# PROJECT GUIDE

## HiMSEN H32C

FOR MARINE

2025 1st EDITION

HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY

HEAVY INDUSTRIES

HiMSEN

# DISCLAIMER

All information provided in this document is for informational purposes only.

It is not a definitive binding document and may be changed without prior notice. In addition, there are no guarantees or guarantees for any particular content. Depending on the requirements of the specific project in the future, related data and documents may be changed, and specifications should be determined after evaluation by specific project. This should be determined according to each individual project, that is, the specifications required for the specific area and specific operating conditions.

**This page is intentionally blanked**

# 1 General information

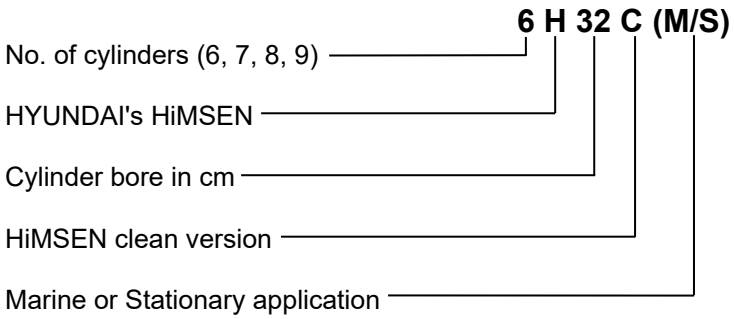
## 1.1 Introduction

This project guide provides necessary information and recommendations for the application of HYUNDAI HiMSEN H32C generating-set (gen-set). ‘HiMSEN'® is the licensed brand name of HYUNDAI's own design engine and the abbreviation of '**Hi**-Touch **M**arine & **S**tationary **EN**gine'. The HiMSEN H32C generating sets are delivered as complete packages, an engine and a generator are mounted on a common base frame together with related auxiliary equipment.

Please note that all data and information prepared in this project guide are for guidance only and subject to revision without notice. Therefore, please contact Hyundai Heavy Industries Co., Ltd. before actual applications of the data. Hyundai Heavy Industries Co., Ltd. (HHI) will always provide the data for the installation of specific project.

Each sheet is identified by the engine type and own 'Sheet Number'. Therefore, please use engine type 'H32C', and 'Sheet No.' for easier communications.

### Engine model designation



## 1.2 Engine nomenclature

### 1.2.1 Cylinder numbering

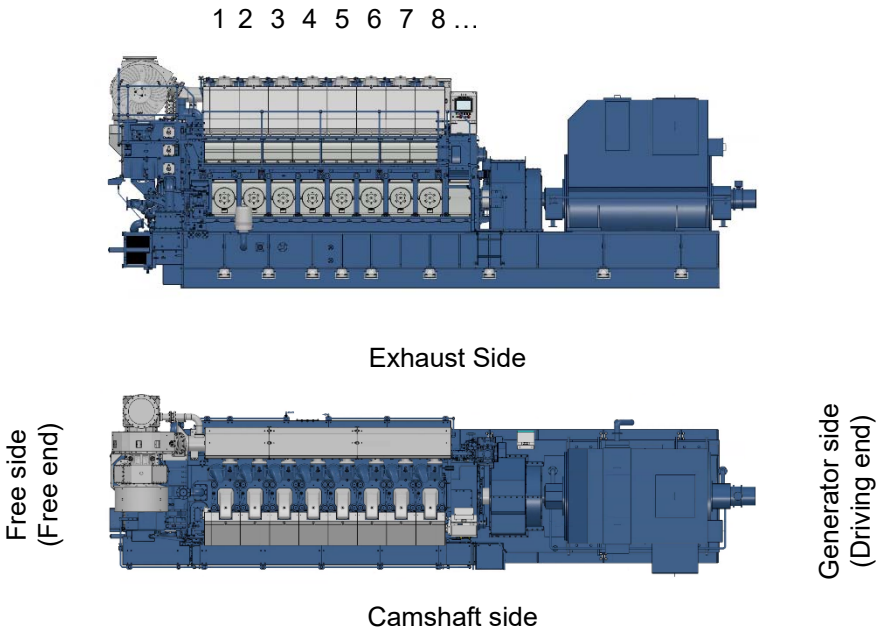



Figure 1.1 Cylinder numbering

### 1.2.2 Direction of engine rotation

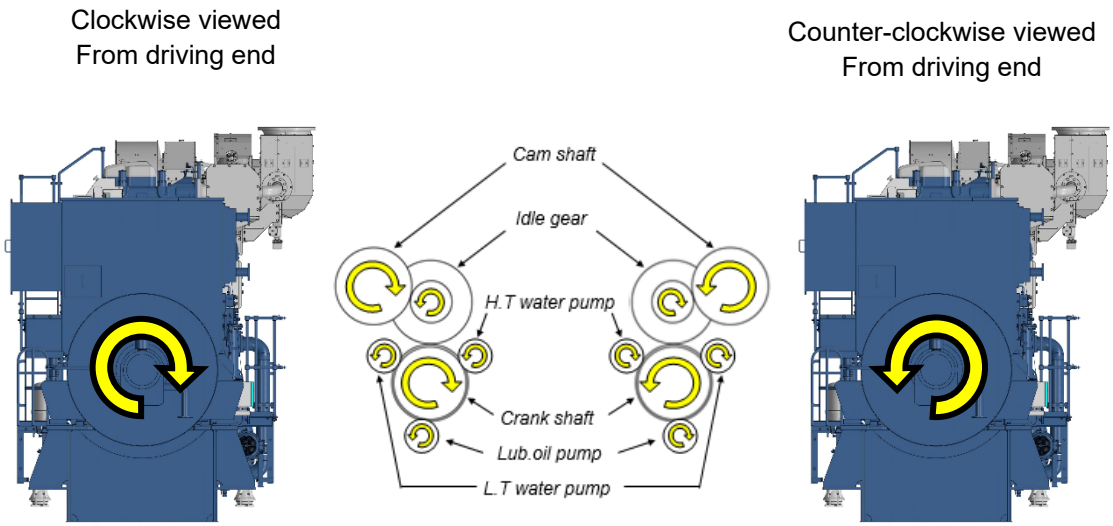



Figure 1.2 Direction of engine rotation

# 2 Structural design and installation

## 2.1 Principal data

Table 2.1 Principal data

| Type of engine | 4-stroke, vertical, direct injection, single acting and trunk piston type with turbocharger and inter-cooler. | | |
|---|---|---|---|
| Cylinder configuration | | In-line | |
| Number of cylinder | | 6 - 7 - 8 - 9 | |
| Rated speed | rpm | 720 | 750 |
| Power per cylinder | kW | 600 | 600 |
| Cylinder bore | mm | 320 | |
| Piston stroke | mm | 450 | |
| Swept Volume per cylinder | dm³ | 36.2 | |
| Mean piston speed | m/s | 10.8 | 11.3 |
| Mean effective pressure | bar | 27.6 | 26.5 |
| Direction of engine rotation | | Clockwise viewed from generator side (Non-reversible) | |
| Cylinder firing order | 6H32C | 1 - 4 - 2 - 6 - 3 - 5 | |
| | 7H32C | 1 - 2 - 4 - 6 - 7 - 5 - 3 | |
| | 8H32C | 1 - 3 - 5 - 7 - 8 - 6 - 4 - 2 | |
| | 9H32C | 1 - 3 - 5 - 7 - 9 - 8 - 6 - 4 - 2 | |

## 2.2 Engine cross section

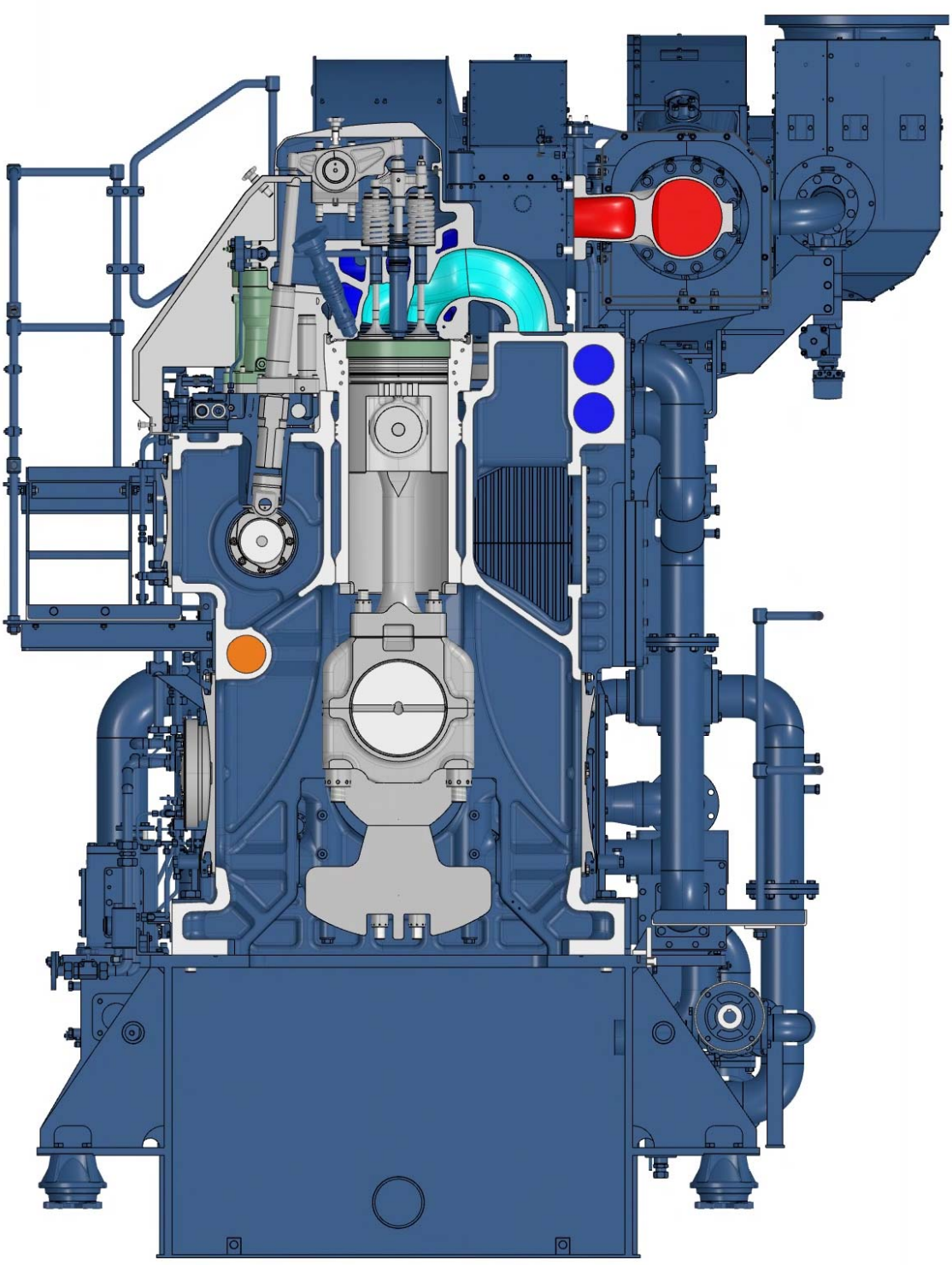


Figure 2.1 Engine cross section

## 2.3 Engine design outline

### 2.3.1 General

Hyundai's Marine Genset “HiMSEN H32C” family have simple and smart design suitable for marine applications with high reliability and performance. The key features are summarized as follows:

1. Heavy Fuel Engine with same fuel of main engine (Uni-Fuel concept).
Hence, the viscosity of the Diesel Fuel and Heavy Fuel is acceptable up to 700 cSt at 50 ℃.

2. Economical and Ecological Engine with low fuel consumption, NOx emission and Smoke, etc. which is based on the following specific designs:

- ✓ High stroke to bore ratio
- ✓ High compression ratio
- ✓ Optimized supercharging with miller cycle
- ✓ High fuel injection pressure

3. Reliable and Practical Engine with simple, smart and robust structure.

- ✓ Number of engine components is minimized.
- ✓ Most of the components are directly accessible for easy maintenance.
- ✓ Both 'individual part' and 'cylinder unit' maintenance concepts are provided.
- ✓ Feed system is fully modularized with direct accessibility.

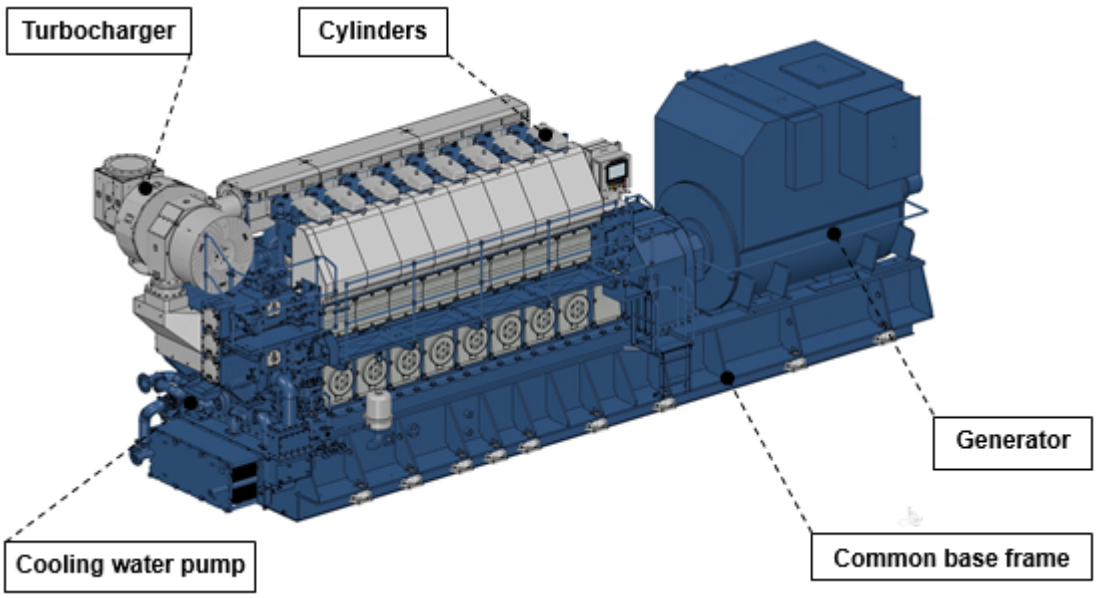



Figure 2.2 Engine design outline

### 2.3.2 Design of main components

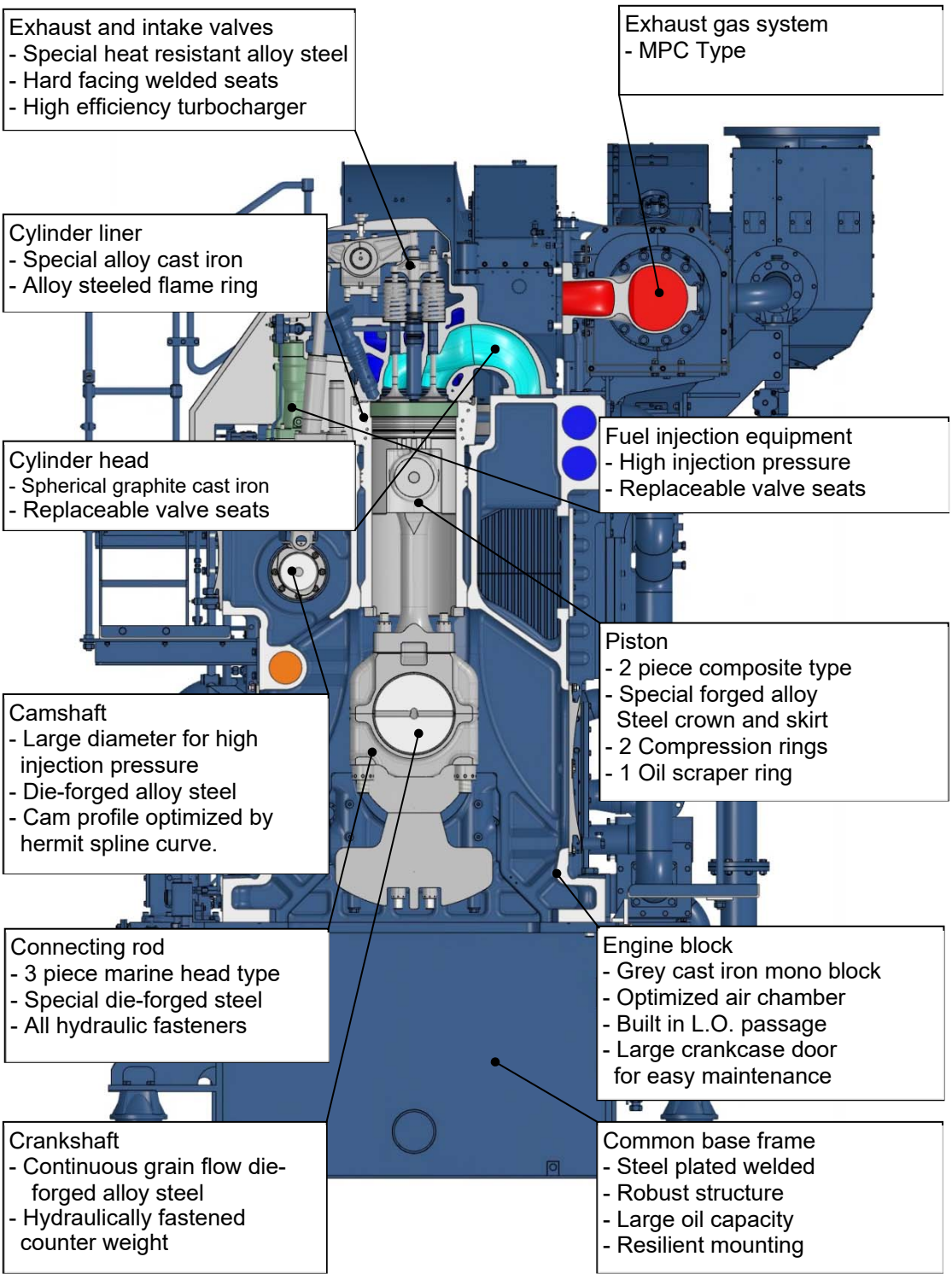
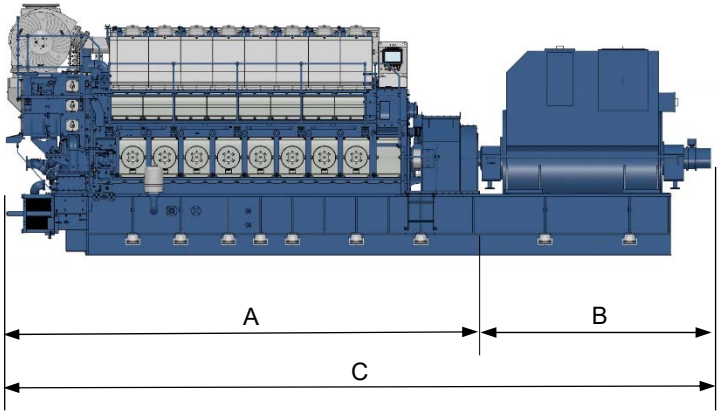



Figure 2.3 Cross section drawing

## 2.4 Generating-set dimension and weight



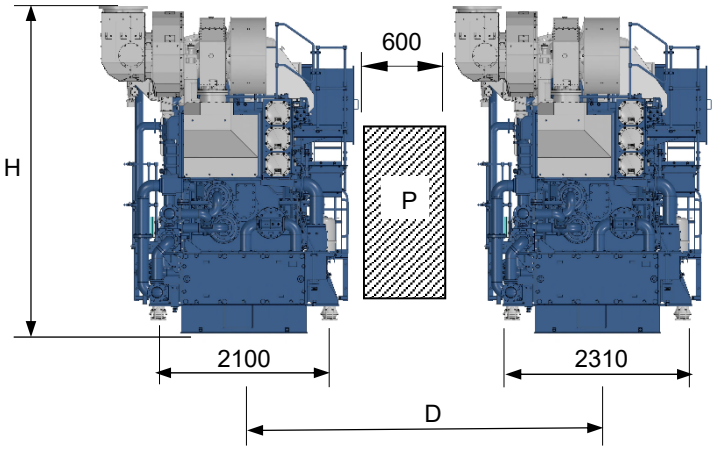




Table 2.2 Generating-set dimension and weight

| Engine type | Dimensions (mm) | | | | | Dry weight (ton) [2] | |
|---|---|---|---|---|---|---|---|
| | A | B [1] | C [1] | D | H | Engine [3] | Generating -set [4] |
| 6H32C | 6520 | 3200 | 9720 | 3595 | 3903 | 40.9 | 67.2 |
| 7H32C | 7030 | 3500 | 10530 | 3595 | 3903 | 45.0 | 75.5 |
| 8H32C | 7540 | 3800 | 11340 | 3725 | 3995 | 49.1 | 83.8 |
| 9H32C | 8050 | 4000 | 12050 | 3725 | 3995 | 53.3 | 92.1 |

1. All dimensions and weight are approximate value and subject to change without prior notice.
1) : Depending on alternator.
2) : Weight including a standard alternator (Maker : HHI-EES)
3) : Without common base frame
4) : With common base frame and generator
D : Min. distance between engines
P : Free passage between the engines, width 600 mm and height 2000 mm.

# 2.5 Mounting

## 2.5.1 General

A HiMSEN generating-set consists of diesel engine, generator and common base frame which supports them. The generating-set is mounted on the foundation by the resilient mounting coupled on a bracket of the common base frame, and shaped conical.
A resilient mounting of the generating-set is made with rubber elements to isolate vibrations between the generating-set and the hull structure. These rubber elements are bolted to brackets of the common base frame as shown below Figure 2.5.

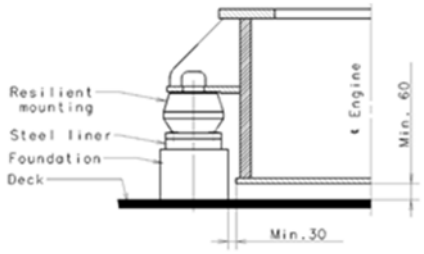



Figure 2.5 Resilient mounting

## 2.5.2 Design of resilient mount

The number and position of the resilient mounting shall depend on the specification of the generating-set and the dynamic characteristics of the ship (or plant). Therefore, the final specification of the resilient mounting shall be decided based on the information from the shipyard (or plant) case by case.

## 2.5.3 Connections to the generating-set

The generating-set mounted on the resilient mounting usually has some relative motions to the hull structure. Any rigid fixing between the generating-set and the hull structure can cause damages of the generating-set or hulls. Therefore, all connections, for example, pipes, gratings, ladders, electric wires, etc., should be flexible enough to absorb the relative movements.

## 2.5.4 Recommendations for seating design and adjustment

The foundation for the generating-set should be rigid enough to support the load from the generating-set. Steel liners with a thickness of minimum 15mm between the resilient mounting and the foundation are required to adjust the level of each mount (Method 1). The additional shim liner (min. thickness 10mm) can be used for adjustments (Method 2) as shown below Figure 2.6. It is also recommended to check the crankshaft deflection before starting up to secure the correct adjustments of the shim liner and leveling of the generating-set.

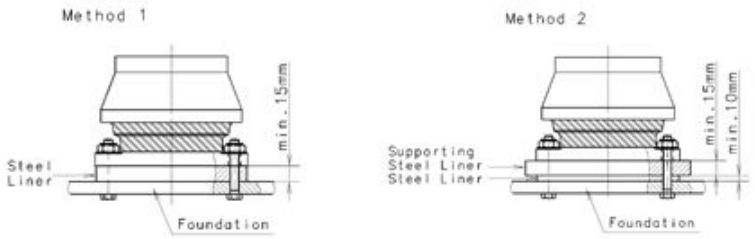
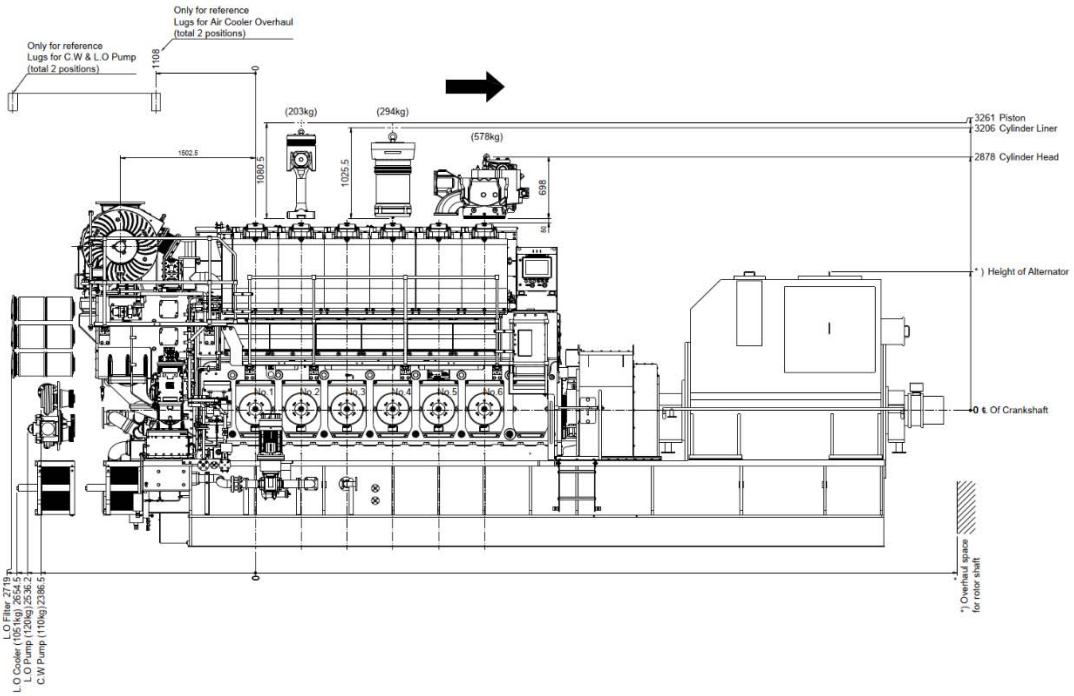
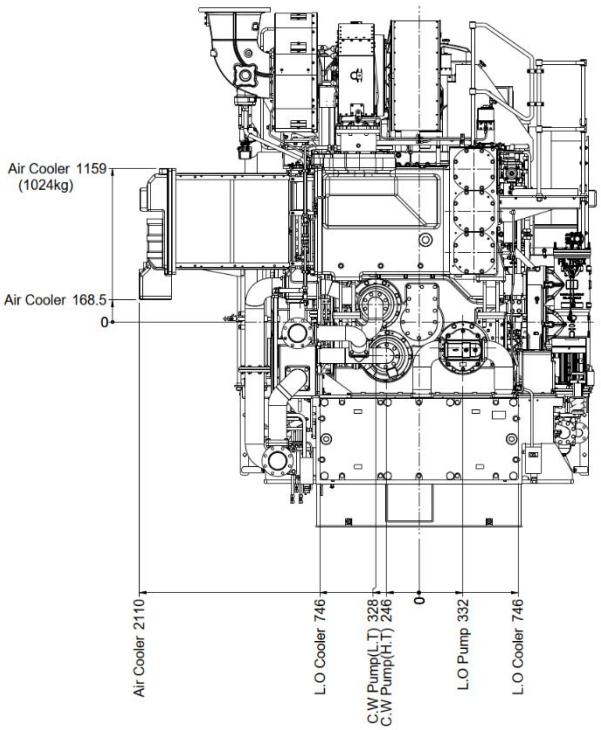



Figure 2.6 Recommendations for seating design

## 2.6 Overhaul dimension



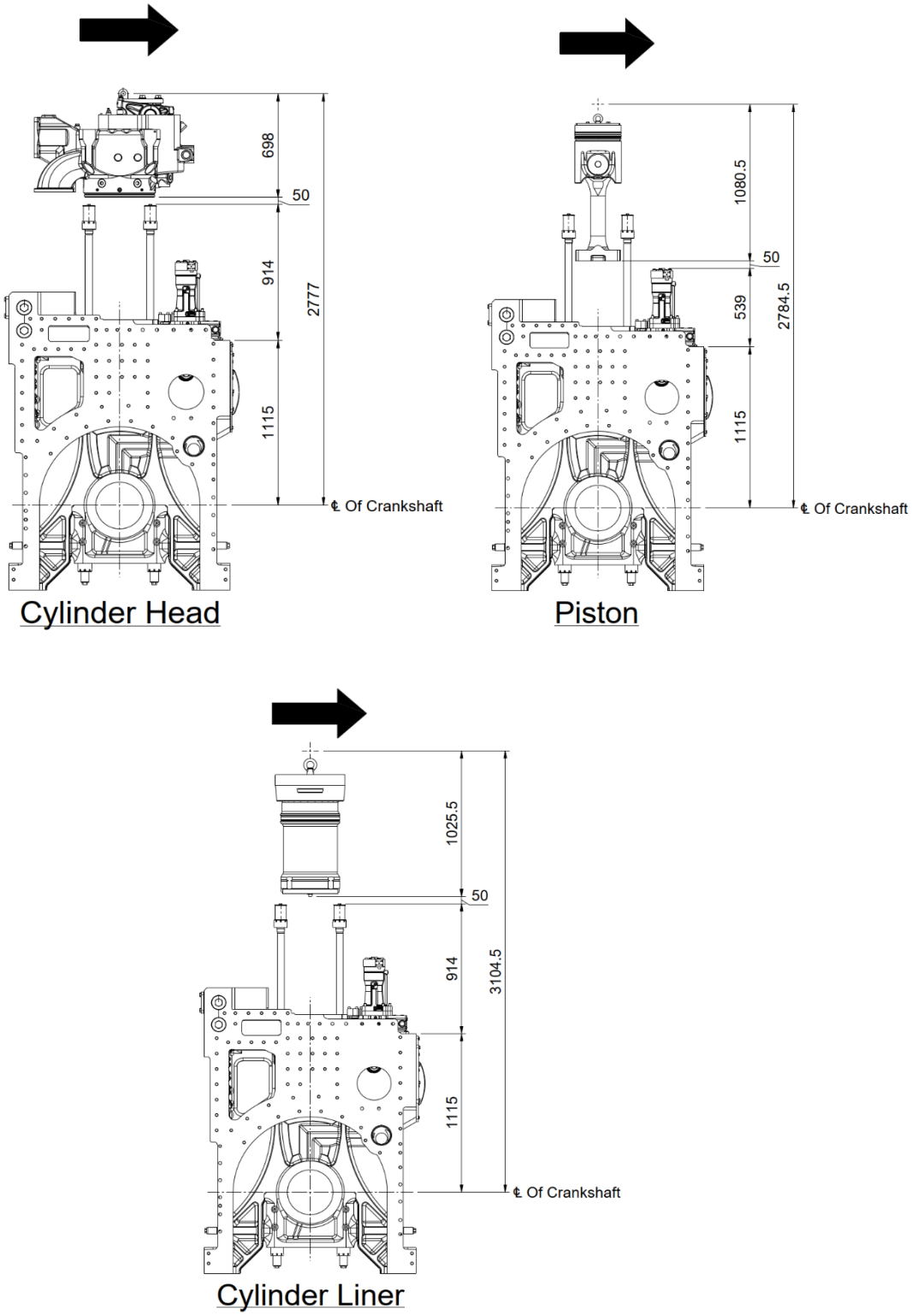



Figure 2.7 Overhaul dimension

# 3 Performance data

## 3.1 Rated power for generating-set

Table 3.1 Rated power for generating-set

| Engine type | Rated output at | | | |
|---|---|---|---|---|
| | 720 rpm / 60 Hz | | 750 rpm / 50 Hz | |
| | Engine (kWm) | Generator (kWe) | Engine (kWm) | Generator (kWe) |
| 6H32C | 3600 | 3474 | 3600 | 3474 |
| 7H32C | 4200 | 4053 | 4200 | 4053 |
| 8H32C | 4800 | 4632 | 4800 | 4632 |
| 9H32C | 5400 | 5211 | 5400 | 5211 |

1. The permissible overload is 10 % for one hour every twelve hours.
2. The alternator outputs are calculated for an efficiency of 96 % and a power factor of 0.8 lagging.
3. Power adjusting of diesel engines must be consulted to engine builder.

### Reference condition

General definition of diesel engine rating is specified in accordance with ISO 3046-1.

