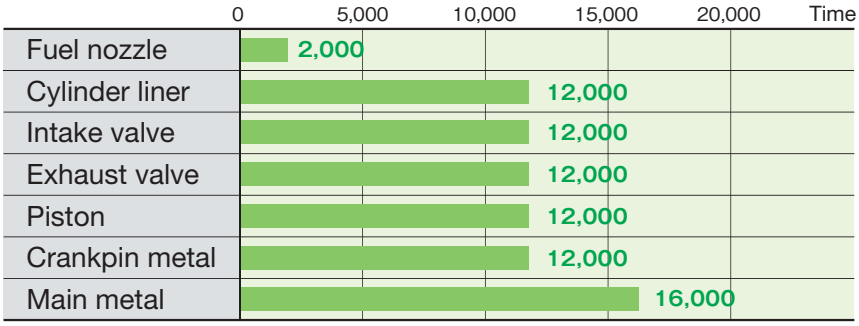


30μm automatic backwash filter

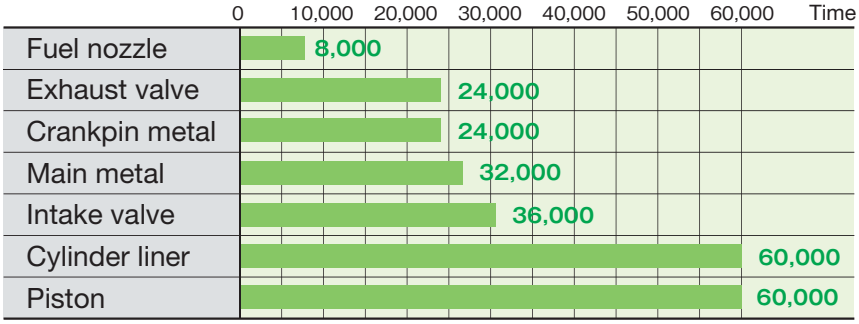


Maintenance Intervals and Life Expectancy

Maintenance intervals



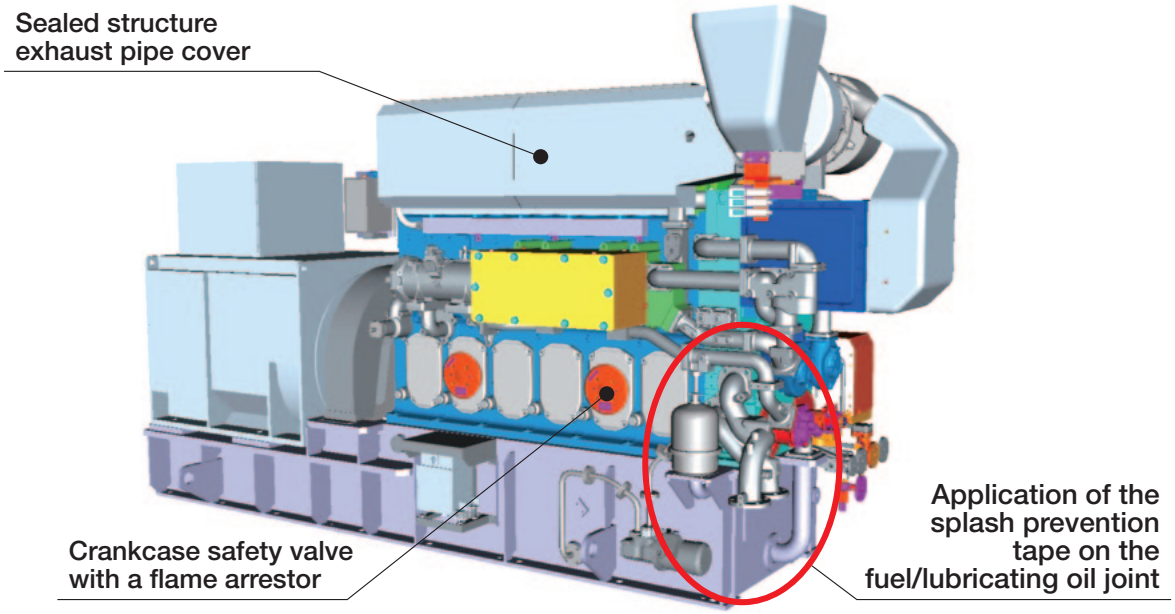
Life expectancy

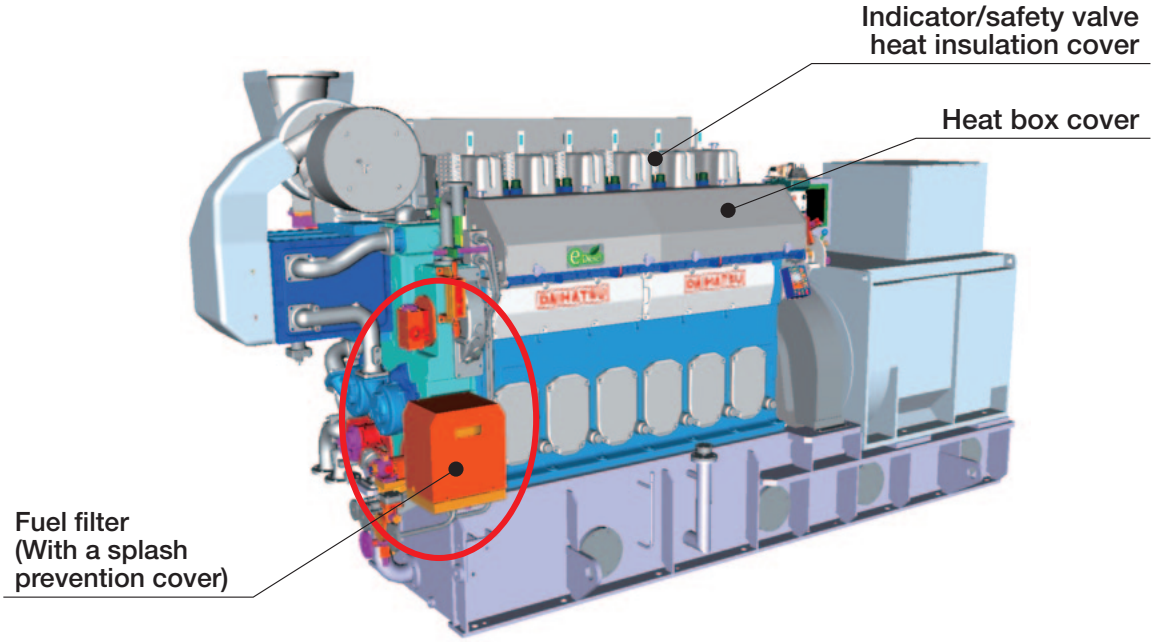


7 Development Concept and Scheme

7-3 Improvement in safety and assurance

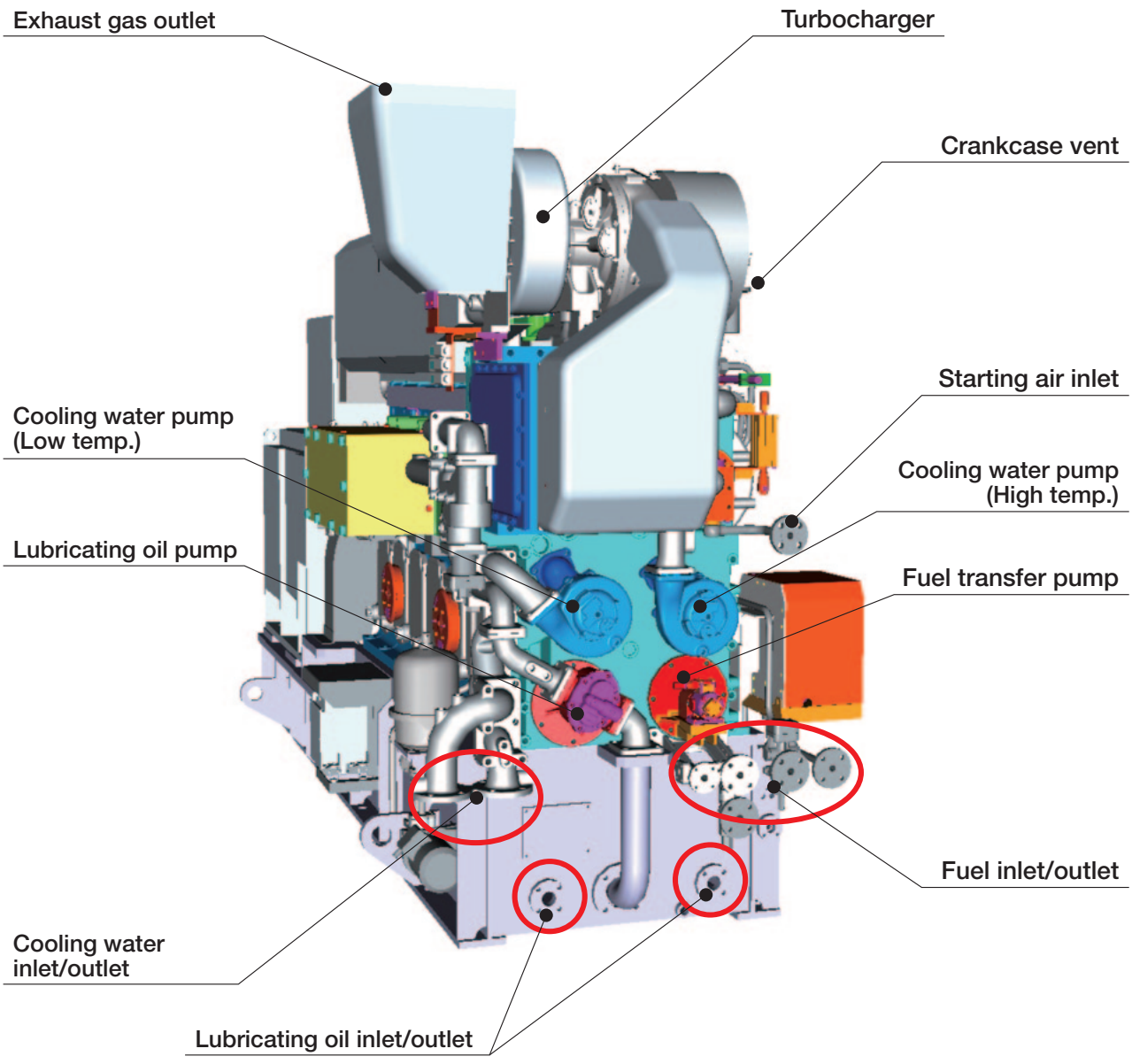