### ISO condition

Turbocharger air inlet pressure : 1000 mbar
Intake air temperature : 298 K (25 ℃)
Relative humidity : 30 %
L.T cooling water temperature : 298 K (25 ℃)

### Tropical condition

Turbocharger air inlet pressure : 1000 mbar
Intake air temperature : 318 K (45 ℃)
L.T cooling water temperature [1)] : 309 K (36 ℃)

1) Valid for central cooling system up to 36 °C normally, 38 °C specially

## 3.2 Engine capacity data

Table 3.2 Engine capacity data (Rated power : 600 kW / cylinder at 720 rpm)

| Engine MCR | Cyl. | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| | KW | 3600 | 4200 | 4800 | 5400 |
| **1. Cooling capacities** | | | | | |
| **Charge air** | | | | | |
| High temperature cooling water - heat dissipation [1] | kW | 1250 | 1430 | 1585 | 1755 |
| Low temperature cooling water - heat dissipation [1] | kW | 410 | 500 | 625 | 725 |
| Cooling water flow (High temperature and low temperature) | ㎥/h | 70 | 70 | 85 | 85 |
| High cooling water temperature, cooler in / out | ℃ | 60 / 75 | 56 / 74 | 58 / 74 | 56 / 73 |
| Low cooling water temperature, cooler in / out | ℃ | 36 / 41 | 36 / 42 | 36 / 42 | 36 / 43 |
| **Lubricating oil** | | | | | |
| Heat dissipation [1] [3] | kW | 545 | 640 | 730 | 820 |
| Low temperature cooling water flow | ㎥/h | 70 | 70 | 85 | 85 |
| Low cooling water temperature, cooler in / out | ℃ | 41 / 48 | 42 / 50 | 42 / 50 | 43 / 52 |
| **Cylinder jacket** | | | | | |
| Heat dissipation [1] | kW | 570 | 660 | 755 | 850 |
| High temperature cooling water flow | ㎥/h | 70 | 70 | 85 | 85 |
| High cooling water temperature, engine in / out | ℃ | 75 / 82 | 74 / 82 | 74 / 82 | 73 / 82 |
| **2. Gas data [2]** | | | | | |
| Combustion air consumption | kg/h | 25360 | 29580 | 33810 | 38040 |
| Exhaust gas flow | kg/h | 26040 | 30380 | 34720 | 39060 |
| Exhaust gas temperature | ℃ | 305 | 305 | 305 | 305 |
| Allowable exhaust gas back pressure max. | mbar | 30 | 30 | 30 | 30 |
| **3. Heat radiation** | | | | | |
| Engine radiation [1] | kW | 130 | 150 | 170 | 190 |
| Alternator radiation | kW | (See separate data from alternator maker) | | | |

| Engine MCR | Cyl. | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| | kW | 3600 | 4200 | 4800 | 5400 |
| **4. Starting air** | | | | | |
| Air consumption per start [7)] | Nm³ | 4.90 | 5.00 | 5.25 | 5.50 |
| Starting air source, pressure (20℃) (Max. /Min.) | bar | 30 / 15 | 30 / 15 | 30 / 15 | 30 / 15 |
| **5. Pump capacities** | | | | | |
| **Engine driven pumps [4)]** | | | | | |
| Lubricating oil pump (6 bar) | m³/h | 120 | 120 | 140 | 140 |
| High temperature cooling water pump (1 ~ 2.5 bar) | m³/h | 70 | 70 | 85 | 85 |
| Low temperature cooling water pump (1 ~ 2.5 bar) | m³/h | 70 | 70 | 85 | 85 |
| **External pumps [5)]** | | | | | |
| Marine diesel oil pump (head) - (8 bar) | m³/h | 2.69 | 3.14 | 3.59 | 4.04 |
| Heavy fuel oil supply pump (head) - (4 bar) | m³/h | 1.35 | 1.57 | 1.79 | 2.02 |
| Heavy fuel oil booster pump (8 bar at engine inlet, F1) [6)] | m³/h | 2.69 | 3.14 | 3.59 | 4.04 |

Remarks

1) Under tropical condition(Turbocharger air inlet pressure 1 bar, intake air temperature 45℃, LT-cooling water temperature 36℃) with heat dissipation tolerance for coolers +10% / for heat recovery -15%.

2) Under ISO condition (ISO 3046-1:2002, Turbocharger air inlet pressure 1 bar, intake air temperature 25℃, LT-cooling water temperature 25℃) with flow tolerance ±10% and exhaust gas temperature tolerance ±25℃, these data are indicative values. For each project, please contact to HHI-EMD.

3) Additional heat for lube oil purification should be included. (30 kJ / kWh)

4) Flow capacity to be within a tolerance of 0% to + 10%.

5) Flushing oil quantity of automatic filter should be included.

6) Heavy fuel oil booster pump head to be designed by external system designer considering pressure loss of external system.

7) Engine performance data depends on LCV (Low Calorific Value) of used fuel oil respectively.

8) This value includes jet assist system consumption. The air amount of jet assist for sudden load to be adjusted depending on the loading condition.

Table 3.3 Engine capacity data (Rated power : 600 kW / cylinder at 750 rpm)

| Engine MCR | Cyl. | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| | KW | 3600 | 4200 | 4800 | 5400 |
| **1. Cooling capacities** | | | | | |
| **Charge air** | | | | | |
| High temperature cooling water - heat dissipation [1)] | kW | 1270 | 1455 | 1610 | 1785 |
| Low temperature cooling water - heat dissipation [1)] | kW | 425 | 520 | 645 | 755 |
| Cooling water flow (High temperature and low temperature) | ㎥/h | 73 | 73 | 88.5 | 88.5 |
| High cooling water temperature, cooler in / out | ℃ | 59 / 75 | 56 / 74 | 58 / 74 | 55 / 73 |
| Low cooling water temperature, cooler in / out | ℃ | 36 / 41 | 36 / 42 | 36 / 43 | 36 / 44 |
| **Lubricating oil** | | | | | |
| Heat dissipation [1) 3)] | kW | 560 | 655 | 745 | 840 |
| Low temperature cooling water flow | ㎥/h | 73 | 73 | 88.5 | 88.5 |
| Low cooling water temperature, cooler in / out | ℃ | 41 / 48 | 42 / 50 | 43 / 50 | 44 / 52 |
| **Cylinder jacket** | | | | | |
| Heat dissipation [1)] | kW | 570 | 665 | 760 | 855 |
| High temperature cooling water flow | ㎥/h | 73 | 73 | 88.5 | 88.5 |
| High cooling water temperature, engine in / out | ℃ | 75 / 82 | 74 / 82 | 74 / 82 | 73 / 82 |
| **2. Gas data [2)]** | | | | | |
| Combustion air consumption | kg/h | 26060 | 30410 | 34750 | 39100 |
| Exhaust gas flow | kg/h | 26750 | 31210 | 35670 | 40130 |
| Exhaust gas temperature | ℃ | 305 | 305 | 305 | 305 |
| Allowable exhaust gas back pressure max. | mbar | 30 | 30 | 30 | 30 |
| **3. Heat radiation** | | | | | |
| Engine radiation [1)] | kW | 130 | 150 | 170 | 195 |
| Alternator radiation | kW | (See separate data from alternator maker) | | | |

| Engine MCR | Cyl. | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|
| | kW | 3600 | 4200 | 4800 | 5400 |
| **4. Starting air** | | | | | |
| Air consumption per start [7] | Nm³ | 4.90 | 5.00 | 5.25 | 5.50 |
| Starting air source, pressure (20℃) (Max. /Min.) | bar | 30 / 15 | 30 / 15 | 30 / 15 | 30 / 15 |
| **5. Pump capacities** | | | | | |
| **Engine driven pumps [4]** | | | | | |
| Lubricating oil pump (6 bar) | m³/h | 125 | 125 | 145 | 145 |
| High temperature cooling water pump (1 ~ 2.5 bar) | m³/h | 73 | 73 | 88.5 | 88.5 |
| Low temperature cooling water pump (1 ~ 2.5 bar) | m³/h | 73 | 73 | 88.5 | 88.5 |
| **External pumps [5]** | | | | | |
| Marine diesel oil pump (head) - (8 bar) | m³/h | 2.72 | 3.17 | 3.63 | 4.08 |
| Heavy fuel oil supply pump (head) - (4 bar) | m³/h | 1.36 | 1.59 | 1.81 | 2.04 |
| Heavy fuel oil booster pump (8 bar at engine inlet, F1) [6] | m³/h | 2.72 | 3.17 | 3.63 | 4.08 |

Remarks

1) Under tropical condition(Turbocharger air inlet pressure 1 bar, intake air temperature 45℃, LT-cooling water temperature 36℃) with heat dissipation tolerance for coolers +10% / for heat recovery -15%.

2) Under ISO condition (ISO 3046-1:2002, Turbocharger air inlet pressure 1 bar, intake air temperature 25℃, LT-cooling water temperature 25℃) with flow tolerance ±10% and exhaust gas temperature tolerance ±25℃, these data are indicative values. For each project, please contact to HHI-EMD.

3) Additional heat for lube oil purification should be included. (30 kJ / kWh)

4) Flow capacity to be within a tolerance of 0% to + 10%.

5) Flushing oil quantity of automatic filter should be included.

6) Heavy fuel oil booster pump head to be designed by external system designer considering pressure loss of external system.

7) Engine performance data depends on LCV (Low Calorific Value) of used fuel oil respectively.

8) This value includes jet assist system consumption. The air amount of jet assist for sudden load to be adjusted depending on the loading condition.

## 3.3 Engine performance – 720 rpm

Table 3.4 Engine performance data (Rated power : 600 kW / cylinder at 720 rpm)

| Performance data | | Engine load (%) | | | | |
|---|---|---|---|---|---|---|
| | | 110 | 100 | 85 | 75 | 50 |
| **1. Cylinder data** | | | | | | |
| Cylinder output | kW | 660 | 600 | 510 | 450 | 300 |
| Mean effective pressure | bar | 30.4 | 27.6 | 23.5 | 20.7 | 13.8 |
| **2. Combustion air data [1]** | | | | | | |
| Mass flow | kg/kWh | 6.8 | 7.0 | 7.3 | 7.4 | 8.2 |
| Air temperature after cooler | ℃ | 45 | 45 | 45 | 45 | 45 |
| **3. Exhaust gas data [1)]** | | | | | | |
| Mass flow | kg/kWh | 7.0 | 7.2 | 7.4 | 7.6 | 8.4 |
| Gas temperature after turbine | ℃ | 325 | 305 | 295 | 290 | 275 |
| **4. Heat balance data [2)]** | | | | | | |
| Charge air, After cooler (High temperature) | kJ/kWh | 1290 | 1250 | 1150 | 1090 | 890 |
| Charge air, After cooler (Low temperature) | kJ/kWh | 435 | 410 | 360 | 330 | 290 |
| Lubricating oil | kJ/kWh | 545 | 545 | 600 | 635 | 865 |
| Jacket cooling water | kJ/kWh | 560 | 570 | 575 | 590 | 705 |
| Radiation | kJ/kWh | 125 | 130 | 135 | 140 | 155 |
| **5. Specific fuel oil consumption [3)]** | | | | | | |
| Specific fuel oil consumption | g/kWh | 186.0 | 185.0 | 178.2 | 177.4 | 179.6 |

Remarks

Reference condition is based on ISO 3046-1:2002 (Turbocharger air inlet pressure 1 bar, intake air temperature 25℃, L.T cooling water temperature 25℃) except heat balance data. For heat balance data, please see No. 2). The above values are based on IMO Tier II emission level without selective catalyst reduction operation.

1) Mass flow tolerance ± 5 %, temperature tolerance ± 25℃ (50 % < load ≤ 110 %).
Mass flow tolerance ± 10 %, temperature tolerance ± 35℃ (Load ≤ 50%).
For heat recovery, additional temperature tolerance - 10℃ should be accounted.
When calculating heat dissipation for heat recovery based on the mass flow & temperature, the mass flow & temperature's tolerance should be considered.

2) Reference condition is based on tropical condition (Turbocharger air inlet pressure 1 bar, intake air temperature 45℃, L.T cooling water temperature 36℃).
Heat dissipation tolerance + 10% for cooler, - 15% for heat recovery.
Additional heat for lube oil purification should be included (30 kJ/kWh).

3) Specific fuel oil consumption tolerance + 6% at 75 % load.
Engine driven pumps detached : lubricating oil pump, high temperature cooling water pump, low temperature cooling water pump.
(For example, the increased specific fuel consumption due to engine-driven pumps is 5.6 g/kWh at 75% load.)
Specific fuel oil consumption excludes clean leakage fuel oil.
Fuel oil based on marine diesel oil, lower calorific value 42700 kJ/kg.
Specific fuel oil consumption is warranted at 75% engine load without selective catalyst reduction operation.

Note) The value are only reference, the values can be modified.

## 3.4 Engine performance – 750 rpm

Table 3.5 Engine performance data (Rated power : 600 kW / cylinder at 750 rpm)

| Performance data | | Engine load (%) | | | | |
|---|---|---|---|---|---|---|
| | | 110 | 100 | 85 | 75 | 50 |
| **1. Cylinder data** | | | | | | |
| Cylinder output | kW | 660 | 600 | 510 | 450 | 300 |
| Mean effective pressure | bar | 29.2 | 26.5 | 22.5 | 19.9 | 13.3 |
| **2. Combustion air data [1)]** | | | | | | |
| Mass flow | kg/kWh | 7.0 | 7.2 | 7.5 | 7.7 | 8.7 |
| Air temperature after cooler | ℃ | 45 | 45 | 45 | 45 | 45 |
| **3. Exhaust gas data [1)]** | | | | | | |
| Mass flow | kg/kWh | 7.2 | 7.4 | 7.6 | 7.8 | 8.9 |
| Gas temperature after turbine | ℃ | 325 | 305 | 295 | 290 | 275 |
| **4. Heat balance data [2)]** | | | | | | |
| Charge air, After cooler (High temperature) | kJ/kWh | 1310 | 1270 | 1175 | 1120 | 940 |
| Charge air, After cooler (Low temperature) | kJ/kWh | 450 | 425 | 370 | 345 | 310 |
| Lubricating oil | kJ/kWh | 540 | 560 | 615 | 650 | 900 |
| Jacket cooling water | kJ/kWh | 565 | 570 | 580 | 595 | 725 |
| Radiation | kJ/kWh | 125 | 130 | 135 | 140 | 160 |
| **5. Specific fuel oil consumption [3)]** | | | | | | |
| Specific fuel oil consumption | g/kWh | 188.0 | 187.0 | 180.2 | 179.4 | 181.6 |

Remarks

Reference condition is based on ISO 3046-1:2002 (Turbocharger air inlet pressure 1 bar, intake air temperature 25℃, L.T cooling water temperature 25℃) except heat balance data. For heat balance data, please see No. 2). The above values are based on IMO Tier II emission level without selective catalyst reduction operation.

1) Mass flow tolerance ± 5 %, temperature tolerance ± 25℃ (50 % < load ≤ 110 %).
Mass flow tolerance ± 10 %, temperature tolerance ± 35℃ (Load ≤ 50%).
For heat recovery, additional temperature tolerance - 10℃ should be accounted.
When calculating heat dissipation for heat recovery based on the mass flow & temperature, the mass flow & temperature's tolerance should be considered.

2) Reference condition is based on tropical condition (Turbocharger air inlet pressure 1 bar, intake air temperature 45℃, L.T cooling water temperature 36℃).
Heat dissipation tolerance + 10% for cooler, - 15% for heat recovery.
Additional heat for lube oil purification should be included (30 kJ/kWh).

3) Specific fuel oil consumption tolerance + 6% at 75 % load.
Engine driven pumps detached : lubricating oil pump, high temperature cooling water pump, low temperature cooling water pump.
(For example, the increased specific fuel consumption due to engine-driven pumps is 5.6 g/kWh at 75% load.)
Specific fuel oil consumption excludes clean leakage fuel oil.
Fuel oil based on marine diesel oil, lower calorific value 42700 kJ/kg.
Specific fuel oil consumption is warranted at 75% engine load without selective catalyst reduction operation.

Note) The value are only reference, the values can be modified.

## 3.5 Exhaust gas emission

### 3.5.1 General

HiMSEN H32C is designed for environment-friendly engine and complies with the IMO $NO_X$ emission limits with low fuel consumption and less smoke**.**
Typical composition of exhaust gas emission in volume ratio at full load are as follows:

Table 3.6 Typical compositions of exhaust gas emission

| Typical exhaust compositions | Volume[%] |
|---|---|
| Nitrogen, $N_2$ | approx. 73 |
| Oxygen, $O_2$ | approx. 13 |
| Carbon Dioxide, $CO_2$ | approx. 6 |
| Water (Vapor), $H_2O$ | approx. 6 |
| Argon, Ar | approx. 1 |
| Soot, Ash, $NO_X$, CO, HC, etc. | residue |

Residue is little in amount but ecologically critical. Therefore, a careful attention on the treatment of fuel oil shall be required for engine operating conditions.

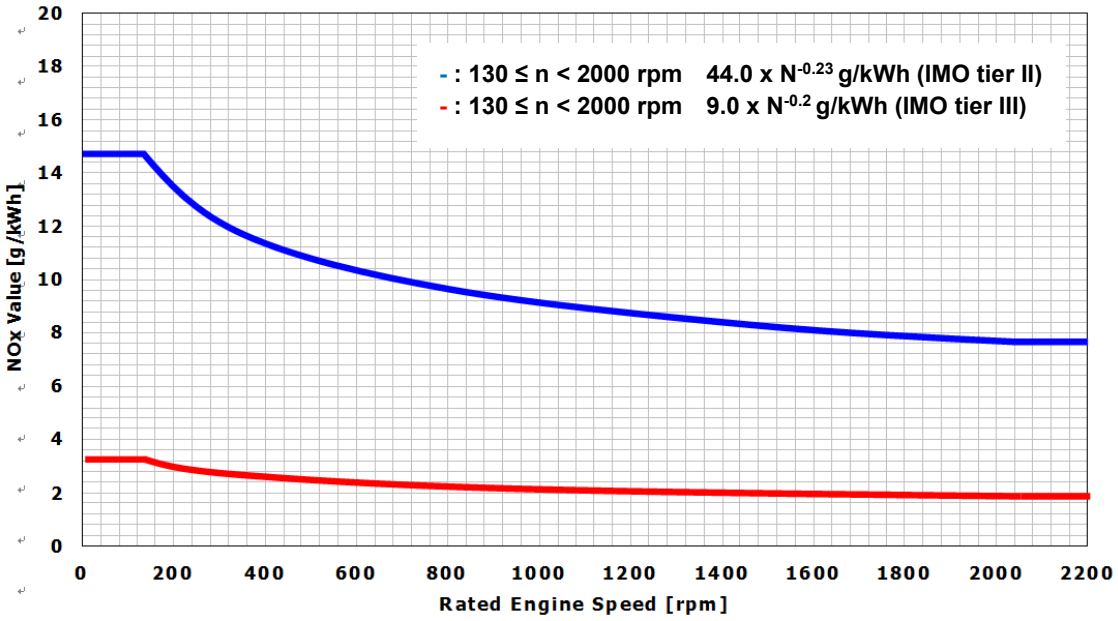
If there is no special requirements from customer regarding the exhaust gas emission, HiMSEN Generating-set shall be delivered with optimized performance conditions fulfilling the MARPOL 73/78 ANNEX VI, Regulation 13 of value of $NO_X$ emissions.

Therefore, it is strongly requested to contact the engine maker if there are any further requirements regarding exhaust gas emission or special operating conditions.

### 3.5.2 Engine international air pollution prevention (EIAPP) certificates

The Engine International Air Pollution Prevention (EIAPP) certificate is related to NOx emissions. If an engine complies with the $NO_X$ emission limits defined in regulation 13 of Annex VI, the EIAPP certificate with approved $NO_X$ technical file shall be issued by the administration or organization on behalf of the administration. Those are necessary for renewal of EIAPP certificate through the on-board $NO_X$ verification. The approved $NO_X$ technical file and EIAPP certificate shall accompany the engine throughout its life and shall be available at all times on the ship.

#### IMO tier II and tier III limits (MARPOL ANNEX VI (73/78))




$NO_X$ Emission from marine diesel engine test Cycle D2
In accordance with ISO 8178-4 and IMO $NO_X$ technical code

Figure 3.3 IMO tier II and tier III limits

# 3.6 Power de-rating diagram

## 3.6.1 Diesel operation

### De-rating due to Intake air temperature, cooling water temperature and altitude

Engine output power at maximum continuous rating shall be reduced depending on the intake air temperature, cooling water temperature and site altitude.

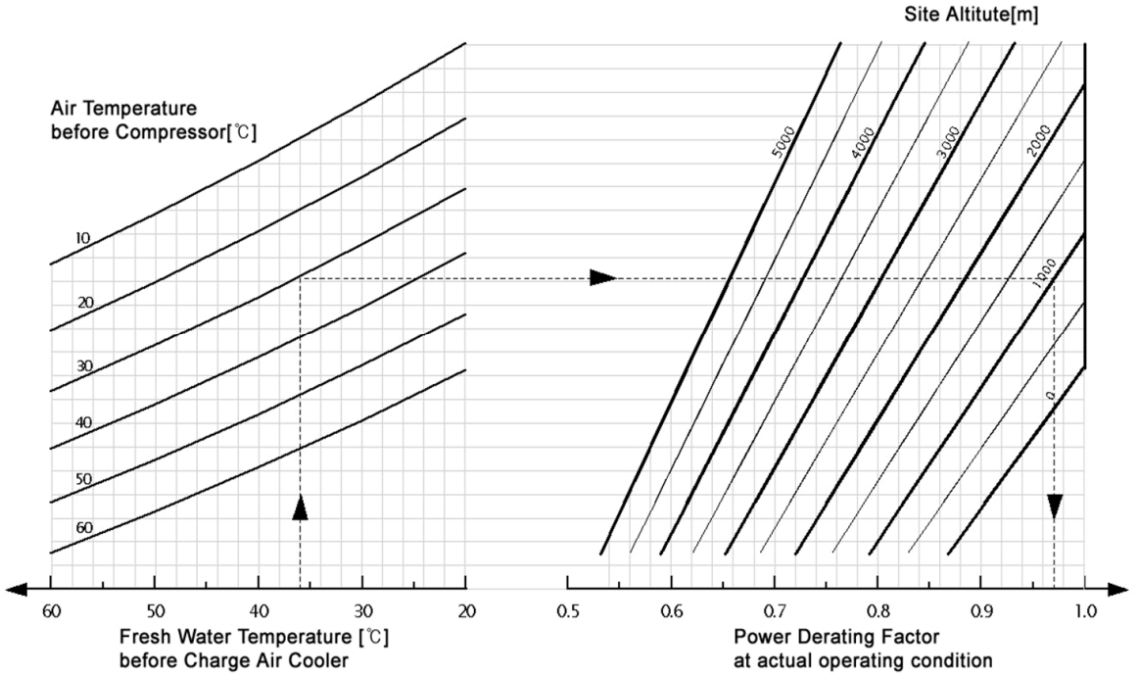



Figure 3.4 De-rating due to intake air temperature, cooling water temperature and altitude

**Example**

Cooling water temperature before charge air cooler : 36 ℃

Intake air temperature : 30 ℃

Site altitude : 1000 m

From the power de-rating diagram, the power de-rating factor at actual operating condition is 0.97. Therefore the engine output power at actual operating condition should be de-rated to the 97 % of the standard engine rated power.

# 3.7 Correction of fuel oil consumption

## 3.7.1 Correction of ambient condition

Specific Fuel Oil Consumption (SFOC) is referred to the ISO 3046-1 standard condition in normally.
However, for the condition other than ISO 3046-1:2002 standard condition, the SFOC at maximum continuous rating can be estimated according to the below formula.

$SFOC_{amb}=SFOC_{ISO}\times dSFOC$
$dSFOC=[100+(T_{intake}-25)\times 0.05-(P_{amb}-1000)\times 0.007+(T_{cw}-25)\times 0.07]/100 \times(42700 / LCV)$

Where :

$SFOC_{amb}$ (g/kWh) : Specific fuel oil consumption at actual operating condition
$SFOC_{ISO}$ (g/kWh) : Specific fuel oil consumption at ISO 3046-1 standard condition
$T_{intake}$ (℃) : Intake air temperature at actual operating condition
$P_{amb}$ (mbar) : Turbocharger inlet air pressure at actual operating condition
$T_{cw}$ (℃) : Cooling water temperature before charge air cooler at actual operating condition
LCV (kJ/kg) : Lower calorific value of the fuel oil

Example,
Intake air temperature ($T_{intake}$) : 30 ℃
TaturbISO : 335°C at 720 rpm, MCR
Cooling water temperature ($T_{cw}$) : 30 ℃
Lower calorific value (LCV) : 42700 kJ/kg
$SFOC_{ISO}$ : 185 g/kWh at 720 rpm, maximum continuous rating
Then, dSFOC = 1.006 and the SFOC at site condition will be increased to 183.1 g/kWh.

## 3.7.2 Clean leak fuel oil

Clean leak fuel oil (recycling fuel oil) during engine operation is subtracted from measured fuel oil consumption.
(Refer to 6.1 Internal fuel oil system)

FOCamb = FOC - clean leak fuel oil *)

*) The FOC and clean leak fuel oil (kg/h) are measured over minimum 10 mins.

### 3.7.3 Correction of additional fuel oil consumption

If additional devices are attached on the engine or operation fuel is changed, the specific fuel oil consumption at maximum continuous rating will be increased as follows approximately:

Table 3.7 Correction of additional fuel consumption

| Item | Additional SFOC at 100% load [g/kWh] |
|---|---|
| Lubricating oil pump | + 2 |
| Low temperature cooling water pump. | + 1 |
| High temperature cooling water pump | + 1 |
| Fuel oil feed pump | Contact to HHI-EMD |
| Charge air pressure control device | Contact to HHI-EMD |
| Operation with marine gas oil | + 2 |
| 500 mm WC > Exhaust gas back pressure after turbine > 300 mmWC | + 0.5 / 100 mmWC |

When low and high temperature cooling water pump is attached on engine,

Additional specific fuel oil consumption by water pump

$$= \text{Additional specific fuel oil consumption at 100 \% load} \times \left(\frac{100}{\text{load}}\right)^{x} \times \left(\frac{\text{actual rpm}}{\text{nominal rpm}}\right)^{3} \ g/kWh$$

When lubricating oil pump is attached on engine,

Additional specific fuel oil consumption by lubricating pump

$$= \text{Additional specific fuel oil consumption at 100 \% load} \times \left(\frac{100}{\text{load}}\right)^{x} \times \left(\frac{\text{actual rpm}}{\text{nominal rpm}}\right) \ g/kWh$$

Table 3.8 Additional specific fuel oil consumption of each load

| Load | 100 ~ 25 % | Under 25 % |
|---|---|---|
| x | 1.15 | 1.25 |

# 3.8 Correction of exhaust gas temperature

## 3.8.1 General

### Correction for ambient condition

Exhaust gas temperature after turbine is referred to ISO 3046-1 standard condition in normally.

However, for the condition other than ISO 3046-1 standard condition,
the exhaust gas temperature after turbine could be estimated according to the below formula :

$T_{exh.amb}=T_{exh.ISO} + dT_{exh}$
$dT_{exh}=(T_{intake}-25) \times 1.5 + (T_{cw} - 25) \times 0.7$

where :

$T_{exh.amb}$ (℃) : Exhaust gas temperature after turbine at actual operating condition

$T_{exh.ISO}$ (℃) : Exhaust gas temperature after turbine at ISO 3046-1 standard condition

$dT_{exh}$ (℃) : Deviation of the exhaust gas temperature after turbine

$T_{intake}$ (℃) : Intake air temperature at actual operating condition

$T_{cw}$ (℃) : Cooling water temperature before charge air cooler at actual operating condition

Example,

Intake air temperature ($T_{intake}$) : 35 ℃

Cooling water temperature ($T_{cw}$) : 35 ℃

$T_{exh.ISO}$ : 290 ℃ at 720 rpm, maximum continuous rating

then, $dT_{exg}$ = 22 ℃ and the $T_{exh.amb}$ at actual operating condition will be increased to 312 ℃.

**This page is intentionally blanked**

# 4 Dynamic characteristics and noise

## 4.1 External forces and couples

Table 4.1 External forces and couples

| Engine type | Speed | External forces and moments | | | | Guide force moments | | |
|---|---|---|---|---|---|---|---|---|
| | | Order | | Moment | | Order | | Moment |
| | | | | Horizontal | Vertical | | | |
| | rpm | No. | Hz | kNm | kNm | No. | Hz | kNm |
| 6H32C | 720 | 1 | 12.0 | 0.0 | 0.0 | 3 | 36.0 | 57.8 |
| | | 2 | 24.0 | 0.0 | 0.0 | 6 | 72.0 | 30.4 |
| | 750 | 1 | 12.5 | 0.0 | 0.0 | 3 | 37.5 | 53.5 |
| | | 2 | 25.0 | 0.0 | 0.0 | 6 | 75.0 | 30.4 |
| 7H32C | 720 | 1 | 12.0 | 0.7 | 29.0 | 3.5 | 42.0 | 107.3 |
| | | 2 | 24.0 | 0.0 | 27.1 | 7 | 84.0 | 21.3 |
| | 750 | 1 | 12.5 | 0.7 | 31.5 | 3.5 | 43.8 | 101.0 |
| | | 2 | 25.0 | 0.0 | 29.4 | 7 | 87.5 | 23.6 |
| 8H32C | 720 | 1 | 12.0 | 0.0 | 0.0 | 4 | 48.0 | 94.1 |
| | | 2 | 24.0 | 0.0 | 0.0 | 8 | 96.0 | 14.4 |
| | 750 | 1 | 12.5 | 0.0 | 0.0 | 4 | 50.0 | 93.6 |
| | | 2 | 25.0 | 0.0 | 0.0 | 8 | 100.0 | 14.4 |
| 9H32C | 720 | 1 | 12.0 | 0.5 | 21.0 | 4.5 | 54.0 | 88.9 |
| | | 2 | 24.0 | 0.0 | 14.7 | 9 | 108.0 | 9.0 |
| | 750 | 1 | 12.5 | 0.5 | 22.8 | 4.5 | 56.3 | 88.9 |
| | | 2 | 25.0 | 0.0 | 16.0 | 9 | 112.5 | 9.0 |

## 4.2 Moment of inertia

Table 4.2 Moment of inertia

| Engine type | Speed | Rating | Moments of inertia ; $J_{1)}$ | | | | |
|---|---|---|---|---|---|---|---|
| | | | Engine MOI | Flywheel $_{1)}$ | | Alternator MOI $_{2)}$ | Total MOI |
| | | | | MOI | Mass | | |
| | rpm | kW | $kgm^2$ | $kgm^2$ | kg | $kgm^2$ | $kgm^2$ |
| 6H32C | 720 | 3600 | 486.8 | 98.0 | 331.2 | 620.0 | 1204.8 |
| | 750 | 3600 | 486.8 | 98.0 | 331.2 | 620.0 | 1204.8 |
| 7H32C | 720 | 4200 | 471.5 | 199.0 | 672.6 | 712.2 | 1382.7 |
| | 750 | 4200 | 471.5 | 199.0 | 672.6 | 712.2 | 1382.7 |
| 8H32C | 720 | 4800 | 531.8 | 40.0 | 135.2 | 970.3 | 1542.1 |
| | 750 | 4800 | 531.8 | 40.0 | 135.2 | 970.3 | 1542.1 |
| 9H32C | 720 | 5400 | 705.6 | 199.0 | 672.6 | 1,178.2 | 2082.8 |
| | 750 | 5400 | 705.6 | 199.0 | 672.6 | 1,178.2 | 2082.8 |

1) The moments of inertia of flywheels are typical values. In case of the different value, it should be confirmed by a torsional vibration analysis.
2) The moments of inertia of alternators are typical values.

Remarks

1. The above data is based on 100% load for 600 kW/cyl. @ 720 / 750 rpm
2. The moment of inertia and mass data of the engine flywheel should be dimensioned depending on specific project specifications.

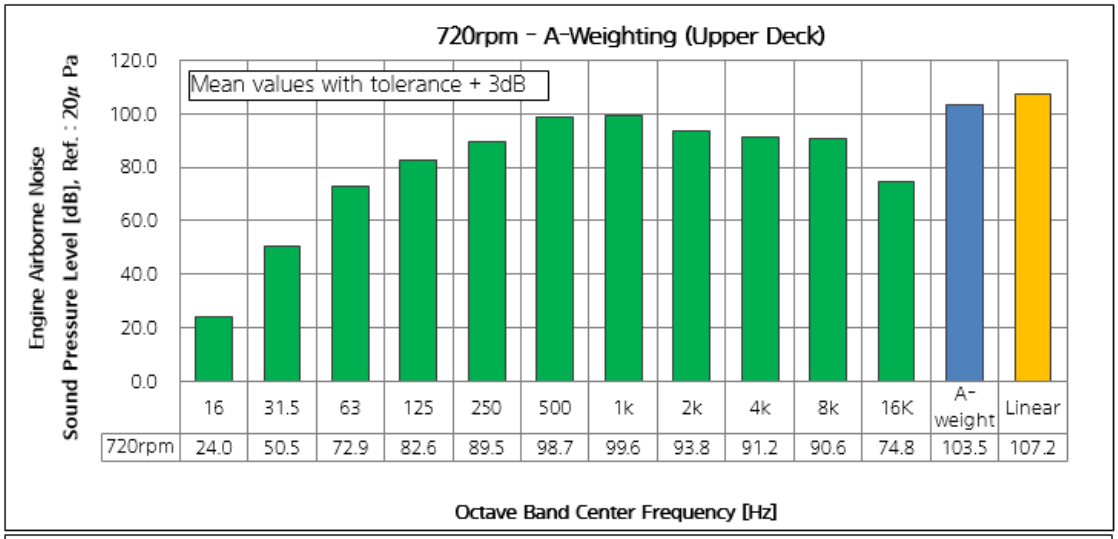
# 4.3 Noise measurement

## 4.3.1 General description

The airborne noise of the engines are defined as a sound pressure level according to ISO 6798 and ISO 8528-10, and measured at the distance 1m away from the engine surface at full load.

Typical measured results are as shown below. The values are average with Linear and A-weighting in one octave band.

**720 rpm - A - weighting (Upper deck/Lower deck)**



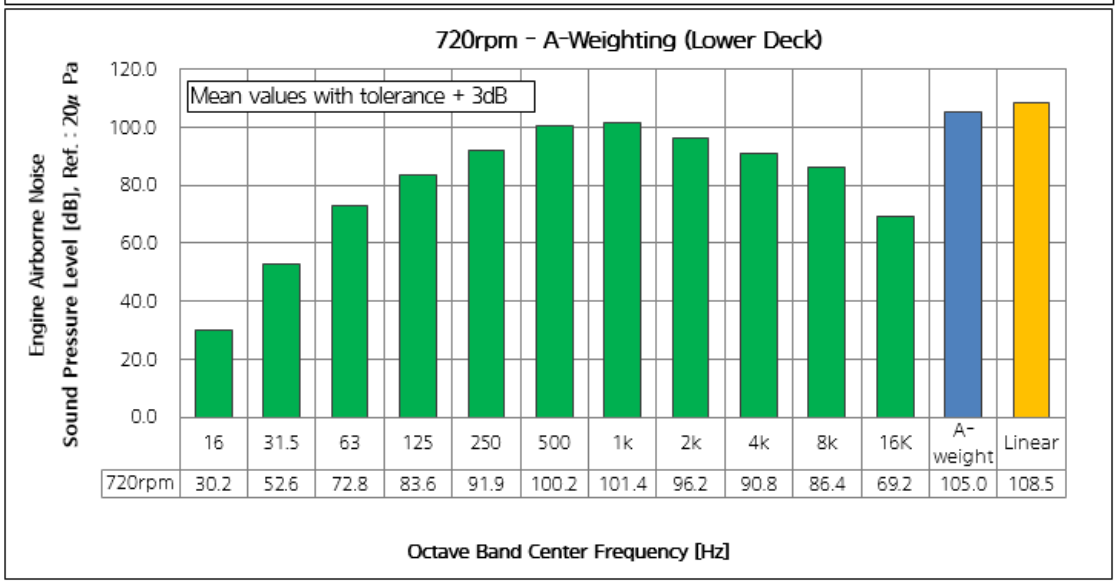




Figure 4.1 Typical noise level

Remark

1. The above measured results can be changed depending on the specific projects.

**This page is intentionally blanked**

# 5 Operation and control system

## 5.1 Engine operation

### 5.1.1 General

HiMSEN is a heavy fuel engine and it is not necessary to change over to diesel fuel at any operating condition, for example, engine start, stop, low load running, etc.

However, there are some recommended to maintain good performance and reliability consistently.

### 5.1.2 Starting condition

#### Normal starting condition

**Lubricating oil**

- ✓ Continuous pre-lubrication is required
- ✓ Temperature : over 40 ℃ (Preheated)

**Cylinder cooling water**

- ✓ Start on marine diesel oil / marine gas oil : over 40 ℃ (Preheated)
- ✓ Start on heavy fuel oil : over 60 ℃ (Preheated)

**Combustion air**

- ✓ Intake air temperature : between 0 ℃ and 45 ℃

**Starting air**

- ✓ Refer to the sheet '3.2 Engine capacity data'.

**Fuel oil (Marine diesel oil / marine gas oil or heavy fuel oil)**

- ✓ Pre-circulation is required
- ✓ Engine inlet viscosity : 12 ~ 18 cSt (Heavy fuel oil)
  2 ~ 14 cSt (Marine diesel oil / marine gas oil)

#### Emergency cold starting condition

**Fuel oil** : only marine diesel oil / marine gas oil is acceptable

**Cooling water** : minimum 15 ℃

**Lubricating oil** : minimum 10 ℃, pre-lubricated
(Approx.1000 cSt based on SAE 40)

**Intake air temperature :** minimum 0 ℃
**Starting air pressure :** Starting condition with warm engine + Min. 5 bar

## 5.1.3 Engine start

### Engine start ready

Engine start ready condition is indicated in local and remote. It is recommended that engine is to be in warm condition before start.

**Start block signals**

- ✓ Lubricating oil pressure at engine inlet low
- ✓ Starting air pressure engine inlet low (Option)
- ✓ High temperature cooling water at engine inlet low (Option)
- ✓ Turning gear engaged
- ✓ Engine speed high before start
- ✓ Start block in test mode
- ✓ Start block from remote system

### Engine start at different mode

Main starting valve is installed in engine side and operated by compressed air and controlled by pneumatic solenoid valve. Start is available when predefined condition for selected start mode is satisfied

- ✓ The engine speed is ramp up to rated speed automatically.
- ✓ Circuit breaker can be closed after engine run condition
- ✓ If black out start mode is selected, start block condition are overridden as below
  - ➢ Lubricating oil pressure at engine inlet low
  - ➢ Starting air pressure at engine inlet low
  - ➢ High cooling water temperature at engine inlet low

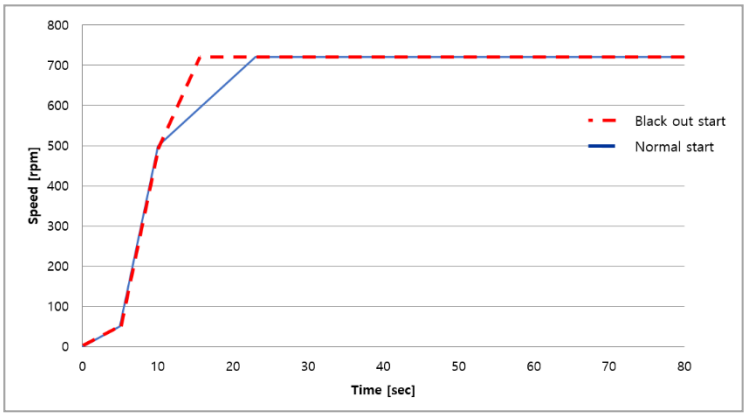



Figure 5.1 Engine start at selected mode

- ✓ In black out start mode, the speed reach to rated RPM as fast as possible

### Start-up

A diesel generator is designed to reach its nominal speed efficiently once a start signal is received. To support clean combustion, the acceleration profile is optimized to a minimum during start-up. If required, the system can be adapted to allow for reduced starting times.

## 5.1.4 Restriction for low load operation

### Idle running

- ✓ Less than 5 minutes of idle running is permitted if the engine is going to stop
- ✓ Maximum 30 minutes of idle running is permitted if the engine is loaded after idle running

### Long term low load operation

### Marine diesel oil and marine gas oil operation

- ✓ Over 15 % load operation : no restriction
- ✓ Below 15 % load operation : load up over 70 % load at every limited time at corresponding load in Figure 5.2

### Heavy fuel oil operation

- ✓ Over 20 % load operation : no restriction
- ✓ Below 20 % load operation : load up over 70 % load at every limited time at corresponding load in Figure 5.2

Duration of flushing operation (See ‘Figure 5.2’)

'Time limits for low load operation' (left) shows admissible operation time at certain load, and 'Duration of flushing operation' (right) shows the required time for duration that engine operates at not less than 70 % of full load in order for burning the deposits away.

Example

1. Time limits for low load operation (line A, A')
   At 10 % of full load, heavy fuel oil operation is permissible for about 17 hours (line A), whereas marine diesel oil/marine gas oil operation for 37 hours. (line A').

2. Duration of flushing operation (line B, B')
   Engine should be operated for roughly 1.15 hours (heavy fuel oil) and 0.75 hours (marine diesel oil / marine gas oil) at not less than 70 % of full load.

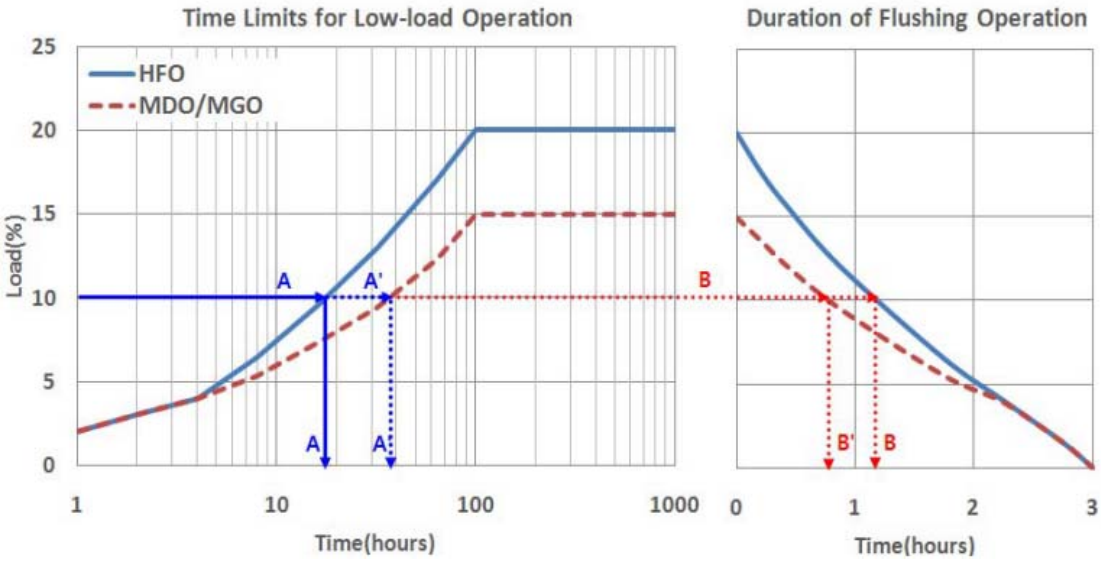



Figure 5.2 Time limits for low load operation

### 5.1.5 Engine load-up

Engine fulfills all requirements regarding the load application of all major classification societies and IACS at diesel mode.

both continuous and step by step load up should be taken carefully for stable and safe operation of engine.

The engine has to be in warm condition for normal or emergency load up. When the engine is in cold condition, the continuous load up should be slower than normal and high step load should be prohibited.

#### Continuous load-up

The continuous load up capacity is referred in Figure 5.3

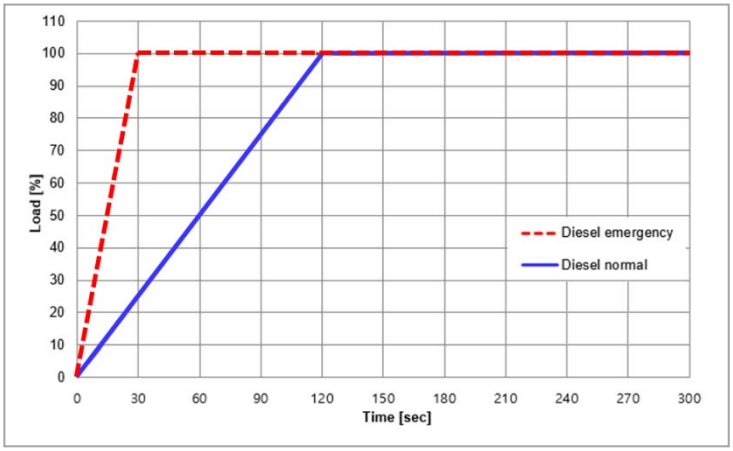



Figure 5.3 Engine load up capacity in ramp

At warm condition, the 100 % load can be achieved in 120 sec by continuous ramping up at normal condition.
At emergency condition, the load can be more quickly increased to 100 % in 30 sec.

## Step by step load-up

Considering the time and safety required for stabilizing the frequency due to sudden load up, it is recommended to load up from idle to full load by more than three steps in diesel mode and four steps in methanol mode. Frequency deviation and recovery time when loading up by step is referred in Figure 5.4 the amount of load step is decreased at high load for stable operation.

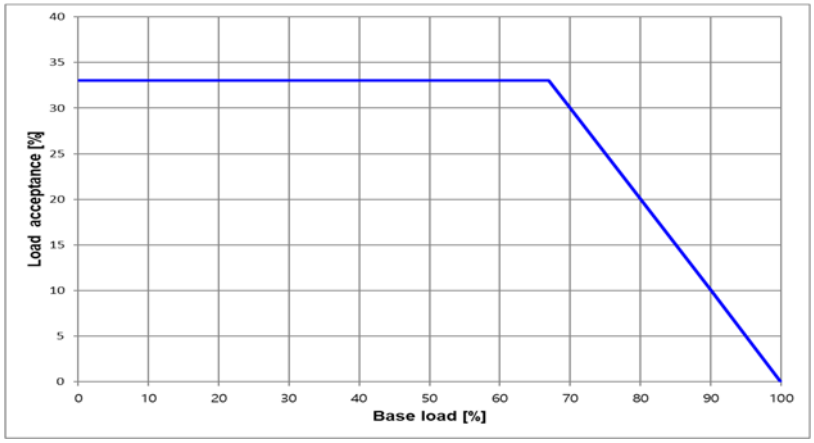



Figure 5.4 Step load acceptance at diesel mode

1. Max instant load step: 0 – 33 – 66 – 100 %
2. Max speed variation ≤ 10 %
3. Steady-state speed band ≤ 1.0 %
4. Recovery time ≤ 5 sec
5. Time between next load step ≥ 10 sec

### 5.1.6 Engine stop

#### Normal stop

Electronic fuel pump injection are stopped immediately when stop command is activated from local operating panel or remote system.

#### Emergency Stop

Electronic fuel pump injection are stopped and fuel oil shut-off valve is closed simultaneously when emergency stop command is activated from local operating panel or remote system.

#### Engine shutdown

When the engine enters predefined shutdown condition due to certain abnormality, the engine is stopped immediately and the circuit breaker is opened automatically without de-load.
If the engine is shutdown, electronic fuel pump injection are stopped and fuel oil shut-off valve is closed simultaneously.

#### Engine safety

The engine control system monitors the signals from all sensors on engine and takes an appropriate action against abnormality of engine for safe operation. All engine reaction including limit value and delay defined in engine control system.
Engine control system fulfills and satisfies redundant and independent safety function against critical shutdown conditions.

#### Alarm

Engine control system release alarm message against abnormal sensor signal or sensor failure. No influence to engine operation but operator has to monitor the value carefully.

## 5.2 Outline of engine automation

### 5.2.1 General

The HiMSEN DIESEL ECS (Engine control system), preforms the complete engine management.

Machinery space for HiMSEN diesel engine is regarded as ‘safe area’ and thus ECS (Engine Control System) is not required to be explosion proof design.

ECS mainly consists of MCP (Main control panel), ICM (Injection Control Module integrated with Cylinder Monitoring Module), LOP (Local Operating Panel)

ECS is responsible for operation, full monitoring of engine and safety function.

All sensors and actuators are connected and dedicated actions are taken for more optimized and safe operation condition.

### 5.2.2

It is also connected to external system via hardwired signal and bus communication.

This configuration provides full operation and monitoring capability to remote system.

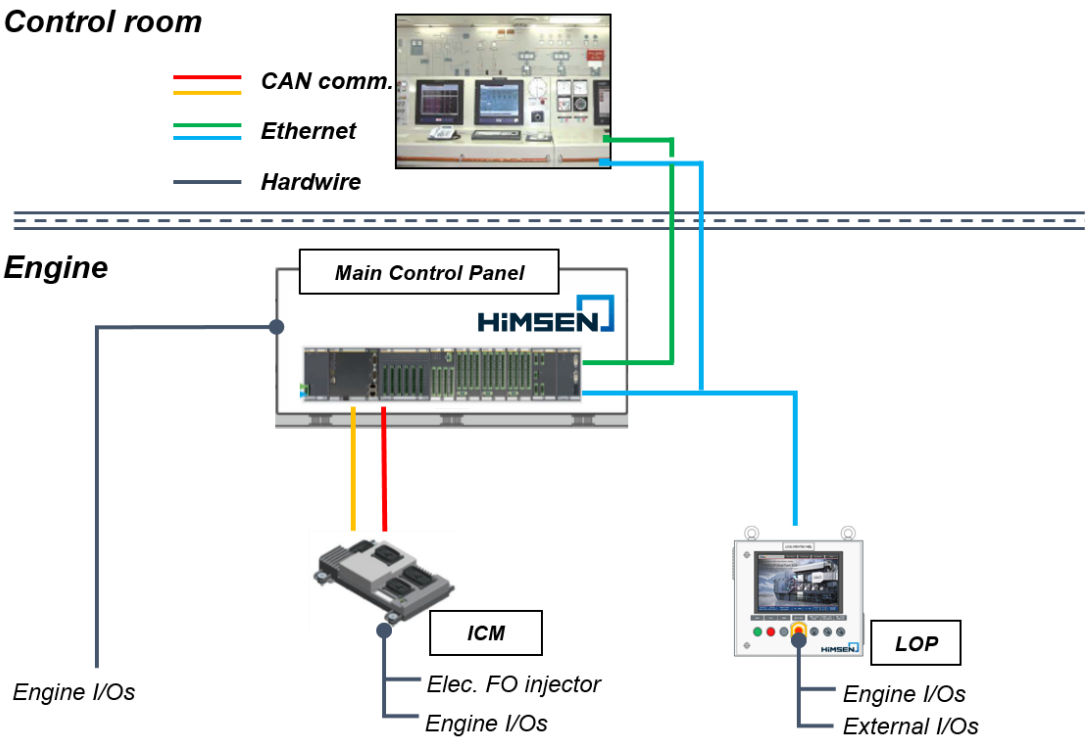



Figure 5.5 HiMSEN Diesel ECS overview

### 5.2.2 Hardware description

**Main Control Panel (MCP)**

MCP is the central control unit of HiMSEN Diesel ECS which consists of the main processor module for engine control and I/O modules for communication and I/O interfaces.

MCP is mounted directly on the engine and interfaced with all other panels and modules of ECS and all instruments on engine for control and monitoring.

- ✓ Location : Mounted on engine (1 set per engine)

- ✓ Consist of
  - Main Control & Alarm Module
  - I/O modules and terminals
  - Communication switches

- ✓ Responsible for
  - Main control and monitoring of diesel engine
  - Engine safety control
  - Engine control and safety parameter tuning

**Injection Control Panel (ICM)**

ICM is mounted on the engine and connected to electronic fuel injection pump, exhaust gas temperature sensor for each cylinder.

- ✓ Location : Mounted on engine (1 set per engine)

- ✓ Responsible for
  - Driving electronic fuel injection
  - Measurement and process of engine I/O and transmit data to MCP for control

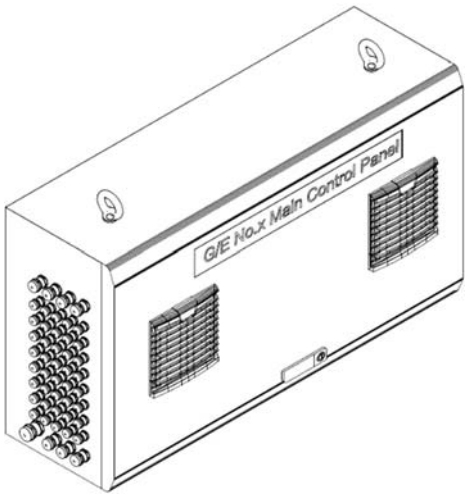



Figure 5.6 Main control panel

Figure 5.7 Injection Controm module

**Local Operating Panel (LOP)**

LOP (Local Operating Panel) is mounted on engine to offer operators the operation and monitoring environment of the engine. All engine information and status can be monitored via HMI on LOP.
Moreover, Engine Safety Module is installed in LOP which shutdown the engine independently from Main control & Alarm Module

- ✓ Location : Mounted on engine (1 set per engine)
- ✓ Consist of
  - Touch screen HMI PC
  - Switches and buttons for engine operation

- ✓ Responsible for
  - Operation through hardwired contacts
  - Display of engine measurement and status
  - Alarm / event display and handling
  - Alarm / event logging
  - Emergency stop button
  - standstill
  - Independent engine shutdown


Figure 5.8 Local operating panel

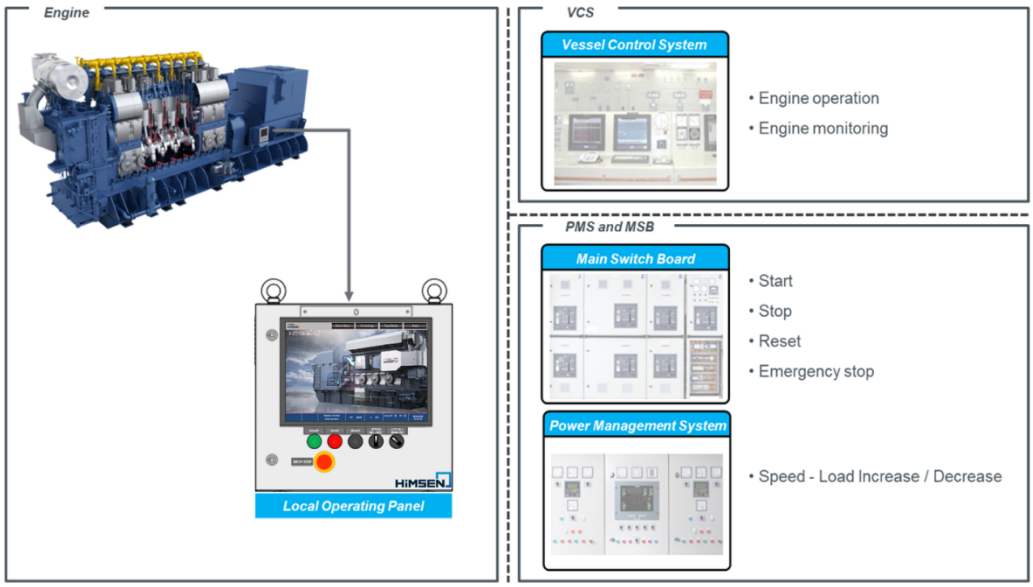



Figure 5.9 Engine operation at Remote (VCS or PMS / MSB)

## 5.3 Operation data and alarm points

Operation data of the engine is listed below table.
Some data may be subject to change and shall be informed separately for specific project.

Table 5.1 Operation data of the engine

| System | Descriptions | Normal operation range at rated power | | Alarm and sensor | | Auto stop of engine | |
|---|---|---|---|---|---|---|---|
| Speed control | Engine speed | SE11 | 720 rpm | | | SD High | 113%(1st) 115%(2nd) |
| | | | 750 rpm | | | | |
| | TC speed | SE14 | | AL High | (E) | | |
| Fuel oil system | Fuel oil filter differential pressure | PT51-52 | | AL High | 1.5 bar | | |
| | Fuel oil pressure engine inlet | PT52 | | | | | |
| | For continuous HFO operation | (MDO/ MGO) | 4.0 ~ 6.0 bar | AL Low | 4 bar | | |
| | | (HFO) | 7.0 ~ 10.0 bar (A) | AL Low | 6 bar | | |
| | For continuous MDO operation | (MDO/ MGO) | 7.0 ~ 8.0 bar | AL Low | 6 bar | | |
| | Fuel oil temperature engine inlet | TE52 | | | | | |
| | | (MDO/ MGO) | 30 ~ 45 °C | | | | |
| | | (HFO) | 110 ~ 140°C | AL High | 155 °C | | |
| | Clean fuel oil leakage tank level | LS54 | | AL High | High level | | |
| Lubricating oil system | Lubricating oil filter differential pressure (D) | PT61-62 | | AL High | 1.5 bar | | |
| | Lubricating oil pressure before filter | PT61 | 4.2 ~ 5.5 bar | | | | |
| | Lubricating oil pressure engine inlet | PT62 | 4.0 ~ 5.0 bar | AL Low | 3.3 bar | SD Low | 3 bar |
| | Lubricating oil temperature engine inlet, SAE40 | TE62 | 60 ~ 73 °C | AL High | 80 °C | | |
| | Lubricating oil pressure TC inlet | PT63 | (E) | AL Low | (E) | | |
| | Lubricating oil temperature TC outlet | TE64 | 65 ~ 75 °C | AL High | (E) | | |
| | Lubricating oil temperature main bearing★) | TE05 | | AL High | 95 ℃ | SD High | 100 ℃ |
| | Lubricating oil mist detector | LS92 | | AL High | High level | SD High | High level |
| | Lubricating oil sump tank level | LS68 | | AL High | High level | | |
| | | | | AL Low | Low level | | |

| System | Descriptions | Normal operation range at rated power | | Alarm and sensor | | Auto stop of engine | |
|---|---|---|---|---|---|---|---|
| Cooling water system | High temperature water pressure engine inlet | PT75 | 2.0 ~ 5.0 bar | AL Low | 0.4+(B) bar | | |
| | High temperature water temperature engine inlet | TE75 | 70 ~ 80 °C | | | | |
| | High temperature water temperature engine outlet | TE76 | 75 ~ 85 °C | AL High | 95 °C | SD High | 100 ℃ |
| | Low temperature water pressure engine inlet | PT71 | 1.0 ~ 5.0 bar | AL Low | 0.4+(B) bar | | |
| | Low temperature water temperature engine inlet | TE71 | 30 ~ 40 °C | AL High | 45 °C | | |
| | Low temperature water temperature air cooler outlet | TE72 | 35 ~ 50 ℃ | | | | |
| Combustion gas / air system | Cylinder pressure(C) | Max. 260 bar | | | | | |
| | Cylinder pressure deviation from average of cylinders | Max. ±5 bar | | | | | |
| | Charge air pressure after cooler | PT21 | 5.0 ~ 6.0 barG (6.0 ~ 7.0 barA) | | | | |
| | Charge air temperature after cooler | TE21 | 35 ~ 55 °C | | | | |
| | Exhaust gas temperature cylinder outlet | TE25 | 350 ~ 570 °C | AL High | 590 ℃ | | |
| | Exhaust gas temperature TC inlet | TE26 | 450 ~ 580 °C | AL High | 600 ℃ | | |
| | | | | LR High | 620 ℃ | | |
| | Exhaust gas temperature TC outlet | TE27 | 300 ~ 400 °C | AL High | 500 ℃ | | |
| Compressed air system | Compressed air inlet pressure | PT41 | 25 ~ 30 bar | AL Low | 15 bar | | |

* Temperature deviation between thermometer and thermocouple can be max. 60°C caused by different measuring point.
* Engine performance data depends on the LCV (Low Calorific Value) of used fuel oil respectively, which influences fuel rack index of fuel injection pump.

(A) F.O pressure not to be maintained below 6 bar at any case to avoid gasification of hot fuel
(B) Depend on the height of expansion tank (static pressure)
(C) Measured at indicator cock
(D) Based on standard cartridge type filter
(E) Depending on cylinder No. and T/C maker

★) Can be applied as option.

Table 5.2 Definition of code

| Code | Description | Code | Description |
|---|---|---|---|
| AL | Alarm | SD | Shutdown |
| LR | Load Reduction | | |

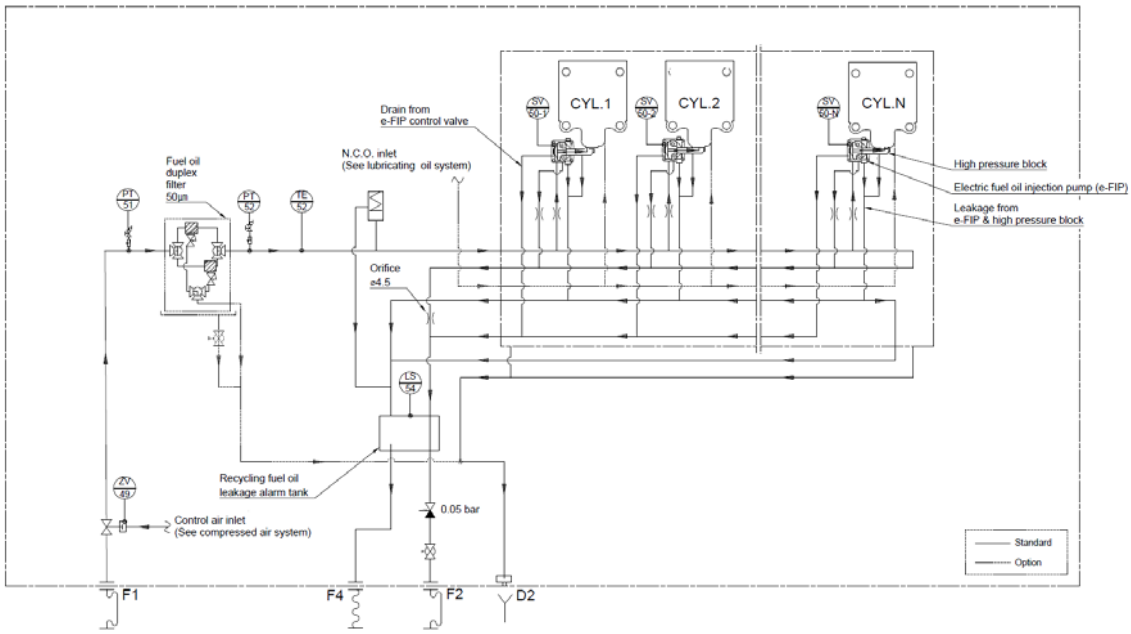
Table 5.3 Operation data for each T/C maker

| T/C maker | T/C type | T/C lubricating inlet pressure | | T/C lubricating outlet temperature | |
|---|---|---|---|---|---|
| | | Pressure range | Alarm | Pressure temperature | Alarm |
| | | Bar | Bar | °C | °C |
| KBB | ST - series | 2.0 ~ 4.0 | 1.5 | 70 ~ 100 | 120 |
| ABB | TPS - series | 2.0 ~ 3.0 | 1.5 | 70 ~ 140 | 160 |
| | A130 ~ A145 | 2.0 ~ 4.5 | 1.5 | 70 ~ 140 | 160 |
| | A150 ~ A155 | 1.5 ~ 3.0 | 1.3 | 70 ~ 125 | 145 |
| | TPL - series | 1.5 ~ 2.5 | 1.3 | 70 ~ 120 | 140 |
| MHI | MET30SRC | 0.6 ~ 1.5 | 0.6 | 60 ~ 95 | 105 |
| | MET37SRC | 0.6 ~ 1.5 | 0.6 | 60 ~ 95 | 105 |
| Napier | Na - series | 1.5 ~2.5 | 1.3 | 60 ~ 95 | 115 |

# 6 Fuel system

## 6.1 Internal fuel oil system

### Diagram for Internal fuel oil system




*) Scope of instrumentations will be according to extent of delivery and engine builder's standard.

Figure 6.1 Diagram for Internal fuel oil system [BP0049145]

Table 6.1 Size of external pipe connections

| Code | Description | Size | Remark |
|---|---|---|---|
| F1 | Fuel oil inlet | 16K-25A | JIS B 2220 |
| F2 | Fuel oil outlet | 16K-25A | JIS B 2220 |
| F4 | Leaked fuel oil drain (clean) | 5K-15A | JIS B 2220 |
| D2 | Waste oil drain (dirty) | OD Ø25 | JIS B 2220 |

### 6.1.1 General description

Fuel system is designed for a reliable combustion of heavy fuel oil as well as diesel fuel oil. Therefore, it is not recommended to change over the fuels except for the cold starting, flushing of the system, maintenance or long term stand still.

## Fuel oil system

The fuel oil injection equipment comprises an injection pump (EFIP, Electronic Fuel Injection Pump), connection block, injection pipe and injection valve, which are installed on each cylinder. The system is designed for operating the high pressure of the fuel injection with better combustion.

Fuel injection is controlled by EFIP which receives the signals from the engine control system.

The clean fuel oil from each injection pump, high pressure connection block, etc. is drained for their normal operation and collected to the recycling fuel oil leakage alarm tank. The estimated drain amount of recyclable fuel oil is like follows;

- ✓ Estimated fuel oil drain amount [liter/hr per a cylinder]
  - ➢ For heavy fuel oil (12 ~ 18 cSt) : 0.3 (Tolerance ± 50 %)
  - ➢ For distillate fuel oil (Min. 2 cSt) : 1.2 (Tolerance ± 50 %)

  *) The above values can be changed by further updates on fuel injection equipment.

The recycling fuel oil can be led to external tank to be reused and this value is only for reference to design this external system for its recycle. It can be recycled without additional separation process. Recycling fuel oil leakage alarm tank is a modularized box for the external connections, which provides :

- ✓ Connections for fuel oil return pipes 25 A
- ✓ Connection for a recycling drain pipe 15 A
- ✓ Alarm switch and tank for excessive leakage

The dirty leak oil is collected to the common drain pipe led to the sludge tank.