Perfect Fire Prevention Measures





Simplified Connection Points for Easier Installation

Converged arrangement of external connection points at the front-end part



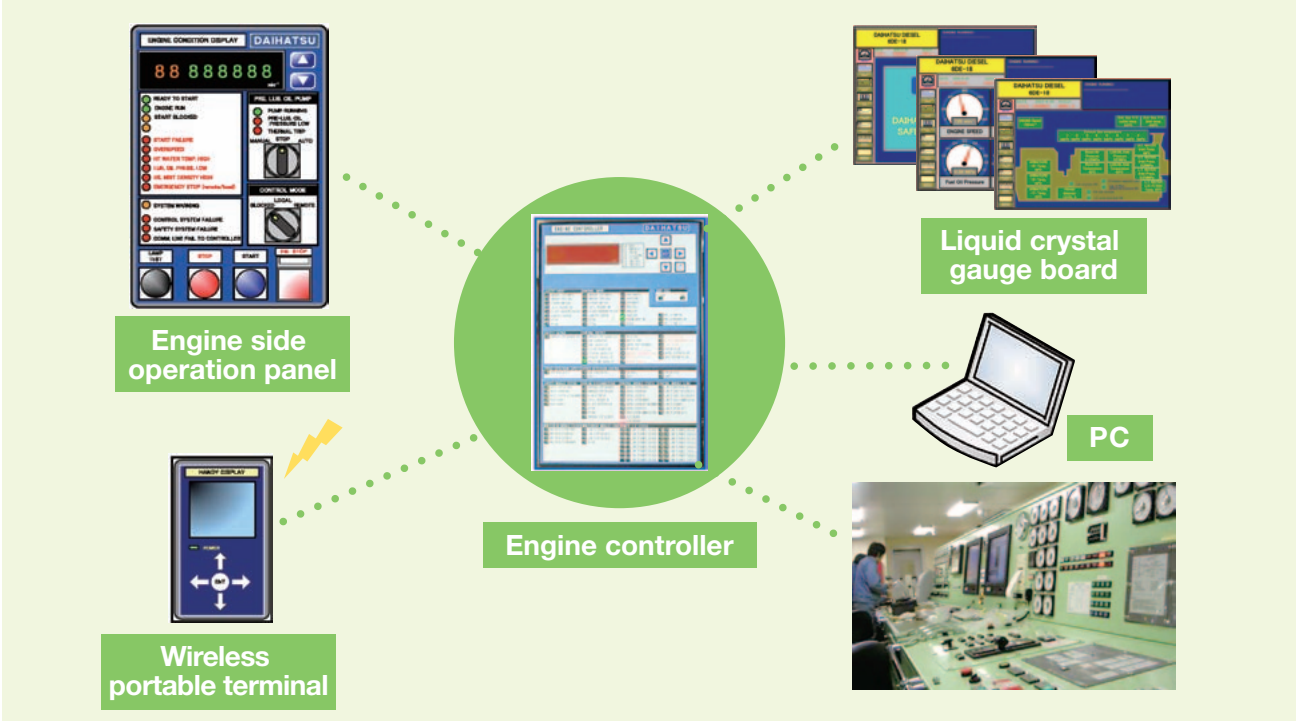
7 Development Concept and Scheme

7-3 Improvement in safety and assurance

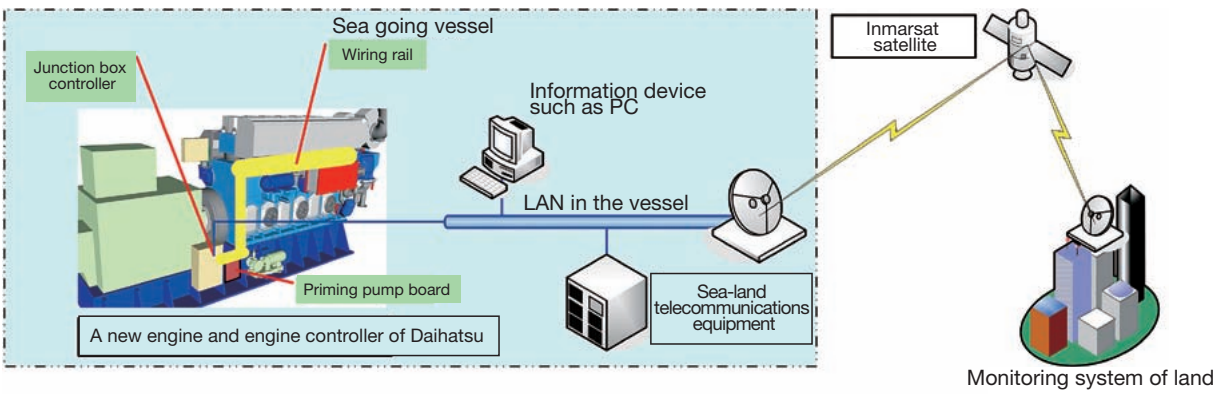
Engine Controller with Easy Handling

Merit 1 Integration of engine start, stop, and protection devices and installation on the engine

- The newest safety/control functions are implemented.
- The engine state data (events) at the ignition, start, and stop are automatically collected, which enables efficient investigations for maintenance and troubleshooting.
- The easy operability and appropriate interlock circuit prevent incorrect operation to run the engine.