## 6.2 External fuel oil system

### Diagram for heavy fuel oil system – Reference for normal operation

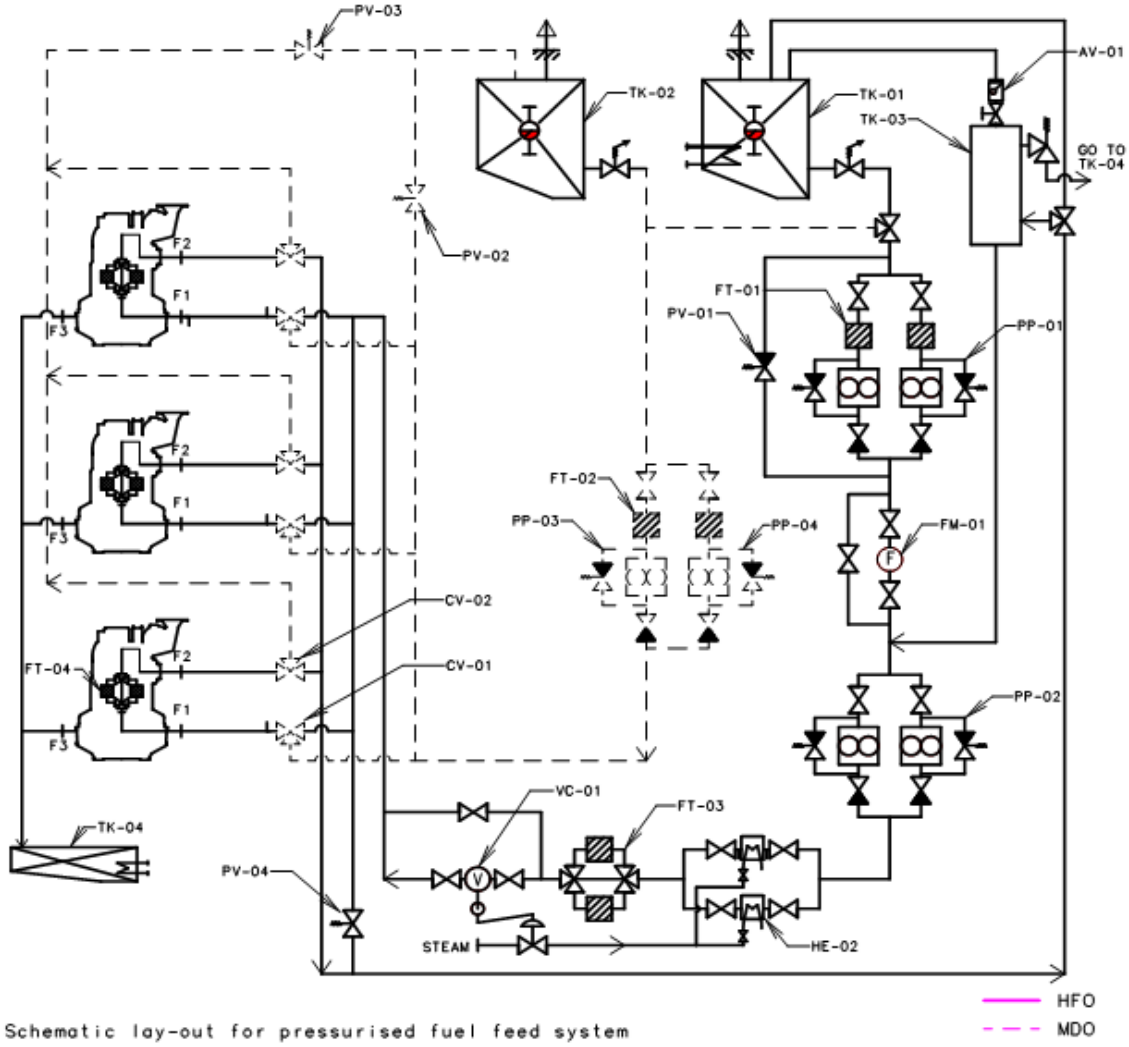



Figure 6.2 Diagram for heavy fuel oil system

Table 6.2 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-01 | Day tank, heavy fuel oil | FT-02 | Suction strainer, marine diesel oil |
| TK-02 | Day tank, marine diesel oil | FT-03 | Automatic filter |
| TK-03 | Mixing tank | FT-04 | Safety filter |
| TK-04 | Drain tank | FM-01 | Flowmeter |
| FT-01 | Suction strainer, heavy fuel oil | HE-02 | Heater |

| Code | Description | Code | Description |
|---|---|---|---|
| VC-01 | Viscosity controller | PP-01 | Heavy fuel oil supply pump (4 bar) |
| AV-01 | Auto deaerating valve | PP-02 | Heavy fuel oil booster pump (8 bar at fuel oil inlet, F1) |
| PV-01 | Heavy fuel oil pressure control valve | PP-03 | Marine diesel oil pump (8 bar) |
| PV-02 | Marine diesel oil inlet pressure control valve (6 bar) | PP-04 | Emergency marine diesel oil pump (6 bar) |
| PV-03 | Marine diesel oil outlet pressure control valve (2 bar) | CV-01/02 | Heavy fuel oil, marine diesel oil change over valve (local & remote control) |
| PV-04 | Heavy fuel oil inlet pressure control valve (9 bar) | | |

1. In case of continuous marine diesel oil operation, contact to HHI-EMD.
2. Additional day tanks for low sulfur heavy fuel oil and / or marine diesel oil could be required due to IMO MARPOL Annex VI, a special notation of classification societies, a local regulation, or other reasons.

### 6.2.1 General requirements

The external fuel system for the auxiliary engines can be a common system with main engine or an independent system depending on the shipbuilder's choice.

In any case, the condition of fuel oil, especially heavy fuel oil, is critical for the reliable operation of the engine. The most important conditions and requirements of the external fuel oil system should be as follows:

#### Well cleaned fuel

Solid particles and water in the fuel cause over wearing and frequent maintenance for the engine itself as well as external fuel system. Therefore, qualified separation equipment should be included in the external fuel oil system not only for heavy fuel oil but also for distillate fuel.

**Proper Viscosity, Temperature and Pressure** are necessary for proper operation of the system. Therefore, Preheating, Insulation with heat tracing, and Pressurizing equipment should be included in the external fuel oil system.

Especially if it is at low viscosity, fuel temperature shall be controlled to meet the required viscosity by fuel cooling device such as cooler unit.

In order to prevent excessive pressure losses and also to minimize possible pressure pulses in the piping system, the fuel oil velocity should not exceed:

- ✓ Marine diesel oil suction pipe : 0.5 ~ 1.0 m/s
- ✓ Marine diesel oil pressure pipe : 1.5 ~ 2.0 m/s
- ✓ Heavy fuel oil suction pipe : 0.3 ~ 0.8 m/s
- ✓ Heavy fuel oil pressure pipe : 0.5 ~ 1.2 m/s

**Diesel fuel oil system** is necessary to back up for heavy fuel system especially for emergency situations and flushing by running on diesel fuel oil before engine stop for long period standstill or an event of major overhaul. The external fuel system normally comprises Fuel Treatment system and Fuel Feed system.

General requirements are described as follows and more detailed information can be provided if needed for specific plant.

#### Fuel oil treatment system

The fuel treatment system should be designed for proper cleaning of heavy fuel oil considering total fuel consumption of the plant.

Centrifugal Separators should be an automatic type with the same additional stand-by unit.
The separator should be capable of purifying the worst grade of fuel oil.
Normally, fuel oil grade of H380 to H700 require the capability of up to 1010 kg/m$^3$.
For distillate fuel, an independent purifier system is required.

It is necessary to ensure a proper cleaning of heavy fuel oil as follows :

- ✓ Selection and operation of fuel oil centrifuges according to supplier's recommendation
- ✓ Correct heavy fuel oil temperature at inlet to centrifuges
  (The centrifuges should be always operated with an inlet temperature of 98 ℃ for heavy fuel oil)
- ✓ Correct throughput of fuel oil through centrifuges

$$Q = \frac{P \times b \times 24(h)}{p \times t}$$

P = maximum continuous output of the engine(s) [kW]
b = specific fuel consumption + safety margin (15 %) [g/kWh]
p = density of the fuel [kg/m$^3$]
t = daily separating time(h) (usually = 23 h or 23.5 h)

- ✓ Proper density of heavy fuel oil in conformance with centrifuge specification
- ✓ Proper maintenance of centrifuges

The centrifuges should be operated in parallel, unless the centrifuge installation comprises manually operated centrifuges, with the purifier followed by the clarifier. To achieve the maximum separation efficiency, it is recommended to always use all available heavy fuel oil centrifuges whenever possible, and to operate them in parallel with an adjusted feed rate lowering the throughput in the centrifuges. This will ensure the longest possible retention time in the centrifuges and optimal efficiency for removal of catalytic fines.

It is important that maintenance and operation of the centrifuge is done according to the recommendations of the manufacturer.
The required capacity of the daily (service) tank and the settling tank for heavy fuel oil is minimum 24 operating hours feed for continuous full load operation. Each tank should be heated to have stable temperature between 50 ~ 70 ℃. Each tank should be equipped with effective sludge and water drain system.

### 6.2.2 Fuel feed system

The fuel feed system can be a common with other engines. The proper control of fuel viscosity is the most important. The system should have proper heating equipment and insulation accordingly. The system should be pressurized to avoid gas separation due to high temperature.

#### Day tank for heavy fuel oil

The heavy fuel day tank should be filled with cleaned fuel by continuous fuel separation.

- ✓ Tank capacity : minimum 24 operating hours feed for full load operation.
- ✓ Tank heating : approx. 75 ℃, as stable as possible.
- ✓ Sludge / water space and drain provided.

#### Suction strainer

To protect the supply pump, a suction strainer with a fineness of approx. 0.5 mm with magnet should be installed on the pump suction side.

## Supply pump

- ✓ Capacity : min. 1.5 x total fuel consumption at maximum continuous rating + back flushing quantity
- ✓ Pump head : 4 bar
- ✓ Operating temperature : 100 ℃
- ✓ Viscosity (for electric motor) : 1000 cSt

## Mixing tank

The major purpose of mixing tank is to ensure the ventilation of the gas from the hot fuel oil and a gradual temperature balance by mixing the hot returned oil from the engine with the oil from the day tank.

The volume of mixing is tank is required not less than 100 liters.

## Pressure control valve

The pressure control valves maintain constant system pressure. The surplus oil return to the supply pump suction side or to the fuel oil return line.

## Flow meter

If a measuring device for fuel oil consumption is required, it has to be fitted between the supply pump and the mixing tank.

A by-pass line has to be installed in parallel with the flow meter to ensure the fuel oil supply free from possible clogging.

## Booster pump

Since the heated fuel oil has to be continuously recirculated, the booster pump should ensure the fuel circulation with the required pressure in the system.

- ✓ Capacity : min. 3.0 x total fuel consumption at maximum continuous rating + back flushing quantity
- ✓ Pump head : 8 bar at Fuel oil inlet, F1
- ✓ Operating temperature : 150 ℃
- ✓ Viscosity (for electric motor) : 500 cSt

## Heater and viscosity controller

In order to ensure the correct injection viscosity at 12 ~ 18 cSt (Heavy fuel oil), the dual heaters are controlled by the viscosity controller.

Each heater should have sufficient capacity for heating the fuel oil for all engines at full load, one heater can therefore be overhauled while the other one is in service.

### Auto back flushing filter

In the circulating lines, absolute 10 μm automatic back-flushing filter must be installed before the branch pipe for each engine to ensure the cleanness of the fuel oil. If the cleaning cycles of the automatic back-flushing filter are increased, the fuel oil treatment system must be optimized in order to protect the engine.

### Safety filter

Fuel oil safety filter, duplex type of absolute 50 ㎛, to be built in the fuel oil supply line of each engine.

### Waste Oil Tank

The leaked fuel oil from the engine is collected and transferred to the sludge tank.
Heating coils are also required in the tank.

## 6.2.3 Marine diesel oil feed system

Even for the heavy fuel oil engine, an independent marine diesel oil feed system is required for the cases as below;

- ✓ Long time low load operation or stop
- ✓ Maintenance of heavy fuel oil system
- ✓ Emergency situation such as a black-out.

### Emergency start

Marine diesel oil must be supplied to start up the stand-by engines with a sufficient fuel oil pressure, which can be supplied by emergency booster pump or a gravity tank which is minimum 8 m above the engine.

### Heavy fuel oil / marine diesel oil changeover valve

The heavy fuel oil / marine diesel oil change-over valve should be installed for each engine, which can be a manual type or an electro-pneumatic remote control type for a flexible selection of marine diesel oil and heavy fuel oil operating at any load condition.

## 6.3 Fuel oil specification

The fuel oil specifications are based on ISO 8217 : 2017. The fuel is largely classified into two categories as distillate fuels and residual fuels. Distillate fuels are categorized into DMX, DMA, DFA, DMZ, DFZ, DMB, and DFB. Residual fuels are categorized into RMA 10, RMB 30, RMD 80, RME 180, RMG 180 to 700, RMK 380 to 700. The usage of DMX is restricted by SOLAS requirement due to its low flash point.

The terminologies of marine fuel oil to be called after 1st January 2020 have been determined as below Table 6.3. In accordance with the most relevant characteristics.

HiMSEN is able to operate with all fuels specified in the below table. The simplified terminologies listed in Table 6.3 allows easy determination if the fuel can be applicable for HiMSEN.

Table 6.3 Designation of fuel grades

| Fuel grade | | Sulfur content (%) | Typical viscosity (cSt) (at 50 ℃ for residual fuels and 40 ℃ for distillate fuels) | | ISO 8217 : 2017 |
|---|---|---|---|---|---|
| | | | Minimum | Maximum | |
| HFO (Heavy fuel oil) | HSFO (High sulfur fuel oil) | $1.0 < S \leq 3.5$ (or even higher) | 10 | 700 | Residual marine fuels (RMB, RMD, RME, RMG, RMK) |
| | LSFO (Low sulfur fuel oil) | $0.5 < S \leq 1.0$ | | | |
| | VLSFO (Very low sulfur fuel oil) | $0.1 < S \leq 0.5$ | 2 ~ 380 (Not decided yet) | | Not defined |
| | ULSFO (Ultra low sulfur fuel oil) | $S \leq 0.1$ | 9 ~ 67 (Not decided yet) | | |
| MGO (Marine gas oil) | | $S \leq 1.0$ | 2 | 6 | Distilled marine fuels (DMA, DFA, DMZ, DFZ) |
| MDO (Marine diesel oil) | | $S \leq 1.5$ | 2 | 11 | Distillate marine fuels (DMB, DFB) Residual marine fuels (RMA 10) |

Table 6.4 Specifications of distillate fuels

| Characteristics | | Unit | Limit | Category ISO-F- | | | | | | | Test method reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | DMX | DMA | DFA | DMZ | DFZ | DMB | DFB | |
| Kinematic viscosity at 40 ℃ | | $mm^2/s$ [a] | max. | 5.5 | 6.0 | | 6.0 | | 11.0 | | ISO 3104 |
| | | | min. | 1.4 | 2.0 | | 3.0 | | 2.0 | | |
| Density at 15 ℃ | | $Kg/m^3$ | min. | - | 890.0 | | 890.0 | | 900.0 | | ISO 3675 or ISO 12185 |
| Cetane index | | - | min. | 45 | 40 | | 40 | | 35 | | ISO 4264 |
| Sulfur [b] | | Mass % | max. | 1.0 | 1.0 | | 1.0 | | 1.5 | | ISO 8754 ISO 14596 ASTM D4294 |
| Flash point | | ℃ | min. | 43.0 | 60.0 | | 60.0 | | 60.0 | | ISO 2719 |
| Hydrogen sulfide | | mg/kg | max. | 2.0 | 2.0 | | 2.0 | | 2.0 | | IP 570 |
| Acid number | | mg KOH/g | max. | 0.5 | 0.5 | | 0.5 | | 0.5 | | ASTM D664 |
| Total sediment by hot filtration | | Mass % | max. | - | - | | - | | 0.10 [c] | | ISO 10307-1 |
| Oxidation stability | | $g/m^3$ | max. | 25 | 25 | | 25 | | 25 [d] | | ISO12205 |
| Fatty acid methyl ester(FAME) [e] | | Volume % | max. | - | - | 7.0 | - | 7.0 | - | 7.0 | ASTM D7963 or IP579 |
| Carbon residue : micro method on the 10 % volume distillation residue | | Mass % | max. | 0.3 | 0.30 | | 0.30 | | - | | ISO 10370 |
| Carbon residue : micro method | | Mass % | max. | - | - | | - | | 0.30 | | ISO 10370 |
| Cloud point [f] | Winter | ℃ | max. | -16 | report | | report | | - | | ISO 3015 |
| | Summer | ℃ | min. | -16 | - | | - | | - | | |
| Cold filter plugging point [f] | Winter | ℃ | max. | - | report | | report | | - | | IP 309 or IP 612 |
| | Summer | ℃ | min. | - | - | | - | | - | | |
| Pour point (upper) [f] | Winter | ℃ | max. | - | -6 | | -6 | | 0 | | ISO 3016 |
| | Summer | ℃ | max. | - | 0 | | 0 | | 6 | | |
| Appearance | | - | - | Clear and bright [g] | | | | | [c] | | |
| Water | | Volume % | max. | - | - | | - | | 0.30 [c] | | ISO 3733 |
| Ash | | Mass % | max. | 0.01 | 0.01 | | 0.01 | | 0.01 | | ISO 6245 |
| Lubricity, corrected wear scar diameter (WSD 1,4) at 60 ℃ [h] | | μm | max. | 520 | 520 | | 520 | | 520 [d] | | ISO 12156-1 |

a) 1 $mm^2/s$ = 1 cSt
b) Notwithstanding the limits given, a purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See introduction of ISO 8217 : 2017.
c) If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required. See 6.8 and 6.12 of ISO 8217 : 2017.
d) If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.
e) See 5.1 and Annex A of ISO 8217 : 2017
f) Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cold filter plugging point) are suitable for the ship's design and intended voyage. See 6.11 of ISO 8217 : 2017.
g) If the sample is dyed and not transparent, then the water limit and test method as given in 6.12 of ISO 8217 : 2017 shall apply.
h) This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0.050 mass %).

Table 6.5 Specifications of residual fuels

| Characteristics | | Unit | Limit | Category ISO-F- | | | | Test method reference |
|---|---|---|---|---|---|---|---|---|
| | | | | RMA | RMB | RMD | RME | |
| | | | | 10 | 30 | 80 | 180 | |
| Kinematic viscosity at 50 ℃ | | $mm^2/s$ [a)] | max. | 10.0 | 30.0 | 80.0 | 180.0 | ISO 3104 |
| Density at 15 ℃ | | $kg/m^3$ | max. | 920.0 | 960.0 | 975.0 | 991.0 | ISO 3675 or ISO 12185 |
| CCAI | | - | max. | 850 | 860 | 860 | 860 | |
| Sulfur [b)] | | mass % | max. | Statutory requirements [*)] | | | | ISO 8754 ISO 14596 ASTM D4294 |
| Flash point | | ℃ | min. | 60.0 | 60.0 | 60.0 | 60.0 | ISO 2719 |
| Hydrogen sulfide | | mg/kg | max. | 2.0 | 2.0 | 2.0 | 2.0 | IP 570 |
| Acid number [c)] | | mg KOH/g | max. | 2.5 | 2.5 | 2.5 | 2.5 | ASTM D664 |
| Total sediment aged | | mass % | max. | 0.1 | 0.1 | 0.1 | 0.1 | ISO 10307-2 |
| Carbon residue : micro method | | mass % | max. | 2.5 | 10.0 | 14.0 | 15.0 | ISO 10370 |
| Pour point(upper) [d)] | Winter | ℃ | max. | 0 | 0 | 30 | 30 | ISO 3016 |
| | Summer | ℃ | max. | 6 | 6 | 30 | 30 | |
| Water | | volume % | max. | 0.30 | 0.50 | 0.50 | 0.50 | ISO 3733 |
| Ash | | mass % | max. | 0.04 | 0.07 | 0.07 | 0.07 | ISO 6245 |
| Vanadium | | mg/kg | max. | 50 | 150 | 150 | 150 | IP 501, IP 470 or ISO 14597 |
| Sodium | | mg/kg | max. | 50 | 100 | 100 | 50 | IP 501, IP 470 |
| Aluminum plus silicon | | mg/kg | max. | 25 | 40 | 40 | 50 | IP 501, IP 470 or ISO 10478 |
| Used lubricating oils (ULO) Calcium and Zinc ; or calcium and phosphorus | | mg/kg | - | Do not use if : calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15 | | | | IP 501 or IP 470, IP 500 |

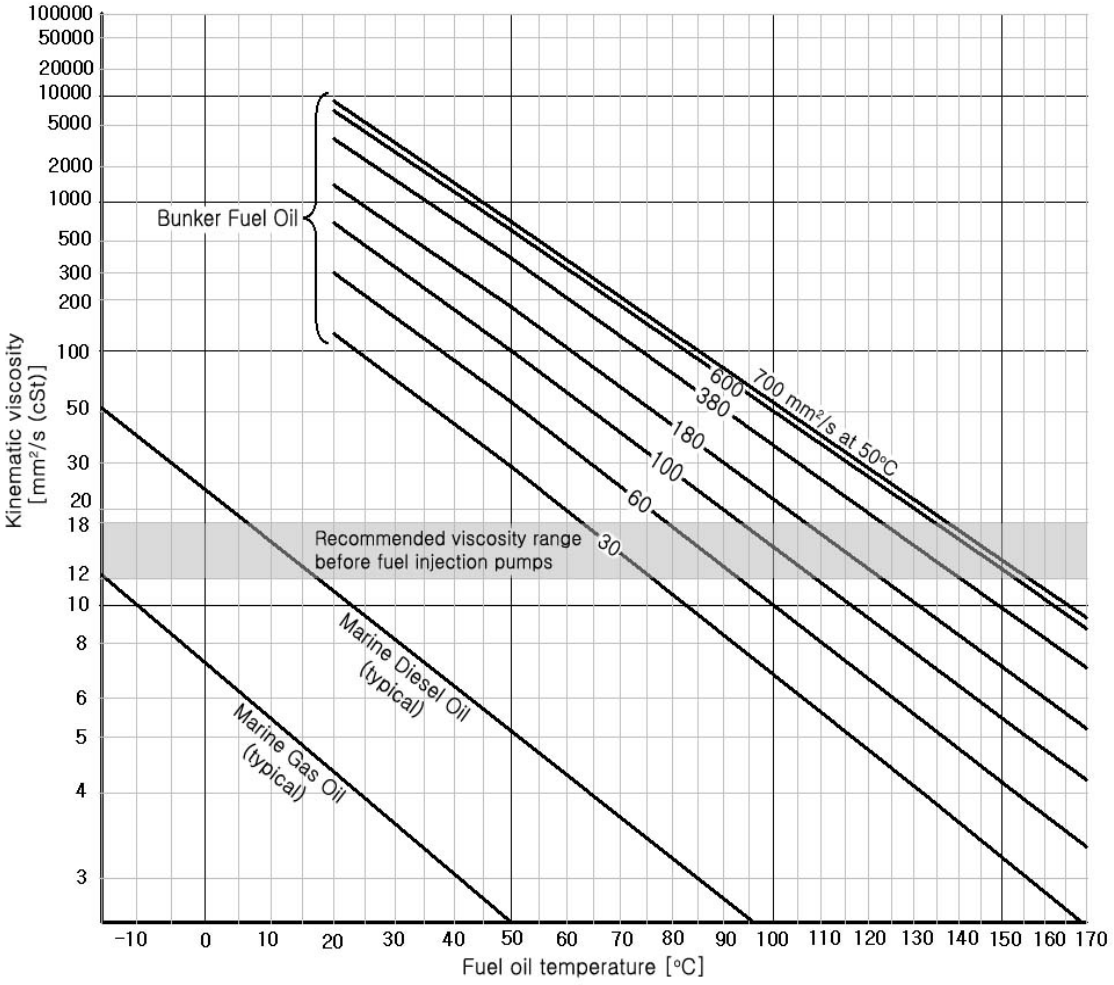
a) 1 $mm^2/s$ = 1 cSt
b) The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations.
c) See Annex H of ISO 8217 : 2017.
d) The purchaser should confirm that this pour point is suitable of the ship's intended area of operation.
*) International statutory requirements
This document specifies allowable minimum flash point limits following the provisions given in the SOLAS convention. MARPOL Annex VI, which controls air pollution from ships, includes a requirement that either the fuel shall not exceed a specified maximum sulfur or an approved equivalent alternative means be used. During the lifetime of this document, regional and/or national bodies may introduce their own local emission requirements, which can impact the allowable sulfur content, for example, the EU sulfur directive. It is the purchaser's and the user's responsibility to establish which statutory requirements are to be met and specify on that basis the corresponding maximum fuel sulfur content to the supplier.

| Characteristics | | Unit | Limit | Category ISO-F- | | | | | | | Test method reference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RMG | | | | RMK | | | |
| | | | | 180 | 380 | 500 | 700 | 380 | 500 | 700 | |
| Kinematic viscosity at 50 ℃ | | $mm^2/s$ [a)] | max. | 180.0 | 380.0 | 500.0 | 700.0 | 380.0 | 500.0 | 700.0 | ISO 3104 |
| Density at 15 ℃ | | $kg/m^3$ | max. | 991.0 | | | | 1,010.0 | | | ISO 3675 or ISO 12185 |
| CCAI | | - | max. | 870 | | | | 870 | | | |
| Sulfur [b)] | | mass % | max. | Statutory requirements [*)] | | | | | | | ISO 8754 ISO 14596 ASTM D4294 |
| Flash point | | ℃ | min. | 60.0 | | | | 60.0 | | | ISO 2719 |
| Hydrogen sulfide | | mg/kg | max. | 2.0 | | | | 2.0 | | | IP 570 |
| Acid number [c)] | | mg KOH/g | max. | 2.5 | | | | 2.5 | | | ASTM D664 |
| Total sediment aged | | mass % | max. | 0.1 | | | | 0.1 | | | ISO 10307-2 |
| Carbon residue : micro method | | mass % | max. | 18.0 | | | | 20.0 | | | ISO 10370 |
| Pour point(upper) [d)] | Winter | ℃ | max. | 30 | | | | 30 | | | ISO 3016 |
| | Summer | ℃ | max. | 30 | | | | 30 | | | |
| Water | | volume % | max. | 0.50 | | | | 0.50 | | | ISO 3733 |
| Ash | | mass % | max. | 0.10 | | | | 0.15 | | | ISO 6245 |
| Vanadium | | mg/kg | max. | 350 | | | | 450 | | | IP 501, IP 470 or ISO 14597 |
| Sodium | | mg/kg | max. | 100 | | | | 100 | | | IP 501, IP 470 |
| Aluminum plus silicon | | mg/kg | max. | 60 | | | | 60 | | | IP 501, IP 470 or ISO 10478 |
| Used lubricating oils (ULO) Calcium and Zinc ; or calcium and phosphorus | | mg/kg | - | Do not use if : calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15 | | | | | | | IP 501 or IP 470, IP 500 |

a) 1 $mm^2/s$ = 1 cSt
b) The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations.
c) See Annex H of ISO 8217 : 2017.
d) The purchaser should confirm that this pour point is suitable of the ship's intended area of operation.
*) International statutory requirements
This document specifies allowable minimum flash point limits following the provisions given in the SOLAS convention. MARPOL Annex VI, which controls air pollution from ships, includes a requirement that either the fuel shall not exceed a specified maximum sulfur or an approved equivalent alternative means be used. During the lifetime of this document, regional and/or national bodies may introduce their own local emission requirements, which can impact the allowable sulfur content, for example, the EU sulfur directive. It is the purchaser's and the user's responsibility to establish which statutory requirements are to be met and specify on that basis the corresponding maximum fuel sulfur content to the supplier.

## 6.4 Fuel oil viscosity diagram

The viscosity of heavy fuel oil to the engine should be kept within the value of 12 ~ 18 cSt. However, the viscosity varies depending on the properties and the temperature of the fuel oil. Maximum preheating temperature of heavy fuel oil is limited up to 155 ℃ to avoid the vaporization of the fuel oil. A typical fuel oil viscosity diagram with temperature is as follows :




1. The viscosity of marine diesel oil / marine gas oil to the engine should be kept within the value of 2 ~ 14 cSt in order to avoid possible sticking of fuel injection pump due to low lubricity of marine diesel oil / marine gas oil.

Figure 6.3 Diagram for fuel oil viscosity

# 6.5 Fuel oil quality

## 6.5.1 Fuel characteristics

### Viscosity

The viscosity of fuel oil to the engine should be kept within the value of 12 ~ 18 cSt for heavy fuel oil and 3 ~ 14 cSt for marine diesel oil / marine gas oil, which could be achieved by proper heating recommended by fuel supplier as the viscosity varies depending on the properties of the fuel oil.

### Density

If the density of the fuel oil is over the maximum density (991 kg/㎥ at 15 ℃), the fuel oil is hard to be used because it is highly expected to be contaminated by water or solid unfiltered from system. The special centrifuging system should be installed for the fuel oil with the maximum density (1010 kg/㎥ at 15 ℃).

### Sulfur

It is important to keep proper sulfur contents in the fuel oil. The high sulfur content in the fuel may increase the risk of low temperature corrosion in the combustion chamber and contribute to the formation of high temperature deposit. It is also recommended to keep the proper alkalinity of the lubricating oil for neutralizing.

### Ash

The ash content comes from natural crude oil and also from contamination during treatment of the fuel. The solid ingredients can be removed mostly by centrifuging of the fuel. However there are soluble compounds such as vanadium and sodium, which can be transformed as ash after combustion. As the ash in any form promotes mechanical wear of engine parts and harmful deposits in the combustion chamber, the ash components should be carefully analyzed and removed in advance.

### Vanadium and sodium

Vanadium is oil – soluble and comes from crude oil mostly. However sodium is water-soluble and comes from crude oil as well as contaminated fuel by salt water. As vanadium and sodium become corrosive ash after combustion, these should be removed as possible. A sodium compound contributes to lower the melting point of vanadium ash, which is very corrosive and harmful to exhaust valves and turbocharger. Therefore, compounds should be less than 1/3 of vanadium contents in weight.

### Conradson carbon

Including much conradson carbon may impair combustion properties of the fuel and cause deposit formation in combustion chamber and exhaust system particularly at low engine output.

### Asphaltenes

High asphaltene contents shall contribute to forming of deposit in combustion chamber as well as exhaust system at low loads and stick the fuel injection pump. It also causes excessive centrifuge sludge and deposits in the fuel system.

### Water

The water contents can be measured by a standardized distillation test. The water causes corrosion and cavitation of the fuel injection pump and fouling of the exhaust system and turbochargers. The water content should be reduced to maximum 0.2 % by centrifuging.

### Abrasive particles

Fuel oil can be contaminated by abrasive particles composed of aluminium and silicon. If the efficient fuel treatment is not applied, these fine catalysts can cause abnormal wear on injection system and cylinder liners / piston rings. The aluminum and silicon should be reduced to maximum 15 mg/kg before engine inlet.

## 6.5.2 Ignition quality

The ignition quality is related to the ignition delay to the intervals between fuel injection and combustion. If the engine is operated at low load or in the condition of low temperature or pressure in the combustion chamber, the ignition delay is lengthened. During the initial operation, the engine can be damaged by the low ignition quality without sufficient preheating. The equation of CCAI (Calculated Carbon Aromaticity Index) developed by Shell can be used to get the ignition quality of the heavy fuel oil.

### Calculated carbon aromaticity index

$$CCAI = D - 81 - 141 \times \log \times [\log \times (Vk + 0.85)]$$

Where :

D (kg/㎥ at 15 ℃) = Density

Vk (cSt at 50 ℃) = Viscosity

If the value of CCAI is increased, the ignition quality has decreased value. The fuel oil with high CCAI value can cause a combustion problem.

To prevent any troubles about poor ignition quality, engine should be preheated sufficiently before start and has proper functions of cooling system and injection system.

From light distillates to residual fuels, net and gross specific energy can be tested or calculated according to various international standards. Basically, the specific energy value provided by fuel supplier is adapted for the determination of the heat of combustion.

If it is not supplied from fuel supplier, it can be calculated by the specification of other properties as the equations given below.

For residual fuels,

$$N = (46.704 - 8.802 \times \rho^2 \times 10^{-6} + 3.167 \times \rho \times 10^{-3}) \times [1 - 0.01 \times (w + a + s)] + 0.0942 \times s - 0.02449 \times w$$

$$G = (52.190 - 8.802 \times \rho^2 \times 10^{-6}) \times [1 - 0.01 \times (w + a + s)] + 0.0942 \times s$$

For marine distillate fuels,

$$N = (46.423 - 8.792 \times \rho^2 \times 10^{-6} + 3.170 \times \rho \times 10^{-3}) \times [1 - 0.01 \times (w + a + s)] + 0.0942 \times s - 0.02449 \times w$$

$$G = (51.916 - 8.792 \times \rho^2 \times 10^{-6}) \times [1 - 0.01 \times (w + a + s)] + 0.0942 \times s$$

Where :

N (MJ/kg) = Net specific energy
G (MJ/kg) = Gross specific energy
$\rho$ (kg/m$^3$) = Density at 15℃
w (mass %) = Water content
a (mass %) = Ash content
s (mass %) = Sulfur content

Ref. ISO 8217:2017(E)

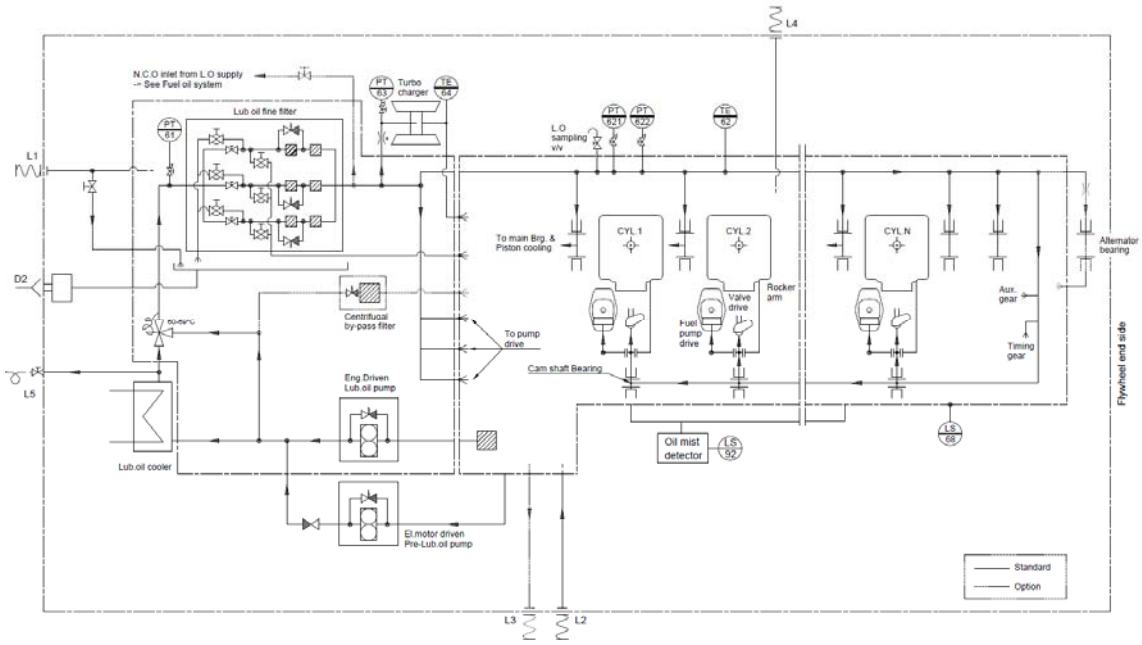
* Refer to that the actual specific energy test method (for example ASTM D 240) takes priority over the specific energy calculation method as above.