Merit 2 Simplification of communications by the sea-land communication system



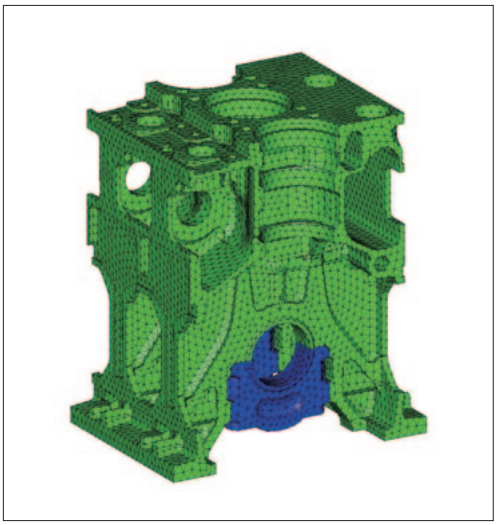
8 Structure of Main Parts

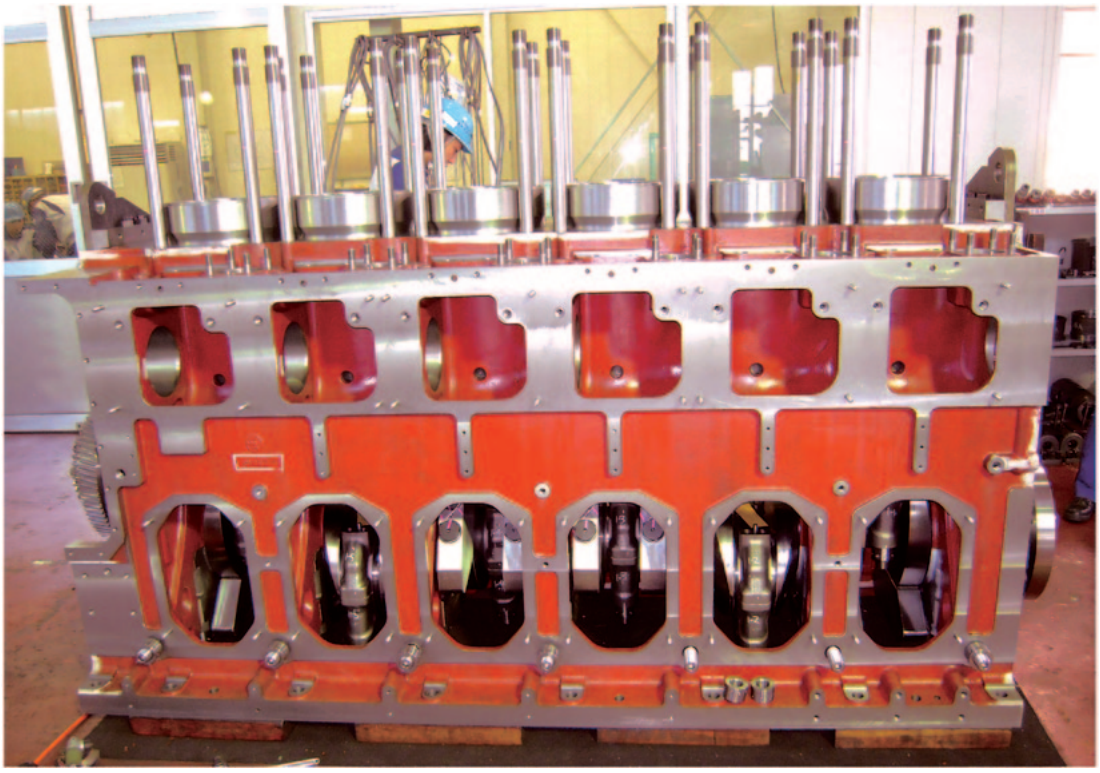
DE-type diesel engine incorporates the tried and tested technology of the DK-type engine, of which over 6,000 engines have been delivered. This technology has been further complemented by new technologies through our development for the purpose to adequately handle future global environmental issues.
At the phase of designing, we made use of all-out computer analysis including CAD, CAE, CFD, and performance simulation. For the reliability and durability, we used testing machines for sufficient prototype endurance tests. We verified that neither fault nor problem was found.
Each component is produced in the method with many types of jigs, tools, and special facilities under strict quality control, which provides excellent precision. Moreover, the materials are particularly screened to have logical correctness for the function of each part and to have durability, too.
Furthermore, major components are under strict inspection throughout all the processes from material selection, treatment processes, and assembly processes.

8 Structure of Main Parts

8-1 Frame and Main Bearing

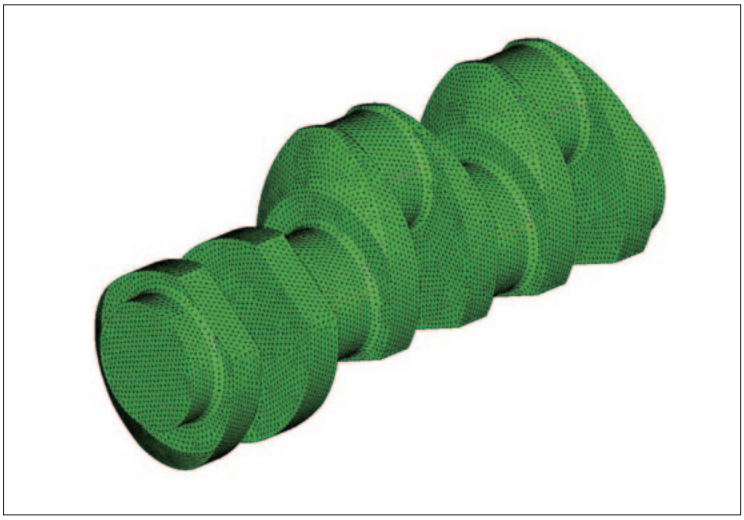
The frame has a monoblock structure made of cast iron. Each of the flow paths is formed integrally with the frame, which includes the air intake path, the lubricating oil path, and the cooling water inlet.
Since the hanging metal method is adopted, the main bearing is firmly mounted by the mounting bolts and the side bolts tightened with hydraulic jack. Thus, the rigidity around the main bearing is enhanced.