**This page is intentionally blanked**

# 7 Lubricating oil system

## 7.1 Internal lubricating oil system

### Diagram for Internal lubricating oil system




*) Scope of instrumentations will be according to extent of delivery and engine builder's standard.

Figure 7.1 Diagram for internal lubricating oil system[BP0049143]

Table 7.1 Sizes of external pipe connections

| Code | Description | Size | Remark |
|---|---|---|---|
| L1 | Oil vapor discharge | 5K - 125A | JIS B 2220 |
| L2 | Lubricating oil from separator | 10K - 50A | JIS B 2220 |
| L3 | Lubricating oil over flow | 10K - 80A | JIS B 2220 |
| L4 | Lubricating oil to separator | 10K - 50A | JIS B 2220 |
| L5 | Lubricating oil to shut-off valve | OD ø10 | |
| D2 | Waste oil drain (Drity) | OD ø25 | |

Remark

1. The scope of instrumentations will be followed according to the extent of delivery and engine builder’s standard.

### 7.1.1 General description

The engine has its own internal lubricating oil system which supplies lubricating oil to all moving parts for lubrication as well as cooling. Most of the oil passages are incorporated into the engine components and the equipment including a turbocharger(s).

The lubricating oil main pump(s) is driven by the engine. The pump is of a gear type with the pressure regulating valves. For the flow rate at MCR, see 3.2 “Engine Capacity Data”.

The pre-lubricating pump is driven by an electric motor. The pump is of a gear type which is operated automatically with the stop state of the engine. When the automatic pre-lubrication has been switched off, the engine must be pre-lubricated sufficiently before start.

The lubricating oil main filters are built on the free side of the engine. The filter is the self-cleaning automatic type with 35μm (absolute) mesh size of AISI 316L filter element cartridge.

The lubricating oil sump of the engine is of a wet sump type. It has the lubricating oil outlet connections which shall be led to the separators in the external system.

The internal lubricating oil system is mainly comprised of the following equipment:

- ✓ Lubricating oil main pump, engine driven
- ✓ Pre-lubricating pump, electric motor driven
- ✓ Lubricating oil cooler
- ✓ Lubricating oil thermostatic valve
- ✓ Lubricating oil main filter
- ✓ Centrifuge (Option)
- ✓ Oil mist detector

## Quantity of lubricating oil

Table 7.2 Total quantity of lubricating oil inside the engine

| Engine type | Oil quantities in liter 720 / 750 rpm | |
|---|---|---|
| | Min. | Max. |
| 6H32C | 2640 | 3480 |
| 7H32C | 2960 | 3910 |
| 8H32C | 3290 | 4340 |
| 9H32C | 3620 | 4770 |

## Lubricating oil consumption

Specific lubricating oil consumption : 0.5 g/kWh

- ✓ Tolerance : +25 % depending on the operating condition
- ✓ Only maximum continuous rating should be used to evaluate the lubricating oil consumption.

## Engine driven lubricating oil pump

The engine driven lubricating oil pump is a gear type, mounted on the engine. The pump is designed to provide sufficient flow even at low speed.

## Pre-lubricating oil pump

The pre-lubricating pump is gear type, and electric motor driven. The pre-lubricating pump is automatically started to operate when engine is stopped. And the pre-lubricating is required during the engine stop period if the fuel oil is circulating. In case that the automatic pre-lubrication has been switched off, the engine must be pre-lubricated sufficiently before starting up.

## Lubricating oil cooler

The lubricating oil cooler is plate type, mounted on the engine.

## Thermostatic valve

The thermostatic valve is the wax element type, working at fixed temperature range of 60 ~ 69 ℃, is mounted on the feed module of the engine.

## Lubricating oil filter

The lubricating oil filter is duplex paper cartridge type, mounted on the engine.
Each filter has a safety cartridge of stainless steel.

- ✓ Paper cartridge fineness : 15 ㎛
- ✓ Safety cartridge fineness : 60 ㎛

## Pressure regulating valve

The pressure regulating valve adjusts inlet pressure after lubricating oil filter at 4 ~ 5 bar and is mounted on the engine.

## Centrifugal oil filter

Centrifugal oil filter can be mounted on engine. The centrifugal force is taken from the oil pressure.

## Lubricating oil sump drain

It is recommended to use the separator suction pipe for draining of the lubricating oil sump.

## 7.2 External lubricating oil system

### Diagram for external lubricating oil system

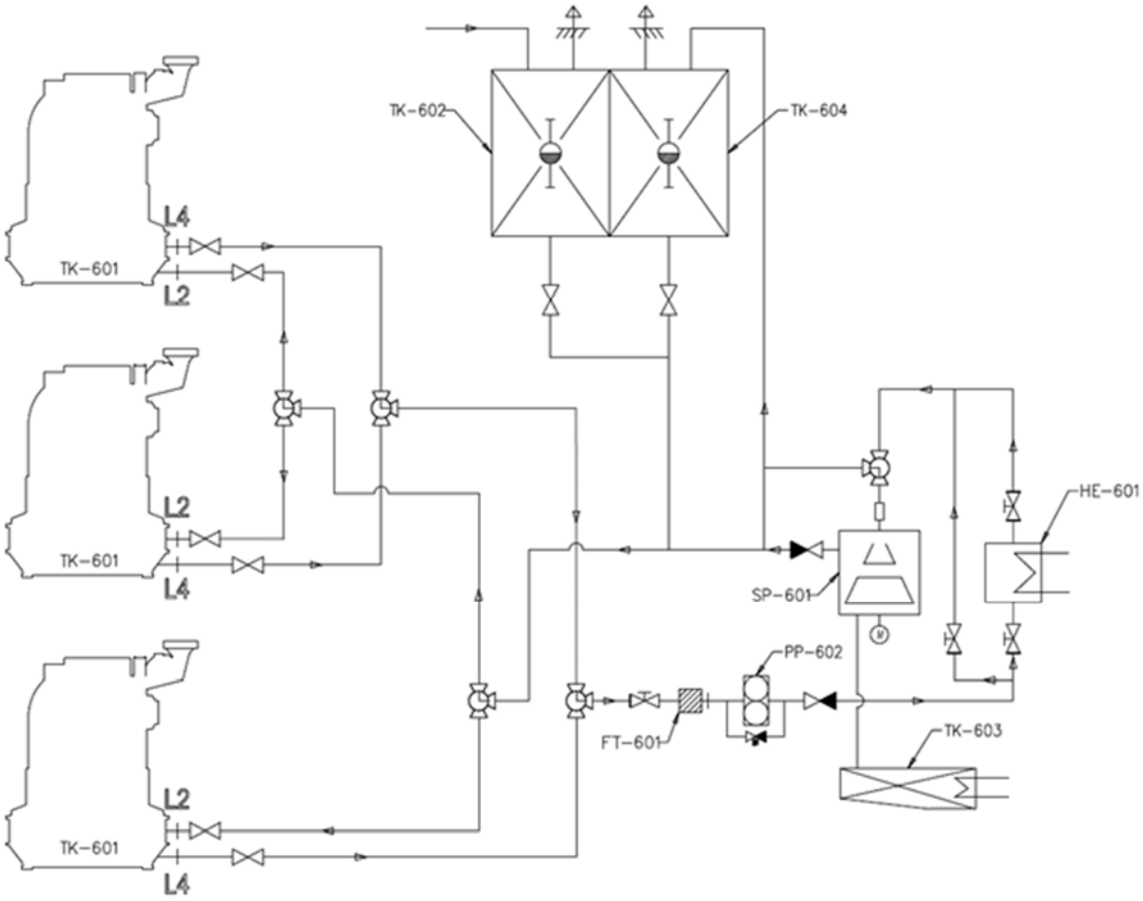



Figure 7.2 Diagram for external lubricating oil system for multi-engine installation [B91-314112-7.1]

Table 7.3 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-601 | System oil tank | HE-601 | Pre-heater for the separator |
| TK-602 | Storage tank | SP-601 | Separator |
| TK-603 | Sludge tank | PP-602 | Feed pump for the separator |
| TK-604 | Separated oil tank | FT-601 | Suction strainer |

### 7.2.1 General description

The external lubricating oil system is required for not only cleaning but also heating the oil to start the engine quickly. The system shall be used commonly for all auxiliary engines.
Though filtering equipment built on engine shall be sufficient for the engine operating only marine diesel oil, the centrifugal purification is commonly required for marine diesel oil and heavy fuel oil operation.

### 7.2.2 Lubricating oil separator

Self-cleaning type or manual cleaning type separator can be used.

#### Separator capacity

The separators should be dimensioned for continuous operation and following formula can be used, as a guidance, for estimating the required flow for the separator capacity :

$F = p \times 1.4 \times n / t$

Where :

F (l / h) = required flow
p (kW) = total engine output
n = number of oil circulation per day (4 for marine diesel oil / marine gas oil, 6 for heavy fuel oil)
t = actual separation time per day (Normally, 23 hour)

For the simple estimation, above formula can be expressed as follows :

$F = 0.3 \times p$ (l/h)

The below formula is used to find the rated capacity for the separator :

$V = F / B$ (l/h)

Where :

V (l/h)= rated capacity for the separator
F (l/h)= required flow
B = throughput factor (0.2 ~ 0.25)

Throughput factor (B) shall be in accordance with the separator maker's recommendations.

#### Separator installation

The separator should be in continuous operation while the engine is on running in order to ensure removal of contaminants as quick as possible. If possible, the separator should be in operation also when the engine on shut-down for the reducing of the contamination level. In the latter case, oil temperature for efficiencies of separation needs to be maintained through heaters. Those installations with their separation plant shut down during engine stop, should consider re-starting the separator prior to engine start-up because contamination (engine leaks, condensation) could occur during engine stop.

With multi-engine plants, it would be the best to install one separator per each engine (Figure 7.3). The cleaning systems of auxiliary engines are often designed such that the separator intermittently serves on engine at a time. If only one separator is in operation, the following lay-outs can be used (Figure 7.4).

Oil cleaning, the discharge depending upon the operating time between two periods of oil cleaning the discharge interval may have to be shortened during the first couple of hours. In this way the separator will be able to cope with the high level of contaminants at the beginning of the cleaning phase. The appropriate discharge interval has to be found by trial and error.

It is important that maintenance and operation of the separator should be performed according to the manufacturer's recommendations.

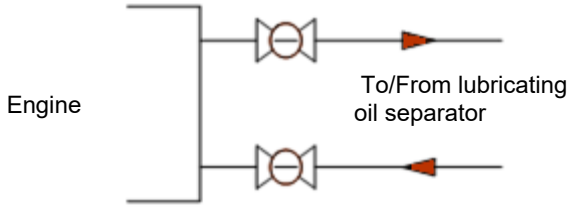



Figure 7.3 Principle layout for direct separating on single engine.

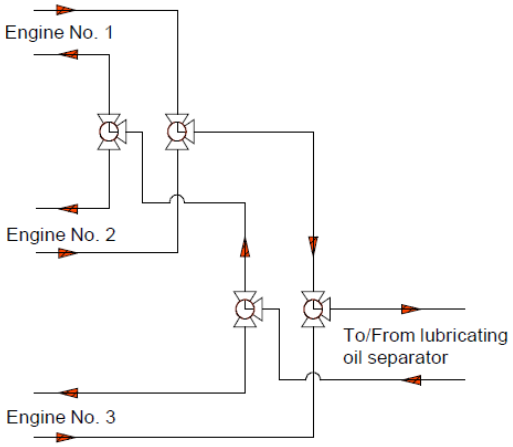



Figure 7.4 Principle layout for direct separating on multi engines

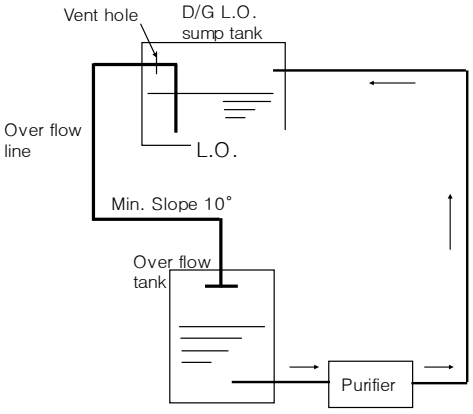



Figure 7.5 Principle layout for overflow system

It should be ensured that the separator is only connected with one engine at a time. In order to ensure that there is no suction and discharging from one engine to another.

To provide the mentioned above, it is recommended that inlet and outlet valves are connected, so that they can be changed-over simultaneously.

With only one engine in operation there are no problems with separating, but if multi engines are in operation for some time it is recommended to split up the time so that there is separation on all engines, which are operating in turns.

### Overflow system

In some cases, overflow system can be applied as an alternative for continuous purification (Figure 7.5). In order to have a better syphon effect, the overflow pipe from sump to overflow tank should have a continuous downward gradient of min. 10 degrees without high and low point.

### Suction strainer

0.8 ~ 1.0 mm mesh size of suction strainer should be inserted before the separator pump.

### Pump for separator

The pump can be either directly driven by the separator or driven by an independent motor as recommended from a separator maker.

### Heater for separator

The lubricating oil in wet sump tank and in the system is to be warm-up to 40 ℃ from the separator heater prior to engine starting. The lubricating oil in sump tank is to be heated-up to approx. 65 ℃ in engine service. Heater for separator is to be designed to heat the lubricating oil from 65 ℃ up to 95 ~ 98 ℃ according to separator maker's recommendation.

If the separation temperature is lowered from 95 ℃ to 90 ℃, the separator throughput has to be reduced by 22 % to maintain the same separation efficiency.

## 7.2.3 Velocities and pressure losses

In order to prevent excessive pressure losses in the piping system, we recommend that the lubricating oil velocity should not exceed :

- ✓ Suction pipe : 0.5 ~ 1.5 m/s
- ✓ Pressure pipe : 1.0 ~ 2.5 m/s

### 7.2.4 Crank case ventilation

Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes should be independent to avoid inter circulation between crankcases.

- ✓ The crankcase vent pipes from each engine shall be led independently to the top of the funnel. The pipes should not be connected to any other branch such as a tank vent, etc.
- ✓ The outlet of vent pipe is to be fitted with corrosion resistant flame screen separately for each engine.
- ✓ The vent pipe should have a continuous upward gradient of minimum 10 degrees without high point or low point.
- ✓ The vent pipe should be equipped with a condensate trap and drain near the engine.
- ✓ The connection between the engine and yard vent pipe is to be flexible, if resilient mounting is applied.
- ✓ The dimension of the flexible connection is 125A, and the vent pipe size after the flexible connection must be min. 125A.
- ✓ The oil mist should not be go into suction side of intake duct located outside (for outdoor type) or engine room (for indoor type).
- ✓ Criteria for high back pressure of crank case ventilation is that the maximum crank case inner pressure should not exceed 35 mmWC at maximum continuous rating.

## 7.3 Lubricating oil specification

### 7.3.1 Oil grade

The medium-alkaline, heavy duty (HD) oils in API-CD class have to be used for HiMSEN engine including turbocharger lubrication. Please refer to the Table 7.5.

### 7.3.2 Oil viscosity

The oil viscosity is based on SAE 40 oil and recommended to be 145 ㎟/sec. at 40 ℃.

The lubricating oil should be heated to 40 ℃ prior to engine start.

### 7.3.3 BN value

BN (Base Number) is a measure of the alkalinity or basicity of the oil. It is expressed in milligrams of potassium hydroxide per gram of the oil (mg KOH/g).

Alkalinity in lubricating oil is necessary to neutralize the acidic combustion products coming from the sulfur in fuel. Therefore, lubricating oil with suitable BN should be selected to maintain proper balance between alkalinity in lubricating oil and the sulfur level in fuel after consulting with lubricating oil supplier or specialist.

- ✓ High sulfur fuel + low BN lubricating oil → Excessive corrosive wear
- ✓ Low sulfur fuel + high BN lubricating oil → Excessive top land deposit formation
  → Lacquering formation on cylinder liner surface

### 7.3.4 Lubricating oil selection

The general lubricating oil BN selection strategy is to match the lubricating oil with the fuel sulfur contents (%). Because BN decreases at various rates in each engine and condition, lubricating oil consumption also should be considered to have sufficient equilibrium during operation.

When the marine diesel oil and marine gas oil are to be used only for temporary engine operation, higher BN lubricating oil used for residual fuel (heavy fuel oil) would not present any problems. The acceptable period of temporary operation is less than 200 hours.

It is necessary to use proper lubricating oil based on sulfur content of fuel as per the lubricating oil list for HiMSEN engine described on the instruction manual in order to avoid excessive deposits in the combustion chamber, exhaust gas line and turbochargers.

**Residual fuel**

Table 7.5 Residual fuel

| Sulfur contents (%) | BN |
|---|---|
| 3.5 - | 40 - 55 |
| 0.5 - 3.5 | 30 - 40 |
| 0.1 – 0.5 | 20 - 30 |
| - 0.1 | 20 |

**Distillated fuel**

- ✓ Distillated fuel (marine gas oil / marine diesel oil) : BN10 ~ 20

* Refer to the Sheet ‘6.3 Fuel oil specification’ for specification of residual and distillated fuel.

## 7.4 List of lubricants

Table 7.6 List of lubricants

| Oil brand | Engines system lubricating oil | | | Governor oil |
|---|---|---|---|---|
| Oil company | Brand name | SAE | BN *) | |
| Shell | Mysella S3 N40 | 40 | 5 | 1) Same as engine system lubricating oil<br>2) Refer to the governor manual for detailed lubricating oil specification, volume of governor.<br>3) Initial filling : oil filled<br>4) Electrical (Digital) governor: not applied |
| | Mysella S5 N40 | | 4.5 | |
| | Shell Gadinia S3 40 | | 12 | |
| | Shell Argina S2 40 | | 20 | |
| | Shell Argina S3 40 | | 30 | |
| | Shell Argina S4 40 | | 40 | |
| | Shell Argina S5 40 | | 50 | |
| TOTAL (Lubmarine) | Aurelia LNG | 40 | 5 | |
| | Nateria X 405 | | 5.2 | |
| | DISOLA M 4012 | | 12 | |
| | DISOLA M 4015 | | 14 | |
| | AURELIA TI 4020 | | 20 | |
| | AURELIA TI 4030 | | 30 | |
| | AURELIA TI 4040 | | 40 | |
| | AURELIA TI 4055 | | 55 | |
| Chevron (Taxaco, Caltex) | HDAX 9700 | 40 | 5.8 | |
| | DELO SHP 40 | | 12 | |
| | DELO 1000 Marine 40 | | 12 | |
| | TARO 20 DP 40(X) | | 20 | |
| | TARO 30 DP 40(X) | | 30 | |
| | TARO 40 XL 40(X) | | 40 | |
| | TARO 50 XL 40(X) | | 50 | |
| ExxonMobil | Pegasus 805 Ultra | 40 | 5.4 | |
| | Pegasus 805 | | 6.2 | |
| | Pegasus 1005 | | 5.4 | |
| | Pegasus 1105 | | 6.2 | |
| | Pegasus 1107 | | 7.3 | |
| | Pegasus 1 | | 6.5 | |
| | Mobilgard ADL 40, Mobil Delvac 1640 | | 12 | |
| | Mobilgard 412 | | 15 | |
| | Mobilgard M420 | | 20 | |
| | Mobilgard M430 | | 30 | |
| | Mobilgard M440 | | 40 | |
| BP (Castrol) | CASTROL Duratex L | 40 | 4.5 | |
| | CASTROL MLC 40 | | 12 | |
| | CASTROL MHP 154 | | 15 | |
| | CASTROL TLX Xtra 204 | | 20 | |
| | CASTROL TLX Xtra 304 | | 30 | |
| | CASTROL TLX Xtra 404 | | 40 | |
| | CASTROL TLX Xtra 504 | | 50 | |
| | CASTROL TLX Xtra 554 | | 55 | |
| SK Lubricants | SUPERMAR 13TP 40 | 40 | 13 | |
| | SUPERMAR 24TP 40 | | 24 | |
| | SUPERMAR 30TP 40 | | 30 | |
| | SUPERMAR 40TP 40 | | 40 | |
| LUKOIL | Navigo TPEO 12/40 | 40 | 12 | |
| | Navigo TPEO 15/40 | | 15 | |
| | Navigo TPEO 20/40 | | 20 | |
| | Navigo TPEO 30/40 | | 30 | |
| | Navigo TPEO 40/40 | | 40 | |
| | Navigo TPEO 50/40 | | 50 | |
| | Navigo TPEO 55/40 | | 55 | |

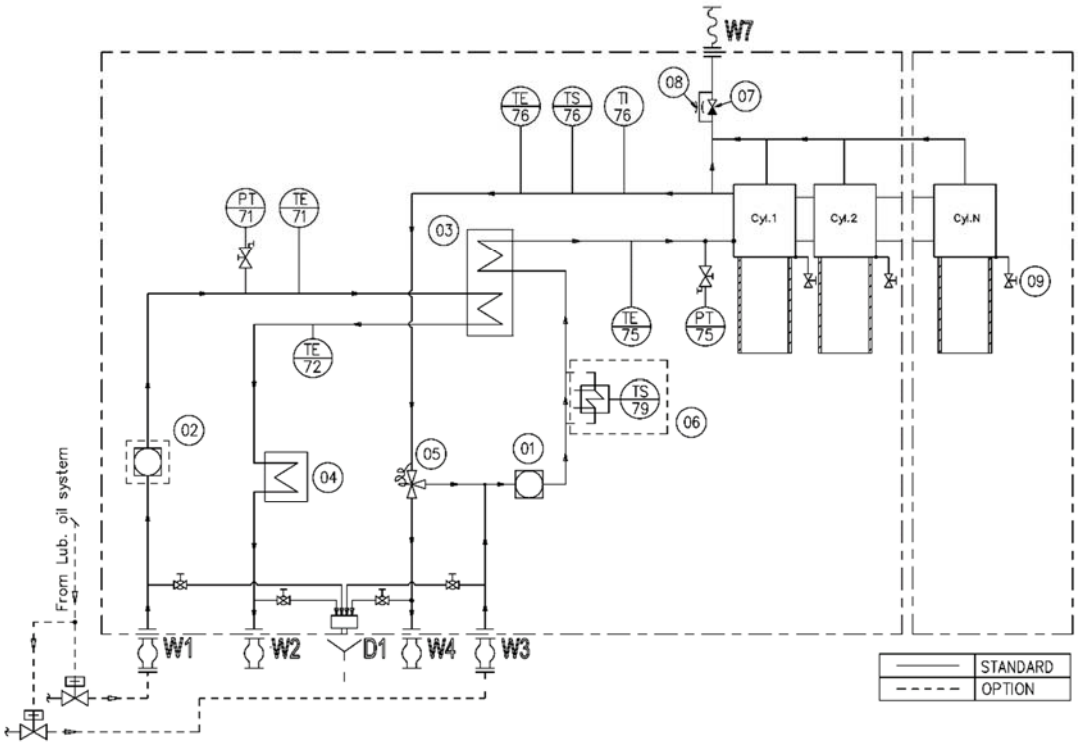
| Oil brand | Engines system lubricating oil | | | Governor oil |
|---|---|---|---|---|
| Oil company | Brand name | SAE | BN *) | |
| Gulf Oil Marine | GulfSea Power MDO 4012, SeaLub Power MDO 4012 | 40 | 12 | 1) Same as engine system lubricating oil<br><br>2) Refer to the governor manual for detailed lubricating oil specification, volume of governor.<br><br>3) Initial filling : oil filled<br><br>4)Electrical (Digital) governor: not applied |
| | GulfSea Power MDO 4015, SeaLub Power MDO 4015 | | 15 | |
| | GulfSea Power MDO 4020, SeaLub Power MDO 4020 | | 20 | |
| | GulfSea Power 4030, SeaLub Power 4030 | | 30 | |
| | GulfSea Power 4040, SeaLub Power 4040 | | 40 | |
| | GulfSea Power 4055, SeaLub Power 4055 | | 55 | |
| ENI S.p.A. | AGIP CLADIUM 120 | 40 | 12 | |
| | AGIP CLADIUM 300 | | 30 | |
| | AGIP CLADIUM 400 | | 40 | |
| | AGIP CLADIUM 500S | | 50 | |
| Petronas | PETRONAS Disrol 50 | 40 | 6 | |
| | PETRONAS Disrol 120 | | 12 | |
| | PETRONAS Disrol 300 | | 32 | |
| | PETRONAS Disrol 400 | | 42 | |
| | PETRONAS Disrol 500 | | 51 | |
| AEGEAN | ALFAMAR 430 | 40 | 30 | |
| | ALFAMAR 440 | | 40 | |
| | ALFAMAR 450 | | 50 | |
| | ALFAMAR 455 | | 55 | |
| SINOPEC TPEO | SINOPEC TPEO 4012 | 40 | 12 | |
| | SINOPEC TPEO 4015 | | 15 | |
| | SINOPEC TPEO 4020 | | 20 | |
| | SINOPEC TPEO 4030 | | 30 | |
| | SINOPEC TPEO 4040 | | 40 | |
| | SINOPEC TPEO 4050 | | 50 | |
| Hyundai Oilbank | Hyundai XTeer HGSL 40 | 40 | 4.5 | |
| | Hyundai XTeer TPEO 4012 | | 12 | |
| | Hyundai XTeer TPEO 4015 | | 15 | |
| | Hyundai XTeer TPEO 4020 | | 20 | |
| | Hyundai XTeer TPEO 4030 | | 30 | |
| | Hyundai XTeer TPEO 4040 | | 40 | |
| | Hyundai XTeer TPEO 4050 | | 50 | |
| Gazpromneft Lubricants | Gazpromneft Ocean TPL 1240 | 40 | 12 | |
| | Gazpromneft Ocean TPL 1540 | | 15 | |
| | Gazpromneft Ocean TPL 2040 | | 20 | |
| | Gazpromneft Ocean TPL 3040 | | 30 | |
| Petro-Canada | Sentinel 445 | 40 | 4.7 | |
| Oil volume | See the separate data for sump volume as per each engine type. | | | UG-25+: 2.1 Liter<br>Europa : 1.5 Liter |

1. This list is given as guidance only.
*) Refer to Table 7.4 when selecting BN value.

# 8 Cooling water system

## 8.1 Internal cooling water system

### Diagram for internal cooling water system




°) Scope of instrumentations will be according to extent of delivery and engine builder's standard.

Figure 8.1 Diagram for internal cooling water system

Table 8.1 System components

| Code. | Description | Remark |
|---|---|---|
| 01 | High temperature Cooling water pump | |
| 02 | Low temperature Cooling water pump | Option |
| 03 | Charge air cooler | |
| 04 | Lubricating oil cooler | |
| 05 | High temperature Cooling water thermostatic valve | 79~88˚C(Setting: 82˚C) |
| 06 | Electric pre-heater | Option |
| 07 | Non-return valve | |
| 08 | Orifice | Ø3 |
| 09 | Cooling water drain cock | |

Table 8.2 Sizes of external pipe connections

| Code. | Description | Size |
|---|---|---|
| W1 | Low temperature cooling water engine inlet | 5K - 125A |
| W2 | Low temperature cooling water engine outlet | 5K - 125A |
| W3 | High temperature cooling water engine inlet | 5K - 125A |
| W4 | High temperature cooling water engine outlet | 5K - 125A |
| W7 | Ventilation to expansion tank | 5K - 25A |

Remark

1. Connection size is according to JIS B 2220.
2. The scope of instrumentations will be followed according to the extent of delivery and engine builder's standard.

### 8.1.1 General description

The engine has two cooling water circuits internally, which are low temperature and high temperature water circuits.

Low temperature water circuit comprises :

- ✓ Engine driven pump (option)
- ✓ Charge air cooler
- ✓ Lubricating oil cooler

High temperature water circuit comprises :

- ✓ Engine driven pump
- ✓ Charge air cooler
- ✓ Engine water jackets and cylinder heads
- ✓ Wax type thermostat valve, dividing type (temp. range : 79 ~ 88 ℃ fixed)

### Scope of supply

The internal cooling system consists of the following built-in equipment. Marked (*) equipment can be supplied as option on request.

- ✓ * Engine driven low temperature cooling water pump (option)
- ✓ Engine driven high temperature cooling water pump
- ✓ Two stage charge air cooler
- ✓ High temperature cooling water control thermostatic valve
- ✓ * Electric pre-heater unit or electric preheat element on engine (option)

1. Low temperature cooling water control thermostatic valve, if required, is to be installed on external piping of engine.

## 8.2 External cooling water system

### Diagram for external cooling water system – 1 with jacket preheating element (for reference)

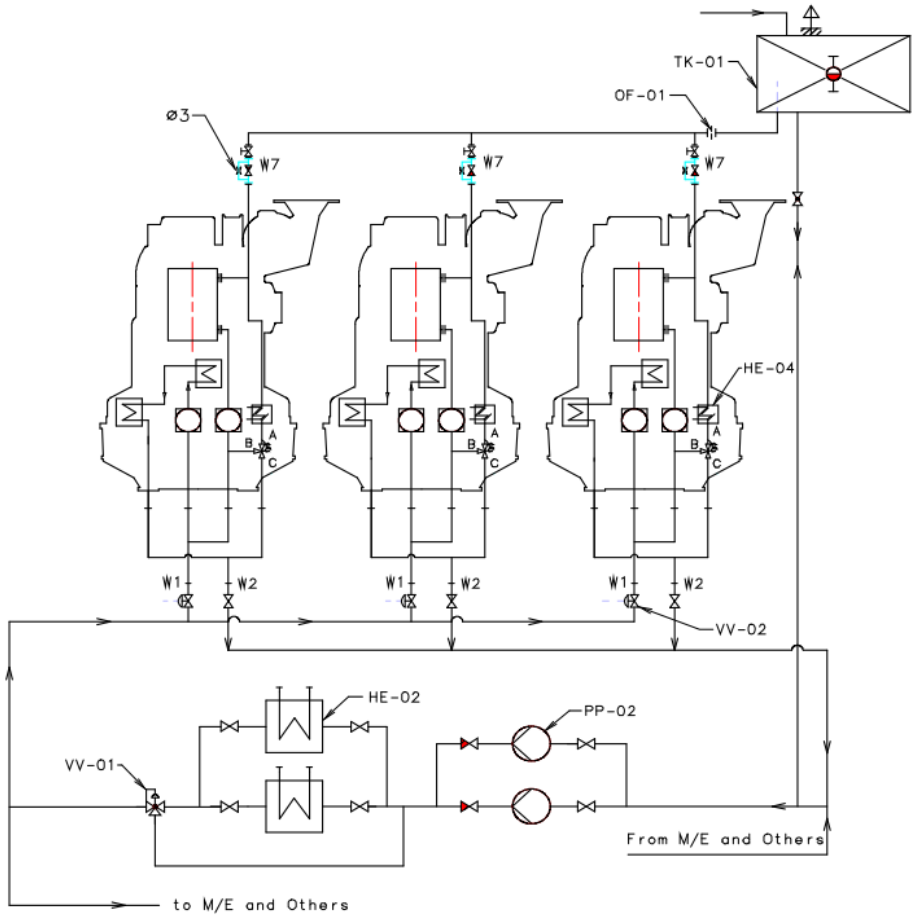



Figure 8.2 Diagram for external cooling water system-1 (electric pre-heating element)

Table 8.3 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-01 | Expansion tank | PP-02 | Central cooling water pump |
| HE-04 | Electric pre-heating element | VV-02 | Auto shut-off valve |
| HE-02 | Central cooler | OF-01 | Orifice (Ø3) |
| VV-01 | Thermostatic valve for central cooling | | |

## Diagram for external cooling water system – 1 with jacket preheating unit (for reference)

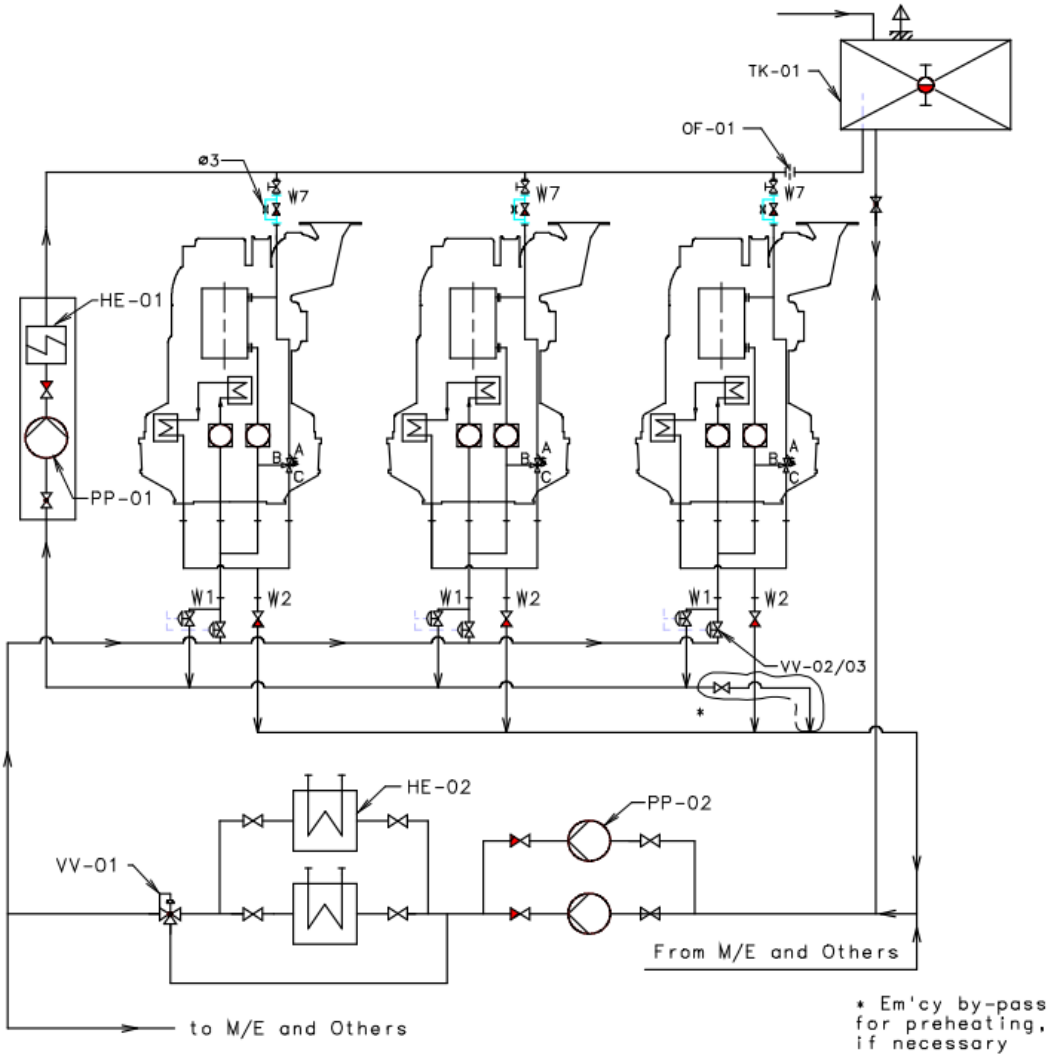



Figure 8.3 Diagram for external cooling water system-1 (pre-heating unit)

Table 8.4 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-01 | Expansion tank | PP-02 | Central cooling water pump |
| HE-01 | Pre-heater | VV-02/03 | Auto shut-off valve |
| PP-01 | Pre-heating pump | OF-01 | Orifice (Ø3) |
| HE-02 | Central cooler | VV-01 | Thermostatic valve for central cooling |

## Diagram for external cooling water system – 2 with jacket preheating element (for reference)

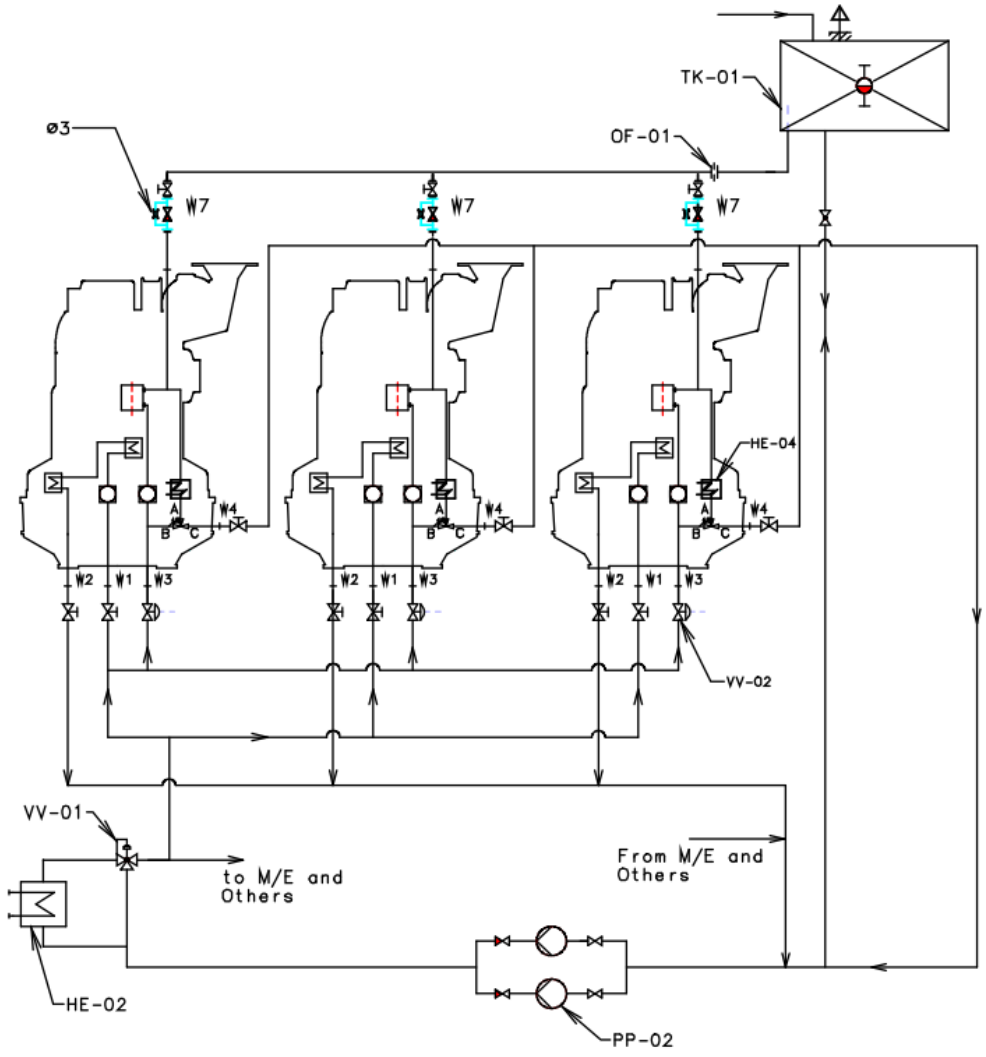



Figure 8.4 Diagram for external cooling water system-2 (electric pre-heating element)

Table 8.5 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-01 | Expansion tank | PP-02 | Central cooling water pump |
| HE-04 | Electric pre-heating element | VV-02 | Auto shut-off valve |
| HE-02 | Central cooler | OF-01 | Orifice (Ø3) |
| VV-01 | Thermostatic valve for central cooling | | |

## Diagram for external cooling water system – 2 with jacket preheating unit (for reference)

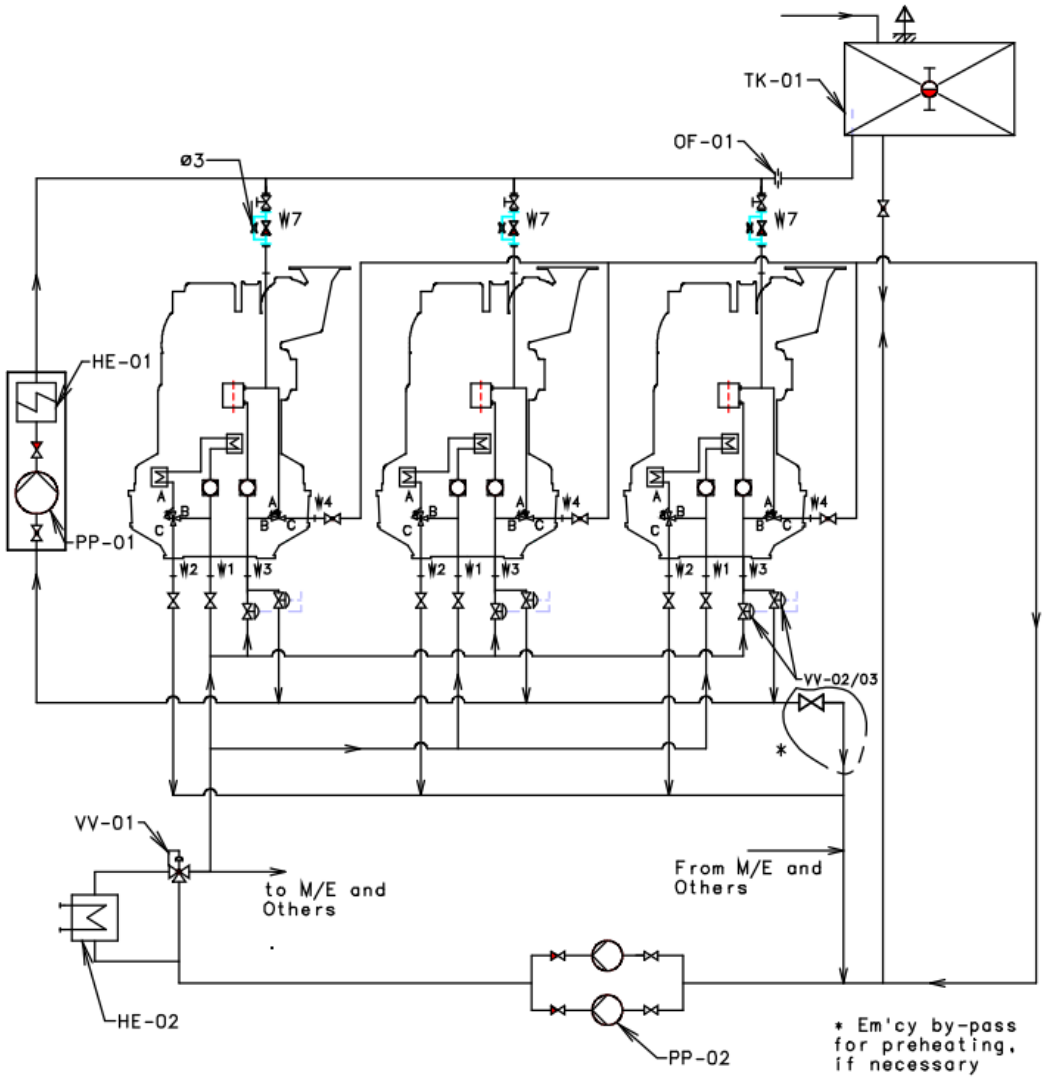



Figure 8.5 Diagram for external cooling water system -2 (pre-heating unit)

Table 8.6 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-01 | Expansion tank | PP-02 | Central cooling water pump |
| HE-01 | Pre-heater | VV-02/03 | Auto shut-off valve |
| PP-01 | Pre-heating pump | OF-01 | Orifice (Ø3) |
| HE-02 | Central cooler | VV-01 | Thermostatic valve for central cooling |

### 8.2.1 General description

The engine has two cooling circuits of low temperature cooling water and high temperature cooling water internally. However, the external connections can be provided for one (system-1) or two string (system-2) cooling circuits.

#### Pressure drop

- ✓ Engine high termperature cooling water system : approx. 0.5 bar
- ✓ Charge air cooler : approx. 0.5 bar
- ✓ Lubricating oil cooler : approx. 0.2 bar
- ✓ Thermostatic valve : approx. 0.5 bar

(These values shall be different depending on the actual design of each vessel or plant.)

#### Fresh water velocity

- ✓ Max. 2.5 m/s

#### Sea water velocity

- ✓ Suction pipe : 1.0 ~ 1.5 m/s
- ✓ Delivery pipe : 1.5 ~ 2.5 m/s

#### Expansion tank

To avoid cavitation in cooling water system, a certain suction head for engine driven cooling water pump is required as follows :

- ✓ Minimum head : 0.5 bar (5 meters above the crank shaft level)
- ✓ Tank volume : 200 liter + α[1)]

1. α : min. 10% of high temperature cooling water and low temperature cooling water volume of additional engine(s).

Table 8.7 Cooling water volume of the engines

| Engine type | High temperature cooling water and low temperature cooling water volume |
|---|---|
| 6H32C | 634.0 liter |
| 7H32C | 677.7 liter |
| 8H32C | 721.5 liter |
| 9H32C | 765.3 liter |

### Central cooling

The central cooler for fresh water can be of the tube or plate type, which can be common for several engines or separate for each engine.

1) Fresh water side

- ✓ Flow quantity and heat dissipation : Refer to '3.2 engine capacity data'.
- ✓ Pressure drop : maximum 0.5 bar.
- ✓ Pump : centrifugal type (Electric motor driven)
- ✓ Water temperature before engine : 36 ℃

2) Sea water side

- ✓ Flow quantity : 1.5 times of fresh water flow
- ✓ Pressure drop : 1.0 ~ 1.5 bar

## 8.2.2 Cooling water pressure of engine inlet

Pressure of engine inlet should be kept under 2.5 bar.

## 8.2.3 Cooling water

The cooling water system is designed for using normal fresh water with dosing corrosion inhibitor.

If sea water or other coolant system should be applied, please contact the engine maker separately in advance.

### Pre-heating

In order to ensure start of engine and quick load up, pre-heating facility must be installed on the internal or external cooling water circuit. Pre-heating for all engines are required.
Pre-heating temperature :

- ✓ Marine diesel oil operation : minimum 40 ℃
- ✓ Heavy fuel oil operation : minimum 60 ℃

### Electric pre-heating element (Option)

The mount type on the cooling water preheating arrangement consists of a thermostat-controlled electric-heating element which is built in high temperature cooling water circuit located on the engine's Feed Module. The pre-heater is activated by thermostat at 60 ℃ which provides water (60 ℃) to jacket water outlet.

Table 8.8 Recommended capacity of pre-heater

| Cyl. | Electric pre-heater (kW) |
|---|---|
| 6 | 40 |
| 7 | 40 |
| 8 | 40 |
| 9 | 40 |

1. The baggiest capacity is applied for all cylinder for better heating effect

## Operation

Before the engine starts on heavy fuel oil / marine diesel oil, the engine jacket must be pre-heated by pre-heater.

It is recommended that the pre-heater is arranged for automatic operation, so that the pre-heater shall be disconnected while the engine is running and connected while the engine is stand-by condition.

When the engine is in standstill, an external valve for pre-heater must be shut off the cooling water inlet.

## Preheating unit (Option)

External pre-heating unit comprising with the follows can be supplied as option :

- ✓ Electric or steam heater
- ✓ Circulating water pump
- ✓ Control panel and circulating pump starter
- ✓ Switch on-off of heating media

The capacity of external pre-heater should be 3.5 kW per cylinder. The flow through the engine for each cylinder should be approx. 3.0 liter / min. with flow top and downwards.

Auto shut off valve must be installed on the external cooling water system to ensure preheating, which prevents cooling water from flowing into the engine during preheating.

## Preheating of stand-by engine

When only one engine sets are in service and others in stand-by, cold cooling water should not be passed into the cooling jackets on stand-by engines, which will cause cold corrosion in cooling system.

Stand-by engines should be kept warm condition through heating source such as thermal heating through venting pipe from a running engine or pre-heater.

## 8.3 Cooling water quality and treatment

### 8.3.1 Quality of cooling water

The cooling of the engine should be done by only distilled (demineralized) or fresh water, which should be checked and treated to satisfy following requirements below table before adding corrosion inhibitor.

It is necessary for keeping effective cooling and preventing corrosion of the system.

Though the distilled water fully satisfy to the requirements for cooling water, it is necessary to add corrosion inhibitor before applying cooling water to engine cooling water system because untreated cooling water absorbs carbon dioxide from the air and then becomes corrosive.

Table 8.9 Quality of cooling water

| pH | 7 to 9 |
|---|---|
| Total Hardness as $CaCO_3$ | Maximum 75 ppm (mg/l) |
| Chlorides Cl- | Maximum. 80 ppm (mg/l) |
| Sulphates as $SO4^{2-}$ | Maximum 100 ppm (mg/l) |
| Silica as $SiO_2$ | Maximum 60 ppm (mg/l) |
| Residue after evaporation | Maximum 400 ppm (mg/l) |

1. Chloride and Sulphate are corrosive even in the presence of an inhibitor.

Sea water or fresh water contaminated by sea water even in small amount is not allowed to be used as cooling water of the engine due to high risk of severe corrosion and deposits formation in the system.

Rainwater is heavily contaminated and highly corrosive in general, which is also not recommended as cooling water.

Tap water (drinking water) is not recommended as cooling water due to risk of chalk deposit formation inside the cooling system.

However, if the distilled water, for example from fresh water generator, is not available, tap water may be used as cooling water after softening and some other treatments according to the ingredients.

### 8.3.2 Treatment of cooling water

Cooling water should be treated properly and corrosion inhibitor should be added.

The analysis and treatment of cooling water are recommended to be carried out by experts. Otherwise, comply the treatment procedures strictly according to the instructions from the supplier.

The recommended products are listed in following table.

Table 8.10 Recommended products list

| Manufacturer | Brand name | Constituent | Delivery form | Recommended Dosage |
|---|---|---|---|---|
| Chevron (FAMM) | DELO XLI(Havoline XLI) | Carboxylates | Liquid | 75 liter / 1000 liter |
| VECOM | Cooltreat NCLT | Nitrite | Liquid | 48 liter / 1000 liter |
| Wilhelmsen Chemicals | Rocor NB | Nitrite, Borate | Liquid | 63 liter / 1000 liter |
| NALCO | NALCOOL2000, TRAC102 | Nitrite, Borate | Liquid | 128 liter / 1000 liter |
| | TRAC100 | Molybdate, silicate | Liquid | 17.5 liter / 1000 liter |
| | TRAC115,TRAC108 | Nitrite, Borate | Liquid | 28 liter / 1000 liter |
| GE Water and Process Technologies | CorrShield NT4200 | Nitrite | Liquid | 30 liter / 1000 liter |
| Shell | Shipcare Cooling Water Treat | Nitrite, Borate | Liquid | 128 liter / 1000 liter |
| Drew marine | LIQUIDEWT | Nitrite | Liquid | 24 liter / 1000 liter |
| | MAXIGARD | Nitrite | Liquid | 64 liter / 1000 liter |

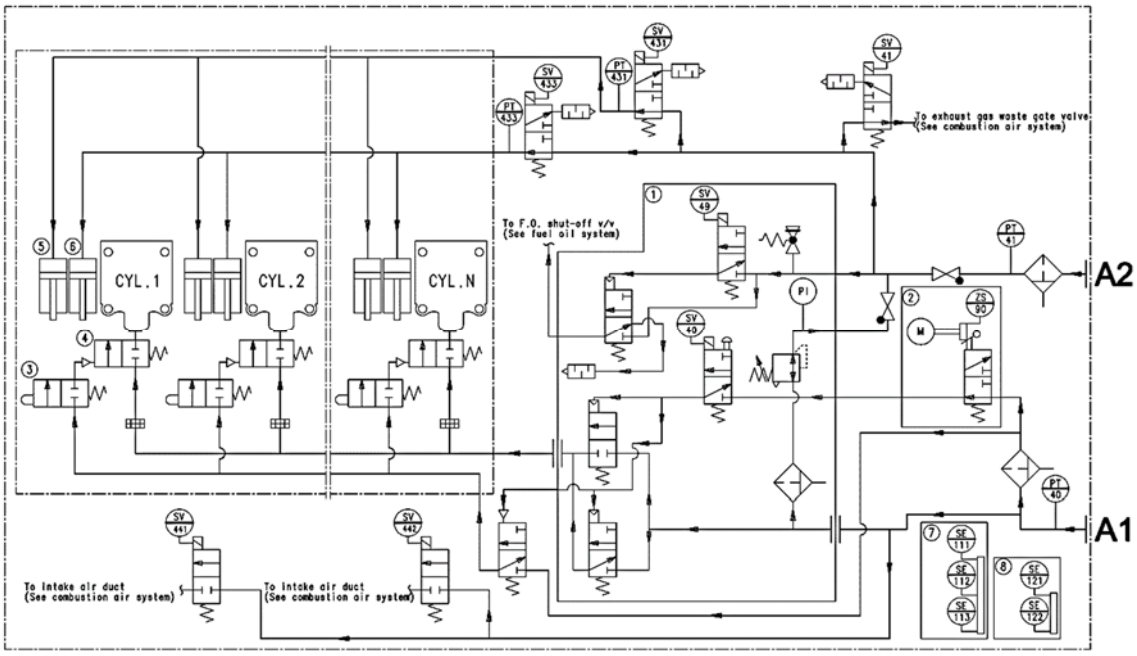
1. Follow the guidelines of corrosion inhibitor manufacturer for cooling water treatment.
2. Oily inhibitors adhere to cooling surface and influence cooling efficiency, which are not recommended for cooling water. Only nitrite-borate based inhibitors are recommended.
3. Some inhibitors may be toxic and hazardous. Strict control is required when handling inhibitors.

**This page is intentionally blanked**

# 9 Air and exhaust gas system

## 9.1 Internal compressed air system

### Diagram for internal compressed air system




*) Scope of instrumentations will be according to extent of delivery and engine builder's standard.

Figure 9.1 Diagram for internal compressed air system [B92-128957-8.1]

Table 9.1 System components

| Code. | Description | Remark |
|---|---|---|
| 1 | Main starting valve module | |
| 2 | Electric turning gear | |
| 3 | Fuel pump drive | - |
| 4 | Starting valve | - |
| 5 | Fuel pump rack | - |
| 6 | DVT pusher | - |
| 7 | Crankshaft | |
| 8 | Camshaft | - |

Table 9.2 Size of external pipe connection

| Code. | Description | Size |
|---|---|---|
| A1 | Starting air inlet | 50A |
| A2 | Control air inlet | 15A |

Remark

1. Connection size is according to JIS B 2220.

### 9.1.1 General description

Compressed air is supplied for engine start, emergency stop and safety system as for the control air.The detail information of engine operation is explained in the chapter ’5. Operation and control system'.

#### Starting system

Starting system mainly consists of main starting valve and air starting valve located in each cylinder. The compressed air with max. 30 bar is directly delivered to the combustion chamber. Without additional devices, the compressed air is distributed as the firing order by means of fuel pump drivers.

#### Scope of supply

The compressed air system consists of the following equipment :

- ✓ Main starting valve
- ✓ Turning gear

## 9.2 External compressed air system

### Diagram for external compressed air system

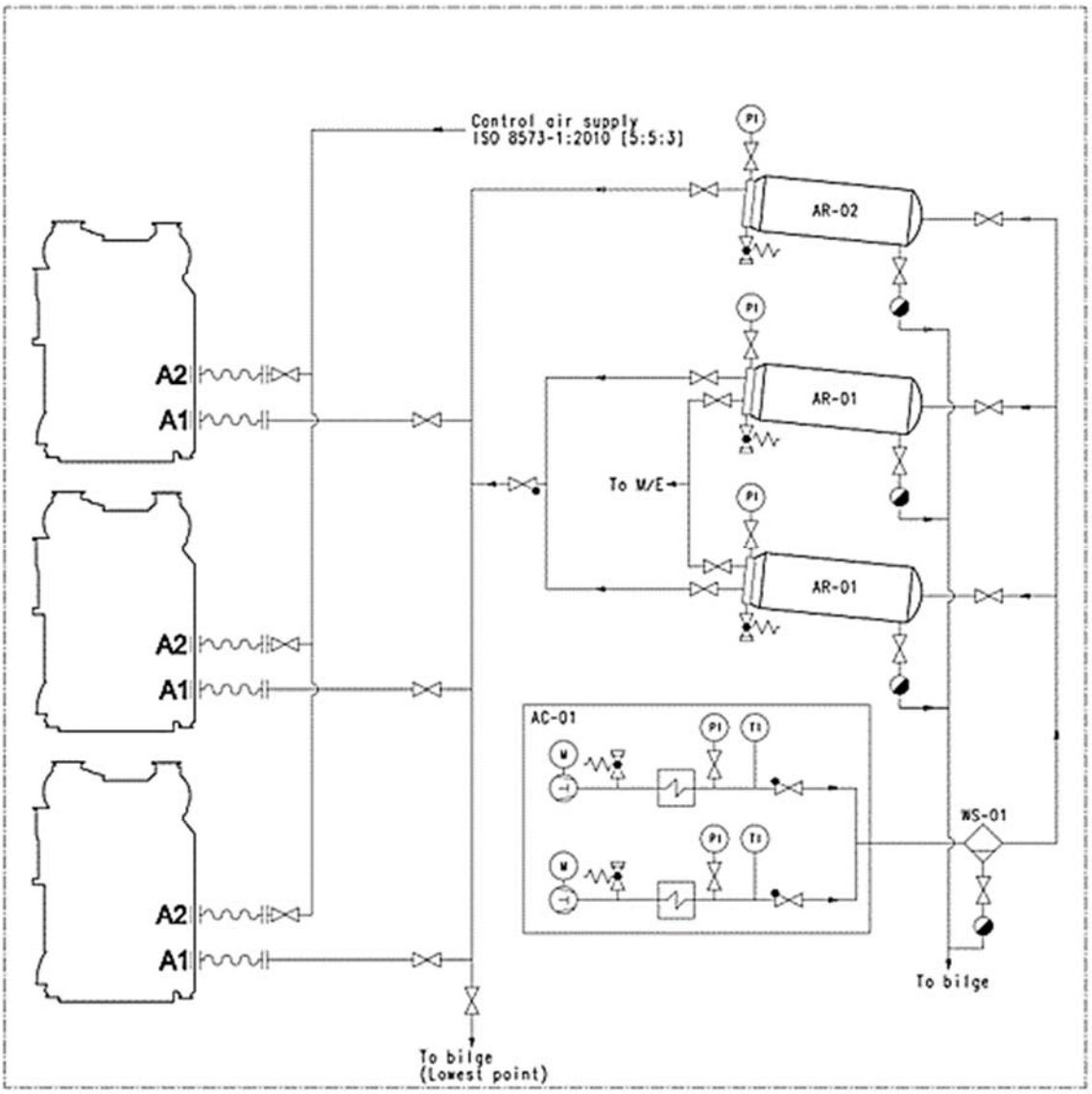



Figure 9.2 Diagram for external compressed air system

Table 9.3 System components

| Code | Description | Code | Description |
|---|---|---|---|
| AR-01 | Main air receiver | WS-01 | Oil and water separator |
| AR-02 | Aux. air receiver | AC-01 | Main air compressor |

### 9.2.1 General requirements

The maximum 30 bar for the compressed air system is required for engine operation. Therefore, all external supply system should be properly designed for this nominal pressure and also should satisfy the rules of corresponding classification society.

Dry and clean air is essential for the reliable function of the engine starting and control system.

Therefore, the compressed air supply system should include oil and water separating equipment. The air supply pipe to engine should also be arranged with slope and the water trap should be positioned at the lowest points.

### 9.2.2 Starting air volume of the engine

Air consumption per one start is specified in '3.2 engine capacity data'. The capacity of starting air vessel varies as per Classification Societies or Customer's requirement.
Volumes for three starts(include jet assist air volume) of one auxiliary engine are as follows;

Table 9.4 Starting air volume of the engines

| Engine type | Volume (liter) |
|---|---|
| 6H32C | 980 |
| 7H32C | 1000 |
| 8H32C | 1050 |
| 9H32C | 1100 |

### 9.2.3 Compressed air specification

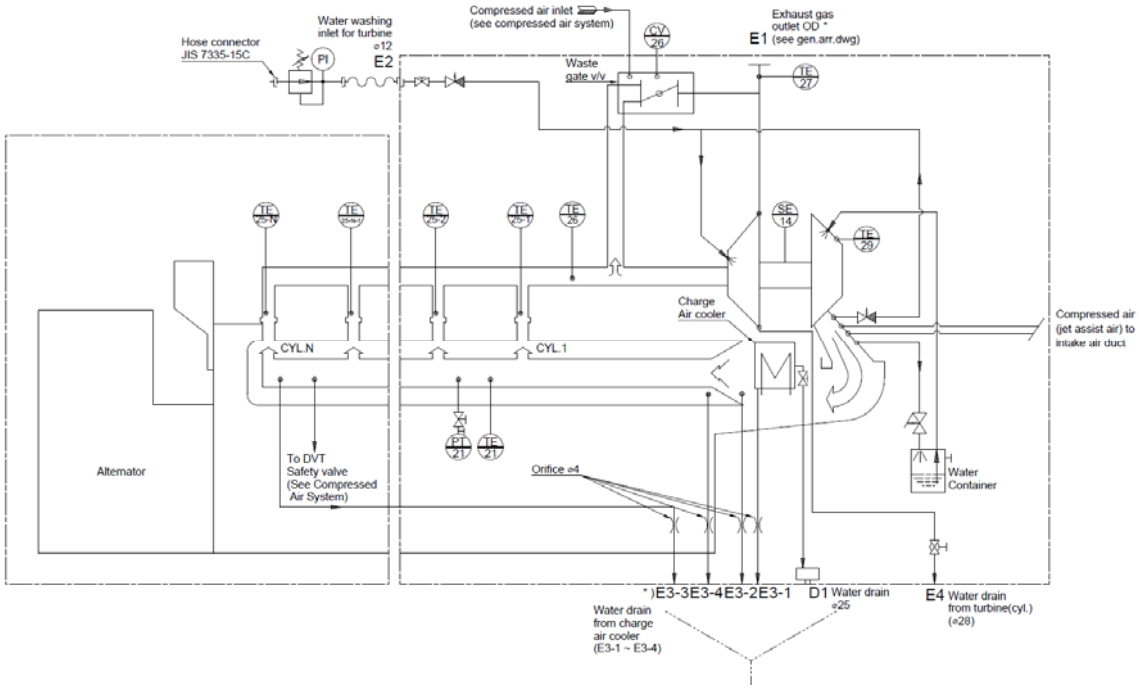
To ensure reliable engine operation and prevent damage to the components in the compressed air system, the compressed air must be free from contaminants such as particles, water, and oil. The required compressed air specification is as follows;

Table 9.5 compressed air specification

| Starting air (A1 conn.) | |
|---|---|
| Design pressure | 30 bar |
| Working pressure | 15~30 bar |
| Compressed air quality at engine connection | ISO 8573-1:2010 [7:8:X] |
| **Control air (A2 conn.)** | |
| Design pressure | 10 bar |
| Nominal pressure | 7 bar (Working pressure 6.5~8 bar) |
| Compressed air quality at engine connection | ISO 8573-1:2010 [5:5:3] |
| Consumption | Max. 2.5$Nm^3/h$ |

## 9.3 Internal combustion air system

### Diagram for internal combustion air system




*) Scope of instrumentations will be according to extent of delivery and engine builder's standard.

Figure 9.4 Diagram for combustion and exhaust gas system [BP0043203]

Table 9.5 Size of external pipe connection

| Code. | Description | Size |
|---|---|---|
| E1 | Exhaust gas outlet | See 9.6 External exhaust gas pipe connection |
| E2 | Water washing turbine side inlet | Ø12 (Quick coupling) |
| E3-1~E3~4 | Water drain from charge air cooler | Ø10 |
| E4 | Water drain form turbine | Ø28 |
| D1 | Drain water | Ø25 (Bite type conn.) |

Remark

1. Connection size is according to JIS B 2220.
2. The scope of instrumentations will be followed according to the extent of delivery and engine builder’s standard.

### 9.3.1 General description

The air required for combustion is taken from the engine room through a filter fitted on the turbocharger. It is imperative that the combustion air be free from sea water, dust and fumes etc.

#### Turbocharger

Turbocharger is a radial type with high efficiency.
The water washing systems for the compressor and turbine are supplied as standard.

#### Charge air cooler

Charge air cooler is two stage high temperature and low temperature cooled type. In general, sea water cooled type charge air cooler is not recommended.

#### Water mist catcher

Water mist catcher is installed between charge air cooler and air chamber of engine block.

#### Waste gate

Waste gate is a butterfly valve in an exhaust by-pass channel, which controls the amount of exhaust gas that passes through the turbine.

#### Air chamber

Air chamber is incorporated into the engine block with large volume for even distribution of induced air to each cylinder.

#### Exhaust pipe system

Exhaust pipe system is modular pulse converter (MPC) type, which has better performance at high load with a simple arrangement and easy maintenance.

#### Water drain pipes

Water drain pipes are installed for the air chamber and water mist catcher.

#### Charge air by-pass valve

Charge air by-pass valve can be installed as optional.

## 9.4 External combustion air system

### 9.4.1 General description

As the engines are consume considerable amount of air in the engine room directly, or the outdoor intake air system is required, the design of combustion air is important not only for man-working but also for engine running.
Various requirements are applicable depending on the ambient condition but the minimum requirements and recommendations for the engines are described as follows.

### 9.4.2 Combustion air

Arrangement of intake air pipes should be made to supply fresh air for engine combustion, which should be free from any risk of water spray, exhaust gas, dust, oil mist and electric equipment, etc.

In case of the engine room intake air system, the intake air temperature of the engine room would be increased by the radiation heat from the engines and generators. Therefore intake air ducts should be installed to face the air intake silencer for each turbocharger as close as possible.

In case of the outdoor direct intake air system, the independent intake air system should be applied for each turbocharger even for the case of engine with two or more turbochargers. A different intake air design for the engine of each project, please contact to HHI-EMD. The piping system of intake air should be considered to allow thermal expansion and harmful vibration to avoid stress of pipe. The end of deep slope position of intake air pipe, cleanable waste trap and water drain should be prepared.

Combustion air intake pipe system, the air velocity must not exceed 15 m/s during engine running. Prior to commissioning, the pressure loss must be checked at compressor side whether the depression of compressor air inlet must not exceed 200 mmWC as maximum. The measuring point is approx. 1 ~ 2 m before from the turbocharger air inlet casing.

Air consumption volume should be designed in accordance with ‘3.2 engine capacity data‘.

Air filteration should be prevented from the outdoor's sand,cement, dust, and other particles. All particles size are not to be entered maximum 5 μm and above.

Oil bath type filter are generally used for the industrial area, cement plants, and sand winded area. Recommendable pressure loss of oil bath intake filter is 50 ~ 70 mmWC and even of fouled condition, it must be kept within 110 mmWC.

Environmental condition of maximum particle size of dust is typically applied depending on site.

- ✓ Non-industerial area in rain / dry condition : 0.8 / 2 μm
- ✓ Area of emissions, chimneys, work area : 60 μm
- ✓ Metropolitan area , residential / Industrial area : 7 / 20 μm
- ✓ Desert area, during sand storms : 500 μm

## Ventilation of engine room

To determine the amount of air ventilation for an engine room, all heat sources of the engine room should be considered.

Total amount of ventilation of auxiliary engine = Qc + Qr + Qv (㎥/h)

Where :

Qc ( ㎥/h ) : Air required for engine combustion,

$$Qr = \frac{\text{Engine radiation heat ( kJ/h )}}{\text{Air conditioning factor ( Qa = 12 )}}$$

Qv (㎥/h ) : Air required for other heat sources such as alternator and exhaust gas pipe , etc.