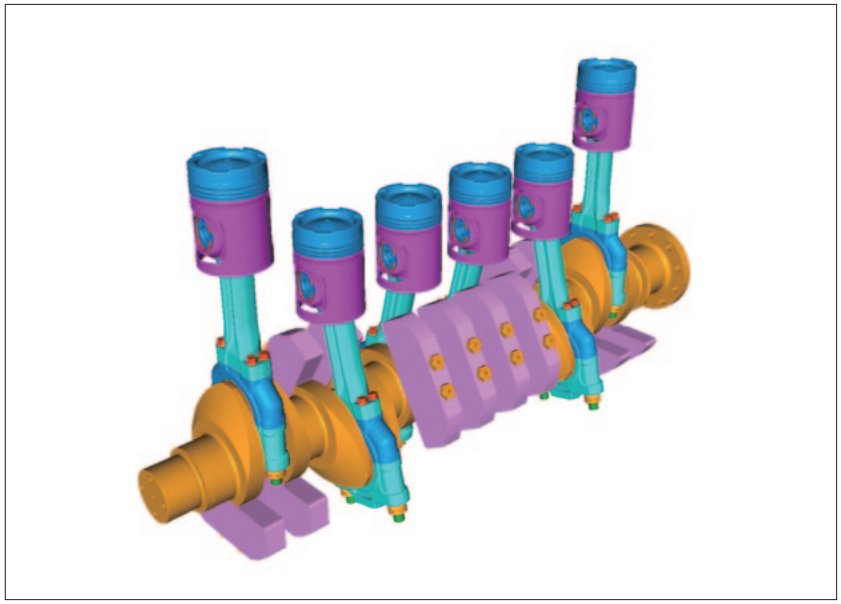




8-2 Crankshaft

The crankshaft is integrally forged from alloyed steel. The crankpin diameter and the journal diameter are so large that adequate bearing surface pressure and sufficient oil film thickness are generated. Moreover, the combination with the large-capacity balance weight adjusts the rotation balance to suppress vibration. There is a flywheel on the rear end (on the output side) of the crankshaft and a camshaft drive crank gear on the front end together with the drive gears for the pumps and the relevant components.
The main bearing and the crankpin bearing are made of thin-wall aluminum alloy metal split into two. There are thrust bearings mounted at the front and the rear of Bearing 1 on the rear side of the engine.



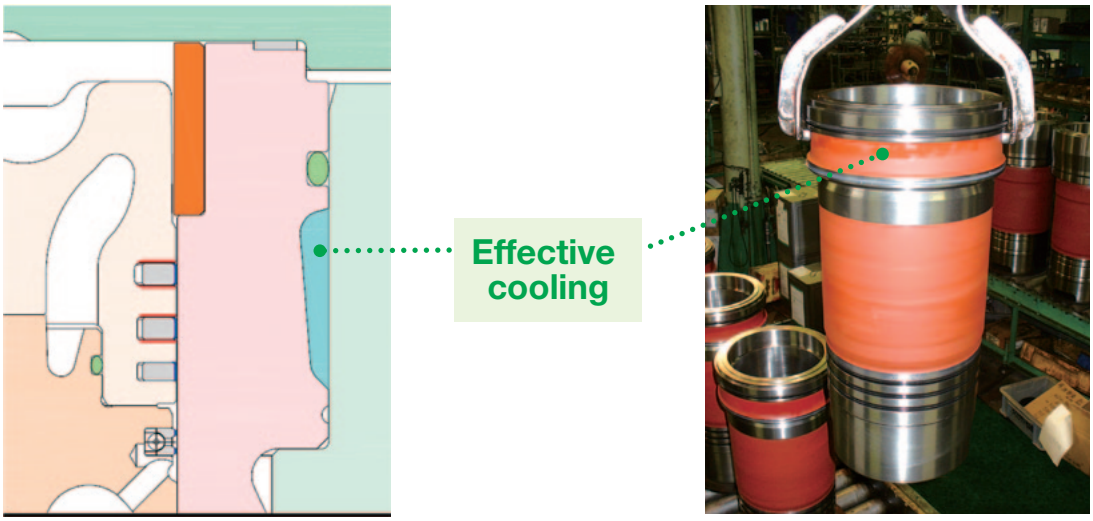


8 Structure of Main Parts

8-3 Cylinder Liner

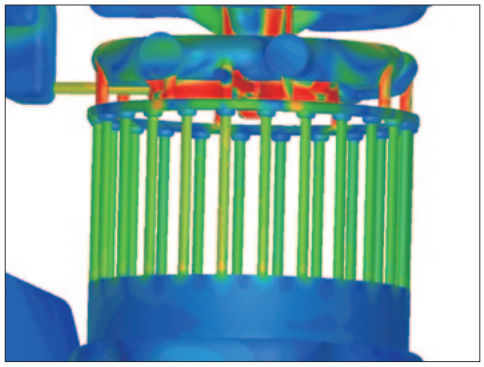
6DE-18

The cylinder liner is made of special cast iron. The high temperature cooling water comes from the frame water chamber and flows from under to over the water chamber formed with the frame and the liner, effectively cooling the liner. After this, the cooling water goes into the water chamber of the cylinder head.



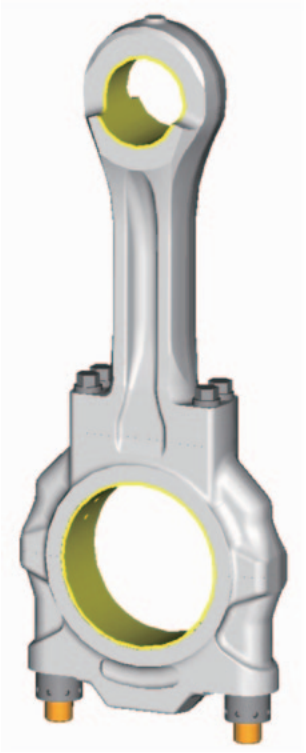
6DE-23

The cylinder liner is of a thick-wall bore cooling type.
The high temperature cooling water is led from the cooling water path in the frame to the bore-cooling hole of the cylinder liner, effectively cooling the upper part of the liner. After this, the cooling water goes into the water chamber in the lower part of the cylinder head.
The image at the lower right corner shows the analysis result of the cooling water flow in the cylinder liner. This image shows that the cooling water distributes evenly into the bore-cooling holes of the liner.