1. Should outdoor intake air system, and shut-off of air intake be necessary, a special provision is required as option.

# 9.5 External exhaust gas system

## 9.5.1 General description

Exhaust gas of the engine flows out from turbocharger to atmosphere via an external exhaust gas system, which may be comprised of expansion bellows, exhaust gas pipe, exhaust gas boiler (possibly) and silencer, exhaust gas ventilation unit, relief valve (or rupture disc), etc.

### Independent exhuast gas system

Independent exhaust gas system should be prepared for each engine even for the case of common boiler system with other engines. In case of applied two or more turbochargers on a single engine, the exhaust gas pipes are recommeded to be combined into a Y-type forked pipe. And each exhaust gas pipe have to be symmetric and each exhaust gas flow should be no interference.

### Exhaust gas back pressure

Back pressure of the exhaust system in total is recommended to be less than 300 mmWC at miximum countious rating. The maximum back pressure should not exceed 500 mm WC at miximum countious rating. Please see the ‘3.7 correction of fuel oil consumption’ for the fuel consumption correction in case of exceeding 300 mmWC at miximum countious rating. The measuring position is approx. 1 ~ 2 m after the turbocharger gas outlet casing.

## 9.5.2 Velocity

External exhaust gas piping is recommended to be designed that velocity of exhaust gas through pipes should not exceed approximately 40 m/sec at maximum continuous rating.

### Insulation

Insulation of the whole exhaust system is required for the safety and to reduce noise and loss of thermal energy, which, of course, should comply with requirements of classification society and other related authorities.

## 9.5.3 Piping design for exhaust gas system

In order to have lower back pressure and thermal loss, following design consideration is required ;

- ✓ Pipe should be as short and straight as possible. Pipe bendings should be minimized and the bending radius should be as large as possible.
- ✓ A water separating pocket and drain should be provided on the pipe.
- ✓ Rigid (fixed) supports and movable supports must be provided considering the thermal expansion and vibration of pipes.
- ✓ The exhaust gas outlet of Turbocharger can be turned on request.

For more information, please refer to the sheet '9.6 external exhaust gas pipe connection'.

### 9.5.4 Expansion bellows

The expansion bellows has to be mounted between the turbocharger outlet and external exhaust gas pipe in order to compensate thermal expansion and mechanical vibration.
The expansion bellows are supplied separately as standard. However, an additional expansion bellows may be required depending on the actual length of exhaust pipe in total.

1. The external exhaust pipe must not exert any force against the gas outlet on the engine.
2. The external exhaust pipe just on expansion bellows should be fixed rigidly so that turbocharger can be free from any forces from the external exhaust pipe.
3. The sturdy fixed-point support must be provided for the expansion bellows on the turbocharger. It should be positioned, immediately above the expansion bellows in order to prevent the transmission of forces, resulting from the weight, thermal expansion or lateral displacement of the exhaust piping, to the turbocharger.
4. The exhaust piping should be mounted with a slope towards the gas outlet on the engine. It is recommended to have drain facilities in order to be able to remove condensate or rainwater.

#### Installation procedure for expansion bellow

- ✓ The generating set (or engine) should be installed in its final position before any external pipes are connected.
- ✓ Remove the counter flange from the engine connection, if fitted.
- ✓ Fasten the counter flange temporarily to the outlet side of the bellows. For the correct orientation of the bellows (flow direction), see the dimensional drawing.
- ✓ Fasten the bellows to the engine temporarily.
- ✓ Align the external pipe to the counter flange. No axial, lateral or angular deflection of the bellows is allowed. Anchor the external pipe to the steel structure within 1 m from flange. Observe that the pipe clamping with bracket must be very rigid in order to prevent vibration and movement of the exhaust gas pipe. Most problems with bursting and vibration originate from poor clamping and support. Especially the support in the axial direction must be rigid.
- ✓ Put some temporary protection cover between the flanges in order to prevent debris from falling into the turbocharger.
- ✓ Tack weld the counter flange to the external pipe.
- ✓ Remove the bellows and weld the flange finally to the external pipe.
- ✓ Remove the protection cover. Place the bellows with gaskets between the flanges.
- ✓ Lubricate the threads of the connection screw with heat resistant grease and tighten first until finger tight. Finally tighten the screw in a diagonal sequence.
- ✓ Remove the guide bar between the flanges of the bellows.

### 9.5.5 Exhaust gas boiler

Thermal energy of exhaust gas can be utilized by boiler. Please refer to the sheets '3.2 engine capacity data' for the exhaust gas data. A boiler may be a separate unit for each engine or a common unit with other engines. In any cases, however, the exhaust gas line for each engine should be separated from other engine's exhaust gas lines.
The back-pressure through boiler should be minimized to be within limited level for total exhaust gas system.

### 9.5.6 Exhaust gas silencer

Exhaust gas silencer can be supplied as option on request. The noise attenuation of silencer shall be either 25 dB(A) or 35 dB(A). For more information, please refer to the sheets for '9.8 exhaust gas silencer with spark arrestor' and '9.9 exhaust gas silencer without spark arrestor'.

## 9.6 External exhaust gas pipe connection

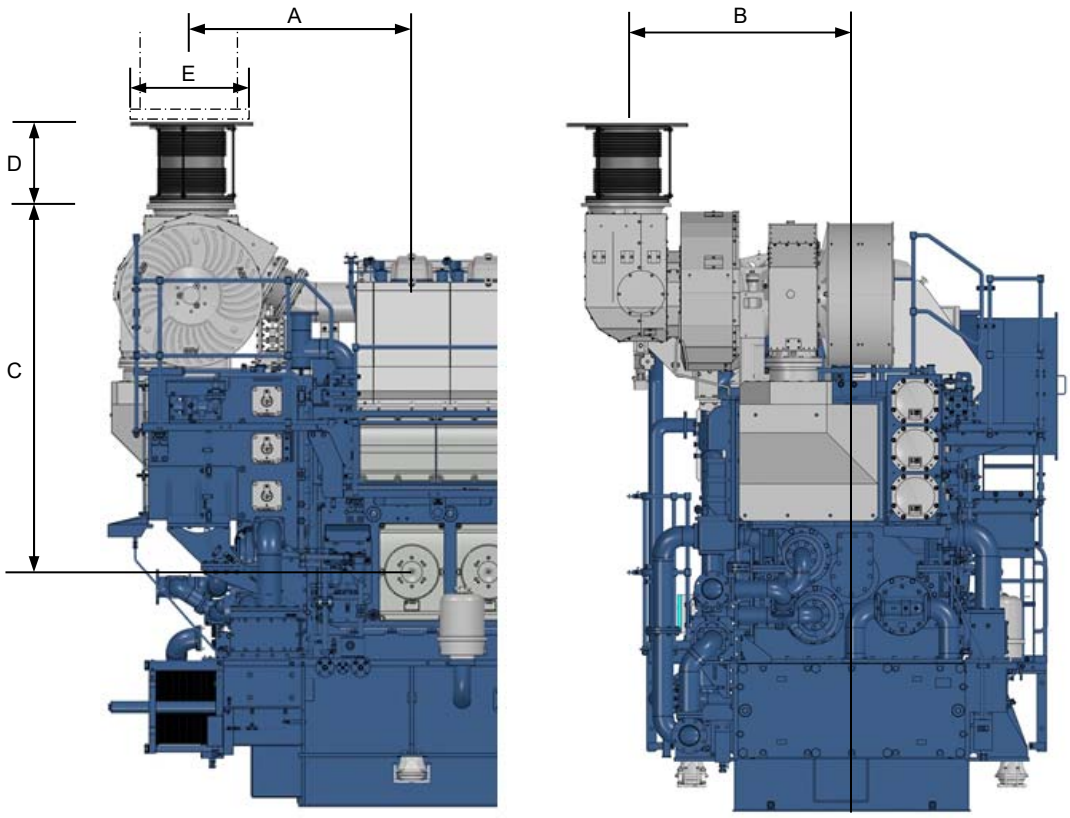



Figure 9.5 External exhaust gas pipe connection.

Table 9.6 Exhaust gas connection size

| Engine type | Exhaust gas outlet position (mm) | | | | E | |
|---|---|---|---|---|---|---|
| | A | B | C | D | Size | Standard |
| 6H32C | 1502 | 1389 | 2368 | 540 | 650A | JIS F 7805 |
| 7H32C | 1502 | 1389 | 2368 | 540 | 700A | JIS F 7805 |
| 8H32C | 1468 | 1478 | 2460 | 540 | 750A | JIS F 7805 |
| 9H32C | 1468 | 1478 | 2460 | 540 | 800A | JIS F 7805 |

# 9.7 Approach of SCR (Selective Catalytic Reduction) system installation

## 9.7.1 General description

IMO NOx Tier III regulation was in effect from the year 2016 according to IMO's environmental policy, in which NOx emission should be reduced by 80 % level comparing to the IMO NOx Tier I. SCR (Selective Catalytic Reduction) system became one of proper solutions to meet the IMO NOx Tier III regulation.

The HiMSEN engine is able to be combined SCR (Selective Catalytic Reduction) systems provided by third parties. However, HHI-EMD recommends using Hyundai NoNOx SCR (Selective Catalytic Reduction) system for convenience such as testing NOx Scheme A test for EIAPP certificate and providing integrated technology. For detailed specifications of Hyundai NoNOx, please see the HYUNDAI HiMSEN ENGINE programme or contact to HHI-EMD.

## 9.7.2 Boundary conditions for SCR (Selective Catalytic Reduction) operation

General boundary conditions for SCR (Selective Catalytic Reduction) operation :

### Main diesel fuel oil

- ✓ The diesel fuel for SCR (Selective Catalytic Reduction) operation should be selected according to the sulfur content in consideration of the sailing region and SCR (Selective Catalytic Reduction) specifications.

### Exhaust gas temperature

- ✓ The minimum required temperature for SCR (Selective Catalytic Reduction) operation is determined by the sulfur content in fuel and SCR (Selective Catalytic Reduction) specifications.

Note !

When SCR (Selective Catalytic Reduction) units are installed, the heat loss of the exhaust gas pipe between engine and SCR (Selective Catalytic Reduction) chamber should be designed to be minimized in order to keep the required exhaust gas temperature. The supports of exhaust gas pipe should be designed and installed to minimize heat loss.

### Maximum exhaust gas back pressure

- ✓ Allowable back pressure in total of the exhaust system to guarantee fuel consumption see the sheet '9.5.1 General description'. It is not recommended that the exhaust gas's total back pressure exceeds 500 mm WC in diesel mode MCR (Maximum Countious Rating).

Other equipment installation such as exhaust gas boiler, silencer, etc. between the engine and the SCR chamber is not recommended in order to keep exhaust gas temperature.

### 9.7.3 Operation and performance change

The HiMSEN engine equipped with an SCR (Selective Catalytic Reduction) system features a waste gate valve. This valve is specifically designed to increase the exhaust gas temperature when operating in Tier III mode to meet the SCR system's required operating temperature.

When the engine is set to Tier III mode and the exhaust gas temperature falls below the required level for SCR operation, the waste gate valve activates to raise the temperature to the target level. This process leads to an increase in fuel consumption proportional to the valve opening ratio

### 9.7.4 Exceptionals

In exceptional cases of SCR (Selective Catalytic Reduction) installation, please contact to HHI-EMD.

## 9.8 Exhaust gas silencer with spark arrestor

The silencer is of an absorption type delivered with spark arrestor and mounting bracket, excluding insulation. The silencer can be mounted horizontally or vertically.

The gas flow passes through a straight perforated tube, surrounded with an efficient sound absorbing material. The silencer gives whereby an excellent sound attenuation suitable for even a wide operating range.

The gas pressure will be dropped into an approximate value shown on the graph, pressure loss vs. gas velocity.

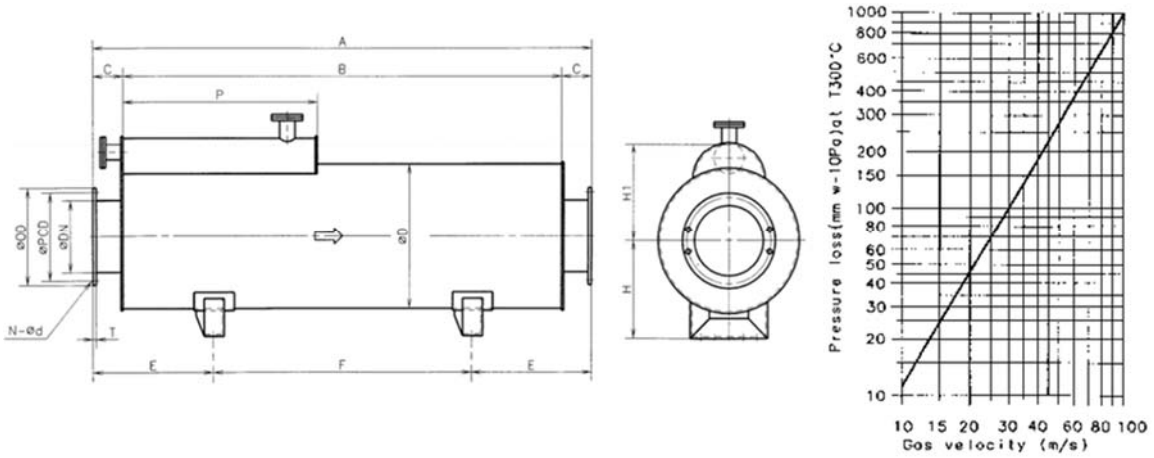



Figure 9.6 Exhaust gas silencer (25 dB type)

Table 9.7 Exhaust gas silencer size (25 dB type) (unit : mm)

| Cylinder type | DN | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| 6H32C | 650 | 5680 | 5380 | 150 | 1110 | 1090 | 3500 |
| 7H32C | 700 | 6220 | 5920 | 150 | 1160 | 1150 | 3920 |
| 8H32C | 750 | 6660 | 6360 | 150 | 1210 | 1170 | 4320 |
| 9H32C | 800 | 7150 | 6850 | 150 | 1260 | 1210 | 4730 |

| Cylinder type | H | H1 | P | PCD | OD | T | N-d | Weight (kg) |
|---|---|---|---|---|---|---|---|---|
| 6H32C | 730 | 819 | 1100 | 720 | 760 | 16 | 16 - Ø23 | 2080 |
| 7H32C | 750 | 885 | 1200 | 775 | 815 | 16 | 16 - Ø23 | 2385 |
| 8H32C | 780 | 910 | 1200 | 825 | 865 | 16 | 20 - Ø23 | 2660 |
| 9H32C | 805 | 956 | 1250 | 875 | 915 | 20 | 20 - Ø23 | 2950 |

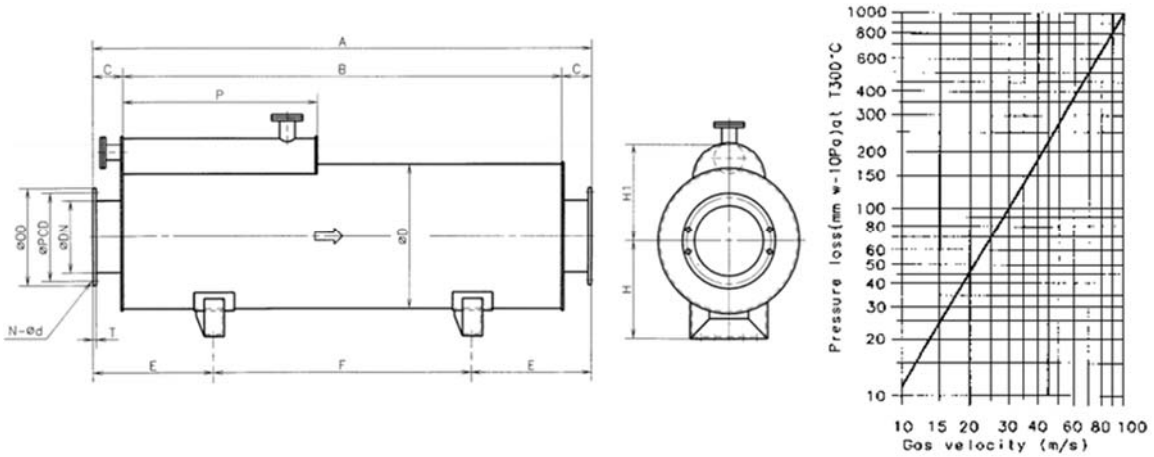



Figure 9.7 Exhaust gas silencer (35 dB type).

Table 9.8 Exhaust gas silencer size (35 dB type) (unit : mm)

| Cylinder type | DN | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| 6H32C | 650 | 6980 | 6680 | 150 | 1110 | 1090 | 4800 |
| 7H32C | 700 | 7570 | 7270 | 150 | 1160 | 1150 | 5270 |
| 8H32C | 750 | 8060 | 7760 | 150 | 1210 | 1170 | 5720 |
| 9H32C | 800 | 8600 | 8300 | 150 | 1260 | 1210 | 6180 |

| Cylinder type | H | H1 | P | PCD | OD | T | N-d | Weight (kg) |
|---|---|---|---|---|---|---|---|---|
| 6H32C | 730 | 819 | 1100 | 720 | 760 | 16 | 16 - Ø23 | 2295 |
| 7H32C | 750 | 885 | 1200 | 775 | 815 | 16 | 16 - Ø23 | 2615 |
| 8H32C | 780 | 910 | 1200 | 825 | 865 | 16 | 20 - Ø23 | 2910 |
| 9H32C | 805 | 956 | 1250 | 875 | 915 | 20 | 20 - Ø23 | 3218 |

## 9.9 Exhaust gas silencer without spark arrestor

The silencer is of an absorption type delivered with mounting bracket, excluding the spark arrestor and insulation. The silencer can be mounted horizontally or vertically.

The gas flow passes through a straight perforated tube, surrounded with an efficient sound absorbing material. The silencer gives whereby an excellent sound attenuation suitable for even a wide operating range.

The gas pressure will be dropped into an approximate value shown on the graph, pressure loss vs. gas velocity.

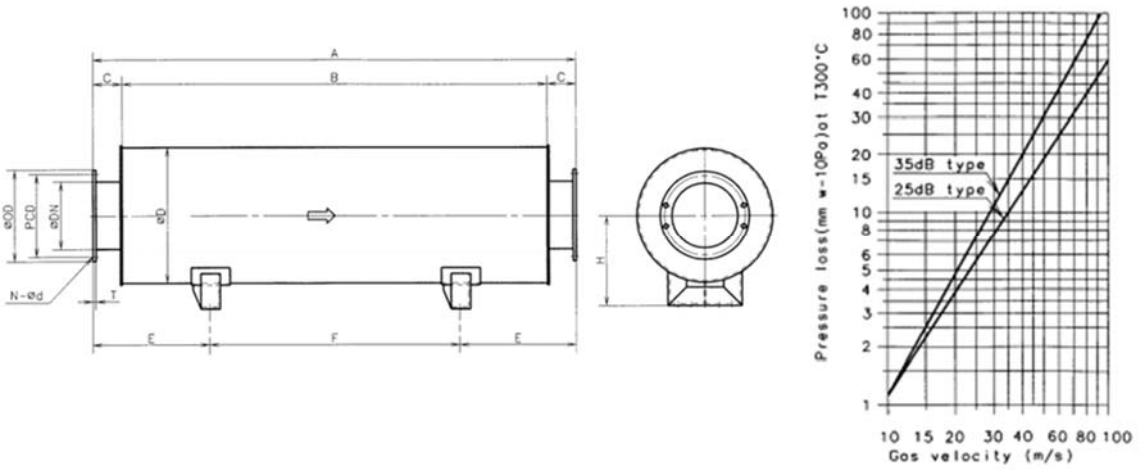



Figure 9.8 Exhaust gas silencer (25 dB type).

Table 9.9 Exhaust gas silencer size (25 dB type) (unit : mm)

| Cylinder type | DN | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| 6H32C | 650 | 4880 | 4580 | 150 | 1110 | 1140 | 2600 |
| 7H32C | 700 | 5320 | 5020 | 150 | 1160 | 1150 | 3020 |
| 8H32C | 750 | 5760 | 5460 | 150 | 1210 | 1170 | 3420 |
| 9H32C | 800 | 6200 | 5900 | 150 | 1260 | 1185 | 3830 |

| Cylinder type | H | PCD | OD | T | N-d | Weight (kg) |
|---|---|---|---|---|---|---|
| 6H32C | 730 | 720 | 760 | 16 | 16 - Ø23 | 1804 |
| 7H32C | 750 | 775 | 815 | 16 | 16 - Ø23 | 2070 |
| 8H32C | 780 | 825 | 865 | 16 | 20 - Ø23 | 2345 |
| 9H32C | 805 | 875 | 915 | 16 | 20 - Ø23 | 2616 |

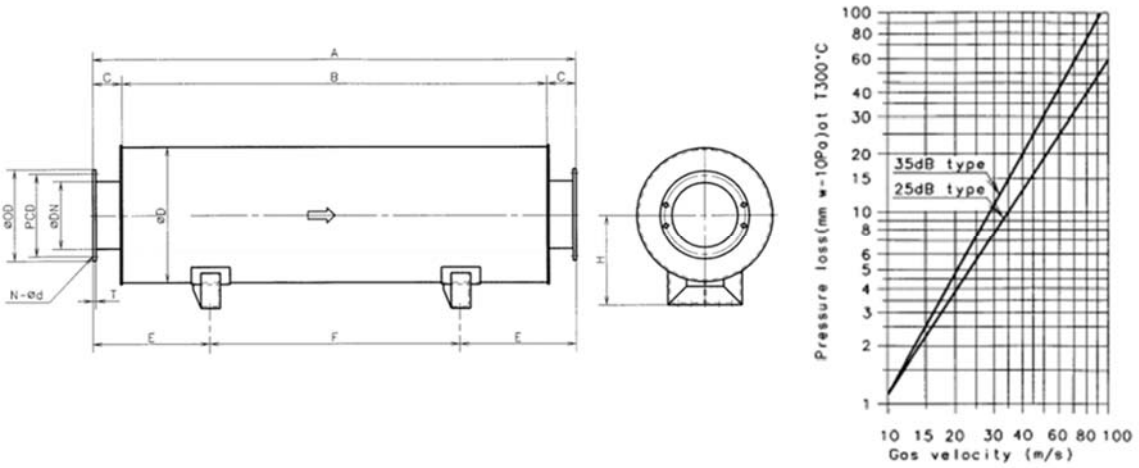



Figure 9.9 Exhaust gas silencer (35 dB type).

Table 9.10 Exhaust gas silencer size (35 dB type) (unit : mm)

| Cylinder type | DN | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| 6H32C | 650 | 5580 | 5280 | 150 | 1110 | 1090 | 3400 |
| 7H32C | 700 | 6070 | 5770 | 150 | 1160 | 1150 | 3770 |
| 8H32C | 750 | 6560 | 6260 | 150 | 1210 | 1170 | 4220 |
| 9H32C | 800 | 7050 | 6750 | 150 | 1260 | 1210 | 4630 |

| Cylinder type | H | PCD | OD | T | N-d | Weight (kg) |
|---|---|---|---|---|---|---|
| 6H32C | 730 | 720 | 760 | 16 | 16 - Ø23 | 1920 |
| 7H32C | 750 | 775 | 815 | 16 | 16 - Ø23 | 2200 |
| 8H32C | 780 | 825 | 865 | 16 | 20 - Ø23 | 2480 |
| 9H32C | 805 | 875 | 915 | 16 | 20 - Ø23 | 2760 |

## 9.10 Generator information

### Mounting of generator

As the standard design of H32C engine, the alternator shall be connected to the engine by flexible coupling and rigidly mounted on base frame.

### Generator bearing

The type of generator bearings is of double sleeves and a forced lubrication type mounted to the end of the generator for H32C engine.

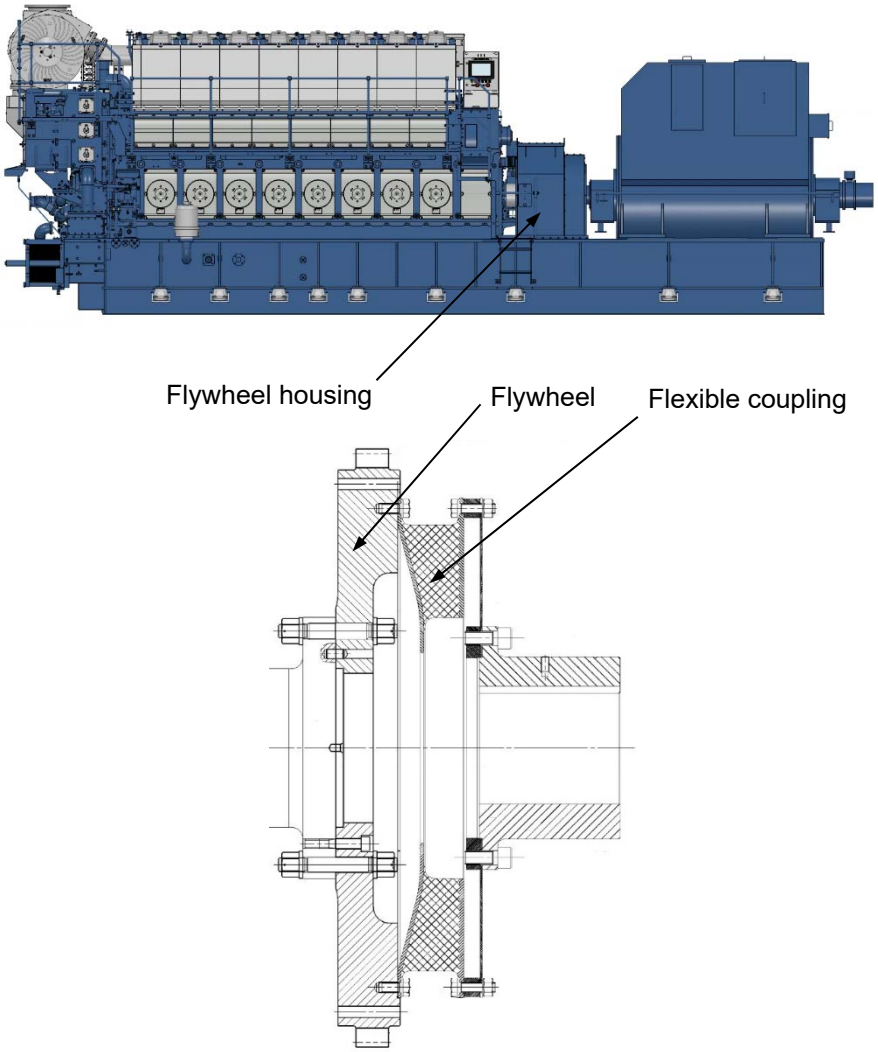



Figure 9.10 Flexible coupling outline

**This page is intentionally blanked**

# 10 Engine maintenance

## 10.1 Maintenance schedule

Table 10.1 Maintenance guidance.

| Section No. | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Major fasteners - confirmation** | | | | | | | | | | | | | | |
| M1130 | HP1130 | Bolt for base frame and resilient mount | | ▲ | | | ◆ | | | | | | | |
| G1130 | - | Nut for resilient mount and foundation | | ▲ | | | ◆ | | | | | | | |
| - | HP1130 | Bolt for engine block and base frame | | ◆ | | | ◆ | | | | | | | |
| M3330 | HP1210 | Hydraulic nut for main bearing cap | | ◆ | | | ◆ | | | | | | | |
| M2110 | HP1210 | Hydraulic nut for cylinder head | | ◆ | | | ◆ | | | | | | | |
| M2410 | HP2410 | Bolt and nut for camshaft | | ▲ | | | ◆ | | | | | | | |
| M3100 | HP3210 | Hydraulic nut for connecting rod (Shaft) | | ◆ | | | ◆ | | | | | | | |
| M3100 | HP3210 | Hydraulic nut for connecting rod (big-end) | | ◆ | | | ◆ | | | | | | | |
| M3321 | HP3310 | Hydraulic nut for counter weight | | ◆ | | | ◆ | | | | | | | |
| M3610 | HP3610 | Bolt and nut for timing gear | | ▲ | | | ◆ | | | | | | | |
| - | HP8320 | Bolt and nut for turbocharger mounting | | ▲ | | | ◆ | | | | | | | |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.

2.The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Resilient mount** | | | | | | | | | | | | | | |
| M1130 | HP1130 | Resilient mount | ● | | | | ● | | | | | | | **) |
| **Major bearing** | | | | | | | | | | | | | | |
| M3330 | HP3330 | Main bearing | | | | | √ | | | | ▣ | | | Replacement based on visual inspection |
| M3330 | HP3330 | Thrust washer : axial clearance | | | | | ◎ | | | | | | ▣ | |
| M2410 /M2430 | HP2430 | Camshaft Bearing : clearance | | | | | √ | | ◎ | | | | ▣ | |
| M3100 | HP3210 | Connecting rod bearing (big-end) | | | | | √ | | ■ | | ▣ | | | |
| M32130 | HP3210 | Connecting rod bearing (small-end) | | | | | √ | | ■ | | | | ▣ | |
| M3610 | HP3610 | Bearing bush for Idle gear : clearance | | | | | | | ◎ | | | | ▣ | |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

**) During on board (site) commissioning, inspection is carried out by HHI-EMD service engineer.

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.
2. The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Cylinder unit and connecting rod** | | | | | | | | | | | | | | |
| M2210 | HP2210 | Cylinder liner | | | | | √ | | ■ | | | | | |
| M2210 | HP2210 | Flame ring | | | | | √ | | ▣ | | | | | |
| M2110 | HP2110 | Cylinder head | | | | | √ | | ■ | | | | | |
| M2310 | HP2310 | Intake/exhaust valve spindle, seat ring and valve guide : overhaul and reconditioning | | | | | √ | | ■ | | ▣ | | | |
| M2310 | HP2310 | Intake/exhaust valve : clearance | | ● | ● | | | | | | | | | **) |
| M2310 | HP2310 | Rocker arm shaft and bush | | | | | √ | | ■ | | | | | |
| M2310 | HP2310 | Rotocap | | | ○ | | | | ■ | | | | | |
| - | HP2140 | Starting valve | | | | | √ | | ■ | | | | | |
| - | HP2130 | Indicator valve | | | | | | | ▣ | | | | | |
| M3110 | HP3110 | Piston rings | | | | | √ | | ▣ | | | | | |
| M3110 | HP3110 | Piston and piston pin | | | | | √ | | ■ | | | | | |
| M3110 /M3211 | HP3210 | Connecting rod bore (big-end) | | | | | √ | | ■ | | | | | |
| M3110 /M3213 | HP3210 | Piston pin and connecting rod (small-end) : clearance | | | | | √ | | ■ | | | | | |
| - | HP3210 | Shim plate for connecting rod | | | | | √ | | ▣ | | | | | |
| - | HP3210 | Stud for connecting rod shaft | | | | | | | | | | | ▣ | |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

**) During on board (site) commissioning, inspection is carried out by HHI-EMD service engineer

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.
2. The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Crankshaft and gears** | | | | | | | | | | | | | | |
| M33100 | HP3310 | Crankshaft : deflection | | | | | ◎ | | | | | | | |
| - | HP3340 /HP3510 | Gear teeth on flywheel and turning gear | | | | | ▲ | | | | | | | |
| - | HP3350 | Torsional vibration damper : fluid sampling (only for viscous damper) | | | | | | | ◎ | | | | | ***) |
| - | HP3360 | Flexible coupling | ▲ | | | | | | | | | | | ***) |
| M3610 | HP3610 | Timing gear and pump driving gear : clearance and backlash | | | | | | | ◎ | | | | | |
| **Valve operating mechanism** | | | | | | | | | | | | | | |
| M2320 | HP2320 | Roller shaft and bush for in/exh. valve tappet | | | | | | | ■ | | | | ▣ | Bush life time |
| M2320 | HP2320 /HP2410 | Contact faces of cam and tappet roller camshaft bearing | | ▲ | | | ▲ | | | | | | | |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

***) See maker manual recommendation.

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.
2. The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Control system** | | | | | | | | | | | | | |
| G4001 | - | Safety device : function check | ○ | | | | | | | | | | Monthly |
| - | HP4100 | Engine RPM pick-up sensor : clearance | | | | | ● | | | | | | |
| - | HP4100 | Temperature / pressure sensor | ○ | | | | | | | | | | In case of necessity |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

***) See maker manual recommendation

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.
2. The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No. | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Fuel system** | | | | | | | | | | | | | | |
| G0510 | - | Analyze fuel oil properties : sampling | ◎ | | | | | | | | | | | Every bunkering |
| M5100 /M5110 | HP5110 | Fuel injection pump | | | | | | | | | | | | |
| | | Plunger assembly | | | | | ■ | | ▣ | | | | | |
| | | Delivery valve assembly (except case) | | | | | ■ | | ▣ | | | | | |
| | | Delivery valve case | | | | | ■ | | | | | | ▣ | |
| | | Roller bush for tappet | | | | | | | ■ | | | | ▣ | |
| | | Control valve for control valve assembly | | | | ● | ▣ | | | | | | | |
| M5120 | HP5120 | Fuel injection valve : opening pressure | | ● | ● | ▣ | | | | | | | | ****) ▣ : Atomizer life time |
| - | HP5410 | O-rings for feed block | | | | | ▣ | | | | | | | |
| M5520 | HP5510 | Fuel oil shock absorber | | | | ■ | | | | | | | | |
| M5310 | HP5310 | Fuel oil filter | ■ | | | | | | | | | | | If pressure drop reaches limit (See G0140) |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

***) See maker manual recommendation

****) Regardless of the nomal check and adjustment inverval, if the exhaust gas temperature deviation alarm occurs, individual cylinders should be inspected according to M52000.

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.