8-4 Piston and Connecting Rod

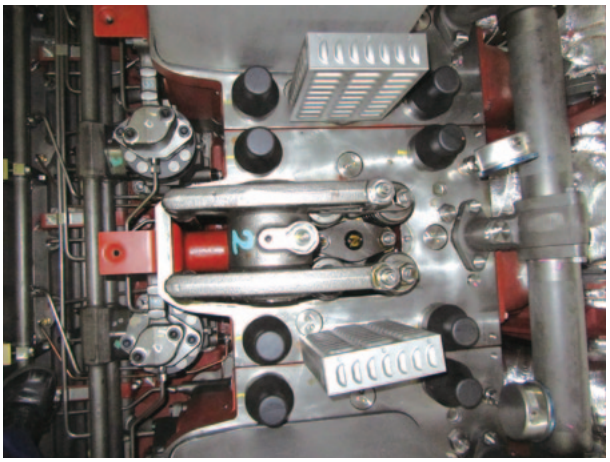
The piston adopted here is a built-up type with the skirt made of ductile iron and with the crown made of alloyed steel, where we have made use of the technologies accumulated from our rich experiences. The surfaces of the top ring groove and the second ring groove are hardened to enhance wear resistance. The piston is cooled forcibly and efficiently by the lubricating oil having passed through the connecting rod and the piston pin.
The connecting rod is die-forged. The big end is horizontally split into three portions. This makes it possible to have an access to the piston without removing the crankpin bearing part. Its disassembly and assembly are easy. In addition, it has been made possible to reduce the height for piston overhaul.

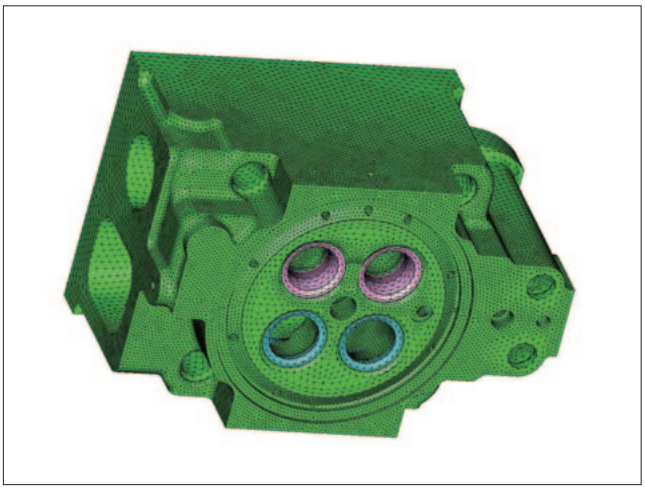


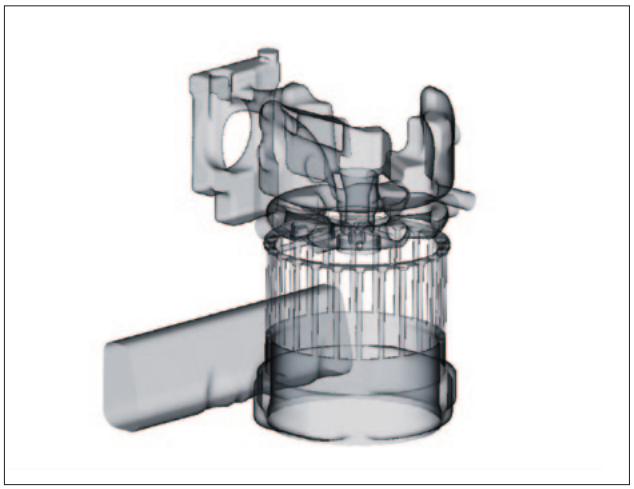
8 Structure of Main Parts

8-5 Cylinder Head

The cylinder head is made of special cast iron, which has excellent heat resistance performance. This cylinder head is fastened with four bolts as is in numerous proven examples of Daihatsu diesel engines; its disassembly and assembly are very easy. With the structure with high rigidity and with the four bolts tightened with hydraulic jack, the structure is reliable enough to resist the combustion pressure.
There are four valves, two intake valves and two exhaust valves, with a valve rotator attached. The drive force comes from the camshaft by way of the swing arm, the pushrod, and the valve arm. The exhaust valve has a water-cooled valve seat directly attached on the cylinder head.
The fuel injection valve and the relevant components are cooled by the special passages that particularly enhance the cooling effect. This makes it possible to make use of the uncooled fuel nozzle even during the operation with low quality fuel.
As pipes are not arranged on or around the cylinder head, the easiness in handling the cylinder head is greatly improved.



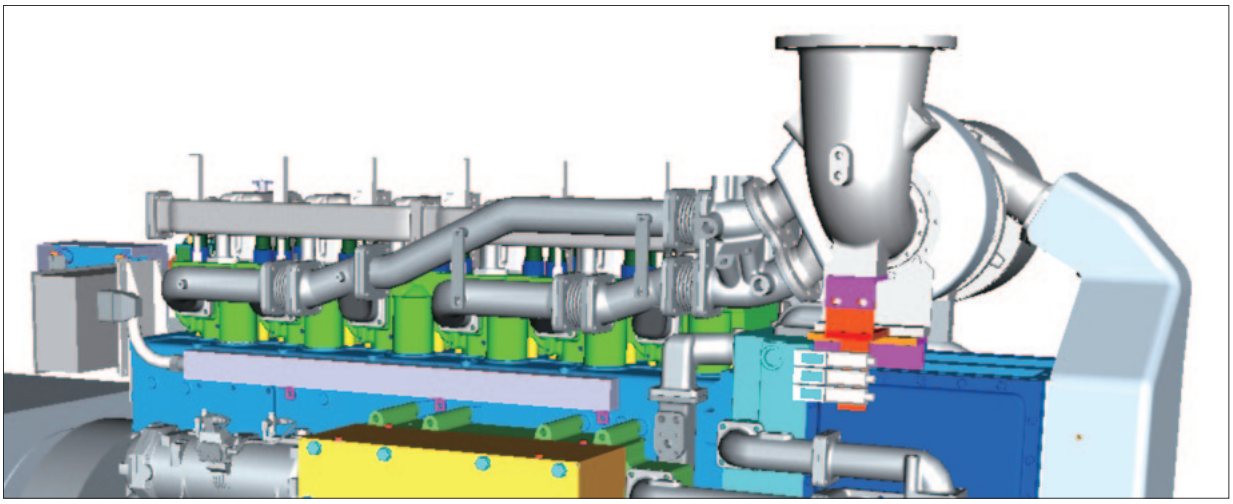




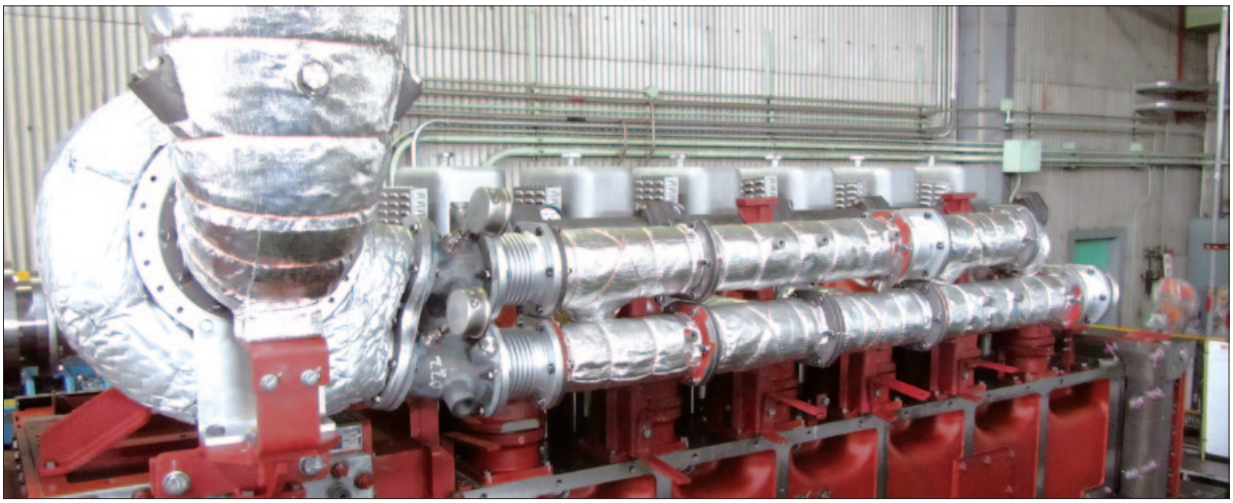
8-6 Intake Air and Exhaust System

The turbocharger includes an radial turbine with high efficiency and high-pressure ratio, which is not cooled but forcibly lubricated as standard.
Each of the turbocharger and the air cooler is independently fixed on the gear case in this structure in consideration of maintenance workability.
A pulse turbocharging method is adopted for the exhaust pipe, which enhances the turbocharging efficiency and is excellent in the transient response characteristics. The exhaust pipe is arranged on the same side as the air intake duct integrated with the frame, improving the easiness in handling.

6DE-18



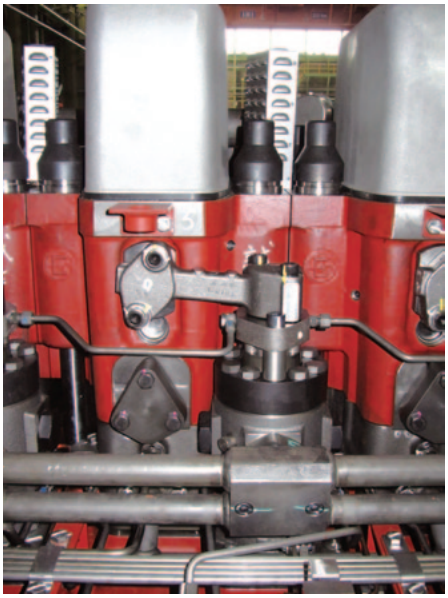
6DE-23

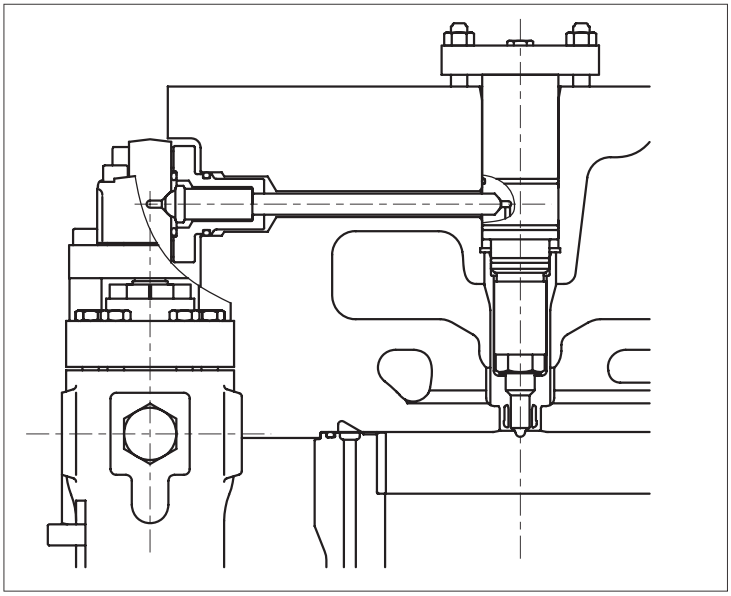


8 Structure of Main Parts

8-7 Fuel Injection System

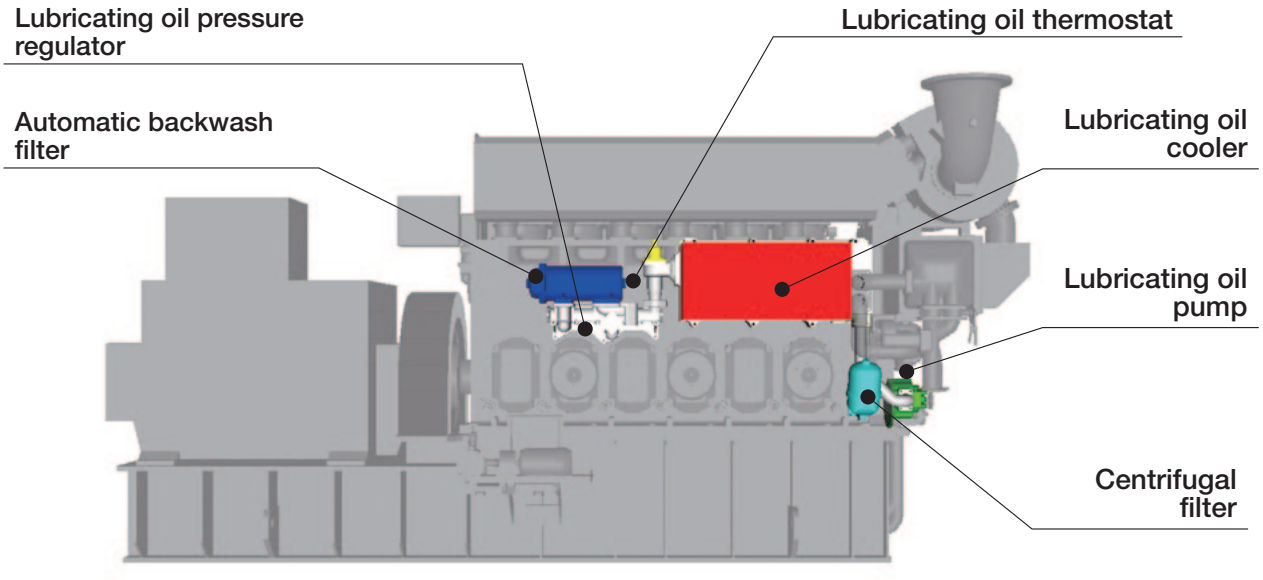
The fuel injection pump is a high-pressure pump of the bosch type with an integrated built-in tappet, in which a closed type plunger barrel and a carbon-coated plunger are adopted as standard.
The joint of the fuel injection valve at the high-pressure oil intake is side mounted and linked with the fuel injection pump by way of a forged high pressure joint. This structure provides the high reliability in respect to the high injection pressure and the excellent easiness in handling at the same time.
The fuel injection valve, which is uncooled type, has been processed by the heat treatment that enables excellent heat resistance.

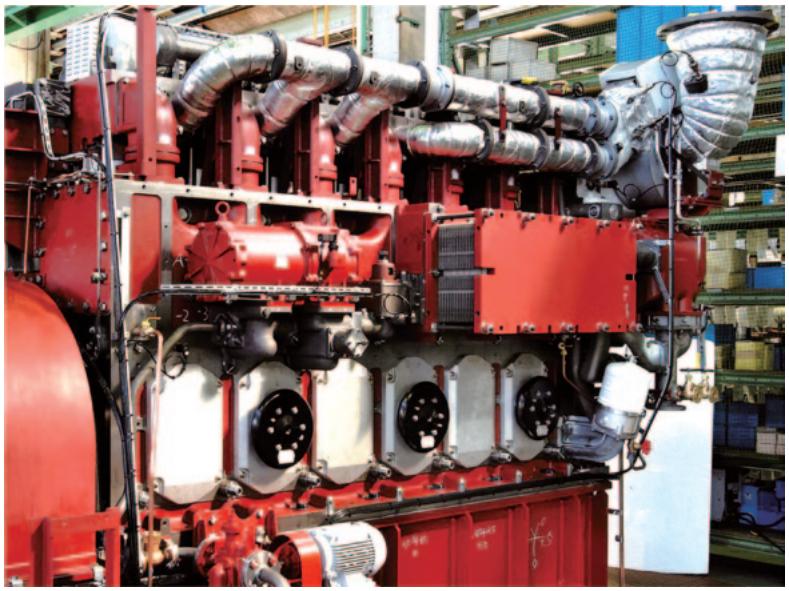




8-8 Lubricating Oil Module

The equipment related to the lubrication system is converged and arranged on a side surface on the exhaust pipe side.
The lubricating oil cooler, the thermostat, the pressure regulator and the automatic backwash filter are connected by the block unit. This module is brought by the consideration to accessibility and workability.
To effectively remove foreign substances and foreign particles, a large-capacity centrifugal filter is equipped in the front part of an engine side as standard.





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