2. The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No. | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Lubricating oil system** | | | | | | | | | | | | | | |
| G0620 | - | Analyze lubricating oil properties : sampling | ◎ | | | | | | | | | | | Every 3 month |
| M6110 | HP6110 | Lubricating oil pump | | | | | | | ■ | | | | | |
| M6210 | HP6210 | Lubricating oil cooler | | | | | | | ■ | | | | | ***) |
| M6310 | HP6310 | Lubricating oil filter (cartridge type) | ■ | | ▣ | | | | | | | | | If pressure drop reaches limit (See G0140) |
| - | - | Auto backwashing filter (If applied) | ■ | | | | | | | | | | | ***) |
| - | HP6410 | Thermostatic valve : clean and check the elements | | | | | | | ■ | | | | | ***) |
| M6320 | HP6320 | Lubricating oil centrifugal filter | ■ | | | | | | | | | | | ***) |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

***) See maker manual recommendation

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.
2. The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No. | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2000 | 4000 | 8000 | 12000 | 16000 | 20000 | 24000 | 28000 | 32000 | |
| **Cooling water system** | | | | | | | | | | | | | | |
| G0710 | - | Analyze cooling water properties : sampling | ◎ | | | | | | | | | | | Weekly : test kit Every 3 month : Lab. test |
| M7110 | HP7110 | Cooling water pump | | | | | | | ■ | | | | | |
| - | HP7210 | Thermostatic valve : clean and check the elements | | | | | | | ■ | | | | | ***) |
| **Compressed air system** | | | | | | | | | | | | | | |
| O0230 | - | Air running | ○ | | | | | | | | | | | Monthly |
| G4001 | - | Check starting and stop system | ○ | | | | | | | | | | | Weekly (over a week stand-still condition) |
| **Combustion air system** | | | | | | | | | | | | | | |
| M8000 | HP8320 | Turbocharger | ■ | | | | | | | | | | | ***) |
| | | Clean air filter (only for filter silencer type) | ■ | | ▣ | | | | | | | | | Every 500 hours running |
| | | Turbine : water-washing | ● | | | | | | | | | | | Every 200 hours running |
| | | Compressor : water-washing | ● | | | | | | | | | | | Every 24 ~ 50 hours running |
| M8110 | HP8110 | Charge air shut-off valve (if applied) | ○ | | | | | | | | | | | Weekly ***) |
| - | HP8360 | Exhaust gas waste gate | ○ | | | | | | | | | | | Weekly |
| M8410 | HP8410 | Charge air cooler | | | | | | | ■ | | | | | |

▣ Expected life time √ 1 Cylinder overhaul. If not good, check all cylinders.

■ Overhaul inspection ◆ Confirm tightening: tighten with specified torque or hyd.pressure. Do not loosen!

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

*) These are not parts of normal maintenance interval, but, the confirmation or visual inspection of the specified ones to be carried out after Overhaul / New.

***) See maker manual recommendation

1. When doing maintenance and overhaul work, seals (o-rings and gaskets, etc.) should be renewed.
2. The overhaul intervals and expected life time stated above are only for guidance as these depend on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

## 10.2 Recommended wearing parts

### List of consumable parts for one engine (C=Number of cylinder / U=Number of unit)

Table 10.2 List of consumable parts for one engine

| Section No. | Parts description | Quantity for the operating hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Set/ea | 0 – 4000 | 0 – 8000 | 0 – 12000 | 0 – 16000 | 0 – 20000 | 0 – 24000 | 0 – 28000 | 0 – 32000 |
| **Covers for engine block** | | | | | | | | | | |
| HP1210 | Gaskets for gear case cover | set | - | 1 | 1 | 2 | 2 | 3 | 3 | 4 |
| HP1220 | O-ring for crankcase cover | ea | - | 2 x C | 2 x C | 4 x C | 4 x C | 6 x C | 6 x C | 8 x C |
| HP1230 | O-ring for camshaft cover | ea | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C |
| **Bearings** | | | | | | | | | | |
| HP3330 | Main bearing (upper and lower) | set | - | - | - | - | - | 1xC+2 | 1xC+2 | 1xC+2 |
| HP3330 | Thrust washer | ea | - | - | - | - | - | - | - | 2 |
| HP2430 | Camshaft bearing | ea | - | - | - | - | - | - | - | 1xC+1 |
| HP3210 | Big-end bearing (upper and lower) | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HP3210 | Small-end bearing | ea | - | - | - | - | - | - | - | 1 x C |
| HP3610 | Bearing bush for idle gear | ea | - | - | - | - | - | - | - | 1 |
| **Cylinder unit and connecting rod** | | | | | | | | | | |
| HP2210 | Flame ring | ea | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HP2210 | O-rings and gasket for cylinder liner | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| HP2110 | O-rings for cylinder head | ea | | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| HP2110 | O-ring for cylinder head cover | ea | 0.5 x C | 1 x C | 1.5 x C | 2 x C | 2.5 x C | 3 x C | 3.5 x C | 4 x C |

1. The list of consumable parts stated above is only for guidance as this depends on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No. | Parts description | Quantity for the operating hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Set/ea | 0 – 4000 | 0 – 8000 | 0 – 12000 | 0 – 16000 | 0 – 20000 | 0 – 24000 | 0 – 28000 | 0 – 32000 |
| **Cylinder unit and connecting rod** | | | | | | | | | | |
| HP2110 | Bush and O-ring for fuel valve | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HP2110 | O-rings for valve guide and exhaust valve seat ring | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 2xC+2 |
| HP2110 HP2310 | Intake valve spindle, seat ring and valve guide | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HP2110 HP2310 | Exhaust valve spindle, seat ring and valve guide | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HP2140 | O-ring for starting valve | set | | 1 | 1 | 1xC+1 | 1xC+1 | 1xC+2 | 1xC+2 | 1xC+2 |
| HP2130 | Indicator valve complete | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HP2320 | O-ring for push rod cover | set | | | | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| HP2320 | Roller bush for fuel oil pump drive tappet | ea | - | - | - | - | - | - | - | 1 x C |
| HP2320 | Roller bush for in/exhaust valve tappet | set | | | | | | | | 1 x C |
| HP2320 | O-ring for valve tappet cover | ea | | | 1 | 1 | 1 | 1 | 1 | 1 |
| HP3110 | Piston ring-top ring / 2nd ring / scraper ring | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HP3210 | Shim plate for connecting rod | ea | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HP3210 | Stud for connecting rod shaft | ea | - | - | - | - | - | - | - | 4 x C |
| **Fuel system** | | | | | | | | | | |
| HP5110 | Plunger assembly for fuel pump | ea | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HP5110 | O-rings and seal ring for plunger assembly | set | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C |
| HP5110 | Gaskets and seal ring for fuel pump | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HP5110 | Delivery valve assembly (except case) | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HP5110 | Delivery valve case | ea | - | - | - | - | - | - | - | 1 x C |
| HP5110 | O-ring for control valve | ea | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C | 4 x C |

1. The list of consumable parts stated above is only for guidance as this depends on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No. | Parts description | Quantity for the operating hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Set/ea | 0 – 4000 | 0 – 8000 | 0 – 12000 | 0 – 16000 | 0 – 20000 | 0 – 24000 | 0 – 28000 | 0 – 32000 |
| **Fuel system** | | | | | | | | | | |
| HP5110 | Control valve assembly | set | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C |
| HP5110 | O-ring for fuel pump | set | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C |
| HP5110 | Roller bush for tappet | ea | - | - | - | - | - | - | - | 1 x C |
| HP5110 | O-ring for fuel pump drive | ea | - | - | - | - | - | - | - | 1 x C |
| HP5120 | Fuel injection nozzle with dowel pin | set | 1 x C | 2 x C | 3 x C | 4 x C | 5 x C | 6 x C | 7 x C | 8 x C |
| HP5120 | O-rings and gasket for fuel injection valve | set | 2 x C | 4 x C | 6 x C | 8 x C | 10 x C | 12 x C | 14 x C | 16 x C |
| HP5130 | O-rings for fuel injection pipe block | set | 2 x C | 4 x C | 6 x C | 8 x C | 10 x C | 12 x C | 14 x C | 16 x C |
| HP5410 | O-rings for fuel feed pipe connection | set | - | 1 | 1 | 2 | 2 | 3 | 3 | 4 |
| HP5410 | Wearing ring and sealing ring for fuel oil shock absorber | set | 1 x U | 2 x U | 3 x U | 4 x U | 5 x U | 6 x U | 7 x U | 8 x U |
| **Lubricating oil System** | | | | | | | | | | |
| HP6110 | Bushes for lubricating oil pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HP6110 | O-rings for lubricating oil pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HP6210 | O-ring for lubricating oil cooler connection (installation on engine side) | ea | - | - | - | 4 | 4 | 4 | 4 | 8 |
| HP6310 | Lubricating oil filter cartridge (paper cartridge type) | ea | 2 x U | 4 x U | 6 x U | 8 x U | 10 x U | 12 x U | 14 x U | 16 x U |
| HP6310 | O-ring for lubricating oil filter assembly (paper cartridge type) | set | 1 x U | 2 x U | 3 x U | 4 x U | 5 x U | 6 x U | 7 x U | 8 x U |
| HP6310 | Spare parts for auto backwashing filter (see manual for auto backwashing filter) | set | - | - | - | - | - | - | - | - |
| HP6310 | Packing for auto backwashing filter | ea | | | | 1 | 1 | 1 | 1 | 2 |
| HP6410 | O-ring for lubricating oil thermostat valve | ea | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |

1. The list of consumable parts stated above is only for guidance as this depends on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

| Section No. | Parts description | Quantity for the operating hours | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Set/ea | 0 – 4000 | 0 – 8000 | 0 – 12000 | 0 – 16000 | 0 – 20000 | 0 – 24000 | 0 – 28000 | 0 – 32000 |
| **Lubricating oil System** | | | | | | | | | | |
| HP6410 | Gasket for thermostatic valve cover | ea | - | - | - | 1 | 1 | 1 | 1 | 2 |
| HP6320 | Spare parts for centrifugal filter (See manual for centrifugal filter) | set | - | - | - | - | - | - | - | - |
| **Cooling water system** | | | | | | | | | | |
| HP7110 | Oil seal, mechanical seal and O-ring for high and low temperature cooling water pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HP7210 | O-ring for cooling water thermostat valve (wax type installed on engine) | ea | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HP7210 | Gasket for thermostatic valve cover (wax type installed on engine) | ea | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HP7410 | Gaskets and O-ring for cooling water connection | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| **Supercharging system** | | | | | | | | | | |
| HP8110 | Gaskets and O-ring for compressor out | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| HP8210 | Gasket for connection flange | ea | - | 1 | 1 | 1xC+ 1 | 1xC+ 1 | 1xC+ 2 | 1xC+ 2 | 2xC+ 2 |
| HP8320 | O-rings for Turbocharger connection | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| **Charge air cooler** | | | | | | | | | | |
| HP8410 | O-rings and gaskets for air cooler | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| **Turbocharger** | | | | | | | | | | |
| - | Spare parts for turbocharger (See manual for turbocharger) | set | - | - | - | - | - | - | - | - |
| - | Air filter mat (Engine room air suction) | ea | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |

1. The list of consumable parts stated above is only for guidance as this depends on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

## 10.3 List of standard spare parts

### List of standard spare parts for each vessel

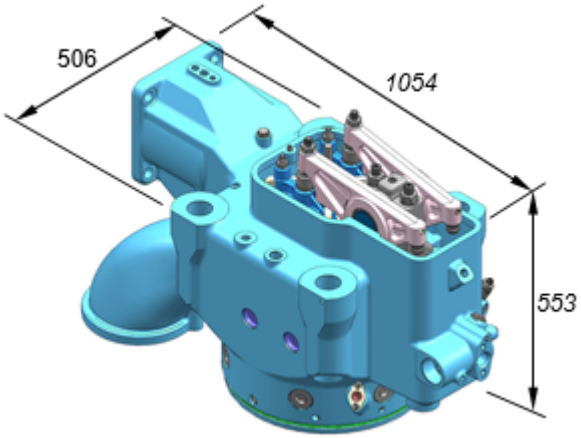
Table 10.3 List of standard spare parts

| Parts description | Q'ty | Section No. | Item No. | Remark |
|---|---|---|---|---|
| **Engine block and covers** | | | | |
| Main bearing cap stud | 2 | LC13000 | 121 | |
| Nut for main bearing cap stud | 2 | LC13000 | 122 | |
| Main bearing, upper | 1 | LC13250 | 101 | |
| Main bearing, lower | 1 | LC13250 | 101 | |
| Thrust washer | 2 | LC13250 | 111 | |
| Sealing ring for crankcase cover | 1 | LC19300 | 380 | |
| **Cylinder head and cylinder liner** | | | | |
| Air starting valve | 1 | LC21400 | 100 | |
| O-ring for air starting valve | 1 | LC21400 | 905 | |
| O-ring for air starting valve | 2 | LC21400 | 906 | |
| O-ring for air starting valve | 2 | LC21400 | 907 | |
| Sealing ring for cylinder liner | 1 | LC15000 | 191 | |
| O-ring for cylinder liner | 1 | LC15000 | 192 | |
| O-ring for cylinder liner | 2 | LC15000 | 193 | |
| O-ring for cylinder liner | 1 | LC15000 | - | |
| Compensation ring for cylinder line | 1 | LC15000 | 121 | |
| O-ring for cylinder head cover | 1 | LC21100 | 805 | |
| O-ring for cylinder head | 2 | LC21100 | 901 | |
| Safety valve | 1 | LC22000 | 600 | |

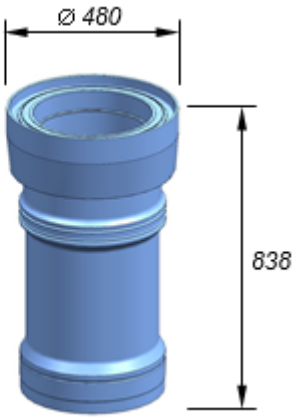
| Parts description | Q'ty | Section No. | Item No. | Remark |
|---|---|---|---|---|
| **Cylinder head and cylinder liner** | | | | |
| O-ring for water connection | 1 | LC15000 | 901 | |
| O-ring for connection piece | 2 | LC15000 | 922 | |
| Intake valve seat | 2 | LC21100 | 111 | |
| Exhaust valve seat | 4 | LC21100 | 112 | |
| O-ring for seat ring exhaust | 4 | LC21100 | 118 | |
| Intake valve spindle | 2 | LC21200 | 201 | |
| Exhaust valve spindle | 4 | LC21200 | 202 | |
| Spring | 4 | LC21200 | 208 | |
| Roto cap | 6 | LC21200 | 204 | |
| Conical piece | 6 | LC21200 | 206 | |
| O-ring for valve guide | 4 | LC21100 | 115 | |
| **Piston and connecting rod** | | | | |
| Big end bush, upper | 1 | LC32000 | 113 | |
| Big end bush, lower | 1 | LC32000 | 113 | |
| Small end bush | 1 | LC32000 | 114 | |
| Connecting rod big end stud | 4 | LC32000 | 191 | |
| Nut for connecting rod big end stud | 4 | LC32000 | 192 | |
| Connecting rod shaft stud | 4 | LC32000 | 194 | |
| Nut for connecting rod shaft stud | 4 | LC32000 | 195 | |
| Cylindrical pin | 4 | LC32000 | 193 | |
| Piston pin | 1 | LC31100 | 105 | |

| Parts description | Q'ty | Section No. | Item No. | Remark |
|---|---|---|---|---|
| **Piston and connecting rod** | | | | |
| Piston ring, top | 1 | LC31100 | 111 | |
| Piston ring, 2nd | 1 | LC31100 | 112 | |
| Piston ring, scraper | 1 | LC31100 | 113 | |
| **Fuel injection equipment** | | | | |
| Fuel injection pump | 1 | LC51000 | 100 | |
| Fuel injection valve | N | LC52000 | 100 | N : half of maximum cylinder No. |
| Gasket for fuel injection valve | 3xZ | LC52000 | 196 | Z : No. of cylinder |
| Fuel high pressure block | 1 | LC52300 | 100 | |
| **Piping system** | | | | |
| Flexible connecting pipe, each type | 1 set | LC98370 | - | |
| Lube oil filter cartridge (primary) | 1 set | LC63000 | 701 | |
| Paper insert (centrifugal filter) | 1 set (25ea) | LC67000 | 702 | |
| **Etc.** | | | | |
| Turning gear spare kit | 1 set | - | - | Maker |
| Air cooler spare kit | 1 set | - | - | Maker |
| Gasket for air cooler cover | 1 | LC84000 | 111 | |
| Gasket for air cooler cover | 1 | LC84000 | 131 | |

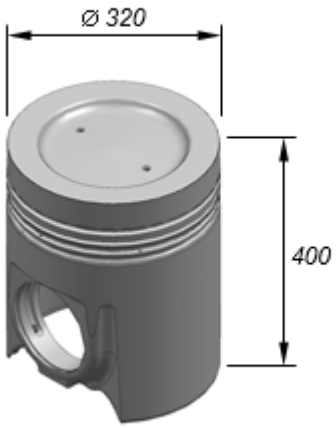
## 10.4 Heavy parts for maintenance



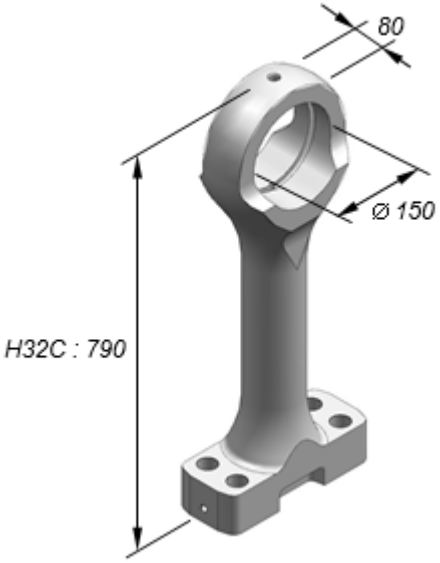

Cylinder head and rocker arms assembly
Approx. 584 kg



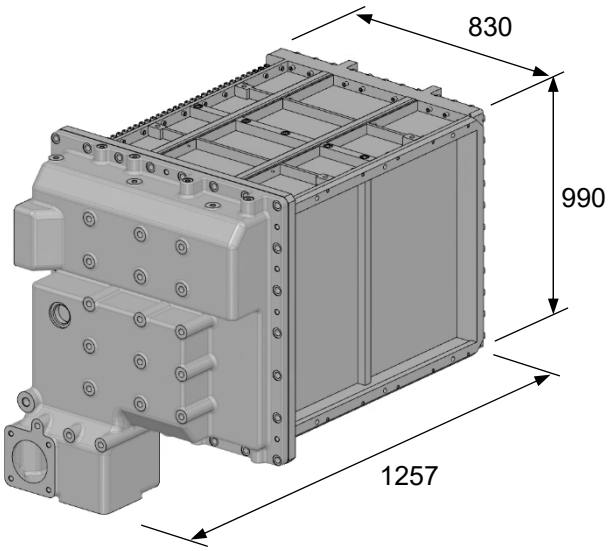

Cylinder liner
Approx. 274 kg



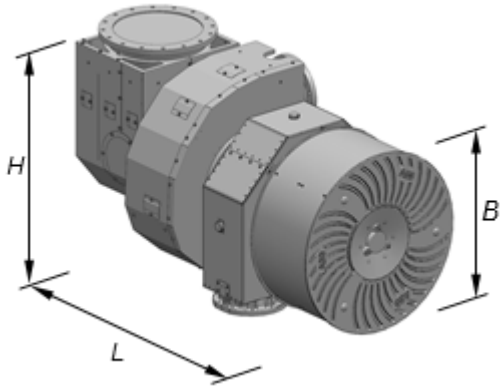

Piston
Approx. 93 kg




Connecting rod shaft
Approx. 71 kg




Air cooler
Approx. 980 kg




Turbocharger
(See the following table)

Figure 10.1 Heavy parts dimension and weight.

Table 10.4 List of turbocharger outline dimension and weight

| Turbocharger type | B (mm) | H (mm) | L (mm) | Weight (kg) | Remarks |
|---|---|---|---|---|---|
| A150 | 800 | 910 | 1840 | 970 | Without insulation |
| A155 | 955 | 1085 | 2170 | 1650 | Without insulation |

## 10.5 List of standard tools

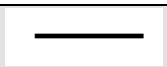
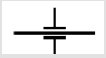
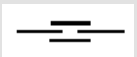
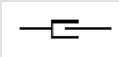
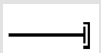
Table 10.5 List of standard tool parts

| Tool description | Q'ty | Remark |
|---|---|---|
| **Cylinder head and liner** | | |
| Lifting tool for cylinder head | 1 | |
| Fitting/removal device for valve conical clamping piece | 1 | |
| Grinding tool for cylinder head and cylinder liner | 1 | |
| Extract / suspension device for cylinder liner | 1 | |
| Cylinder bore gauge | 1 | |
| Removing device for flame ring | 1 | |
| Air gun for roto cap | 1 | |
| Feeler gauge for inlet and exhaust valve. | 1 | |
| Plier for locking ring | 1 | |
| **Piston and connecting rod** | | |
| Piston guide | 1 | |
| Piston lifting | 1 | |
| Holding piece for crank pin bearing | 2 | |
| Guide support for connecting rod | 1 | |
| Turning bracket for connecting rod | 1 | |
| Clamping support for connecting rod | 2 | |
| Plier 125 for piston pin locking ring | 1 | |
| Plier for piston ring opener | 1 | |
| Lapping device for inlet and exhaust valve seat | 1 | |
| Removal device for valve seat | 1 | |
| fitting tool for Indicator valve | 1 | |

| Tool description | Q'ty | Remark |
|---|---|---|
| **Crankshaft and main bearing** | | |
| Lifting device for main bearing cap | 4 | |
| Fitting device for main bearing | 1 | |
| Deflection gauge for crankshaft | 1 | |
| **Fuel injection valve** | | |
| Test tool for fuel valve nozzle | 1 | |
| Lapping device for fuel injection valve bush | 1 | |
| Removal tool for atomizer nut | 1 | |
| Cleaning tool for fuel injection valve nozzle | 1 | |
| Removal device for fuel injection valve | 1 | |
| Long socket for nozzle nut | 1 | |
| Removal device for fuel injection valve bush | 1 | |
| **Hydraulic tools** | | |
| Hydraulic tightening devices M56 (cylinder head, main bearing cap) | 4 | |
| Hydraulic tightening devices M48 (connecting rod big end) | 2 | |
| Hydraulic tightening devices M39 (side stud) | 2 | |
| Hydraulic tightening devices M33 (connecting rod shaft, counter weight, wheel) | 2 | |
| Angle piece | 2 | |
| Set of spare parts for hydraulic tools M56 | 1 | |
| Set of spare parts for hydraulic tools M48 | 1 | |
| Set of spare parts for hydraulic tools M39 | 1 | |
| Set of spare parts for hydraulic tools M33 | 1 | |
| Support for hydraulic tools M56 (main bearing cap,cylinder head) | 4 | |
| Support for hydraulic tools M48 (connecting rod big end) | 2 | |

| Tool description | Q'ty | Remark |
|---|---|---|
| **Hydraulic tools** | | |
| Support for hydraulic tools M39 (side stud) | 2 | |
| Support for hydraulic tools M33 (connecting rod shaft, counter weight, flywheel) | 2 | |
| Insert screw for hydraulic tool M33 (connecting rod shaft, counter weight, flywheel) | 2 | |
| Distribution pieces 2-PORT | 1 | |
| Distribution pieces 4-PORT | 1 | |
| High pressure hose (L=800) | 4 | |
| High pressure hose (L=4000) | 2 | |
| Adapter for hydraulic pump | 1 | |
| Turning pin (Ø10) | 2 | |
| Turning pin (Ø6) | 2 | |
| **General tools** | | |
| Max. pressure indicator | 1 | |
| Tool for air starting valve | 1 | |
| Lapping device for starting valve | 1 | |
| Turbocharger cleaning hose | 1 | |
| Spare and tool box | 5 | |
| Spanner-replaceable head (1/2 inch&M16 nut) | 1 | |
| Spanner-replaceable head (3/4 inch&M20 nut) | 1 | |
| Fit/removal tool for cooling water pump | 1 | |

# 11 Appendix 1 (Piping symbols)

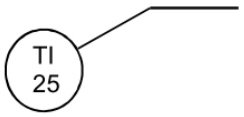
| No. | Symbol | Symbol designation | No. | Symbol | Symbol designation |
|---|---|---|---|---|---|
| **General conventional symbols** | | | | | |
| 1.1 |  | Pipe | 1.5 |  | Indicating and measuring instruments |
| 1.2 |  | Pipe with indication of direction of flow | 1.6 |  | High pressure pipe |
| 1.3 |  | Valves, gate valves, cocks and flaps | 1.7 |  | Tracing |
| 1.4 |  | Appliances | 1.8 |  | Enclosure for several components assembled in one unit |
| **Pipes and pipe joint** | | | | | |
| 2.1 |  | Crossing pipes, not connected | 2.13 |  | Blank flange |
| 2.2 |  | Crossing pipes, connected | 2.14 |  | Spectacle flange |
| 2.3 |  | Tee pipe | 2.15 |  | Bulkhead fitting water tight, flanged |
| 2.4 |  | Flexible pipe | 2.16 |  | Bulkhead crossing, non-water tight |
| 2.5 |  | Expansion pipe | 2.17 |  | Test piece with plug |
| 2.6 |  | Joint, Screwed | 2.18 |  | Orifice |
| 2.7 |  | Joint, flanged | 2.19 |  | Reducer |
| 2.8 |  | Joint, sleeve | 2.20 |  | Open drain and air vent |
| 2.9 |  | Joint, hose coupling | 2.21 |  | Orifice |
| 2.10 |  | Expansion joint with gland | 2.22 |  | Loop expansion joint |
| 2.11 |  | Expansion pipe | 2.23 |  | Snap-coupling |
| 2.12 |  | Cap nut | | | |

| No. | Symbol | Symbol designation | No. | Symbol | Symbol designation |
|---|---|---|---|---|---|
| **Valves, gate valves, cocks and flaps** | | | | | |
| 3.1 |  | Valve, straight | 3.24 |  | Suction valve chest with non-return valves |
| 3.2 |  | Valve, angle | 3.25 |  | Double-seated changeover valve, straight |
| 3.3 |  | Stop valve (Screw ended) | 3.26 |  | Double-seated changeover valve, angle |
| 3.4 |  | Valve, Three-way | 3.27 |  | Cock, straight through |
| 3.5 |  | Non-return valve (Flap) straight | 3.28 |  | Cock, angle |
| 3.6 |  | Non-return valve (Flap) angle | 3.29 |  | Cock, three-way, L-port in plug |
| 3.7 |  | Non-return valve (Flap) straight, screw down | 3.30 |  | Cock, three-way, T-port in plug |
| 3.8 |  | Non-return valve (Flap) angle, screw down | 3.31 |  | Cock, four-way, straight through in plug |
| 3.9 |  | Flap, straight through | 3.32 |  | Cock, with bottom connection |
| 3.10 |  | Flap, angle | 3.33 |  | Cock, straight through with bottom connection |
| 3.11 |  | Reducing valve | 3.34 |  | Cock, angle with bottom connection |
| 3.12 |  | Safety valve | 3.35 |  | Cock, three-way, with bottom connection |
| 3.13 |  | Angle safety valve | 3.36 |  | Solenoid valve |
| 3.14 |  | Self-closing valve | 3.37 |  | 3-way test valve |
| 3.15 |  | Quick-opening valve | 3.38 |  | Thermostatic valve |
| 3.16 |  | Quick-closing valve | 3.39 |  | Valve with test flange |
| 3.17 |  | Regulating valve | 3.40 |  | 3-way valve with remote control (Actuator) |
| 3.18 |  | Angle valve | 3.41 |  | Non-return valve (Air) |
| 3.19 |  | Ball valve (-Cock) | 3.42 |  | 3/2 spring return valve, normally closed |
| 3.20 |  | Butterfly valve | 3.43 |  | 2/2 spring return valve, normally closed |
| 3.21 |  | Gate valve | 3.44 |  | 3/2 spring return valve, control by solenoid |
| 3.22 |  | Double-seated changeover valve | 3.45 |  | On/off valve controlled by solenoid and pilot directional valve and with spring return |
| 3.23 |  | Suction valve chest | | | |

| No. | Symbol | Symbol designation | No. | Symbol | Symbol designation |
|---|---|---|---|---|---|
| **Control and regulating part** | | | | | |
| 4.1 |  | Hand-operated | 4.10 |  | Electric motor driven |
| 4.2 |  | Remote control | 4.11 |  | Air motor driven |
| 4.3 |  | Spring | 4.12 |  | Manual<br>(At pneumatic valve) |
| 4.4 |  | Mass | 4.13 |  | Push button |
| 4.5 |  | Float | 4.14 |  | Spring |
| 4.6 |  | Piston | 4.15 |  | Solenoid |
| 4.7 |  | Membrane | 4.16 |  | Solenoid and pilot<br>directional valve |
| 4.8 |  | Electro-magnetic | 4.17 |  | By plunger or tracer |
| 4.9 |  | Flame trap | | | |
| **Appliances** | | | | | |
| 5.1 |  | Mudbox | 5.13 |  | Heat exchanger |
| 5.2 |  | Simplex strainer | 5.14 |  | Electric pre-heater |
| 5.3 |  | Duplex strainer | 5.15 |  | Air filter |
| 5.4 |  | Magnetic filter | 5.16 |  | Air filter with manual<br>control |
| 5.5 |  | Separator | 5.17 |  | Air filter with automatic<br>drain |
| 5.6 |  | Steam trap | 5.18 |  | Water trap with manual<br>control |
| 5.7 |  | Centrifugal pump | 5.19 |  | Air lubricator |
| 5.8 |  | Gear-or screw pump | 5.20 |  | Silencer |
| 5.9 |  | Hand pump (Bucket) | 5.21 |  | Fixed capacity pneumatic<br>motor with spring returned |
| 5.10 |  | Ejector | 5.22 |  | Single acting cylinder with<br>spring returned |
| 5.11 |  | Various accessories<br>(Text to be added) | 5.23 |  | Double acting cylinder with<br>spring returned |
| 5.12 |  | Piston pump | 5.24 |  | Auto drain trap |

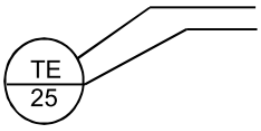
| No. | Symbol | Symbol designation | No. | Symbol | Symbol designation |
|---|---|---|---|---|---|
| **Fittings** | | | | | |
| 6.1 |  | Funnel | 6.8 |  | Air pipe with pressure-vacuum valve |
| 6.2 |  | Bell-mouthed pipe end | 6.9 |  | Deck fittings for sound's or filling pipe |
| 6.3 |  | Air pipe | 6.10 |  | Short sounding pipe with self-closing cock |
| 6.4 |  | Air pipe with net | 6.11 |  | Stop for sounding rod |
| 6.5 |  | Air pipe with cover | 6.12 |  | Oil tray coaming |
| 6.6 |  | Air pipe with cover and net | 6.13 |  | Bearing |
| 6.7 |  | Air pipe with pressure-vacuum valve | 6.14 |  | Water jacket |
| **Reading instruments with ordinary symbol designations** | | | | | |
| 7.1 |  | Sight flow indicator | 7.4 |  | Distance level indicator |
| 7.2 |  | Observation glass | 7.5 |  | Counter (Indicate function) |
| 7.3 |  | Level indicator | 7.6 |  | Recorder |

# 12 Appendix 2 (Instrumentation code)



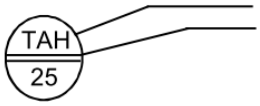

Measuring device
Locally reading

Temperature Indicator
No. 25*




Measuring device
Sensor mounted on engine/unit
Reading/identification mounted in a panel on the engine/unit

Temperature element
No. 25*




Measuring device
Sensor mounted on engine/unit
Reading/identification outside the engine/unit

Temperature Alarm High
No. 25*

*Refer to standard location and text for instruments on the following page

| Specification of letter code for measuring devices | | | |
|---|---|---|---|
| 1st letter | | Following letters | |
| F | Flow | A | Alarm |
| L | Level | D | Differential |
| P | Pressure | E | Element |
| S | Speed, Solenoid | H | High |
| T | Temperature | I | Indicating |
| U | Voltage | L | Low |
| V | Viscosity | S | Switching, Stop |
| Z | Position | T | Transmitting |
| | | X | Failure |
| | | V | Valve |

## Combustion gas system

21 Charge air at cooler outlet
25 Exhaust gas at cylinder outlet
26 Exhaust gas at turbocharger inlet
27 Exhaust gas at turbocharger outlet
49-1 Alternator winding 1
49-2 Alternator winding 2
49-3 Alternator winding 3

## Compressed air system

40 Air starting valve / emergency stop valve
41 Compressed air at engine inlet
42 Turbocharger speed
43 Charge air condition valve
45 Stop solenoid on governor
46 Micro switch for turning gear
47 Engine speed
48 Over speed
49 On-off valve for shut down and overs peed stop
50 Fuel rack limiter solenoid valve

## Fuel oil system

51 Fuel oil at engine inlet
52 Fuel oil filter inlet
54 Leakage alarm tank

## Lubricating oil system

61 Lubricating oil at filter inlet
62 Lubricating oil at engine inlet
63 Lubricating oil at turbocharger inlet
65 Pre-lubricating
68 Level in base frame
92 Oil mist detector

## Cooling water system

71 Low temperature water at air cooler inlet
72 Low temperature water at air cooler outlet
75 High temperature water at engine inlet
76 High temperature water at engine outlet
77 High temperature water each cylinder outlet

# 13 Note

## Global Leader

www.hhi.co.kr



HYUNDAI HiMSEN

HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY