# PROJECT GUIDE

## HiMSEN H32DF-LM

FOR MARINE

2026 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.

# List of updates for H32DF-LM Project Guide

## Revision: 1st edition 2026

Issued date: June 2026

| No. | Section No. | Section name | Description |
|---|---|---|---|
| 1 | 6.4 | Fuel oil specification | 6.4 Fuel oil specification updated |
| 2 | 9.5 | External exhaust gas system | 9.5.3 Piping design for exhaust gas system updated |
| 3 | 10.1 | Maintenance schedule | Table 10.1 Maintenance guidance updated |
| 4 | 10.2 | Recommended wearing parts | Table 10.2 List of consumable parts for one engine updated |
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Remark
The above information is the major updates from the previous version, and it doesn't include the minor changes.

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# 1 General information

## 1.1 Introduction

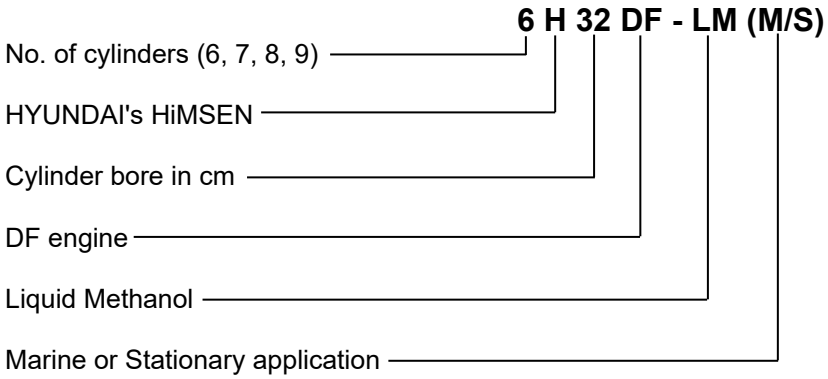
This project guide provides necessary information and recommendations for the application of HYUNDAI HiMSEN H32DF-LM (Dual Fuel-Liquid Methanol) generating-set (gen-set). "HiMSEN'® is the licensed brand name of HYUNDAI's own design engine and the abbreviation of '**Hi**-Touch **M**arine & **S**tationary **EN**gine'. The HiMSEN H32DF-LM 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 'H32DF', and 'Sheet No.' for easier communications

Some phrase or figures mention SF(second fuel). SF means methanol in this document.

### Engine model designation



# 1.2 Engine nomenclature

## 1.2.1 Cylinder numbering

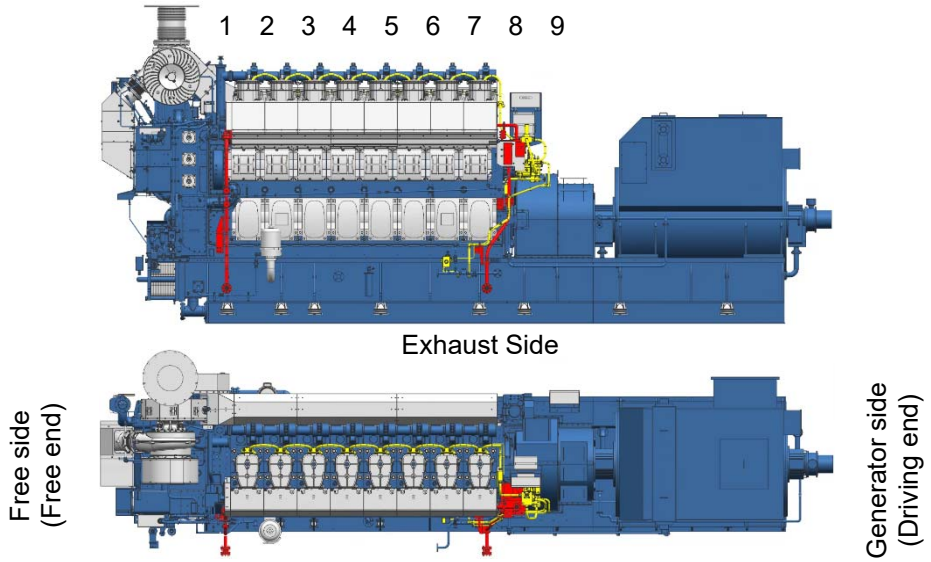



Figure 1.1 Cylinder numbering

## 1.2 Direction of engine rotation

Clockwise Engine : Clockwise viewed from driving end (Counter-clockwise viewed from free end)

Counter-clockwise Engine : Counter-clockwise viewed from driving end
(Clockwise viewed from free end)

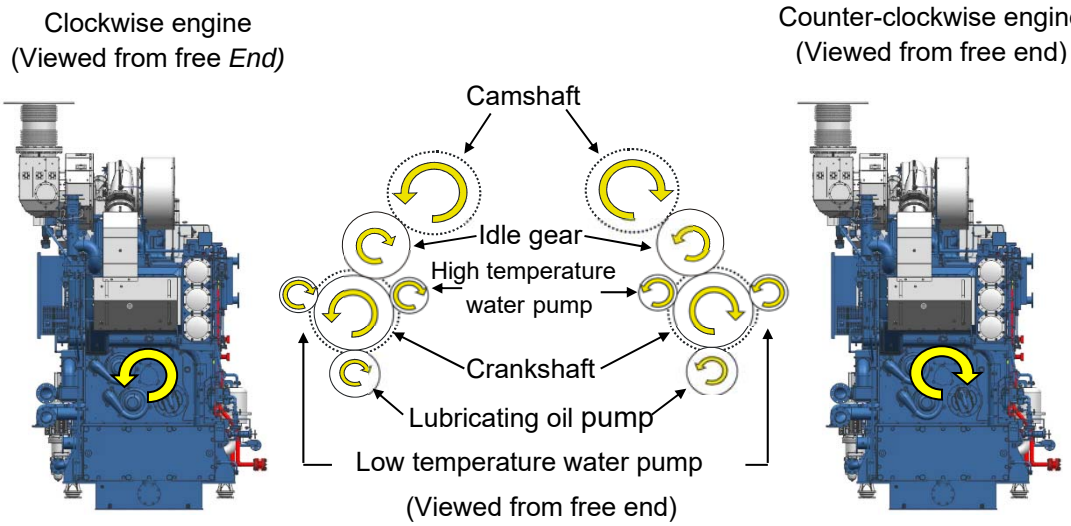



Figure 1.2 Direction of engine rotation

# 2 Structural design and installation

## 2.1 Principal data

Table 2.1 Principal data

| Type of engine | 4-stroke, turbocharged and inter-cooled, dual fuel engine, trunk piston type. | |
|---|---|---|
| Cylinder configuration | | In-line |
| Number of cylinder | | 6 - 7 - 8 – 9 |
| Rated speed | rpm | 720 750 |
| Power per cylinder | kW | 500 500 |
| Cylinder bore | mm | 320 |
| Piston stroke | mm | 400 |
| Swept Volume per cylinder | dm³ | 32.2 |
| Mean piston speed | m/s | 9.6 10.0 |
| Mean effective pressure | bar | 25.9 24.9 |
| Compression ratio | | 15 : 1 |
| Direction of engine rotation | | Clockwise viewed from generator side (Non-reversible) |
| Cylinder firing order | 6H32DF-LM | 1 - 4 - 2 - 6 - 3 - 5 |
| | 7H32DF-LM | 1 - 2 - 4 - 6 - 7 - 5 - 3 |
| | 8H32DF-LM | 1 - 3 - 5 - 7 - 8 - 6 - 4 - 2 |
| | 9H32DF-LM | 1 - 3 - 5 - 7 - 9- 8 - 6 - 4 - 2 |

## 2.2 Engine cross section

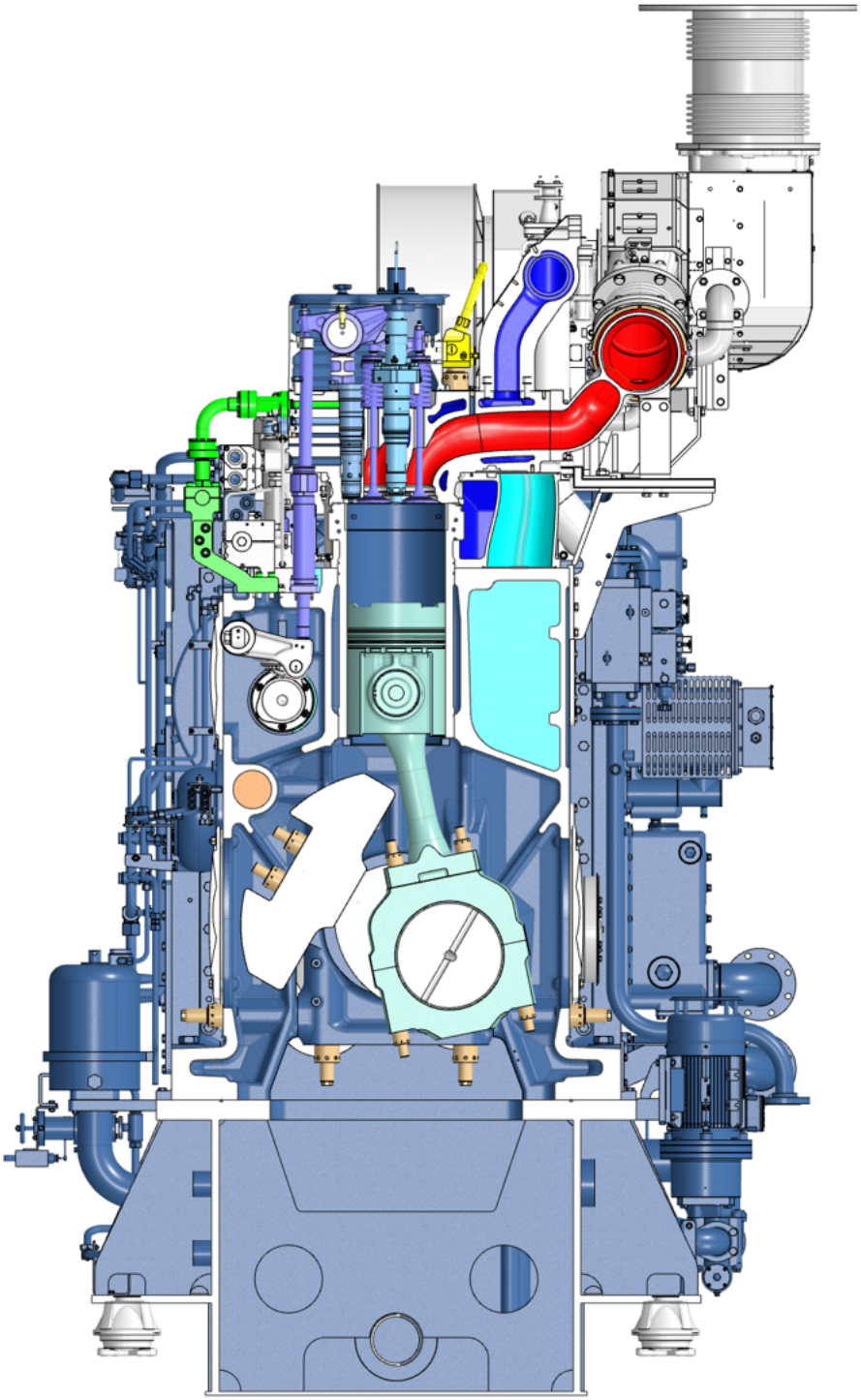


Figure 2.1 Engine cross section

## 2.3 Engine design outline

### 2.3. 1 General

Hyundai dual fuel engine 'HiMSEN H32DF-LM' family have simple and smart design suitable for marine application with high reliability and performance. The key features are summarized as below :

1. DF-LM engine can be run with liquid methanol or liquid fuel oil alternatively.

2. Eco-friendly and economical engine with the lowest fuel consumption and $NO_X$ emission which are 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.

   - ✓ A number of engine components are minimized with pipe-free design
   - ✓ Most of the components are directly accessible for easy maintenance.
   - ✓ Maintenance concept for each parts is to be provided
   - ✓ Feed system is fully modularized with direct accessibility
   - ✓ Highly integrated control system
   - ✓ Raven components are applied
   - ✓ Free from methanol leakage
   - ✓ Up-to-date technology is adopted

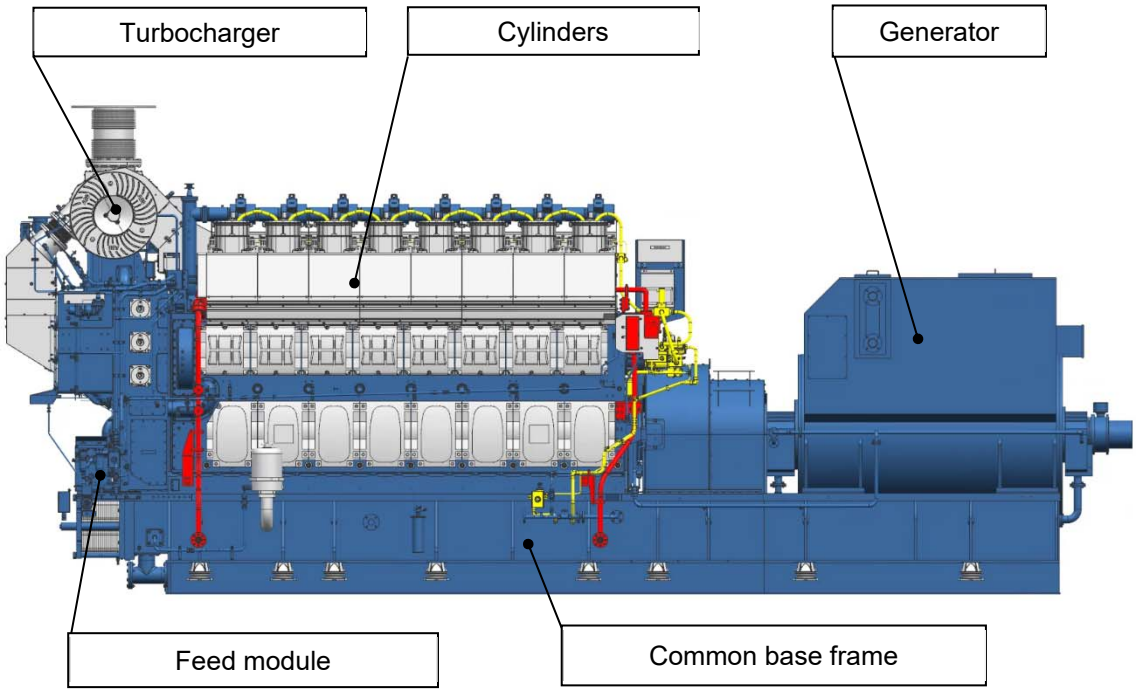



Figure 2.2 Engine design outline

### 2.3.2 Design of main components

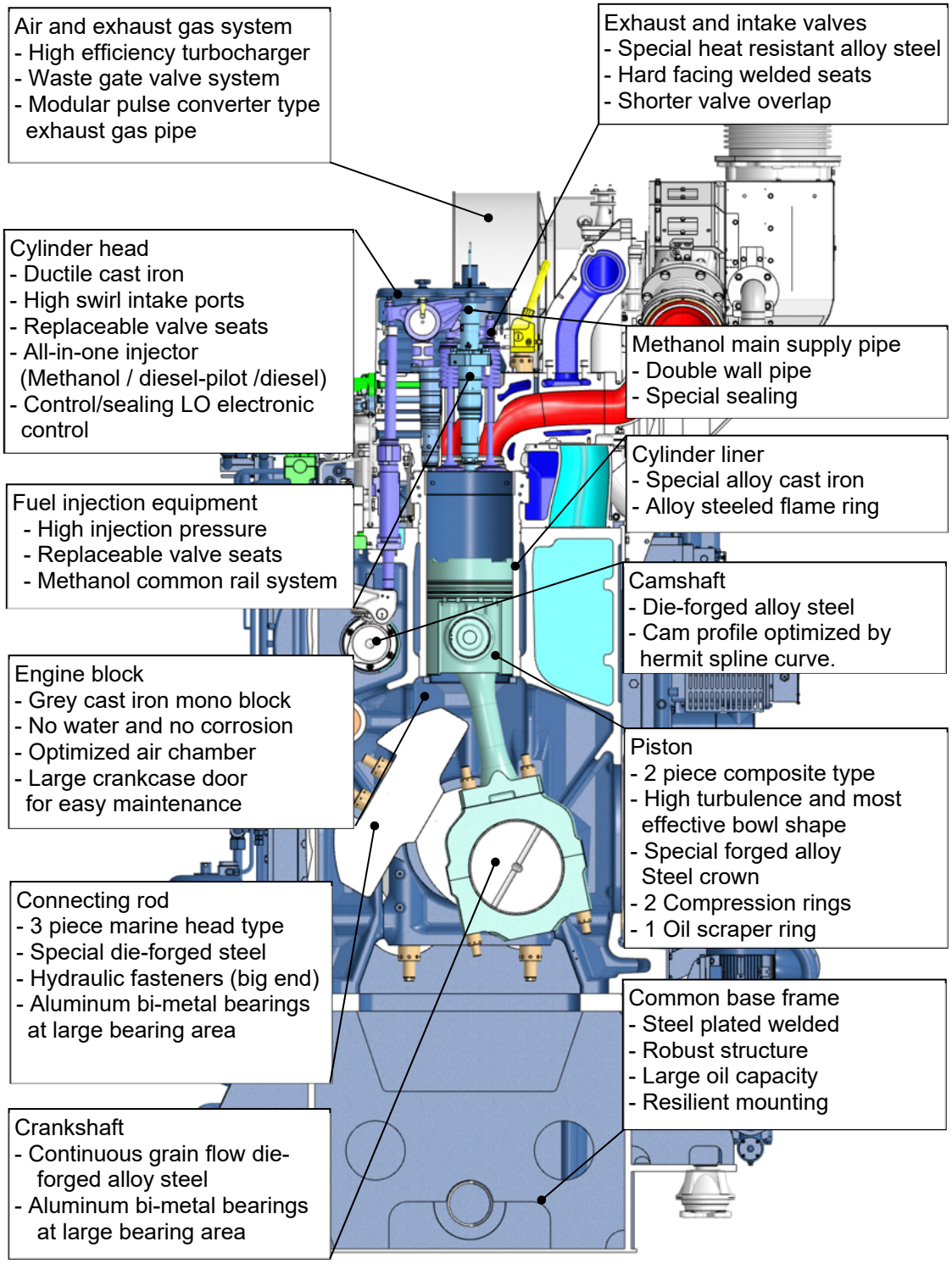



Figure 2.3 Cross section drawing

### 2.3.3 Description of feed module

HiMSEN has a unique design of feed module for better reliability and easy maintenance such as cooling water and lubricating oil system are fully modularized into the feed module with the following key features.

- ✓ All the components of the system, for example, pumps, valves, filters and coolers are mounted on feed block without any pipe connection, which provides direct accessibility with fewer parts for easy maintenance as shown below Figure 2.4

- ✓ Feed block has cast-in flow channels for cooling water and lubricating oil circuits, which are arranged to secure water-tight to oil space and simplified in combination with pumps and valve housings for better flow characteristics to avoid any risk of corrosion due to cavitation.

**Outline of feed module**

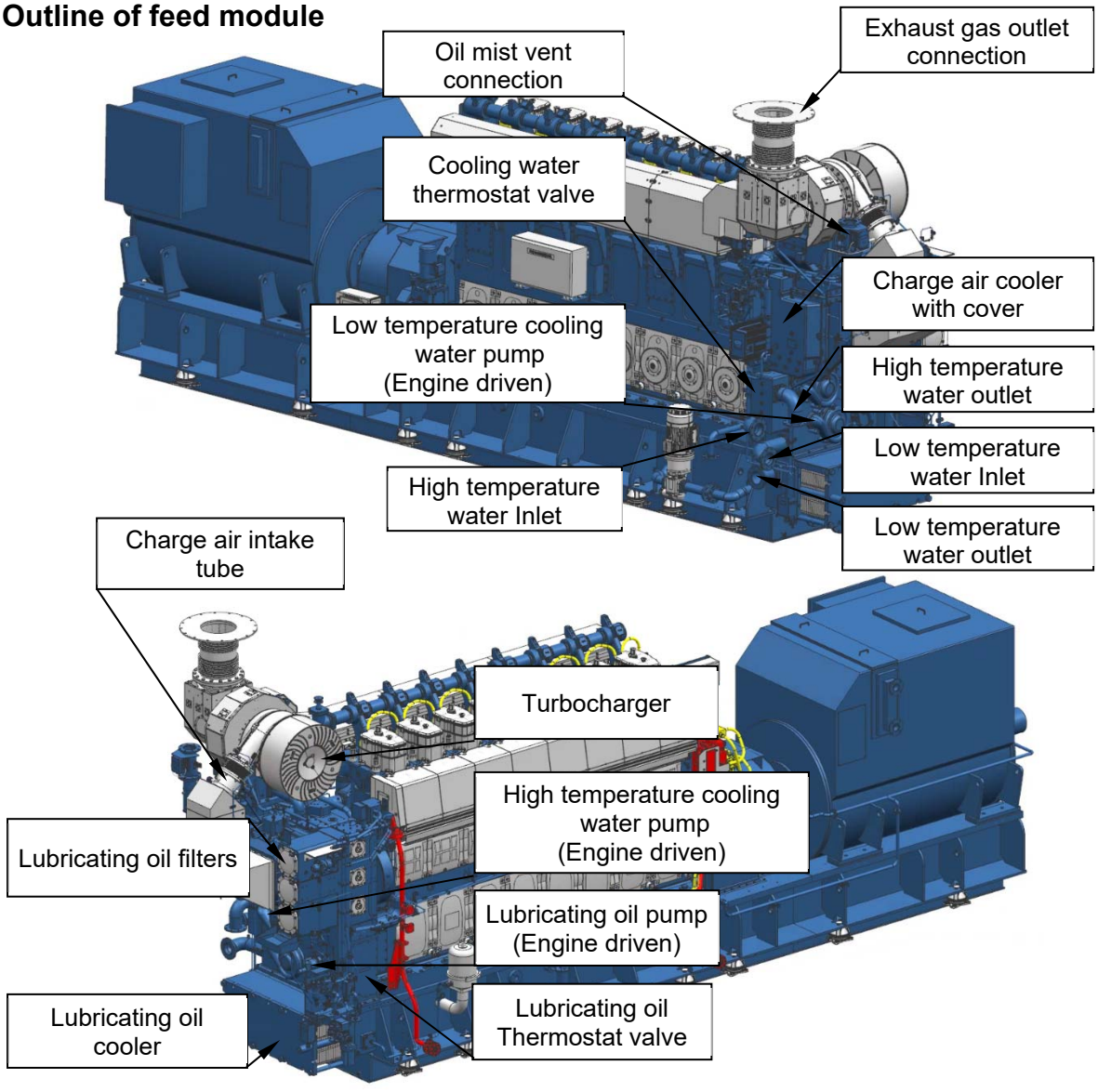



Figure 2.4 Outline of feed module

## 2.4 Generating-set dimension and weight

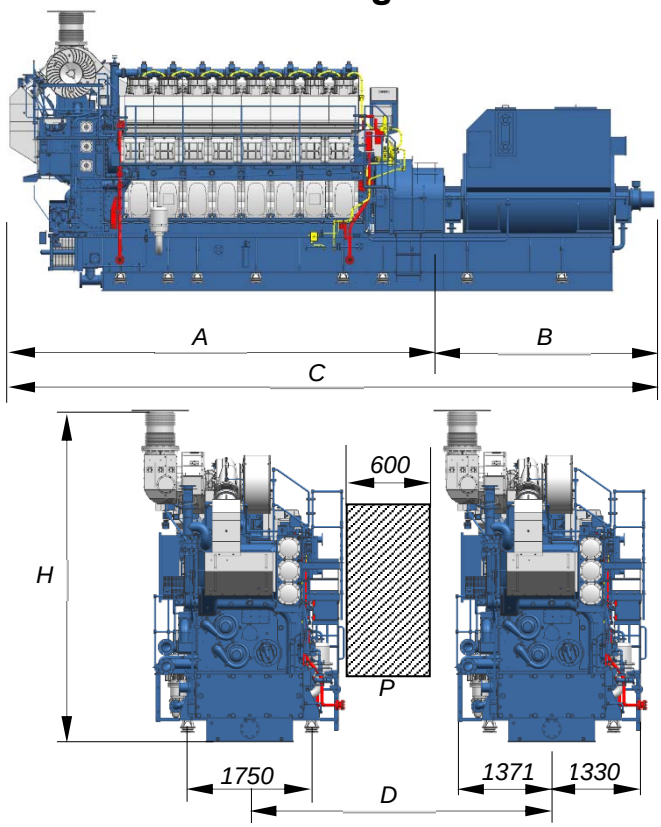



Table 2.2 Generating-set dimension and weight

| Engine type | Dimensions (mm) | | | | | Dry weight (ton) [2] | |
|---|---|---|---|---|---|---|---|
| | A | B [1] | C [1] | D [5] | H | Engine [3] | Generating-set [4] |
| 6H32DF-LM | 5,765 | 3,415 | 9,180 | 3,677 | 4,520 | 40.2 | 62.5 |
| 7H32DF-LM | 6,255 | 3,669 | 9,924 | 3,677 | 4,684 | 43.5 | 70.2 |
| 8H32DF-LM | 6,881 | 3,923 | 10,804 | 3,677 | 4,684 | 46.7 | 77.8 |
| 9H32DF-LM | 7,008 | 4,063 | 11,071 | 3,677 | 4,684 | 51.4 | 85.0 |

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
5) : Depending on methanol pipe connection
D : Min. distance between engines
P : Free passage between the engines, width 600 mm and height 2,000 mm.

# 2.5 Mounting

## 2.5.1 General

The HiMSEN generating-set consists of dual fuel engine and alternator mounted on common base frame. The common base frame is installed on resilient mounts on the foundation in the ship.

The resilient mounting for the generating-set is made with a number of rubber elements in order to isolate from vibrations between generating-set and hull structure. These rubber elements are bolted to brackets of the common base frame as shown below Figure 2.5.

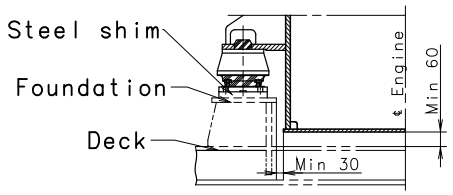



Figure 2.5 Resilient mounting

## 2.5.2 Design of resilient mount

The quantities and position of the resilient mount are determined by the dynamic characteristics of vessel. Therefore, the final specification of the resilient mount shall be decided based on the information from vessel contractor

## 2.5.3 Connections to the generating-set

Generating-set mounted on resilient mount is usually influenced by a relative motions from the hull structure. Due to the reason, any rigid fixing between generating-set and hull structure causes damages to generating-set or hull. 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 common base frame mounting should be rigid enough to support the load from generating-set. Steel shim plates with thickness of minimum 25mm between rubber elements and foundation are required to adjust leveling of each mount (Method 1). Additional shim plate (Minimum thickness 10 mm) 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 the engine to secure the correct adjustments of the shim plate and leveling of the generating-set.

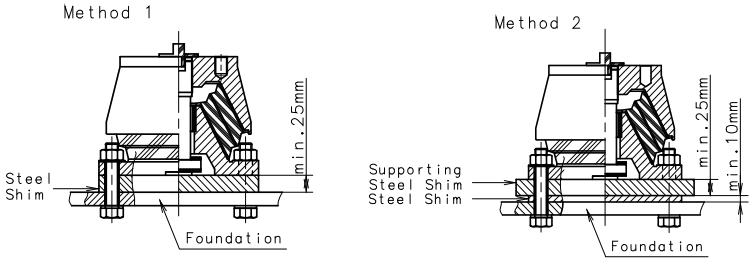
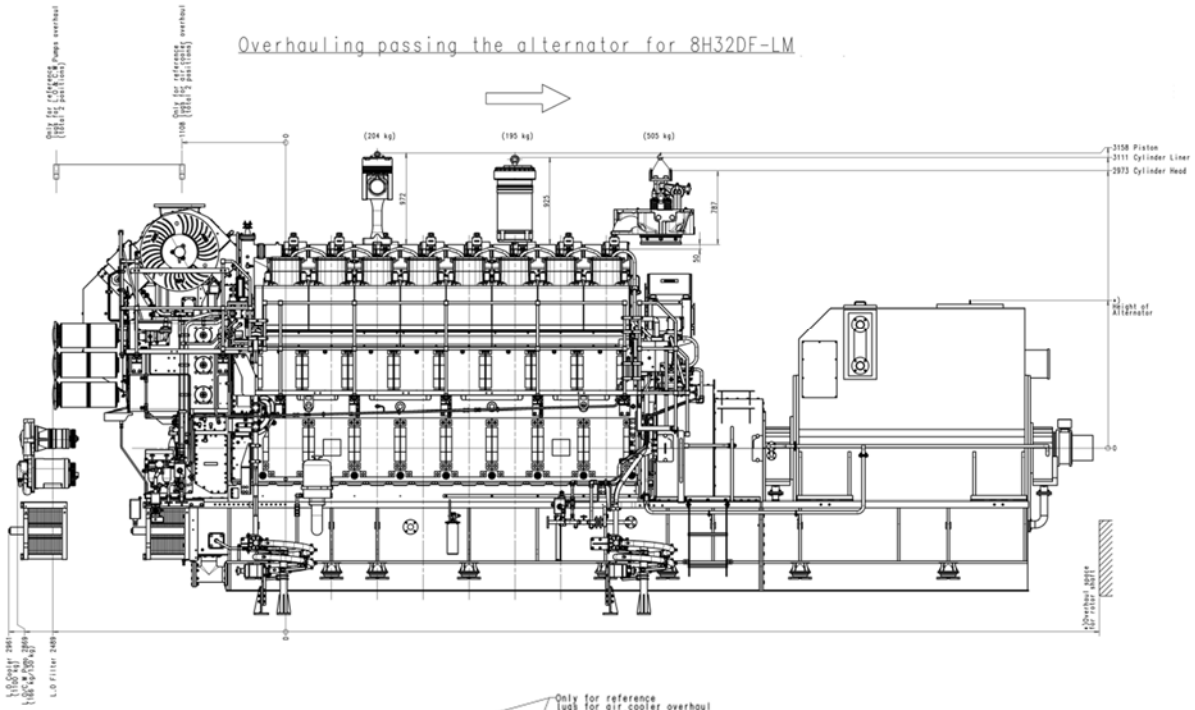
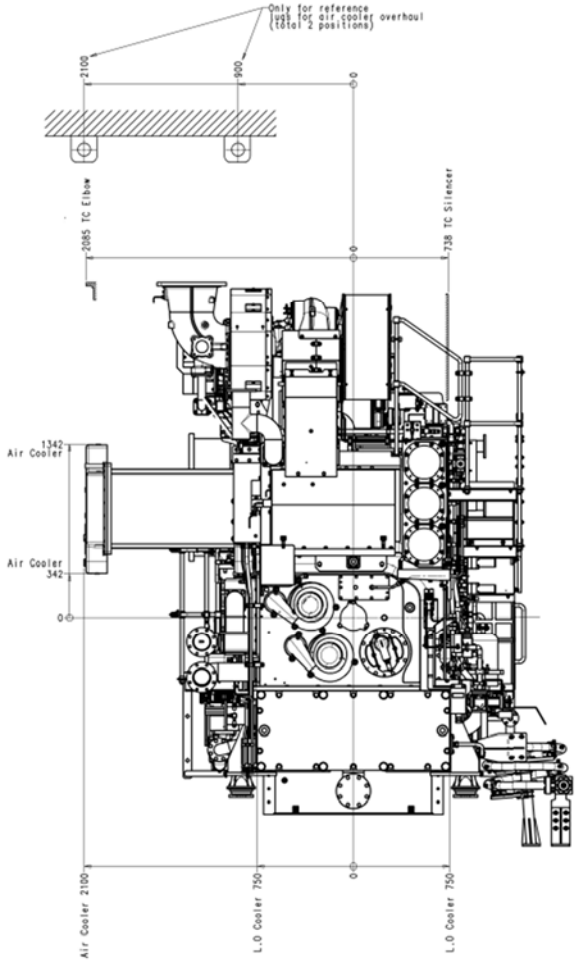



Figure 2.6 Recommendations for seating design

## 2.6 Overhaul dimension



# 3 Performance data

## 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) |
| 6H32DF-LM | 3,000 | 2,880 | 3,000 | 2,880 |
| 7H32DF-LM | 3,500 | 3,360 | 3,500 | 3,360 |
| 8H32DF-LM | 4,000 | 3,840 | 4,000 | 3,840 |
| 9H32DF-LM | 4,500 | 4,320 | 4,500 | 4,320 |

1. No overload operation is permissible except 10 % overload of diesel mode during official factory test only.
2. The alternator outputs are calculated for an efficiency of 96 % and a power factor of 0.8 lagging.
3. Power adjusting of dual fuel engines must be consulted to engine builder.

### Reference condition

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

### ISO condition

Turbocharger air inlet pressure : 1,000 mbar
Intake air temperature : 298 K (25 ℃)
L.T cooling water temperature : 298 K (25 ℃)

### Tropical condition

Turbocharger air inlet pressure : 1,000 mbar
Intake air temperature : 318 K (45℃)
L.T cooling water temperature : 309 K (36℃)

## Please check the attached drawing for the engine data information below :

| Drawing No. | Description |
|---|---|
| BH4-097899-2 | Engine performance data |

# 4 Dynamic characteristics and noise

## 4.1 External forces and couples

Table 4.1 External forces and couples (Diesel mode)

| Engine type | Speed | External forces and moments | | | | Guide force moments | | |
|---|---|---|---|---|---|---|---|---|
| | | Order | | Moment | | Order | | Moment |
| | | | | Horizontal | Vertical | | | |
| | rpm | No. | Hz | kNm | kNm | No. | Hz | kNm |
| 6H32DF-LM | 720 | 1 | 12.0 | 0.0 | 0.0 | 3 | 36.0 | 42.4 |
| | | 2 | 24.0 | 0.0 | 0.0 | 6 | 72.0 | 20.6 |
| | 750 | 1 | 12.5 | 0.0 | 0.0 | 3 | 37.5 | 39.3 |
| | | 2 | 25.0 | 0.0 | 0.0 | 6 | 75.0 | 20.6 |
| 7H32DF-LM | 720 | 1 | 12.0 | 3.7 | 28.5 | 3.5 | 42.0 | 78.3 |
| | | 2 | 24.0 | 0.0 | 21.7 | 7 | 84.0 | 14.2 |
| | 750 | 1 | 12.5 | 4.1 | 30.9 | 3.5 | 43.8 | 78.3 |
| | | 2 | 25.0 | 0.0 | 23.5 | 7 | 87.5 | 14.2 |
| 8H32DF-LM | 720 | 1 | 12.0 | 0.0 | 0.0 | 4 | 48.0 | 69.8 |
| | | 2 | 24.0 | 0.0 | 0.0 | 8 | 96.0 | 9.1 |
| | 750 | 1 | 12.5 | 0.0 | 0.0 | 4 | 50.0 | 69.5 |
| | | 2 | 25.0 | 0.0 | 0.0 | 8 | 100.0 | 9.1 |
| 9H32DF-LM | 720 | 1 | 12.0 | 2.7 | 20.6 | 4.5 | 54.0 | 63.5 |
| | | 2 | 24.0 | 0.0 | 11.8 | 9 | 108.0 | 5.3 |
| | 750 | 1 | 12.5 | 2.9 | 22.3 | 4.5 | 56.3 | 63.5 |
| | | 2 | 25.0 | 0.0 | 12.8 | 9 | 112.5 | 5.3 |

Table 4.2 External forces and couples (Methanol mode)

| Engine type | Speed | External forces and moments | | | | Guide force moments | | |
|---|---|---|---|---|---|---|---|---|
| | | Order | | Moment | | Order | | Moment |
| | | | | Horizontal | Vertical | | | |
| | rpm | No. | Hz | kNm | kNm | No. | Hz | kNm |
| 6H32DF-LM | 720 | 1 | 12.0 | 0.0 | 0.0 | 3 | 36.0 | 27.4 |
| | | 2 | 24.0 | 0.0 | 0.0 | 6 | 72.0 | 18.8 |
| | 750 | 1 | 12.5 | 0.0 | 0.0 | 3 | 37.5 | 24.5 |
| | | 2 | 25.0 | 0.0 | 0.0 | 6 | 75.0 | 18.8 |
| 7H32DF-LM | 720 | 1 | 12.0 | 3.7 | 28.5 | 3.5 | 42.0 | 64.2 |
| | | 2 | 24.0 | 0.0 | 21.7 | 7 | 84.0 | 14.5 |
| | 750 | 1 | 12.5 | 4.1 | 30.9 | 3.5 | 43.8 | 64.2 |
| | | 2 | 25.0 | 0.0 | 23.5 | 7 | 87.5 | 14.5 |
| 8H32DF-LM | 720 | 1 | 12.0 | 0.0 | 0.0 | 4 | 48.0 | 56.7 |
| | | 2 | 24.0 | 0.0 | 0.0 | 8 | 96.0 | 11.2 |
| | 750 | 1 | 12.5 | 0.0 | 0.0 | 4 | 50.0 | 56.7 |
| | | 2 | 25.0 | 0.0 | 0.0 | 8 | 100.0 | 11.2 |
| 9H32DF-LM | 720 | 1 | 12.0 | 2.7 | 20.6 | 4.5 | 54.0 | 53.1 |
| | | 2 | 24.0 | 0.0 | 11.8 | 9 | 108.0 | 8.4 |
| | 750 | 1 | 12.5 | 2.9 | 22.4 | 4.5 | 56.3 | 53.1 |
| | | 2 | 25.0 | 0.0 | 12.8 | 9 | 112.5 | 8.4 |

## 4.2 Moment of inertia

Table 4.3 Moment of inertia

| Engine type | Speed | Rating | Moments of inertia ; $J_{1)}$ | | | | |
|---|---|---|---|---|---|---|---|
| | | | Engine MOI | Flywheel | | Alternator $MOI_{2)}$ | Total MOI |
| | | | | MOI | Mass | | |
| | rpm | kW | $kgm^2$ | $kgm^2$ | kg | $kgm^2$ | $kgm^2$ |
| 6H32DF-LM | 720 | 3000 | 358.5 | 190.0 | 938.2 | 524.6 | 1073.1 |
| | 750 | 3000 | 358.5 | 190.0 | 938.2 | 524.6 | 1073.1 |
| 7H32DF-LM | 720 | 3500 | 416.9 | 400.0 | 1688.6 | 618.3 | 1435.2 |
| | 750 | 3500 | 416.9 | 400.0 | 1688.6 | 618.3 | 1435.2 |
| 8H32DF-LM | 720 | 4000 | 475.4 | 386.0 | 1431.7 | 716.3 | 1577.7 |
| | 750 | 4000 | 475.4 | 386.0 | 1431.7 | 716.3 | 1577.7 |
| 9H32DF-LM | 720 | 4500 | 533.8 | 100.0 | 568.3 | 944.5 | 1578.3 |
| | 750 | 4500 | 533.8 | 100.0 | 568.3 | 944.5 | 1578.3 |

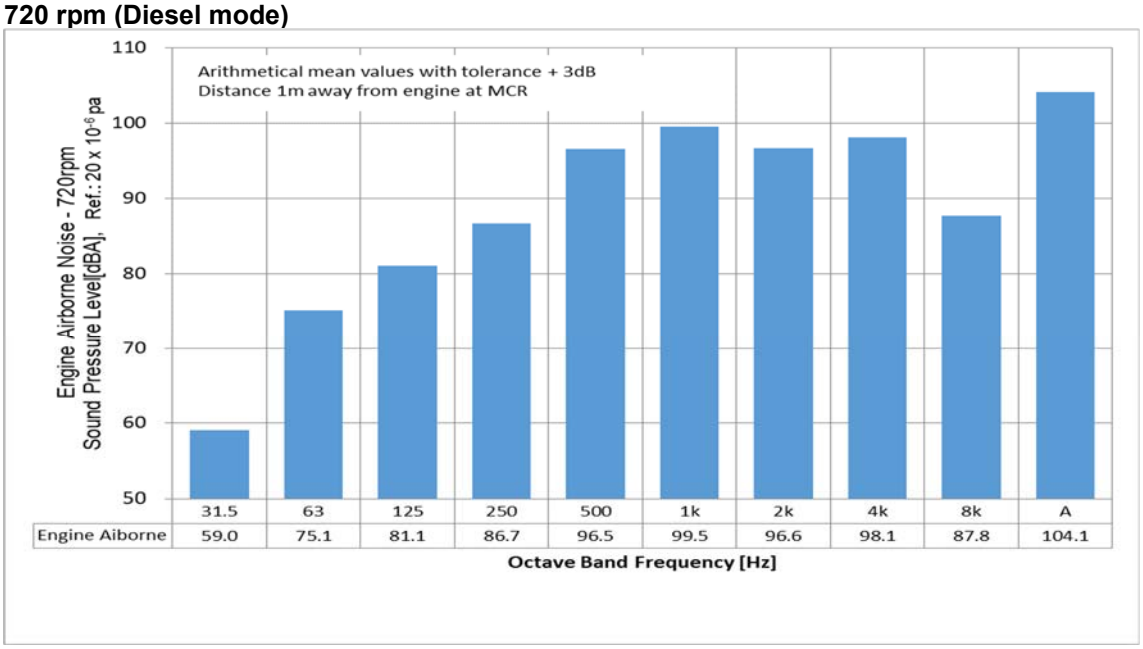
1) Moment of Inertia : $GD^2 = 4 \times J$ ($kgm^2$)
2) Recommended values, the case of different MOI should be confirmed by a torsional vibration analysis

## 4.3 Noise measurement

### 4.3.1 General description

The airborne noise of the engine is defined as a sound pressure level according to ISO 6798 and ISO 8528-10. The total 19 point at distance 1 m away from the engine surface at full load should be measured. The values are averaged with A-weighting in one octave band.
In the octave level diagram, the minimum and maximum octave levels of all measuring points have been linked by results. The data can be changed, depending on the acoustical properties of the environment and the number of cylinder

**720 rpm (Diesel mode)**




**720 rpm (Methanol mode)**

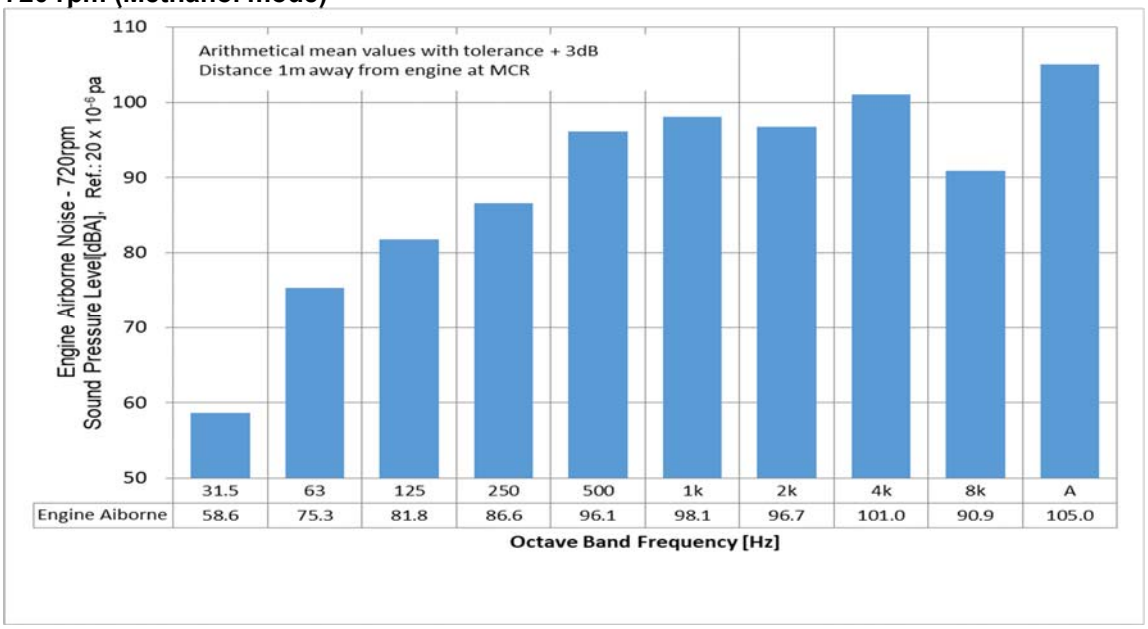



Figure 4.2 Engine air airborne noise level (Methanol mode)

# 5 Operation and control system

## 5.1 Engine operation

### 5.1.1 General

HiMSEN DF-LM engine is able to run in both diesel and methanol fuel.

The operation characteristics at diesel and methanol mode are different. Suitable fuel mode should be selected at each required operation capacity and proper action should be taken based on fuel mode.

### 5.1.2 Engine fuel mode

**Diesel mode**

- ✓ Diesel fuel oil system active.
- ✓ Diesel FO is injected by electronic fuel injection pump (E-FIP) system and the timing and amount of injected fuel is controlled by ECS.(Engine control system)
- ✓ When manually selected or methanol mode operation is not available (methanol trip condition).

**Methanol mode**

- ✓ Methanol fuel and pilot fuel oil system active.
- ✓ Diesel fuel oil system is used for pilot fuel injection and its timing and amount of fuel is adjusted for its purpose
- ✓ Methanol fuel is injected by fuel injection valve(FIV) and the timing and amount of injected fuel is controlled by ECS.
- ✓ When manually selected.

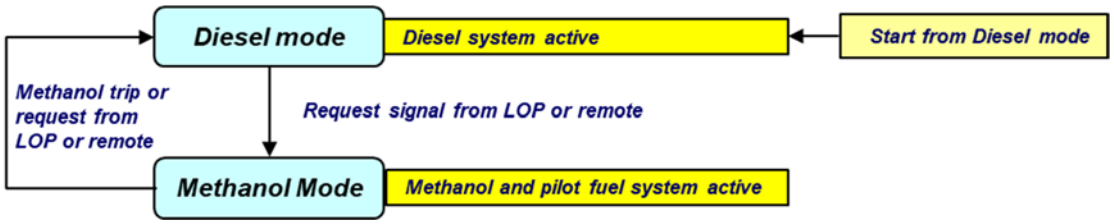



Figure 5.1 Engine fuel mode

Fuel mode can be selected from

- ✓ At switch on local operating panel(LOP) (On engine)
- ✓ From remote system (Power management system or ship management system)

The methanol trip condition is specified in alarm list.

### 5.1.3 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 ℃

**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.1,000 cSt based on SAE 40)

**Intake air temperature :** minimum 0 ℃

## 5.1.4 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
- ✓ Slow turning failure
- ✓ Engine speed high before start
- ✓ Start block in test mode
- ✓ Start block from remote system

### Engine start at different start mode

Main starting valve is installed in engine side and operated by compressed air and controlled by pneumatic solenoid valve. (See the diagram Figure 9.1)

Starting is performed only in diesel mode (or diesel mode with blackout start) regardless of requested fuel mode since methanol mode is possible only above predefined load operation.

This is to guarantee safe operation of DF-LM engine in terms of stable combustion in combination of pilot fuel and methanol injection.

**Engine start at diesel mode**

① Engine begin to start
Slow turning is performed depends on predefined conditions.

After completion of slow turning sequence, actual start sequence is started and after reaching “speed limit for diesel fuel injection”, main fuel oil begins to be injected. The amount of FO injection will follow the predefined value at engine start.

At “speed limit starter off”, the starting sol. valve is deactivated. After predefined speed, engine status changed to “engine run”.

Engine reaches idle speed in predefined fuel injection profile to minimize smoke emission.

② Speed ramp up from idle speed to rated speed
Ramp up rate “Period between idle and rated speed” is applied

③ Engine running at rated speed
Ready for circuit breaker closed

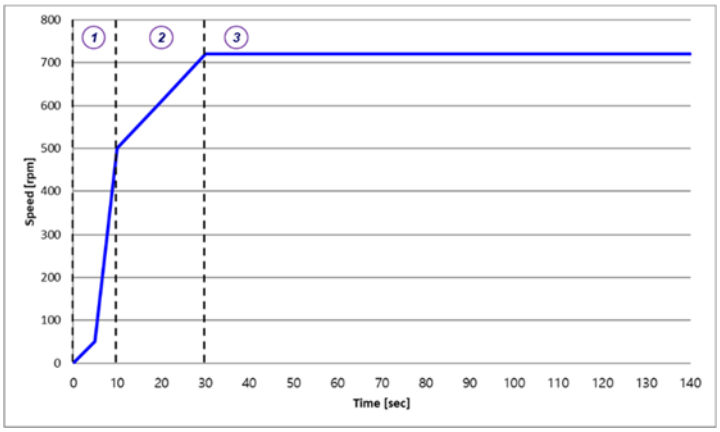



Figure 5.2 Engine start at diesel mode

**Engine start at diesel black out start mode**

① Engine begin to start

Slow turning is ignored regardless of engine control mode (local/remote), request from remote and below conditions are overridden.

- Lubricating oil pressure at engine inlet low
- Starting air pressure at engine inlet low
- High cooling water temperature at engine inlet low
- Slow turning failure

After predefined speed, after reaching “speed limit for diesel fuel injection”, main fuel oil begins to be injected. The amount of fuel oil injection will follow the predefined value at engine start.

At “speed limit starter off”, the starting sol. valve is deactivated. After predefined speed, engine status changed to “engine run”. The speed is increased without staying in idle speed and reach to rated speed as fast as possible

② Engine running at rated speed: Ready for circuit breaker closed

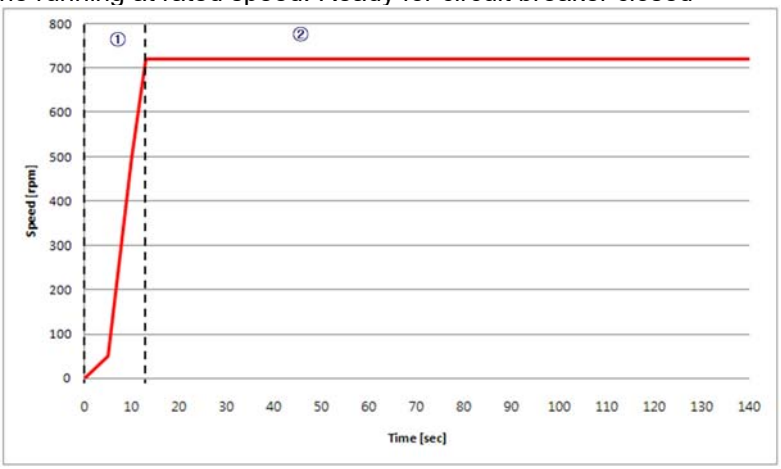



Figure 5.3 Engine start at black-out start mode

### 5.1.5 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 5.4.

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 5.4.

Methanol fuel operation

- ✓ Over 20 % load operation : no restriction
- ✓ Below 20 % load operation : not permitted

Duration of flushing operation (See Figure 5.4)

'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.

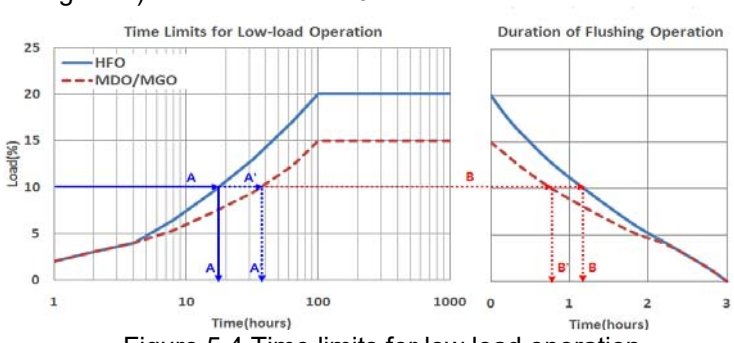



Figure 5.4 Time limits for low load operation

### 5.1.6 Engine load-up

Engine fulfills all requirements regarding the load application of all major classification societies and IACS at diesel mode.
At methanol 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 at each fuel mode is referred in Figure 5.5

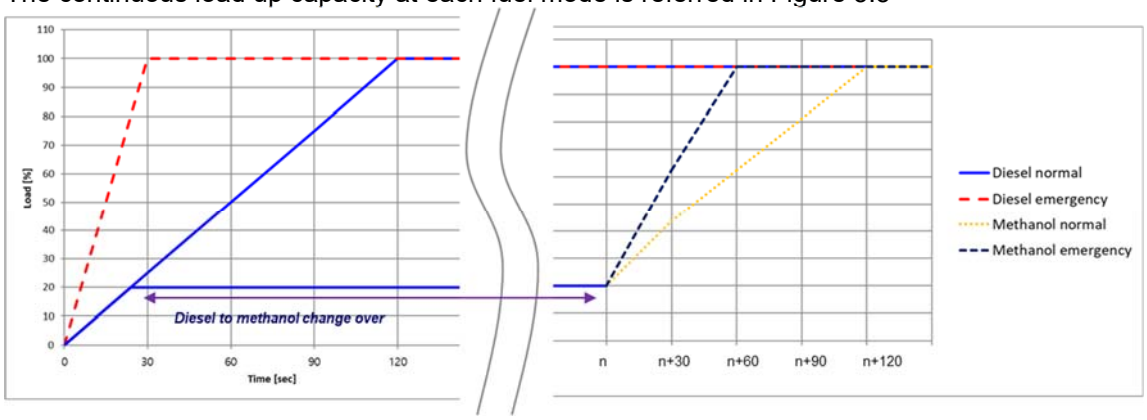



Figure 5.5 Engine load up capacity in ramp

**Diesel mode**

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.

**Methanol mode**

After change over from diesel to methanol, the load from 20% to 100 % can be achieved in 120sec by continuous ramping up at normal condition.
At emergency condition, the load can be more quickly increased from the load 20% to 100% in 60sec.

## 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 5.6 and Figure 5.7. At methanol mode, the amount of load step is decreased at high load for stable operation.

### Diesel mode

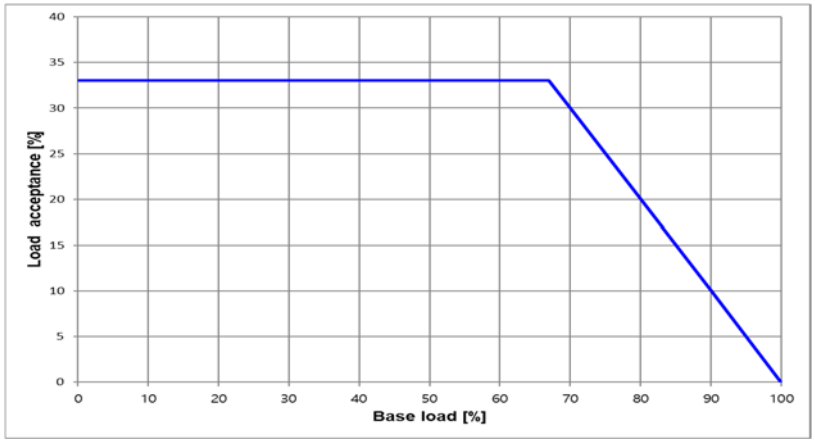



Figure 5.6 Step load acceptance at diesel mode

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

### Methanol mode

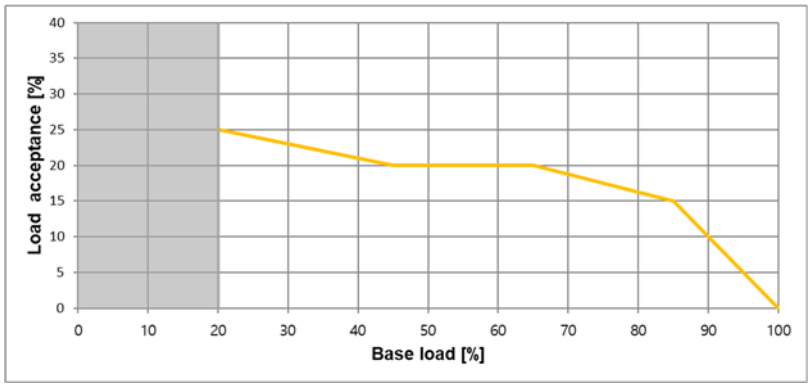



Figure 5.7 Step load acceptance at methanol mode

1. Max instant load step: 20 – 45 – 65 – 85 – 100 %
2. Max speed variation ≤ 10 %
3. Steady-state speed band ≤ 1.5 %
4. Recovery time ≤ 5 sec
5. Time between next load step ≥ 15 sec

### 5.1.7 Fuel mode changeover

HiMSEN DF-LM engine operation at diesel or methanol mode is possible when predefined condition for each mode is satisfied.
Fuel mode changeover is available from

- ✓ Switch in local (Engine room)
- ✓ Switch in remote (Engine control room)

When predefined trip condition at each fuel mode is detected, fuel mode is automatically transferred to safer fuel mode (methanol to diesel) for continuous operation without engine shutdown (Refer to Figure 5.1).

#### From methanol to diesel mode

- ✓ Changeover is available at entire load range 0 % ~ 100 %
- ✓ Changeover takes only a second (Refer to Figure 5.8)

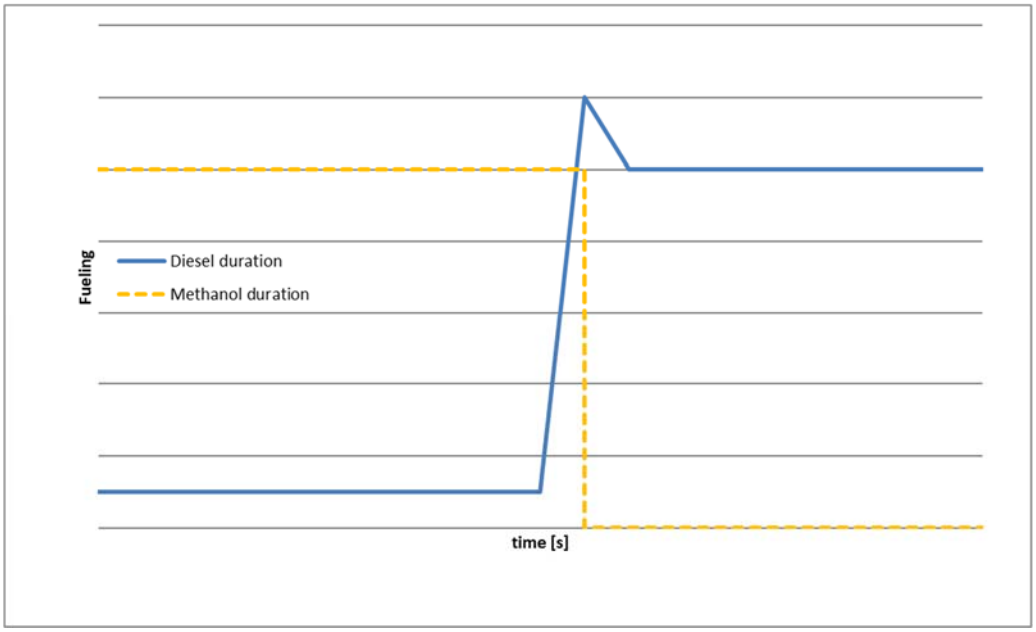



Figure 5.8 Fuel mode changeover from methanol to diesel

## From diesel to methanol mode

- ✓ Before changing over from diesel to methanol mode, below conditions shall be met.
  - Low flashpoint fuel supply systeam ready
  - Methanol high pressure pump ready
  - Not methanol trip condition
- ✓ Changeover is available at load range of 20 % ~ 80 %
- ✓ Methanol leakage test is performed before changeover.
- ✓ Changeover takes approx. 10 min. including methanol leakage test and it depends on pipe system. (Refer to Figure 5.9).
- ✓ In order to change over to methanol mode, marine diesel oil or marine gas oil are required as pilot fuel oil. HFO is not permitted to be used as pilot fuel oil.

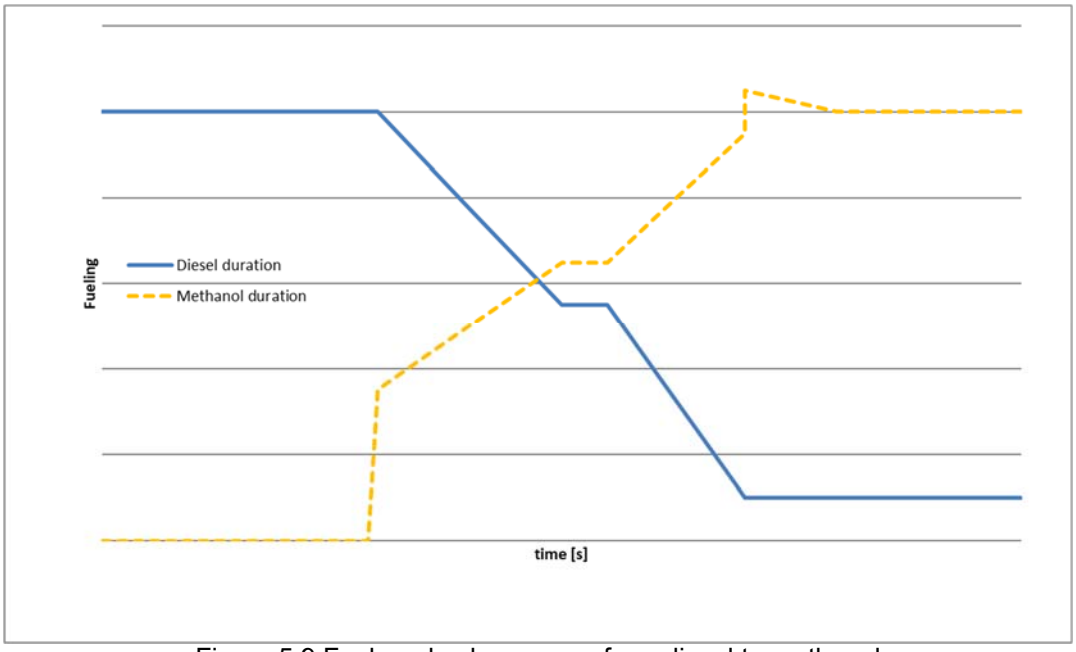



Figure 5.9 Fuel mode changeover from diesel to methanol

## 5.1.8 Engine stop

### Normal stop

Normal stop is applied when stop command is active at circuit braker(CB) open condition.
Therefore, the de-loading and CB open action has to be taken either from local or remote in advance of normal stop.

Normal stop is only available at diesel mode because low load operation is prohibited at methanol mode operation.
If stop command is activated at methanol mode, engine shutdown signal is activated.

Before engine stop, the engine will run at cool-down speed to dissipate the heat of engine. After that, electronic fuel injection is stopped and engine stops safely.

### 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 shutdown at methanol mode operation, pilot fuel oil injection and methanol injection are stopped and fuel oil shut off valve is closed simultaneously.
Also, methanol shut off valves and drain valves at fuel valve train are activated and methanol circuit both on methanol high pressure pump and engine is purged with inert gas.
If the engine shutdown at diesel operation, main fuel oil injection is stopped and fuel oil shut-off valve is closed simultaneously and it forces the fuel cut to engine.

### Emergency stop

When emergency stop signal is entered from local operating panel and/or remote system by activating the switch signal or engine speed is over the limit, the engine is stopped immediately.
The stop sequence is same as shutdown.

## 5.1.9 Engine safety

The HiMSEN DF-LM 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 HiMSEN DF-LM engine control system.

HiMSEN DF-LM engine control system fulfills and satisfies redundant and independent safety function against critical shutdown conditions. HiMSEN DF-LM engine control system implements safety functions written in next Figure 5.10 describes layout of HiMSEN DF-LM engine safety system.

### 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.

## Start block

Engine control system release alarm message and engine start is blocked. The start block condition has to be cleared before start the engine.

## Load reduction

Engine control system release alarm message and the load is reduced automatically (in fixed kW mode) or request a commend to its power management system for the load reduction (in droop mode).

## Methanol trip

Engine control system release alarm message and the fuel mode is transferred from methanol to diesel mode and the purging sequence with inert gas is fulfilled. The methanol trip condition has to be cleared before go back to methanol mode.

## Shutdown

Engine control system release shutdown message and the engine is shutdown after predefined delay.

## Emergency stop

Engine control system release emergency stop message and the engine is shutdown immediately.

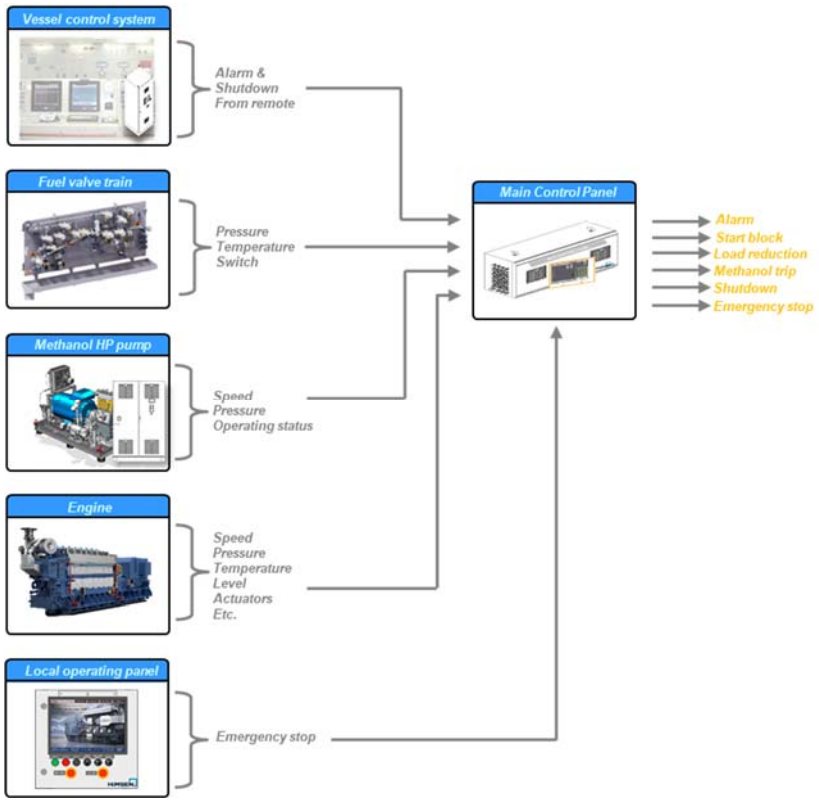



Figure 5.10 H32DF-LM engine safety function layout

## 5.2 Engine control system

### 5.2.1 General

The HiMSEN DF-LM ECS performs the complete engine management.

HiMSEN DF-LM engine shall be equipped with double wall methanol piping system, machinery space is regarded as ‘safe area’ and thus HiMSEN DF-LM ECS is not required to be explosion proof design.
However based on explosion zone definition of the engine and auxiliary components, some signals can be interfaced with IS barrier.

HiMSEN DF-LM ECS mainly consists of MCP (Main control panel), ICM (Injection Control Module), CMM(Cylinder Monitoring Module), LOP (Local Operating Panel), and ACP (Auxiliary Control Panel)

HiMSEN DF-LM 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.

It is also connected to external system via hardwired signal and bus communication.
This configration provides full operation and monitoring capability to remote system.

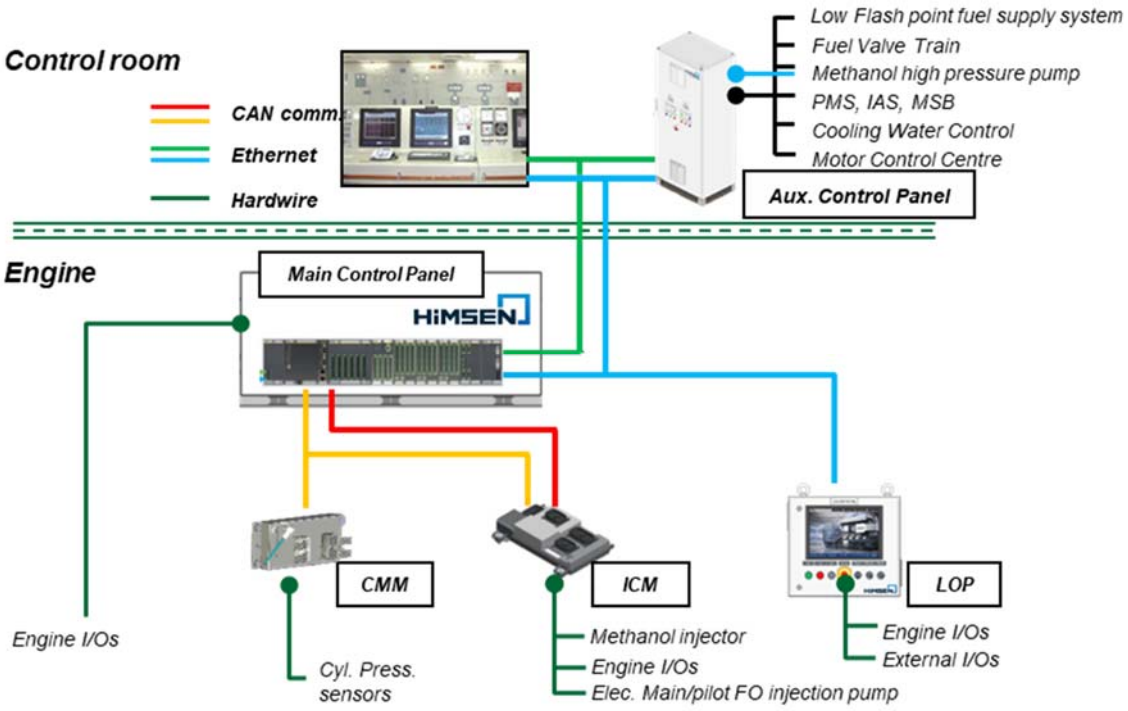



Figure 5.11 HiMSEN DF-LM ECS overview

## 5.2.2 Hardware description

**Main Control Panel (MCP)**

MCP is the central control unit of HiMSEN DF-LM 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 HiMSEN DF ECS and all instruments on engine for control and monitoring.
Moreover, Engine Safety Module is installed in MCP which shutdown the engine independently from Main control & Alarm Module

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

- ✓ Consist of
  - Main Control & Alarm Module
  - I/O modules and terminals
  - Communication switches
  - Engine Safety Module (ESM)

- ✓ *Responsible for*
  - Main control and monitoring of DF-LM engine
  - Engine safety control
  - Engine control and safety parameter tuning

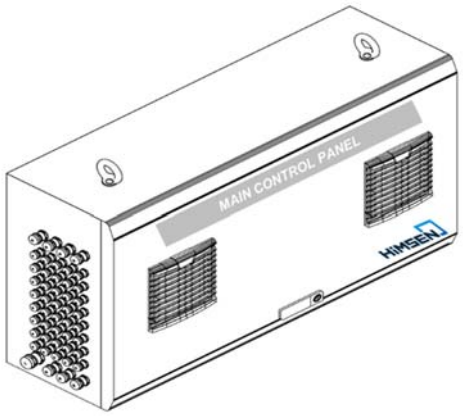



Figure 5.12 Main control panel

**Injection Control Module (ICM)**

ICM is mounted on the engine and connected to electronic main/pilot fuel injection pump and Methanol injector on each cylinder.

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

- ✓ Responsible for
  - Driving main/pilot fuel electronic injection
  - Driving methanol electronic injection
  - Measurement and process of analogue/digital engine I/O and transmit data to MCP for control
  - Measurement and process of knock signal and transmit data to MCP for control

Figure 5.13 Injection control module

**Cylinder Monitoring Module(CMM)**

In order to achieve higher thermal efficiency and more stable & safe engine operation, combustion of individual cylinder have to be monitored & controlled. For this matter of fact, CMM is integrated and monitors both combustion characteristics and knock intensity of each cylinder and communicates this information with MCP for control and monitoring.

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

- ✓ Responsible for
  - Measurement of cylinder pressure signal
  - Calculation of combustion characteristics and knock intensity
  - Transmission of data to MCP for control
  - On/Off line analysis of combustion data via PC

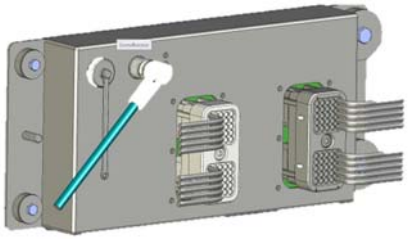


Figure 5.14 Cylinder monitoring module

**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.

- ✓ 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
  - Test of electronic injection valves, valves on engine and FVT
  - standstill
  - Independent engine shutdown

Figure 5.15 Local operating panel

**Auxiliary Control Panel (ACP)**

ACP (Auxiliary Control Panel) is normally installed in ECR (Engine control room) or shall be installed in a location where temperature is kept low as self-standing cabinet.
ACP is in charge of not only FVT, methanol high pressure pump and cooling water control but also interface with VCS, MSB and PMS via communication and hard-wire.

- ✓ Location : Standalone separarted from engine (1 set per engine)

- ✓ Consist of
  - Remote Control Module
  - Buttons and lamps for status indication

- ✓ Responsible for
  - Control of FVT, methanol high pressure pump and cooling water valve
  - Communication with methanol high pressure pump
  - Engine status indication via lamp
  - Emergency stop button
  - Interface with MSB, PMS and VCS

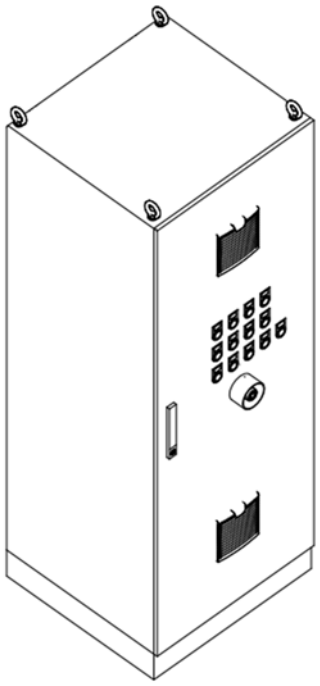


Figure 5.16 Auxiliary control panel

## Local and remote operation of engine

Engine operation at local (Engine)

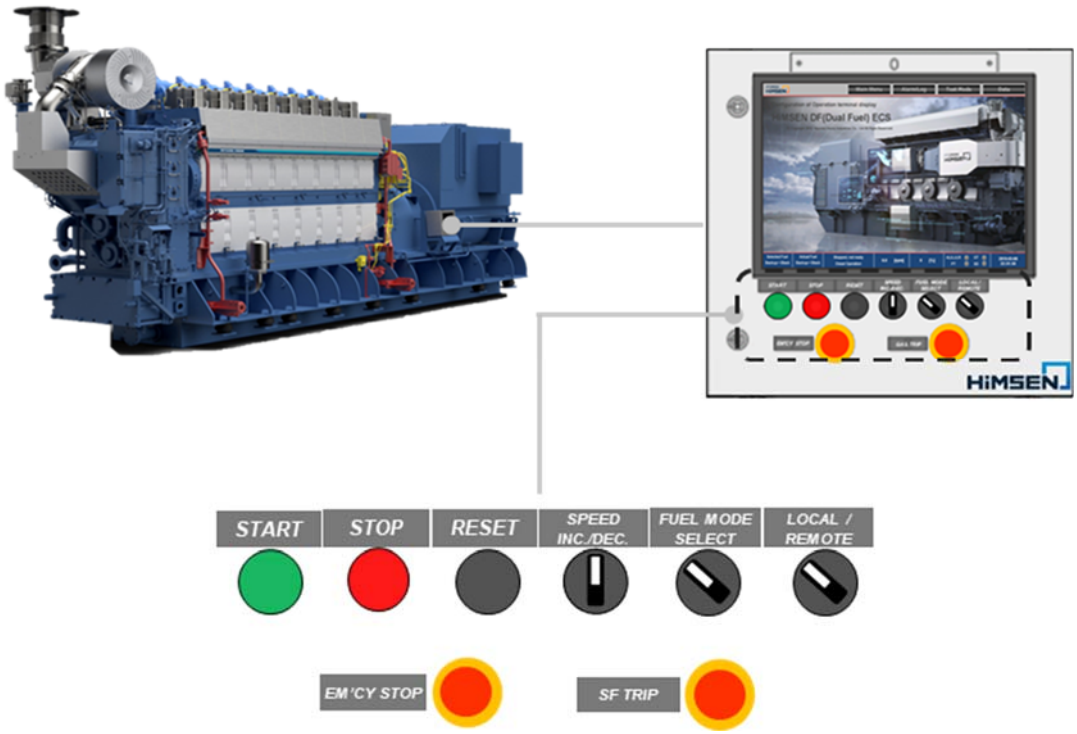



Figure 5.17 Engine operation at local

Engine operation at Remote (VCS or PMS / MSB)

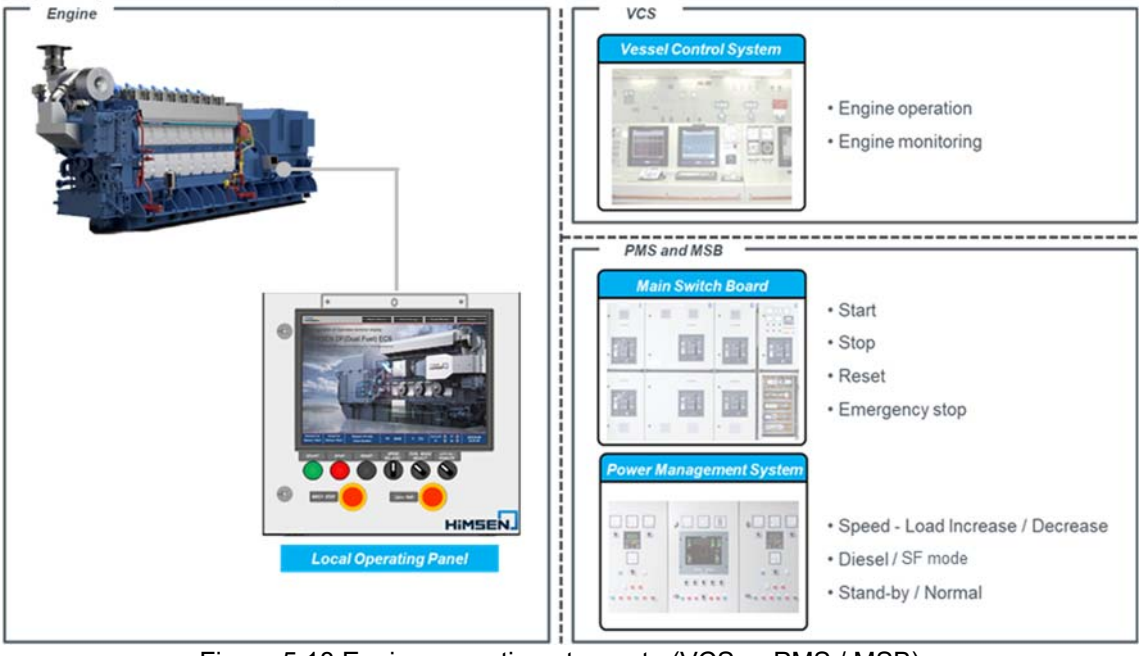



Figure 5.18 Engine operation at remote (VCS or PMS / MSB)

### 5.2.3 Functional description

**Speed control**

At methanol mode, ECS regulates the duration of fuel injection valve for speed & power control.

At diesel mode, ECS regulates the duration of electronic fuel injection pump for speed & power control.

**Exhaust gas waste gate(EWG) valve control**

Exhaust gas temperature at turbo charger outlet is controlled by adjusting the opening ratio of EWG valve. The EWG valve controls the amount of bypassed gas of exhaust gas to turbocharger.

This is for use in combination of an emission after treatment system like selective catalytic reduction (SCR).

During fuel mode changeover or engine operation in SF mode, EWG valve control is active based on the charge air pressure.

**Pilot fuel injection control**

In HiMSEN DF-LM engine, pilot fuel oil injection is ignition source of combustion in methanol mode. Diesel fuel injection system is commonly used with main and pilot fuel oil injection.

ECS should control pilot fuel oil injection timing and duration of electronic fuel injection pump.

**Methanol pressure control**

HiMSEN DF-LM ECS manages the control of stable methanol pressure by controlling methanol high pressure pump speed.

**Cylinder balancing control**

Cylinder combustion pressure monitoring function is integrated in HiMSEN DF-LM ECS.

This control function guarantees cylinder combustion balancing control.

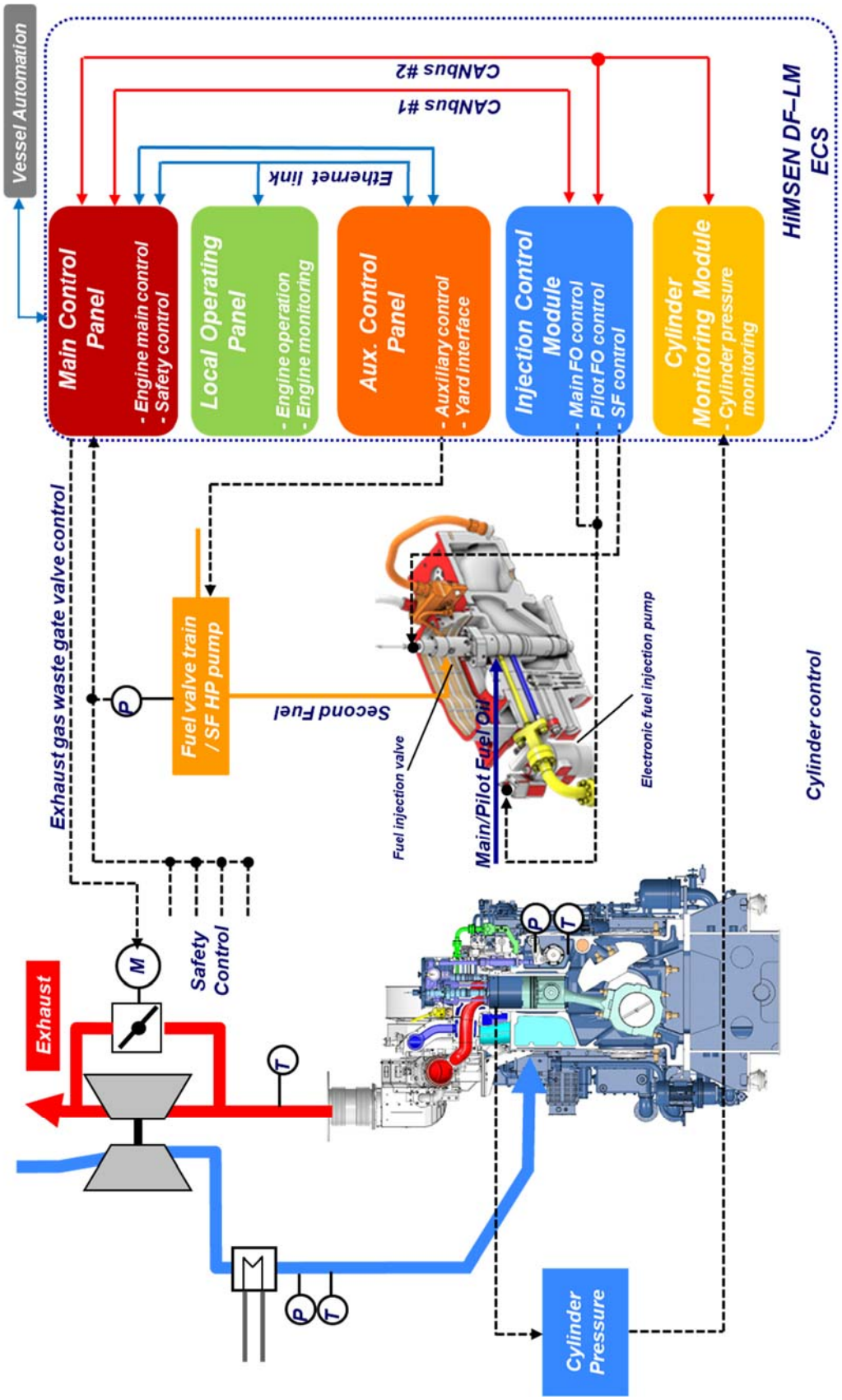



Figure 5.19 Overview of HiMSEN DF-LM engine control function

## 5.3 Outline of engine automation

### 5.3.1 General

HiMSEN DF-LM ECS is closely interfaced with external system and provide full capability for optimum operation at different fuel mode.

The external system should also recognize the current fuel mode and take a proper action based on fuel mode.

Refer to Fig. 5.20 for system schematic of the external interface.

This information is only for reference with single engine diagram.

The external interface can be different and depending on the project.

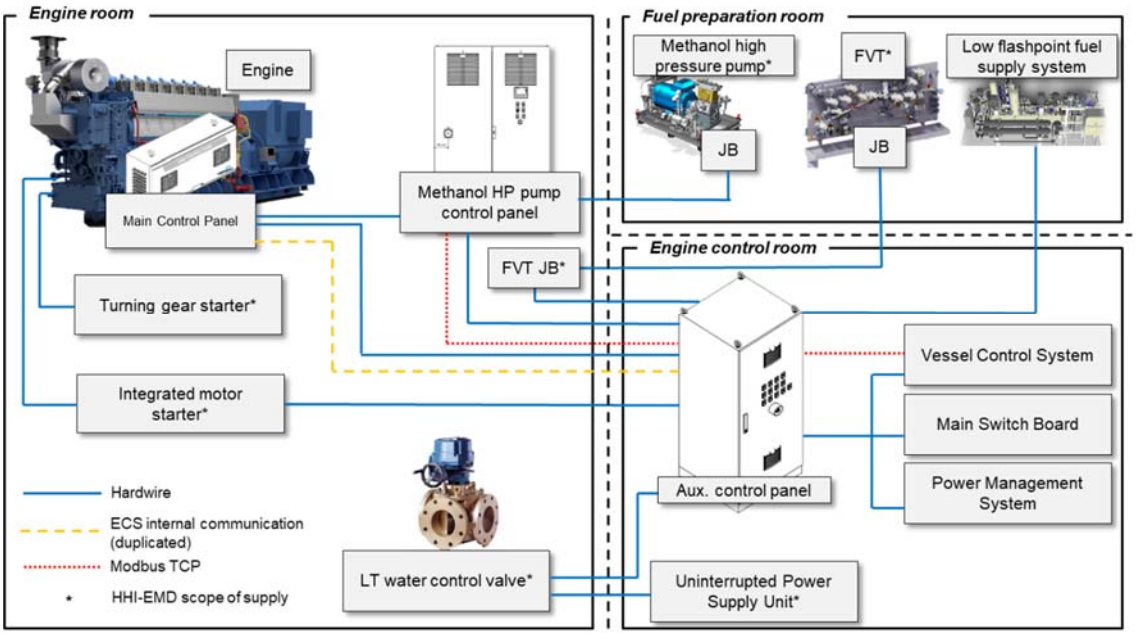



Figure 5.20 HiMSEN DF ECS external interface (system schematic)

### 5.3.2 Communication interface

HiMSEN DF-LM ECS provides all information including status of engine, monitored value and operation condition through ether net (modbus TCP) to external system.

The external system is modbus master and HiMSEN DF-LM ECS is always mod bus slave.

Refer to Fig. 5.21 for concept of communication interface

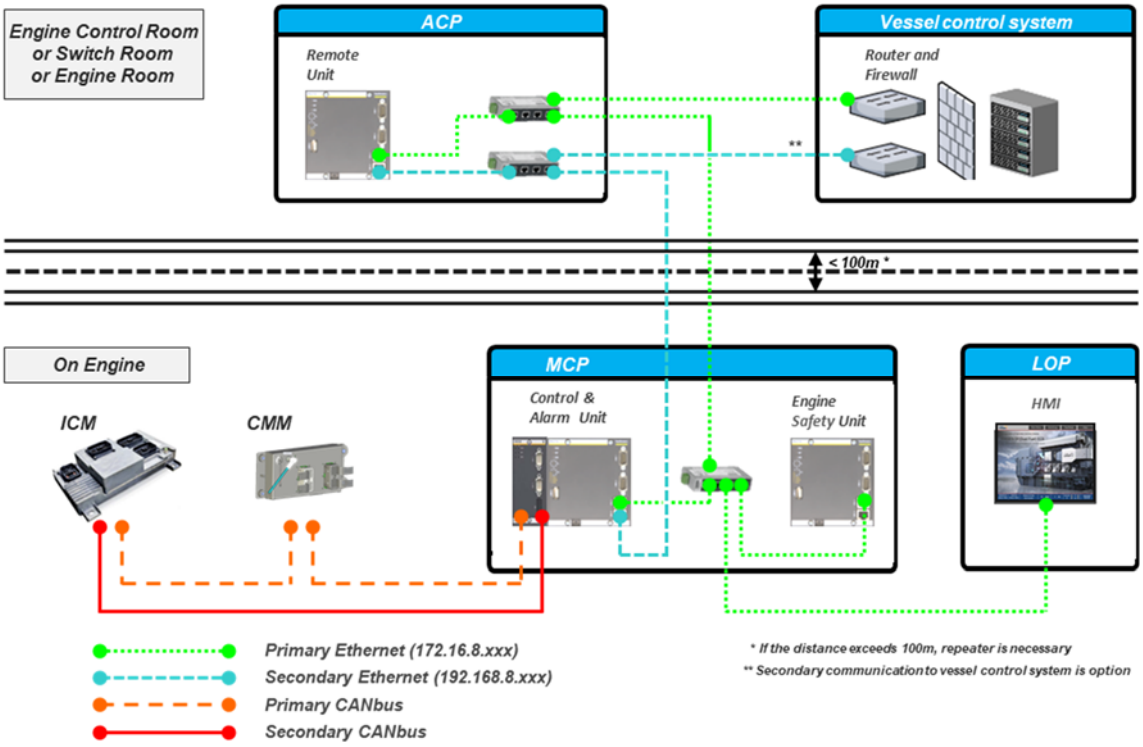



Figure 5.21 HiMSEN DF-LM ECS communication interface

### 5.3.3 Power distribution

Redundant powers are supplied to HiMSEN DF-LM ECS and provide high availability to operate the engine against single power failure.

Moreover, the power for ESM can be supplied independently to satisfy the requirement for specific applications.

Redundant 220VAC power should be supplied to Uninterrupted Power Supply (UPS).

UPS converts 24VDC power for control and the battery for 30 min. of engine running at diesel mode is installed inside.

Refer to Fig. 5.22 for the concept of power distribution to ECS and specification of UPS.

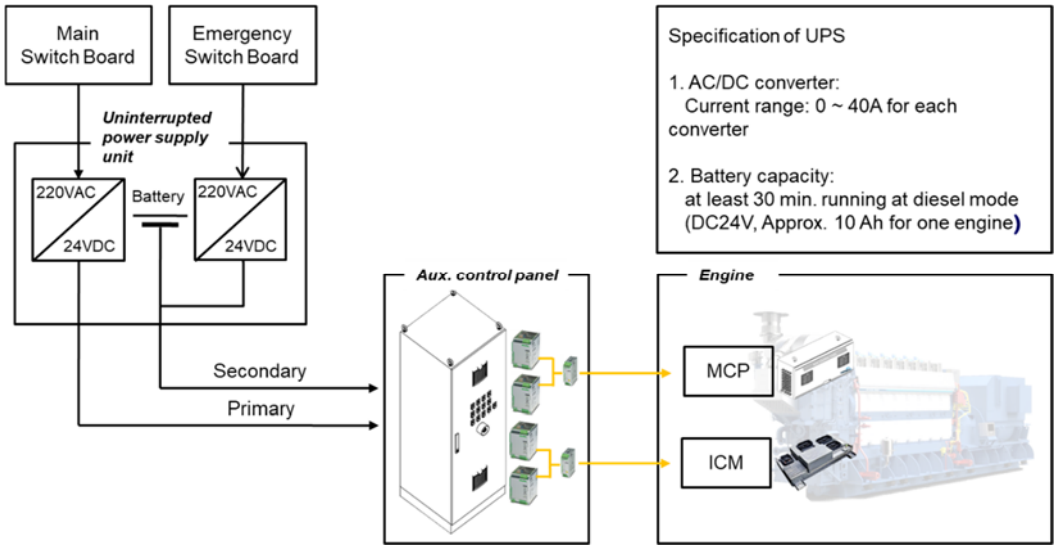



Figure 5.22 HiMSEN DF ECS power distribution

## 5.4 Operation data and alarm points

### Please check the attached drawing for the engine operation data information below :

| Drawing No. | Description |
|---|---|
| BH4-126950-8.1 | Operation data of the engine |

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# 6 Fuel system

## 6.1 Modes of engine operation

### Engine operation mode

Dual fuel engine can be operated by using the diesel oil or methanol as main fuel. The operating mode can be changed without any interruption while engine is running. The fuel mode for the engine can be chosen by operator depending on the condition of vessel or plant. Also if there are any abnormal conditions in methanol mode, the engine is automatically transferred to diesel mode without power de-rating. The engine operating modes are as follows :

- ✓ Methanol mode : Methanol + pilot oil(MDO, MGO)
- ✓ Diesel mode : Heavy fuel oil or marine diesel oil

Both fuels are injected by the main injector which has separate lines for methanol and fuel oil. For fuel oil, main oil and pilot oil also are injected by the main injector through the same lines.

### Methanol mode(Second Fuel mode)

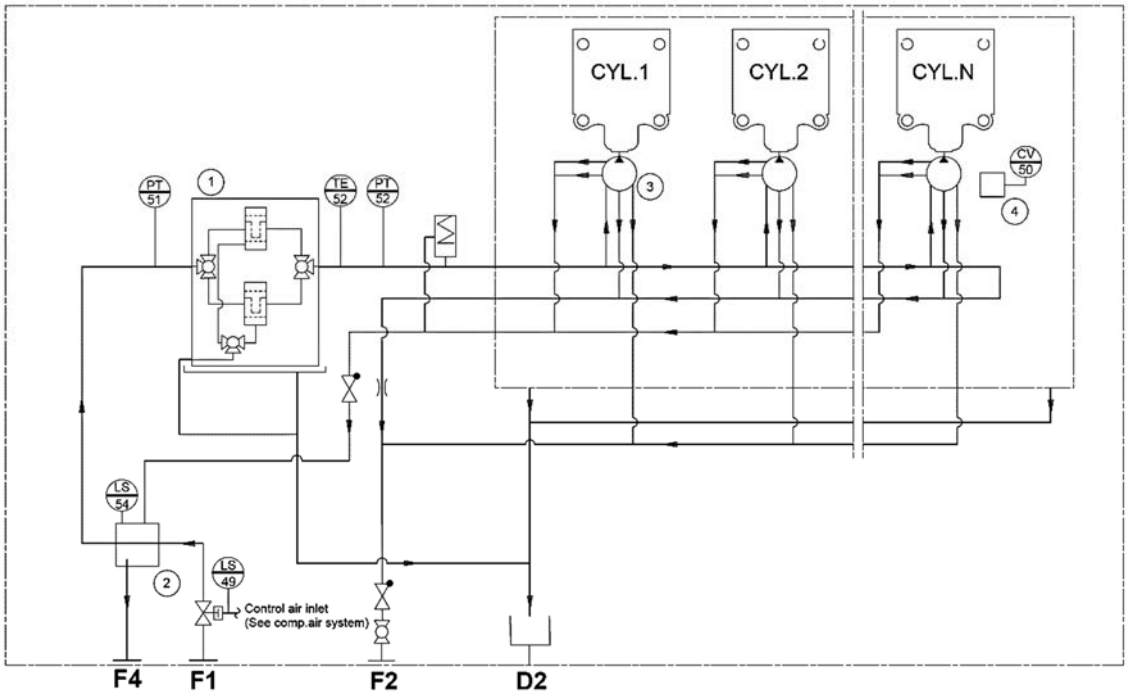
In methanol mode, liquid methanol as main fuel is injected through the main injector which is controlled electrically. The liquid methanol is ignited by pilot oil which is injected by the main injector to the main combustion chamber. The injection timing, the amounts of methanol and / or pilot oil shall be adjusted at each cylinder by the engine control system.

### Diesel mode

In diesel mode, it is same as the conventional diesel engine operation, i.e. heavy fuel oil or marine diesel oil can be used as the main fuel. When the charge air is compressed in the combustion chamber, the liquid oil is injected through the main injector which is controlled electrically.

# 6.2 Internal fuel oil system

## Diagram for Internal fuel oil system




*) Supply scope and instrument will be determined by EOD(Extent of Delivery) and engine builder's standard.

Figure 6.1 Diagram for Internal fuel oil system [BP0068569-0.0]

Table 6.1 Size of external pipe connections

| Code | Description | Size | Remark |
|---|---|---|---|
| F1 | Fuel oil inlet | 25 A | JIS B 2220 |
| F2 | Fuel oil outlet | 25 A | JIS B 2220 |
| F4 | Leaked fuel oil drain (clean) | 15 A | JIS B 2220 |
| D2 | Waste Oil Drain (dirty) | Φ25 | JIS B 2220 |

Table 6.2 System components

| No | Description | Remark |
|---|---|---|
| 1 | Fuel oil filter | 50㎛ |
| 2 | Clean fuel oil leakage alarm tank | |
| 3 | Electronic Fuel injection pump (EFIP) | |

| No | Description | Remark |
|---|---|---|
| 4 | Governor | |

### 6.2.1 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.

The timing and amount of fuel injection is controlled by EFIP which receives the signals from the engine control system.

The clean leak oil from each injection pump, high pressure connection block, etc. is drained and collected to the recycling fuel oil leakage alarm tank. 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.
The total leak rate of fuel oil is 0.30 x $C_f$[1)] liter / cylinder hour (Tolerance ± 50 %). The recycling fuel oil can be led to external tank to be reused.

1) $C_f$ : Heavy fuel oil = 0.5, Marine diesel oil = 1.0, Marine gas oil = 2.0

## 6.3 External fuel oil system

### Diagram for heavy fuel oil system – Normal operation

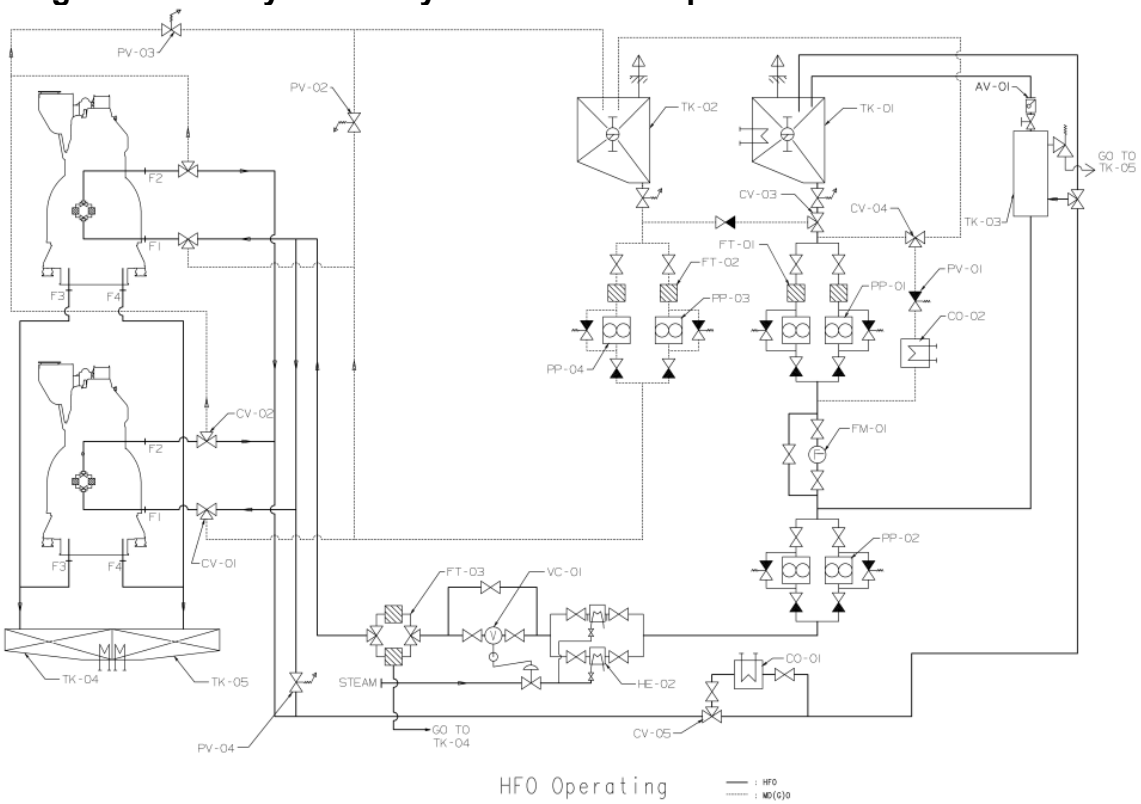



Figure 6.2 Diagram for heavy fuel oil system [B91-328883-6.0]

Table 6.3 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-01 | Day tank, heavy fuel oil | FT-01 | Suction strainer, heavy fuel oil |
| TK-02 | Day tank, marine diesel oil | FT-02 | Suction strainer, marine diesel oil, pilot oil |
| TK-03 | Mixing tank | FT-03 | Automatic filter |
| TK-04 | Drain tank for dirty oil | CO-01 | Marine diesel oil cooler |
| TK-05 | Drain tank for clean oil | CO-02 | Cooler |
| AV-01 | Auto deaerating valve | HE-02 | Heater |
| FM-01 | Flow meter | VC-01 | Viscosity controller |
| PP-01 | Heavy fuel oil supply pump (4 bar) | PV-01 | Pressure control valve |

| Code | Description | Code | Description |
|---|---|---|---|
| PP-02 | Heavy fuel oil booster pump (8 bar at fuel oil inlet, F1) | PV-02 | Marine diesel oil inlet pressure control valve (6 bar) |
| PP-03/04 | Emergency marine diesel oil pump (6 bar) | PV-03 | Marine diesel oil outlet pressure control valve (2 bar) |
| CV-01~05 | Heavy fuel oil, marine diesel oil change over valve | 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.
3. This heavy fuel oil system is only for guidance for generator engines. All external piping design and system arrangement should be designed by shipbuilder in accordance to the classification rules and building specifications.

## Diagram for marine diesel oil (marine gas oil) – Normal operation

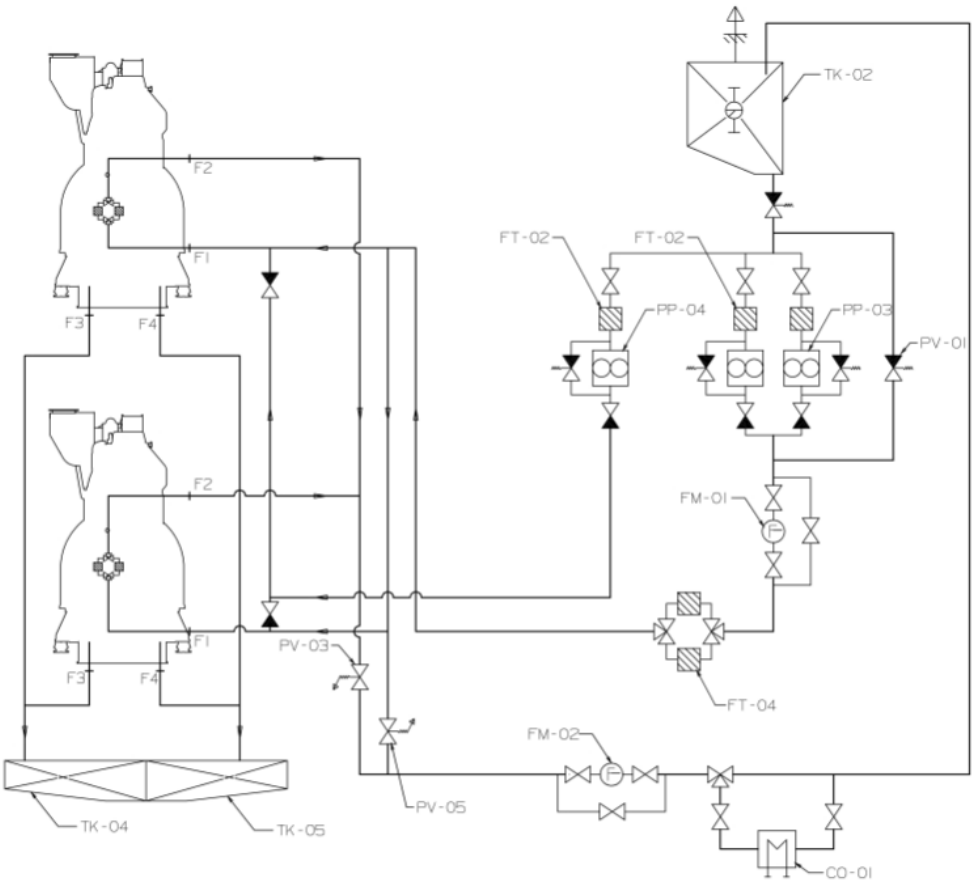



Figure 6.3 Diagram for marine diesel oil (marine gas oil) system [B91-328883-6.1]

Table 6.4 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-02 | Day tank, marine diesel oil | FT-02 | Suction strainer, marine diesel oil |
| TK-04 | Drain tank | FT-04 | Duplex filer |
| TK-05 | Drain tank for clean oil | CO-01 | Marine diesel oil cooler |
| FM-01 | Flow meter | PP-03/04 | Emergency marine diesel oil pump (6 bar) |
| PV-01 | Pressure control valve | PV-03 | Marine diesel oil outlet pressure control valve (2 bar) |
| FM-02 | Flow meter | | |

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.
3. This heavy fuel oil system is only for guidance for generator engines. All external piping design and system arrangement should be designed by shipbuilder in accordance to the classification rules and building specifications

### 6.3.1 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 cases, 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 are described 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, the proper and reliable 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, pressure

The appropriate viscosity, temperature and pressure are necessary. Therefore, preheating, insulation with heat tracing, and pressurizing equipment should be included in the external fuel oil system. Especially if the fuel is at low viscosity, fuel temperature should 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

#### Marine diesel fuel oil

Diesel fuel oil system is necessary to back up (especially for emergency situations) and, it is also used for flushing before engine stop for long period standstill and in the event of major overhaul.

#### External fuel oil system

Normally the external fuel system comprises the fuel treatment system and fuel feed system. General requirements described on next section and more detailed information can be provided if needed for specific vessel or plant.

### Fuel treatment system

The fuel treatment system should be designed for proper cleaning of heavy fuel oil considering total fuel consumption of the vessel. 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 the fuel oil. Normally, the fuel oil grade of H380 to H700 requires the capability of up to 1010 kg/㎥.
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 centrifuge according to supplier's recommendation
- ✓ Correct heavy fuel oil temperature at inlet to centrifuge
  (The centrifuge should be always operated with an inlet temperature of 98 ℃ for heavy fuel oil)
- ✓ Correct throughput of fuel oil through centrifuge

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

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 centrifuge

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.

## 6.3.2 Fuel feed system

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

## Day tank for heavy fuel oil and marine diesel 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.

## Heavy fuel oil / marine diesel oil changeover valve

The heavy fuel oil and marine diesel oil changeover valves should be installed before the supply pump and the cooler for fuel oil outlet respectively. The valve can be a manual type or an electro-pneumatic remote control type for the flexible fuel mode selection at any load conditions.

## 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 (HFO)
- ✓ Operating temperature : 100 ℃
- ✓ Viscosity (for electric motor) : 1000 cSt

## 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.

## 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 tank is to be dimensioned to ensure fuel supply for 10~15 minutes at full load operation, but not less than 50 liters in any case..

## 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.

## 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 (HFO), 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.

## Drain tank for dirty oil

The dirty leak oil from the engine is drained by gravity and collected to the drain tank for dirty oil, where heating coils are required. The drain tank should be transferred to the sludge tank.

## Drain tank for clean oil

The clean leak oil from the engine is drained by gravity and collected to the drain tank for clean oil, in where heating coils are required. It can be pumped to the day tank and reused to the engine without additional separation process.

## Marine diesel oil cooling system

The marine diesel oil cooler or alternative should be applied on the fuel oil return line of engines in order to maintain suitable viscosity of marine diesel oil in continuous marine diesel oil operation.

When changeover from heavy fuel oil to marine diesel oil, the fuel oil return passes through the marine diesel oil cooler or alternative by changeover valve operation.

## 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

In emergency situation such as black out, marine diesel oil must be supplied to start up stand-by engines with a sufficient fuel oil pressure, which can be supplied by emergency booster pump or a gravity tank which is located minimum 8 m above the engine.

## 6.4 Fuel oil specification

The fuel oil specifications are based on ISO 8217 : 2024(en). The fuel is largely classified into two categories as distillate fuel and residual fuel. Distillate fuel 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.

ISO 8217:2024 also specifies the requirements for FAME-based bio-distillate and bio-residual fuels. HiMSEN engines are fully compatible with biofuels that satisfy the specifications set forth in both ISO 8217:2024 and Table 6.12.

The terminologies of marine fuel oil to be called after 1st January 2020 have been determined as below Table 6.5. 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 6.5 allows easy determination if the fuel can be applicable for HiMSEN.

Table 6.5 Designation of fuel grades

<table>
<tr><th colspan="2" rowspan="2">Fuel grade</th><th rowspan="2">Sulfur content (%)</th><th colspan="2">Typical viscosity (cSt) (at 50 ℃ for residual fuels and 40 ℃ for distillate fuels)</th><th rowspan="2">ISO 8217 : 2024(en)</th></tr>
<tr><th>Minimum</th><th>Maximum</th></tr>
<tr><td rowspan="4">HFO (Heavy fuel oil)</td><td>HSFO (High sulfur fuel oil)</td><td>1.0 ＜S ≤ 3.5 (or even higher)</td><td rowspan="2">10</td><td rowspan="2">700</td><td rowspan="2">Residual marine fuels (RMB, RMD, RME, RMG, RMK)</td></tr>
<tr><td>LSFO (Low sulfur fuel oil)</td><td>0.5 ＜S ≤ 1.0</td></tr>
<tr><td>VLSFO (Very low sulfur fuel oil)</td><td>0.1 ＜S ≤ 0.5</td><td colspan="2">2 ~ 380 (Not decided yet)</td><td rowspan="2">Not defined</td></tr>
<tr><td>ULSFO (Ultra low sulfur fuel oil)</td><td>S ≤ 0.1</td><td colspan="2">9 ~ 67 (Not decided yet)</td></tr>
<tr><td colspan="2">MGO (Marine gas oil)</td><td>S ≤ 1.0</td><td>2</td><td>6</td><td>Distilled marine fuels (DMA, DFA, DMZ, DFZ)</td></tr>
<tr><td colspan="2">MDO (Marine diesel oil)</td><td>S ≤ 1.5</td><td>2</td><td>11</td><td>Distillate marine fuels (DMB, DFB) Residual marine fuels (RMA 10)</td></tr>
</table>

Table 6.6 Distillate and bio-distillate marine fuels

| Characteristics | Unit | Limit | Category ISO-F-[m] | | | | | | | Test method (reference) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | DMX | DMA | DFA | DMZ | DFZ | DMB | DFB | |
| General requirements | | | Clauses 5 to 10 | | | | | | | |
| Kinematic viscosity at 40 °C | $mm^2/s$[a] | max. | 5,500 | 6,000 | | | | 11,00 | | ISO 3104 |
| | | min. | 1,400 | 2,000 | | 3,000 | | 2,000 | | |
| Density at 15 °C | $kg/m^3$ | max. | - | 890,0 | | | | 900,0 | | ISO 3675 or ISO 12185; see 6.1 |
| Cetane index | | min. | 45,0 | 40,0 | - | 40,0 | - | 35,0 | - | ISO 4264; see 6.19 |
| Cetane number | | min. | - | - | 40,0 | - | 40,0 | - | 35,0 | ISO 5165 or ASTM D6890/EN 15195 or ASTM D7668/EN 16715 or ASTM D8183/EN 17155; see 6.19 |
| Sulfur content by mass | % | max. | Statutory requirements[b] | | | | | | | ISO 8754 or ISO 14596, ASTM D4294; see 6.3 |
| Flash point | °C | min. | 43,0 | 60,0 | | | | | | ISO 2719; see 6.4 |
| Hydrogen sulfide | mg/kg | max. | 2,00 | | | | | | | IP 570; see 6.5 |
| Acid number[c] | mg KOH/g | max. | 0,5 | | | | | | | ASTM D664; see 6.6 |
| Existent total sediment (TSE) content by mass | % | max. | - | | | | | 0,10[d] | | ISO 10307-1; see 6.8 |
| Oxidation stability | $g/m^3$ | max. | 25 | 25 | - | 25 | - | 25[e] | - | ISO 12205; see 6.7 |
| | h | min. | - | - | 8,0 | - | 8,0 | - | 8,0[e] | EN 15751; see 6.7 |
| Fatty acid methyl ester(FAME) | % | | f | f | Report[g] | f | Report[g] | f | Report[g] | ASTM D7963 or EN 14078/ASTM D7371; see 6.9 |
| Net heat of combustion | MJ/kg | | - | - | Report[h] | - | Report[h] | - | Report[h] | ASTM D240; see 6.18 |
| Carbon residue content by mass – Micro method on the 10 % volume distillation residue | % | max. | 0,30 | | | | | - | | ISO 10370 |
| Carbon residue content by mass – Micro method | % | max. | - | | | | | 0,30 | | ISO 10370 |
| Cloud point[i] | °C | max. | -16 | Report[h] | | | | j | Report[h,j] | ISO 3015; see 6.10 |
| Cold filter plugging point[i] | °C | | - | Report[h] | | | | j | Report[h,j] | EN 116 or EN 16329; see 6.10 |
| Pour point (upper)[i] Winter | °C | max. | - | -6 | | | | 0 | | ISO 3016; see 6.10 |
| Pour point (upper)[i] Summer | °C | max. | - | 0 | | | | 6 | | |
| Appearance | | | Clear and bright[k] | | | | | d | | See 6.11 |
| Water content by volume | % | max. | - | | | | | 0,30[d] | | ISO 3733 |
| Ash content by mass | % | max. | 0,010 | | | | | | | ISO 6245 |
| Lubricity, wear scar diameter (WSD) at 60 °C[l] | µm | max. | 520 | | | | | 520[e] | | ISO 12156-1 |

a) 1 mm2/s = 1 cSt.
b) The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.
c) See Annex E.
d) If the sample is not clear and bright, the existent total sediment and water tests shall be required. See 6.8 and 6.11.
e) If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.
f) See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.
g) The seller shall report the FAME content according to the test method given or as per blend ratio (stating whether it is a mass or volume ratio).
h) The value shall be reported according to the test method given.
i) Pour point cannot guarantee operability for all ships in all climates. The buyer should confirm that the cold flow characteristics (pour point, cloud point, cold filter plugging point) are suitable for the ship's design and intended voyage. See 6.10.
j) For some products, it is possible that this test does not work due to appearance, therefore other means to evaluate usability of the product should be considered.
k) If the sample is dyed and not transparent, then the water limit and test method as given in 6.11 shall apply.
L) This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0,050 % by mass).
M) These categories are defined in ISO 8216-1.

Table 6.7 Residual marine fuels with sulfur content below or at 0,50 % by mass

| Characteristics | Units | Limit | Category ISO-F[j] | | | | Test method (reference) |
|---|---|---|---|---|---|---|---|
| | | | RMA | RME | RMG | RMK | |
| | | | 20-0,5 | 180-0,5 | 380-0,5 | 500-0,5 | |
| | | | 20-0,1 | 180-0,1 | 380-0,1 | 500-0,1 | |
| General requirements | | | Clauses 5 to 10 | | | | |
| Kinematic viscosity at 50 °C[a] | $mm^2/s$[b] | max. | 20,00 | 180,0 | 380,0 | 500,0 | ISO 3104 |
| | | min. | 2,000[c] | 20,00 | 120,0 | 150,0 | |
| Density at 15 °C | $kg/m^3$ | max. | 955,0 | 991,0 | | 1010,0 | ISO 3675 or ISO 12185; see 6.1 |
| CCAI | | max. | 860 | 870 | | | See 6.2 |
| Sulfur content by mass | % | max. | 0,50 or statutory requirement, whichever is lower[d] | | | | ISO 8754 or ISO 14596 or ASTM D4294; see 6.3 |
| Flash point | °C | min. | 60,0 | | | | ISO 2719; see 6.4 |
| Hydrogen sulfide | mg/kg | max. | 2,00 | | | | IP 570; see 6.5 |
| Acid number[e] | mg KOH/g | max. | 2,5 | | | | ASTM D664; see 6.6 |
| Carbon residue content by mass – Micro method | % | max. | 10,00 | 15,00 | 18,00 | 20,00 | ISO 10370 |
| Pour point (upper)[f] | °C | max. | 6 | 30 | | | ISO 3016 |
| Water content by volume | % | max. | 0,30 | 0,50 | | | ISO 3733 |
| Ash content by mass | % | max. | 0,070 | 0,100 | | 0,150 | ISO 6245 |
| Vanadium | mg/kg | max. | 150 | 350 | | 450 | IP 501, IP 470 or ISO 14597; see 6.13 |
| Sodium | mg/kg | max. | 50 | 100 | | | IP 501, IP 470; see 6.14 |
| Aluminium plus silicon | mg/kg | max. | 40 | 60 | | | IP 501, IP 470 or ISO 10478; see 6.15 |
| Unrefined used lubricating oil (ULO) present: Calcium and zinc or Calcium and phosphorus | mg/kg | | Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15 | | | | IP 501 or IP 470, IP 500; see 6.16 |
| Potential total sediment content by mass (TSP) | % | max. | 0,10[g] | | | | ISO 10307-2, Procedure A; see 6.8 |
| Accelerated total sediment content by mass (TSA) | % | | Report[h] | | | | ISO 10307-2, Procedure B; see 6.8 |
| Existent total sediment content by mass (TSE) | % | | Report[h] | | | | ISO 10307-1; see 6.8 |
| Fatty acid methyl ester (FAME) content by mass or volume | % | | i | | | | ASTM D7963; see 6.9 |

a) Actual viscosity to be reported to the ship. For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.
b) 1 mm2/s = 1 cSt.
c) For fuels with viscosity in the range of 2 mm2/s to 5 mm2/s (2 cSt to 5 cSt), the minimum viscosity requirement of the engine should be checked against the original equipment manufacturers' recommendations.
d) The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.
e) See Annex E.
f) The buyer should confirm that this pour point is suitable for the ship's intended area of operation.
g) This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.
h) The value shall be reported in accordance with the test method given.
i) See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.
j) These categories are defined in ISO 8216-1.

Table 6.8 Bio-residual marine fuels

| Characteristics | Units | Limit | Category ISO-F[j] | | | | | Test method (reference) |
|---|---|---|---|---|---|---|---|---|
| | | | RF20 | RF80 | RF180 | RF380 | RF500 | |
| General requirements | | | Clauses 5 to 10 | | | | | |
| Kinematic viscosity at 50 °C[a] | $mm^2/s$ [b] | max. | 20,00 | 80,00 | 180,0 | 380,0 | 500,0 | ISO 3104 |
| | | min. | 2,000[c] | 20,00 | 80,00 | 120,0 | 380,0 | |
| Density at 15 °C | $kg/m^3$ | max. | 955,0 | 991,0 | | | 1010,0 | ISO 3675 or ISO 12185; see 6.1 |
| CCAI | | max. | 860 | 870 | | | | See 6.2 |
| Sulfur content by mass | % | | Statutory requirements[d] | | | | | ISO 8754 or ISO 14596 or ASTM D4294; see 6.3 |
| Flash point | °C | min. | 60,0 | | | | | ISO 2719; see 6.4 |
| Hydrogen sulfide | mg/kg | max. | 2,00 | | | | | IP 570; see 6.5 |
| Acid number[e] | mg KOH/g | max. | 2,5 | | | | | ASTM D664; see 6.6 |
| Carbon residue content by mass – Micro method | % | max. | 10,00 | 15,00 | | 18,00 | 20,00 | ISO 10370 |
| Pour point (upper)[f] | °C | max. | 6 | 30 | | | | ISO 3016 |
| Water content by volume | % | max. | 0,30 | 0,50 | | | | ISO 3733 |
| Ash content by mass | % | max. | 0,070 | 0,100 | | | 0,150 | ISO 6245 |
| Vanadium | mg/kg | max. | 150 | 350 | | | 450 | IP 501, IP 470 or ISO 14597; see 6.13 |
| Sodium | mg/kg | max. | 50 | 100 | | | | IP 501, IP 470; see 6.14 |
| Aluminium plus silicon | mg/kg | max. | 40 | 60 | | | | IP 501, IP 470 or ISO 10478; see 6.15 |
| Unrefined used lubricating oil (ULO) present: Calcium and zinc or Calcium and phosphorus | mg/kg | | Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15 | | | | | IP 501 or IP 470, IP 500; see 6.16 |
| Potential total sediment content by mass (TSP) | % | max. | 0,10[g] | | | | | ISO 10307-2 Procedure A; see 6.8 |
| Accelerated total sediment content by mass (TSA) | % | | Report[h] | | | | | ISO 10307-2 Procedure B; see 6.8 |
| Existent total sediment content by mass (TSE) | % | | Report[h] | | | | | ISO 10307-1; see 6.8 |
| FAME content by mass | % | | Report[i] | | | | | ASTM D7963 or IP 631; see 6.9 |
| Net heat of combustion | MJ/kg | | Report[h] | | | | | ASTM D240; see 6.18 |

a) Actual viscosity to be reported to the ship. For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.
b) 1 mm2/s = 1 cSt.
c) For fuels with viscosity in the range of 2 mm2/s to 5 mm2/s (2 cSt to 5 cSt), the minimum viscosity requirement of the engine should be checked against the original equipment manufacturers' recommendations.
d) The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.
e) See Annex E.
f) The buyer should confirm that this pour point is suitable for the ship's intended area of operation.
g) This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.
h) The value shall be reported in accordance with the test method given.
i) The seller shall report the FAME content in accordance with the test method given or as per blend ratio (stating whether it is a mass or volume ratio).
j) These categories are defined in ISO 8216-1.

Table 6.9 Residual marine fuels with sulfur content above 0,50 % by mass

| Characteristics | Unit | Limit | Category ISO-F-j | | | | | Test method (reference) |
|---|---|---|---|---|---|---|---|---|
| | | | RME | RMG | RMG | RMK | RMK | |
| | | | 180H | 180H | 380H | 500H | 700H | |
| General requirements | | | Clauses 5 to 10 | | | | | |
| Kinematic viscosity at 50 °C[a] | $mm^2/s$[b] | max. | 180,0 | 180,0 | 380,0 | 500,0 | 700,0 | ISO 3104 |
| | | min. | 20,00[c] | 20,00[c] | 120,0 | 150,0 | | |
| Density at 15 °C | $kg/m^3$ | max. | 991,0 | | | 1010,0 | | ISO 3675 or ISO 12185; see 6.1 |
| CCAI[d] | | max. | 860 | 870 | | | | See 6.2 |
| Sulfur content by mass | % | max. | Statutory requirements[e] | | | | | ISO 8754 or ISO 14596 or ASTM D4294; see 6.3 |
| Flash point | °C | min. | 60 | | | | | ISO 2719; see 6.4 |
| Hydrogen sulfide | mg/kg | max. | 2,00 | | | | | IP 570; see 6.5 |
| Acid number[f] | mg KOH/g | max. | 2,5 | | | | | ASTM D664; see 6.6 |
| Accelerated or potential total sediment content by mass | % | max. | 0,10[g] | | | | | ISO 10307-2; see 6.8.2 |
| Carbon residue content by mass – Micro method | % | max. | 15,00 | 18,00 | | 20,00 | | ISO 10370 |
| Pour point (upper)[h] | °C | max. | 30 | | | | | ISO 3016 |
| Water content by volume | % | max. | 0,50 | | | | | ISO 3733 |
| Ash content by mass | % | max. | 0,070 | 0,100 | | 0,150 | | ISO 6245 |
| Vanadium | mg/kg | max. | 150 | 350 | | 450 | | IP 501, IP 470 or ISO 14597; see 6.13 |
| Sodium | mg/kg | max. | 50 | 100 | | | | IP 501 or IP 470; see 6.14 |
| Aluminium plus silicon | mg/kg | max. | 50 | 60 | | | | IP 501, IP 470 or ISO 10478; see 6.15 |
| Unrefined used lubricating oil (ULO) present: Calcium and zinc or Calcium and phosphorus | mg/kg | | Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15 | | | | | IP 501 or IP 470, IP 500; see 6.16 |
| Fatty acid methyl ester (FAME) content by mass or volume | % | | i | | | | | ASTM D7963; see 6.9 |

a) For fuels with high pour point, the viscosity can be calculated provided that the kinematic viscosities at two temperatures are known.
b) 1 mm2/s = 1 cSt.
c) Fuels with viscosity below 20,00 mm2/s (20,00 cSt) can be agreed between seller and buyer. It is recommended to check the minimum viscosity requirement with the original equipment manufacturer recommendations.
d) See Annex C.
e) The buyer is expected to define the maximum sulfur content according to relevant statutory limitations.
f) See Annex E.
g) This limit applies to 10 g of test specimen only. Failure to complete filtration of 10 g within 25 min means the fuel does not meet the specification. In such case and for information only, 5 g filtration results can be reported according to the test method.
h) The buyer should confirm that this pour point is suitable for the ship's intended area of operation.
i) See 5.1 and Annex A. De minimis level amount of FAME means an amount not exceeding approximately 0,5 %.
j) These categories are defined in ISO 8216-1.

## Biofuels

Biofuels are largely classified into 3 categories as transesterified biofuels(biodiesel), bio-blends and others. (Classify biofuels with or without International standard)

- ✓ Transesterified Biofuels (International standards EN 14214 or ASTM D 6751-19)
  ex) Biodiesel (Fatty Acid Methyl Ester – FAME)
- ✓ HVO (Hydrotreated Vegetable Oil) (International standards EN 15940, Paraffinic Diesel Fuel from Hydrotreatment)
- ✓ Bio-blends (Mixture of Biofuels and Fossil fuels)
- ✓ Other biofuels
  ex) Crude biofuels (Palm oils, Vegetable oil, Animal fat), Refined biofuels, etc.

HiMSEN is able to operate continuously with biofuels specified in the below Table 6.10 and Table 6.11

- ✓ When using biofuels included in quality standards Table 6.10 and Table 6.11, you need to get confirmation from HiMSEN.

## Biodiesel / Fatty Acid Methyl Ester (FAME)

Biodiesel (FAME) is derived from Crude biofuels by using transesterification processes. It can be used alone or blended with petro-diesel in any proportions.

International standards EN 14214 or ASTM D 6751-19 are commonly used to specify the quality of biodiesel. (See the Table 6.10)

Table 6.10 Specifications of biodiesel(FAME)

| Characteristics b) | Unit | Min. limit | Max. limit | Test method reference |
|---|---|---|---|---|
| FAME content | % (m/m) | 96.5 | - | EN 14103 |
| Density at 15°C | kg/m³ | 860 | 900 | EN ISO 3675 / EN ISO 12185 |
| Viscosity at 40°C | mm²/s | 3.5 | 5.0 | EN ISO 3104 / EN 14105 |
| Cold filter plugging point(CFPP) | °C | - | a) | EN 116 |
| Flash point | °C | 101 | - | EN ISO 2719 / EN ISO 3679 |
| Sulfur content | mg/kg | - | 10 | EN ISO 20846 / EN ISO 20884 |
| Cetane number | - | 51.0 | - | EN ISO 5165 |
| Sulfated ash content | % (m/m) | - | 0.02 | ISO 3987 |
| Water content | mg/kg | - | 500 | EN ISO 12937 |
| Total contamination | mg/kg | - | 24 | EN 12662 |

| Characteristics b) | Unit | Min. limit | Max. limit | Test method reference |
|---|---|---|---|---|
| Copper strip corrosion (3 hours at 50 °C) | rating | **1b(Class1)** | 1a | EN ISO 2160 |
| Oxidation stability, 110°C | hours | 8 | - | EN 14112 |
| Total Acid Number (TAN) | mg KOH/g | - | 0.5 | EN 14104 |
| Iodine value | - | - | 120 | EN 14111 |
| Linolenic Acid Methylester | % (m/m) | - | 12 | EN 14103 |
| Polyunsaturated (>= 4 Double bonds) Methylester | % (m/m) | - | 1 | EN 14103 |
| Methanol content | % (m/m) | - | 0.2 | EN 14110 |
| Monoglyceride content | % (m/m) | - | 0.7 | EN 14105 |
| Diglyceride content | % (m/m) | - | 0.2 | EN 14105 |
| Triglyceride content | % (m/m) | - | 0.2 | EN 14105 |
| Free Glycerine | % (m/m) | - | 0.02 | EN 14105 / EN 14106 |
| Total Glycerine | % (m/m) | - | 0.25 | EN 14105 |
| Group I metals (Na+K) | mg/kg | - | 5 | EN 14108 / EN 14109 / EN 14538 |
| Group II metals (Ca+Mg) | mg/kg | - | 5 | EN 14538 |
| Phosphorus content | mg/kg | - | 4 | EN14107 |

a) The temperatures related to filterability have to be at least 10~15℃ above the minimum fuel oil temperature (maximum temperature among cloud point, pour point, CFPP, and LTFT) in the whole fuel treatment process, even during engine stop unless flushing using pure diesel oil were performed before engine stop.

b) The information of storage and deterioration of Biodiesel regarding EN14214 should be discussed/checked by fuel oil supplier before biodiesel is applied to engine.

## Hydrotreated Vegetable Oil (HVO)

The EN 15940:2016 + A1:2018 + AC:2019 standard covers hydrotreated paraffinic renewable diesel fuel and synthetic Fischer-Tropsch products GTL, BTL and Coal-to-Liquid (CTL).
Since HVO consists of paraffinic hydrocarbons, it cannot meet the requirements set by EN 14214:2013+ A2:2019, which is a standard developed and valid only for methyl ester chemistry type biodiesel, namely FAME. As a matter of fact, HVO meets EN 590, except the requirement for minimum density. International standards EN 15940 are commonly used to specify the quality of HVO. (See the Table 6.11)

Table 6.11 Specifications of HVO(EN15940)

| Characteristics | Unit | Min. limit | Max. limit | Test method reference |
|---|---|---|---|---|
| FAME content | % (v/v) | - | 7.0 | EN 14103 |
| Density at 15°C | kg/m³ | 765 | 800 | ISO 3675 / ISO 12185 |
| Total aromatics | % (m/m) | - | 1.1 | EN 12916 |
| Kinematic viscosity at 40°C | mm²/s | 2.0 | 4.5 | ISO 3104 / EN 14105 |
| Cold filter plugging point(CFPP) | °C | - | a) | EN 116 |
| Flash point | °C | 55.0 | - | ISO 2719 |
| Sulfur content | mg/kg | - | 5 | ISO 20846 / ISO 20884 |
| Cetane number | - | 70 | - | ISO 5165 / EN 15195 |
| Sulfated ash content | % (m/m) | - | 0.01 | ISO 3987 |
| Water content | % (m/m) | - | 0.020 | ISO 12937 |
| Total contamination | mg/kg | - | 24 | EN 12662 |
| Copper strip corrosion (3 hours at 50 °C) | rating | - | Class 1 | ISO 2160 |
| Oxidation stability | hours | 20 | - | EN 14112 |
| Oxidation stability | g/m3 | - | 25 | EN 14112 |
| Carbon residue : on the 10% volume distillation residue | mass % | - | 0.30 | ISO 10370 |
| Ash | % (m/m) | - | 0.010 | ISO 6245 |
| Lubricity HFRR at 60°C | µm | - | 460 | EN 12156-1 |
| Evaporated at 250°C | % (v/v) | - | 65 | ISO 3405 |
| Evaporated at 350°C | % (v/v) | - | 85 | ISO 3405 |
| Distillation 95% (v/v) | °C | - | 360.0 | ISO 3924 |

a) The temperatures related to filterability have to be at least 10~15℃ above the minimum fuel oil temperature (maximum temperature among cloud point, pour point, CFPP, and LTFT) in the whole fuel treatment process, even during engine stop unless flushing using pure diesel oil were performed before engine stop.

## Bio-blends

Bio-blends are mixture of biofuels and fossil fuels.
The volume ratio of the biofuel in the bio-blends are referred to as follows.

- ✓ B##, BD## (## : the volume ratio of the biofuel in the bio-blends)
  ex) BD20 = Biodiesel 20% + Distillate marine fuels 80%
  (In the case of Biodiesel mixture, it is specially referred to as BD##)
  B20 = Biofuel 20% + Fossil fuel 80%
  (Except for Biodiesel mixture, the other bio-blends are referred to as B##)

The quality standards of biodiesel-blends(BD##) are referred to the Table 6.10 and the bio-blends(B##) except for biodiesel-blends(BD##) are referred to the Table 6.12.

## General biofuels

The quality standards of general liquid biofuels except biodiesel(FAME) are as shown below Table 6.12.(General biofuels include a wide range of specifications. In order to reduce confusion when applying biofuel standards, HiMSEN set the integrated standard with the Table 6.12.)
Only biofuels that meet EN14214 or EN15940 can be applied to Micro-Pilot (MP) injector. The information of storage and deterioration of biofuels should be discussed/checked by fuel oil supplier before the biofuel is applied to engine.

Table 6.12 Specifications of general biofuel, bio-blends.

| Characteristics | Unit | Min. limit | Max. limit | Test method reference |
|---|---|---|---|---|
| Viscosity before injection pumps | cSt | 2 | 18 | ISO 3104 |
| Kinematic viscosity at 50℃ | mm²/s | - | 700 | |
| Density at 15℃ | kg/m³ | - | 1010 | ISO 3675 / ISO 12185 |
| Sulfur | mass % | Statutory requirements | | ISO 8754 / ISO 14596 / ASTM D4294 |
| Flash point | ℃ | 60 | - | ISO 2719 |
| Cloud point | ℃ | - | a) | ISO 3015 |
| Cold filter plugging point (CFPP) | ℃ | - | a) | IP 309 |
| Pour point | ℃ | - | a) | ISO 3016 |
| Total sediment by hot filtration | mass % | - | 0.1 | ISO 10307-1 |
| Total sediment aged | mass % | - | 0.1 | ISO 10307-2 |

| Characteristics | Unit | Min. limit | Max. limit | Test method reference |
|---|---|---|---|---|
| Ash | mass % | - | 0.15 | ISO 6245 |
| Carbon residue (a) : micro method on the 10% volume distillation residue | mass % | - | 0.3 | ISO 10370 |
| Carbon residue (b) : micro method | mass % | - | 20 | ISO 10370 |
| Asphaltenes | mass % | - | 8 | - |
| Water | vol % | - | 0.5 | ISO 3733 |
| Total Acid number (TAN) | mg KOH/g | - | 2.5 b) | ASTM D664 |
| Strong acid number | mg KOH/g | - | 0 | ASTM D664 |
| Oxidation stability | g/m³ | - | 25 | ISO 12205 |
| Hydrogen sulfide | mg/kg | - | 2 | IP 570 |
| Copper strip corrosion (3h at 50℃) | Rating | 1b | 1a | ASTM D130 |
| Lubricity, corrected wear scar diameter | μm | - | 520 | ISO 12156-1 |
| Vanadium | mg/kg | - | 450 | IP 501 / IP 470 / ISO 14597 |
| Sodium | mg/kg | - | 100 | IP 501 / IP 470 |
| Aluminium + Silicon | mg/kg | - | 60 c) | IP 501 / IP 470 / ISO 10478 |
| Used lubricating oils (ULO): | - | - | - | IP 501 / IP 470 / IP 500 |
| - Calcium (Ca) | mg/kg | 30 | - | |
| - Zinc (Zn) | mg/kg | 15 | - | |
| - Phosphorus (P) | mg/kg | 15 d) | - | |
| Cetane number | - | 51 | - | ISO 4264 |
| Alkali content (Na+K) | mg/kg | - | 100 | EN 14108 / EN 14109 / 14538 |
| Alkali content (Ca+Mg) | mg/kg | - | 30 | EN 14538 |
| Lead (Pb) content | mg/kg | - | 10 | ASTM D 5059 |
| Steel corrosion (24/72h at 20, 60, 120degC) | rating | No signs of corrosion | | LP 2902 |

| Characteristics | Unit | Min. limit | Max. limit | Test method reference |
|---|---|---|---|---|
| Iodine number | g I/100g | - | 120 | ISO 3961 |
| Oxidation stability | h | 17 | - | EN 14112 |
| Synthetic polymers | %m | - | 0 | LP 2501 |
| Lower calorific value | MJ/kg | 35 | - | DIN 51900-3 |

a) The temperatures related to filterability have to be at least 10~15℃ above the minimum fuel oil temperature (maximum temperature among cloud point, pour point, CFPP, and LTFT) in the whole fuel treatment process, even during engine stop unless flushing using pure diesel oil were performed before engine stop.

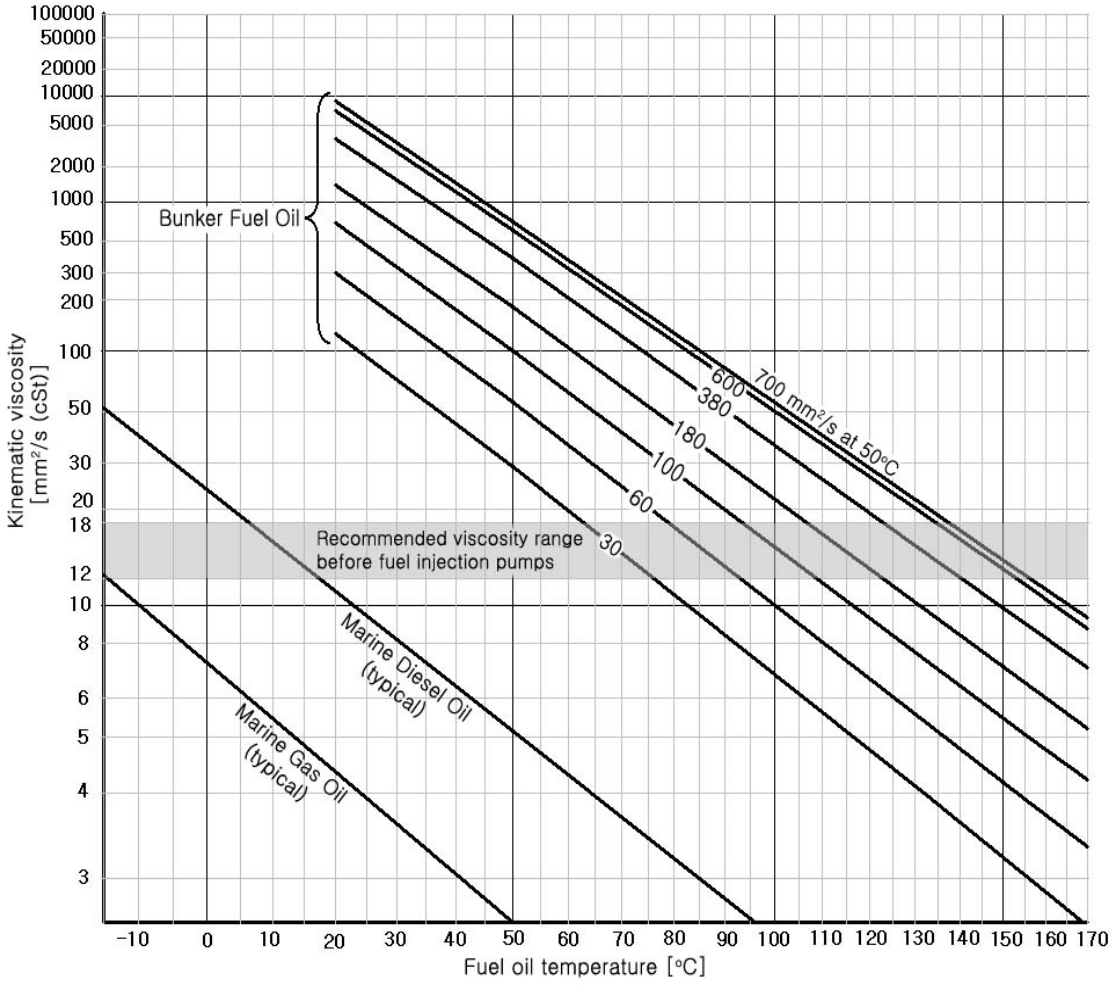
b) It is required the agreement of FIP maker and HHI if the total acid number is more than 2.5 mg KOH/g.

c) Aluminium and Silicon contents shall be less than 10 ppm at engine inlet although those contents is required less than 60 mg/kg in fuel oil.

d) It is required the agreement of SCR maker if the project is required the SCR with engine.

## 6.5 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 6.4 Diagram for fuel oil viscosity

# 6.6 Fuel oil quality

## 6.6.1 Fuel characteristics

### Viscosity

The viscosity of fuel oil to the engine should be kept within the value of 12 ~ 18 cSt for HFO and 3 ~ 14 cSt for MDO / MGO, 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.

## 6.6.2 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,

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

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

Where :

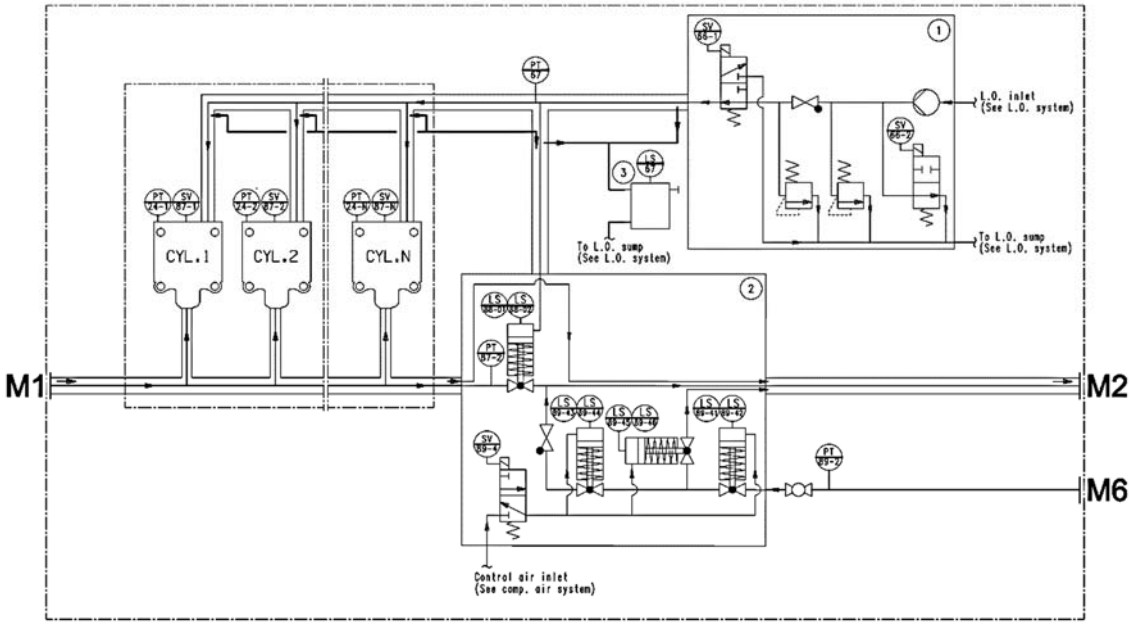
N (MJ/kg) = Net specific energy
G (MJ/kg) = Gross specific energy
ρ (kg/m$^3$) = Density at 15℃
w (mass %) = Water content
a (mass %) = Ash content
s (mass %) = Sulfur content

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.

# 6.7 Internal methanol system

## Diagram for Internal fuel methanol system




*) Supply scope and instrument will be determined by EOD(Extent of Delivery) and engine builder's standard.

Figure 6.5 Diagram for internal methanol system [B92-128968-5.0]

Table 6.8 External pipe connection size

| Code. | Description | Size |
|---|---|---|
| M1 | Methanol inlet (double wall) | Special flange |
| M2 | Methanol outlet | Special flange |
| M6 | Inert gas inlet | 10K-25A |

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

Table 6.9 System components

| No | Description | Remark |
|---|---|---|
| 1 | C&S oil supply pump unit | |
| 2 | SVU (Safety valve unit) | |
| 3 | Leakage alarm tank | |

### 6.7.1 General description

In methanol mode, liquid methanol as main fuel is injected through the main injector which is controlled electrically. The liquid methanol is ignited by pilot oil which is injected by the main injector to the main combustion chamber. The injection timing, the amounts of methanol and / or pilot oil shall be adjusted at each cylinder by the engine control system.

When changing over from methanol to diesel, all of methanol in double wall pipes purge out to the service tank with inert gas (nitrogen), which is supplied via FVT(Fuel valve train).

The methanol pipes on the engine are made of double walled structure. The annular intermediate space of double walled pipes shall be continuously ventilated under the negative pressure by the ventilation fan.

#### Fuel injection valve

Liquid methanol is injected by fuel injection valves (the main injector) into the combustion chamber with suitable timing and duration. To regulate the power and speed of the engine, the amount of methanol fed into each cylinder is individually controlled by the main injector which receive the signals from engine control system

#### Safety valve unit

The safety valve unit is located after the last cylinder in the methanol pipe. It has several roles as follow :

- ✓ It blocks the methanol pipe after filling the methanol pipe with methanol in order to make pressure (high pressure) of methanol to the certain level for methanol mode operation.
- ✓ It relieves methanol pressure when the pressure exceeds the normal operation ranges.
- ✓ It purges residual methanol in the purging pipe (from engine outlet to the service tank) out to the service tank by inert gas.

#### Lub. Oil high pressure pump and pipes for control/sealing

Lub. Oil high pressure pump and pipes are applied for methanol injection. They are used for as follow :

- ✓ Hydraulic system of the main injector with solenoid valve to inject methanol properly.
- ✓ Sealing methanol from the main injector to other internal system of engine for safety (The pressure of Lub. Oil should be over than the pressure of methanol.)

## 6.8 External methanol system

**For diagram for external fuel methanol system and related information, refer to the specification :**

| Drawing No. | Description |
|---|---|
| BH4-097895-5 | Installation specification |
| BH4-097894-3 | General information for LFSS |
| BH4-097898-0 | Methanol specification |
| BH2-115770-3 | Methanol supply system |
| BH2-107335-7 | External ventilation system |
| BH4-097896-7 | Inner/Outer pipe |
| BH4-097897-9 | Inert gas |
| BH4-113214-8 | Fuel valve train |
| BH4 -097913-2 | Methanol high pressure pump |

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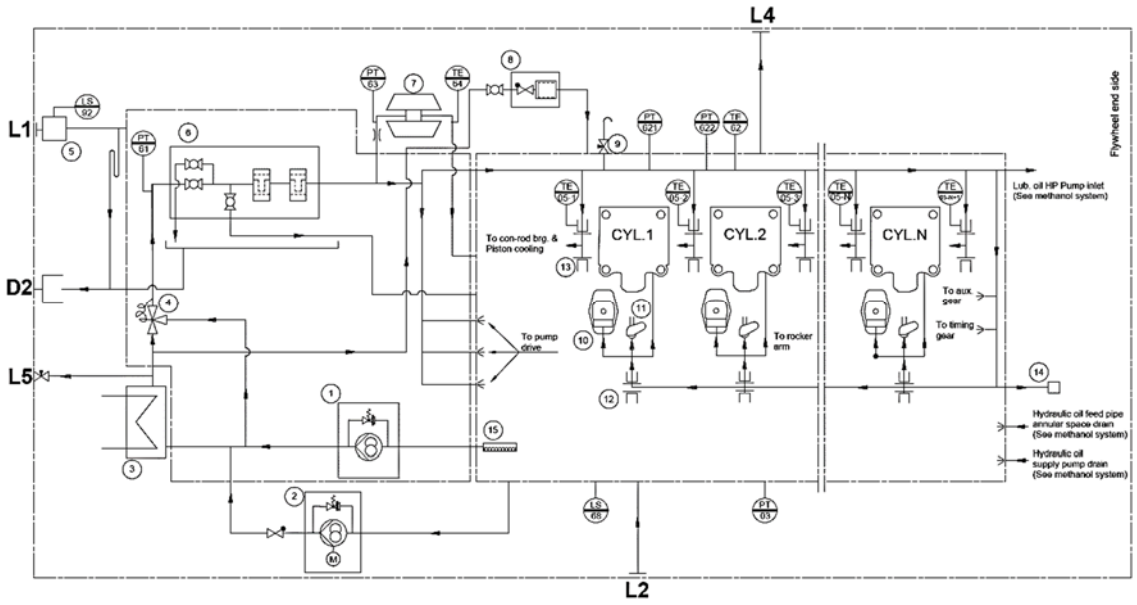
# 7 Lubricating oil system

## 7.1 Internal lubricating oil system

### Diagram for Internal lubricating oil system




*) Supply scope and instrument will be determined by EOD(Extent of Delivery) and engine builder's standard.

Figure 7.1 Diagram for internal lubricating oil system [BP0068710-0.2]

Table 7.1 Sizes of external pipe connections

| Code | Description | Size |
|---|---|---|
| L1 | Lubricating oil vapor discharger | 125A |
| L2 | Lubricating oil from separator | 50A |
| L4 | Lubricating oil to separator | 50A |
| L5 | C.W. auto shut off valve | PF1/4 |
| D2 | Oil drain | Ø25 |

1. Connection size is according to JIS B 2220.

Table 7.2 System components

| No | Description | Remark |
|---|---|---|
| 1 | Eng. Driven lub oil pump | |
| 2 | Ele. Motor driven pre-lub oil pump | |

| No | Description | Remark |
|---|---|---|
| 3 | Lub oil cooler | |
| 4 | Lub oil thermostatic valve | 60/69℃ |
| 5 | Oil mist detector | |
| 6 | Lub oil fine filter | 1st : 15㎛, 2nd : 60㎛<br>Chamber : 3EA |
| 7 | Turbocharger | |
| 8 | Centrifugal by-pass filter | |
| 9 | Lub oil sampling valve | |
| 10 | Fuel pump drive | |
| 11 | Valve drive | |
| 12 | Cam shaft bearing | |
| 13 | Main bearing | |
| 14 | Hydraulic oil supply pump drive | |
| 15 | Suction mesh | |

### 7.1.1 General description

The engine has its own internal lubricating oil system with the wet type oil sump, which supplies lubricating oil to all moving parts for lubricating as well as cooling.
Most of oil passages are incorporated into engine components and equipment in the system, which are mounted directly on feed module without pipe connections.

The internal lubricating oil system comprises following equipment :

- ✓ Lubricating oil cooler
- ✓ Engine driven lubricating oil pump (with pressure regulating valve)
- ✓ Electric motor driven pre-lubricating pump
- ✓ Lubricating oil thermostatic valve
- ✓ Lubricating oil filter
- ✓ Wet sump tank
- ✓ Centrifugal oil filter
- ✓ Oil mist detector

## Quantity of lubricating oil (wet sump)

Table 7.3 Total quantity of lubricating oil inside the engine

| Engine type | Oil quantities in liter 720/750rpm | |
|---|---|---|
| | Min. | Max. |
| 6H32DF-LM | 1,900 | 2,450 |
| 7H32DF-LM | 2,080 | 2,710 |
| 8H32DF-LM | 2,460 | 3,160 |
| 9H32DF-LM | 2,730 | 3,520 |

## Lubricating oil consumption

Methanol mode : 0.5 g / kWh + 1.1 liter / 24hrs per cylinder
Diesel mode : 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 feed module of 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 feed module of 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 feed module of 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 feed module of 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

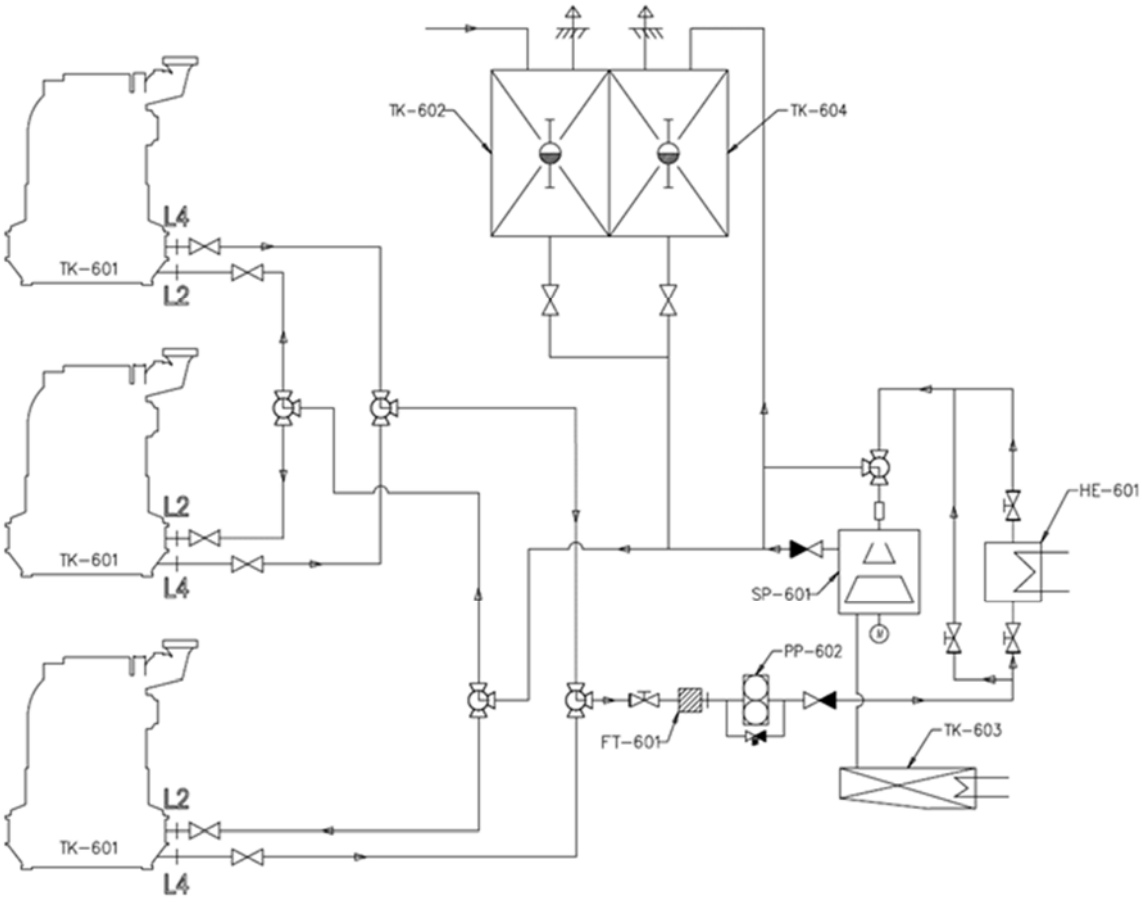



Figure 7.2 Diagram for external lubricating oil system (B91-314112-7.1)

Table 7.4 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 with natural gas or marine gas 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 / natural gas, 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 :

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

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

$$V = F / B \text{ (l / h)}$$

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.

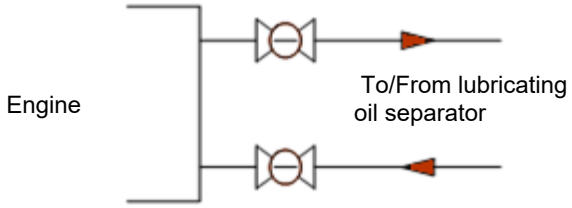



Figure 7.3 Principle layout for direct separating on single engine.

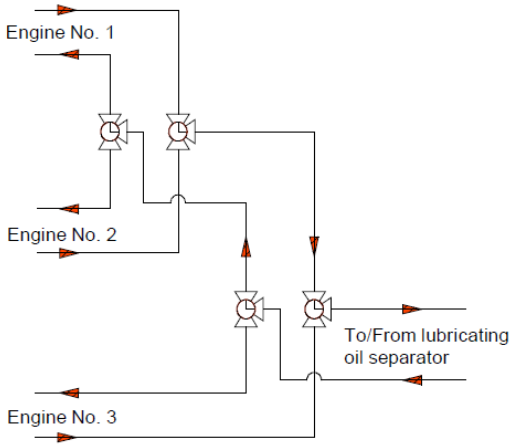



Figure 7.4 Principle layout for direct separating on multi engines

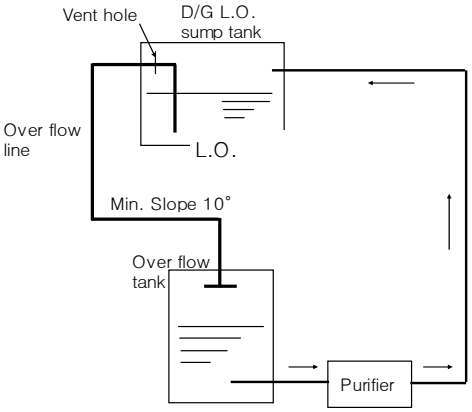



Figure 7.5 Principle layout for overflow system

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 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 a safe location outside of engine room distant from any source of ignition. 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 125 A, and the vent pipe size after the flexible connection must be min. 125 A.
- ✓ The oil mist should not be go into suction side of intake duct located outside (for outdoor type) or engine room (for indoor type)

## 7.3 Lubricating oil specification and list of lubricants

### 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 7.7

### 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.

DF engines can be operated using methanol, distillate fuel and residual fuel, and these fuels have different sulfur level.

For the recommendation considering the lubricating oil BN, please refer to the following table. If DF engines are operated in turn on three fuels with methanol as main fuel and distillate / residual fuel as auxiliary fuel, limitations of auxiliary fuel should be followed based on residual fuel.

Refer to the 6 or specification of fuel oil and methanol.

Table 7.5 Recommended BN for DF-LM engine operation cases

| Aux. fuel \ Main fuel | | | Methanol |
|---|---|---|---|
| | | | No sulfur |
| Methanol | | No sulfur | BN 3 ~ 7 |
| Distillated fuel (MGO / MDO) | | - 0.1% S | BN 3 ~ 15<br>Limit 1 on Table 7.5 |
| | | 0.1 - 0.5% S | BN 3 ~ 15<br>Limit 1 on Table 7.5 |
| Residual fuel | ULSFO | - 0.1% S | BN 3 ~ 20<br>Limit 2 on Table 7.5 |
| | VLSFO | 0.1 - 0.5% S | BN 3 ~ 30<br>Limit 3 on Table 7.5 |
| | HSHFO | 0.5 - 3.5% S | BN 20 ~ 30 with limit [4)] |
| | | 3.5 - % S | BN 30 ~ 40 with limit [5)] |

Table 7.6 Limitation (Allowed Max. operating hours)

| Limit | X (Fuel kinds) | 'X' fuel operating hours / Total monthly cumulative operating hours | Required BN |
|---|---|---|---|
| 1 | Distillated fuel | < 15 % | 3 ~ 7 |
| | | ≥ 15 % | 10 ~ 15 |
| 2 | ULSFO | 0 ~ 5 % | 3 ~ 7 |
| | | 5 ~ 10 % | 10 ~ 15 |
| | | 10 ~ 15 % | 15 ~ 20 |
| | | ≥ 15 % | 20 |
| 3 | VLSFO | 0 ~ 5 % | 3 ~ 7 |
| | | 5 ~ 10 % | 10 ~ 15 |
| | | 10 ~ 15 % | 15 ~ 20 |
| | | ≥ 15 % | 20 ~ 30 |
| 4 | HSHFO | 0 ~ 5 % | 3 ~ 7 |
| | | 5 ~ 10 % | 15 ~ 20 |
| | | 10 ~ 15 % | 20 ~ 30 |
| | | ≥ 15 % | 30 ~ 40 |
| 5 | | 0 ~ 5 % | 3 ~ 7 |
| | | 5 ~ 10 % | 20 ~ 30 |
| | | 10 ~ 15 % | 30 ~ 40 |
| | | ≥ 15 % | 40 ~ 55 |

## 7.4 List of lubricants

Table 7.7 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><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 |
| | 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 (Texaco, 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 | |
| | Mobilgard M50 | | 50 | |
| BP (Castrol) | CASTROL Duratex L | 40 | 4.5 | |
| | CASTROL MHP 154 | | 15 | |
| | CASTROL TLX 2-40 | | 20 | |
| | CASTROL TLX 3-40 | | 30 | |
| | CASTROL TLX 4-40 | | 40 | |
| | CASTROL TLX 5-40 | | 53 | |
| 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 12 | 40 | 12 | |
| | PETRONAS Disrol 15 | | 15 | |
| | 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 |

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

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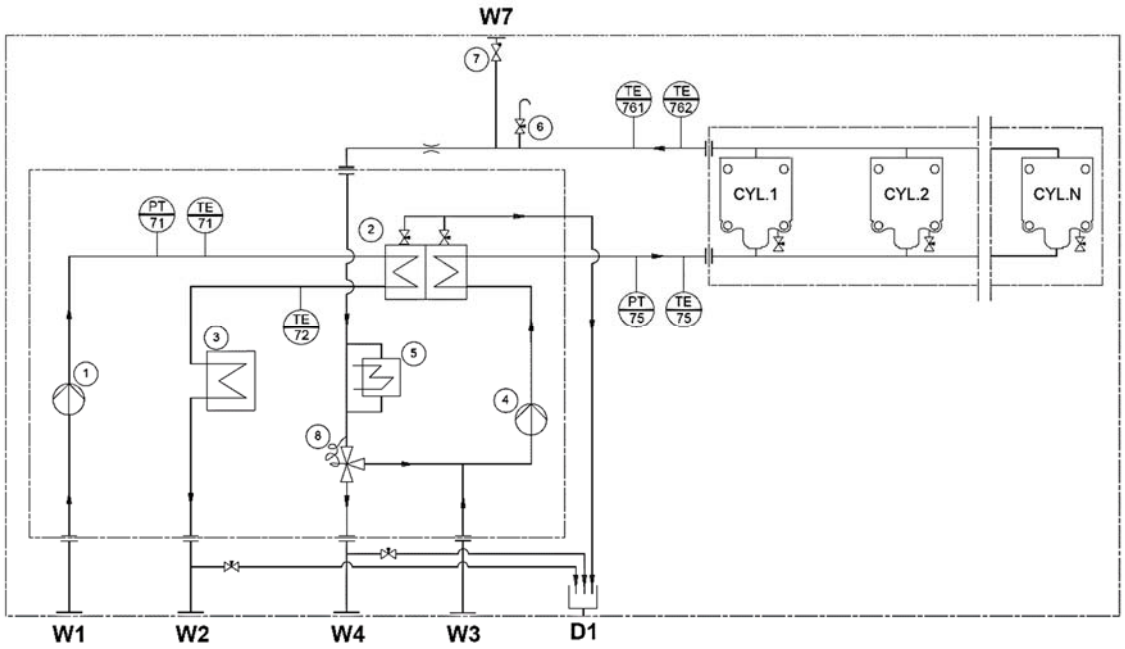
# 8 Cooling water system

## 8.1 Internal cooling water system

### Diagram for internal cooling water system (electric pre-heating element)




*) Supply scope and instrument will be determined by EOD(Extent of Delivery) and engine builder's standard.

Figure 8.1 Diagram for internal cooling water system [BP0061793-0.4]

Table 8.1 Sizes of external pipe connections

| Code. | Description | Size |
|---|---|---|
| W1 | Low temperature cooling water engine inlet | 125A |
| W2 | Low temperature cooling water engine outlet | 125A |
| W3 | High temperature cooling water engine inlet | 125A |
| W4 | High temperature cooling water engine outlet | 125A |
| W7 | Ventilation to expansion tank | 25A |
| D1 | Water drain | Ø25 |

1. Connection size is according to JIS B 2220.

Table 8.2 System components

| No | Description | Remark |
|---|---|---|
| 1 | Eng. Driven LT pump | |
| 2 | Charge air cooler | |
| 3 | Lub oil cooler | |
| 4 | Eng. Driven HT pump | |
| 5 | Electric pre heater | |
| 6 | Air venting valve | |
| 7 | Non return valve with hole | |
| 8 | HT Thermostatic valve | 79/88℃ |

### 8.1.1 General description

The engine has two cooling water circuits internally, which are low temperature and high temperature water circuits. Most of the components of circuits are modularized and directly mounted on the feed module. Please refer to Figure 2.4.

Low temperature water circuit comprises :

- ✓ Engine driven pump
- ✓ Charge air cooler
- ✓ Lubricating oil cooler
- ✓ Motor operated valve type thermostat

High temperature water circuit comprises :

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

## Scope of supply

The internal cooling system consists of the following built-in equipment :

- ✓ Engine driven low temperature cooling water pump
- ✓ Engine driven high temperature cooling water pump
- ✓ Two stage charge air cooler
- ✓ high temperature cooling water control thermostatic valve
- ✓ low temperature cooling water control thermostatic valve
- ✓ Electric pre-heater unit (option)

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

## 8.2 External cooling water system

### Diagram for external cooling water system with electric pre-heating element

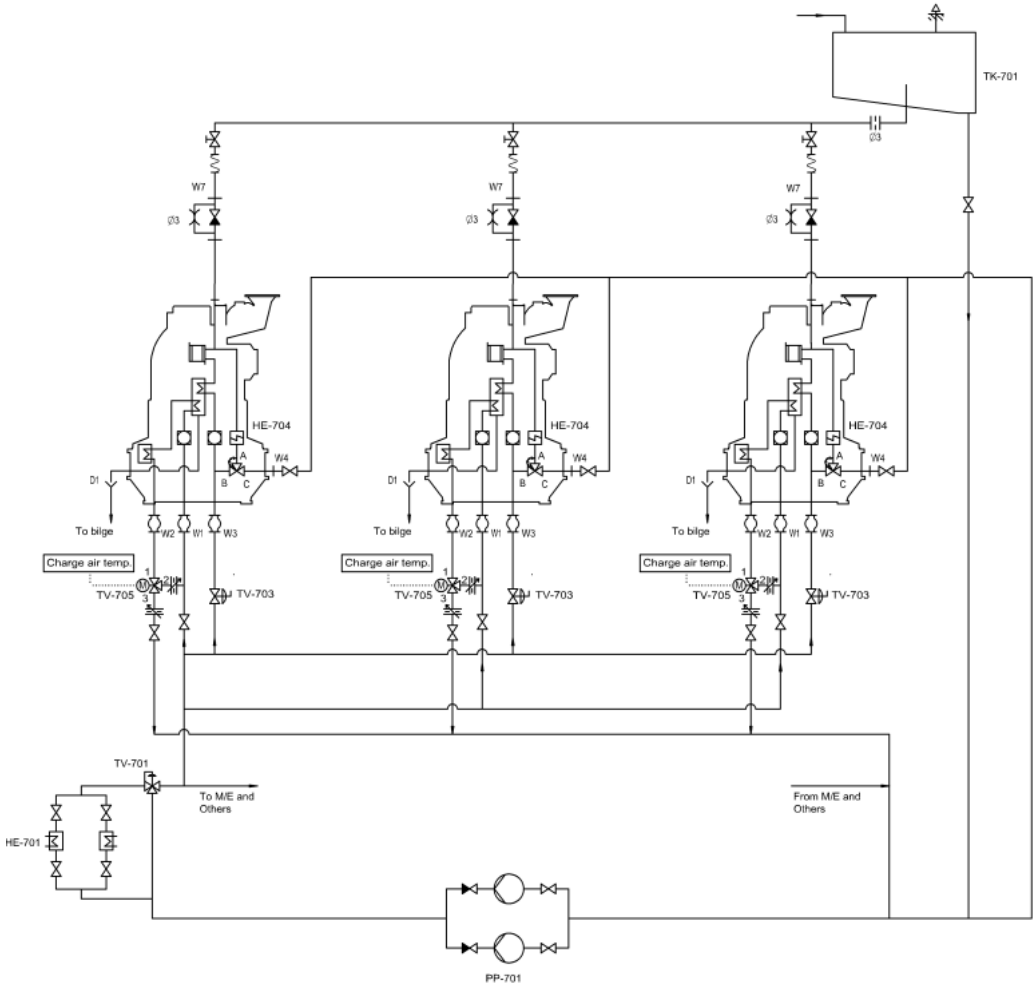



Figure 8.3 Diagram for external cooling water system with electric pre-heating element (BH2-126860-9)

Table 8.3 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-701 | Expansion tank | TV-703 | Auto shut-off valve |
| HE-701 | Central cooler | TV-705 | Thermostatic valve for low temperature cooling water |
| HE-704 | Electric pre-heating element | PP-701 | Circulation pump for fresh water |
| TV-701 | Thermostatic valve for central cooling | | |

## Diagram for external cooling water system with electric pre-heating unit

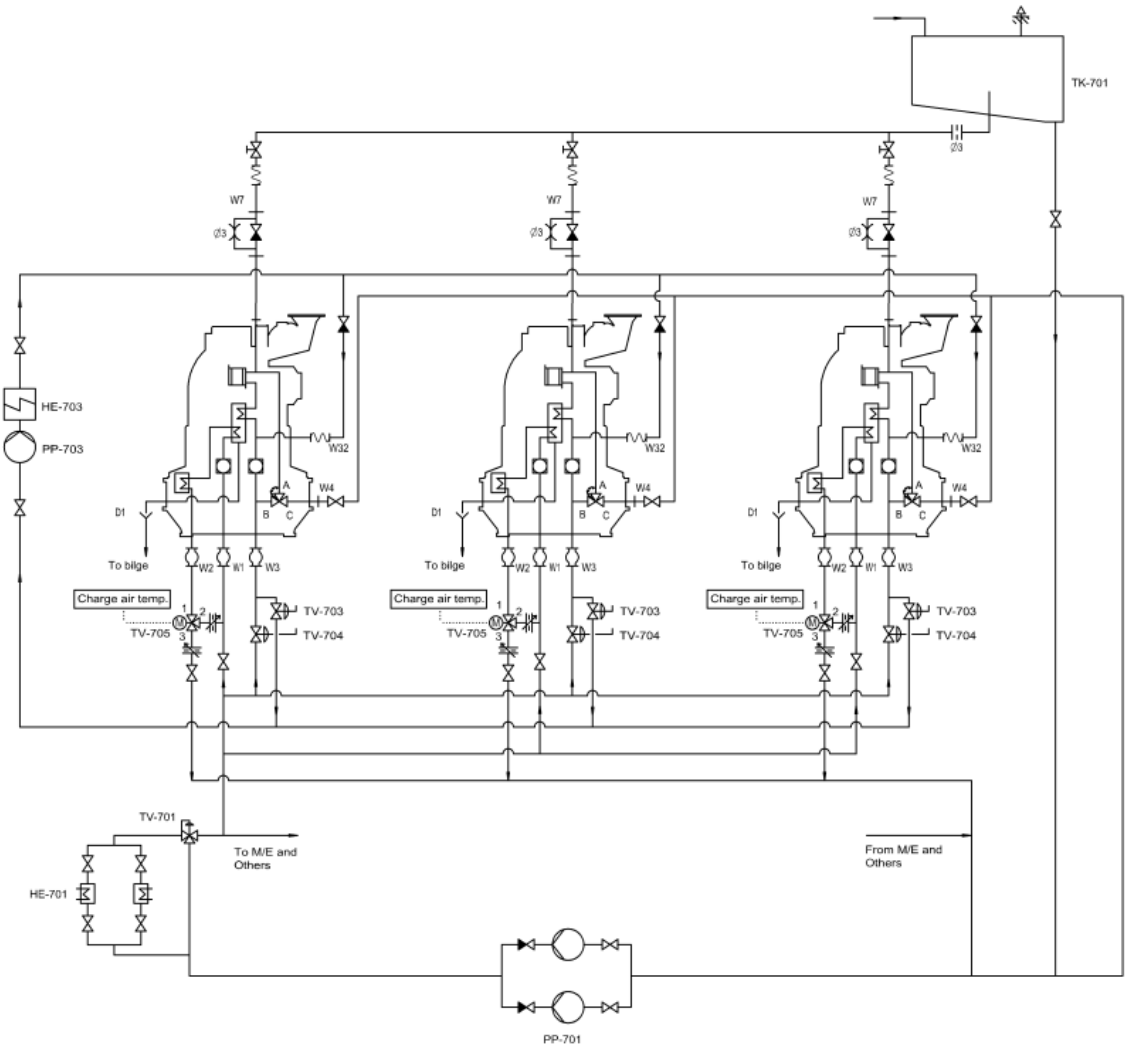



Figure 8.4 Diagram for external cooling water system with pre-heating unit (BH2-126862-2)

Table 8.4 System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-701 | Expansion tank | TV-703/704 | Auto shut-off valve |
| HE-701 | Central cooler | TV-705 | Thermostatic valve for low temperature cooling water |
| HE-703 | Preheater for high temperature cooling water | PP-701 | Circulation pump for fresh water |
| TV-701 | Thermostatic valve for central cooling | PP-703 | Circulation pump for preheating |

## 8.2.1 General description

### 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 high temperature 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 each engine(s).

Table 8.5 Cooling water volume of the engines

| Engine type | High temperature cooling water and low temperature cooling water volume |
|---|---|
| 6H32DF-LM | 582 liter |
| 7H32DF-LM | 617 liter |
| 8H32DF-LM | 651 liter |
| 9H32DF-LM | 686 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 Performance data'.
- ✓ Pressure drop : maximum 0.5 bar.
- ✓ Pump : centrifugal type (Electric motor driven)
- ✓ Water temperature before engine : 36 ℃

2) Sea water side

- ✓ Flow quantity : 1.1 ~ 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 8.6 Recommended capacity of pre-heater

| Cyl. | Electric pre-heater (kW) |
|---|---|
| 6 | 32 |
| 7 | 32 |
| 8 | 32 |
| 9 | 32 |

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
- ✓ 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 l / 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 set 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 8.7 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 8.8 Recommended products list

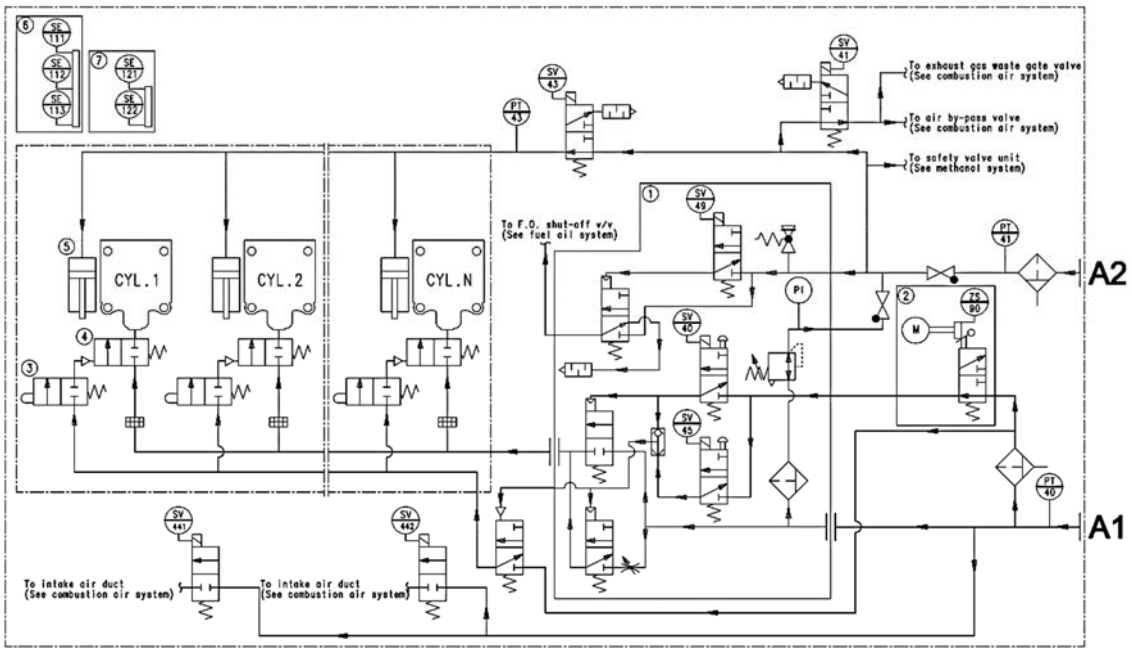
| Manufacturer | Brand name | Constituent | Delivery form | Recommended Dosage |
|---|---|---|---|---|
| Chevron (FAMM) | DELO XLI(Havoline XLI) | Carboxylates | Liquid | 75 liter / 1000 liter |
| VECOM | Cooltreat NCLT | Nitrite | Liquid | 48 liter / 1000 liter |
| Wilhelmsen Chemicals | Rocor NB | 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 |
| Houghton | Tectyl CW-70N-TEA | Nitrite | Liquid | 66 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.

# 9 Air and exhaust gas system

## 9.1 Internal compressed air system

### Diagram for internal compressed air system




*) Supply scope and instrument will be determined by EOD(Extent of Delivery) and engine builder's standard.

Figure 9.1 Diagram for internal compressed air system [B92-128949-6.1]

Table 9.1 Size of external pipe connection

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

1. Connection size is according to JIS B 2220.

Table 9.2 System components

| No | Description | Remark |
|---|---|---|
| 1 | Main starting valve unit | |
| 2 | Electric turning gear | |
| 3 | Fuel pump drive | |
| 4 | Starting valve | |

| No | Description | Remark |
|---|---|---|
| 5 | DVT pusher | |
| 6 | Crankshaft | |
| 7 | Camshaft | |

## 9.1.1 General description

Compressed air is supplied for engine start, slow turn, waste gate valve and etc. as for the control air. In addition, the start block is activated in case of turning gear engagement.The detail information of engine operation is explained in the chapter ’5.operation and control system'.

### Starting system

Startng system mainly consists of main starting valve, starting pilot valve, 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.

### Slow turn

Slow turn function is few flywheel revolutions without fuel injection in order to ensure that there is no residual gas or other foreign liquids in the combustion chamber. In stand-by mode, slow turn is automatically conducted every 24 hours before start. On the contrary, slow turn will be skipped when engine has been operated 30 minutes earlier.

### Scope of supply

The internal compressed air system consists of the following equipment :

- ✓ Main starting valve
- ✓ Turning gear
- ✓ Slow turn valve assembly

## 9.2 External compressed air system

### Diagram for external compressed air system

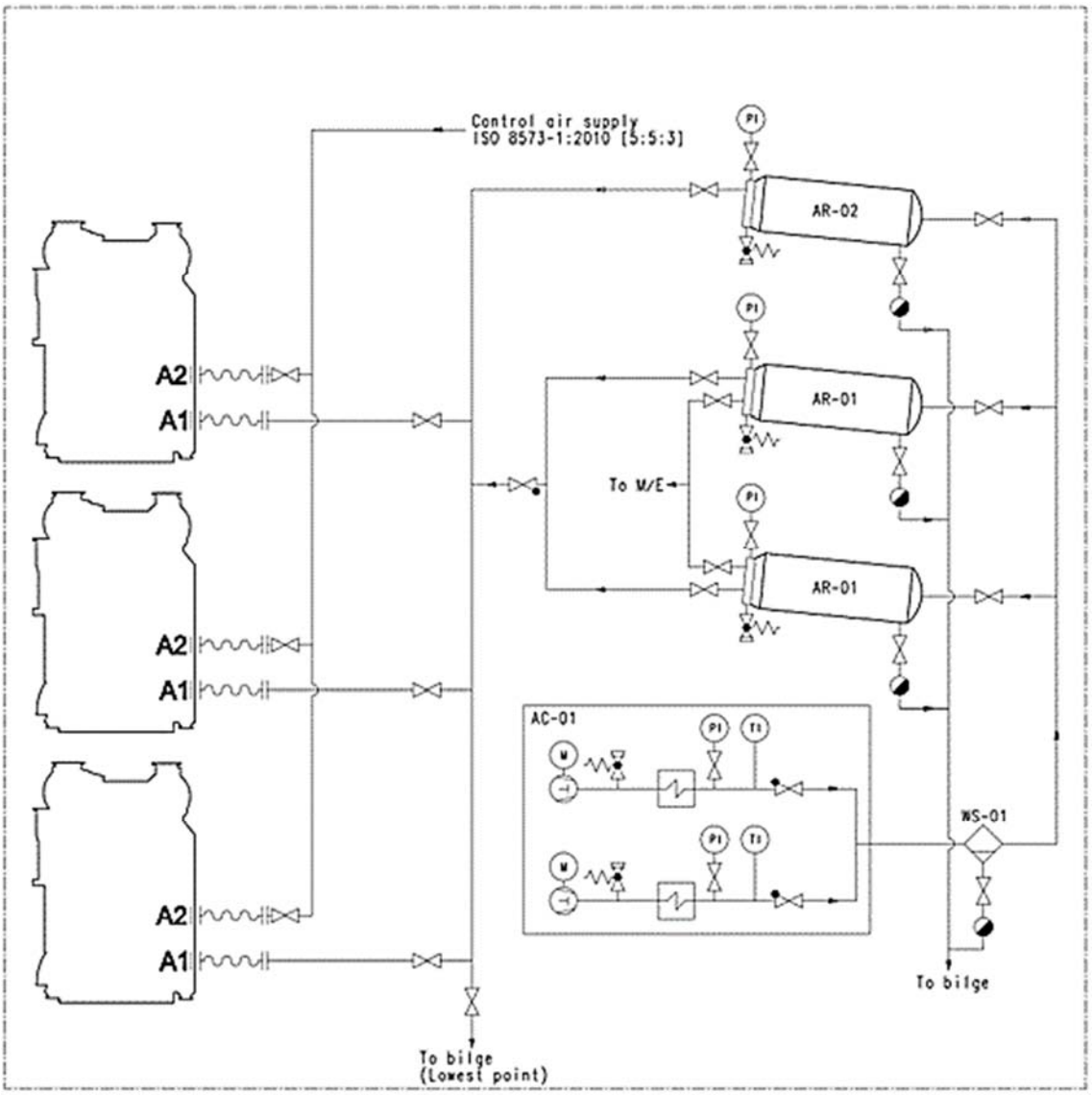



Figure 9.2 Diagram for external compressed air system

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.

For the external compressed air system, the requirements are as follows:

- ✓ A dry and clean air is essential for the reliable functions of the engine starting and control system. And the required air quality shall be referred to the ISO 8573-1:2010 Class 4.5.3. Therefore, the appropriate separation equipment should be included in the external system.
- ✓ The air pipes and vessels should be arranged with a slope to ensure a good drainage of condensate. In addition, it is required to be equipped with the automatic or manual drain system at the lowest point.
- ✓ Compressed air quality of starting air (According to ISO 8573-1 : 2010)
  Humidity and Liquid Water Classes : Dew point temperature $\leq -8℃$
  Particle Classes : Maximum Particle size $40\mu m$ [Class 6]
  Oil Classes : Concentration $\leq$ 5 $mg/m^3$ [Class 4]
- ✓ Compressed air quality of control air (According to ISO 8573-1 : 2010) - 100% Dry air
  Humidity and Liquid Water Classes : Class 4
  Particle Classes : Particle Classes :Class 5
  Oil Classes : Class 3

### 9.2.2 Starting air volume of the engine

Air consumption per one start is specified in '3 Performance data'. The capacity of starting air vessel varies as per Classification Societies or Customer's requirement.
Volumes for three starts of one auxiliary engine(includes jet assist and slow turn) are as follows;

Table 9.4 Starting air volume of the engines

| Engine type | Volume (liter) |
|---|---|
| 6H32DF-LM | 1,480 |
| 7H32DF-LM | 1,520 |
| 8H32DF-LM | 1,615 |
| 9H32DF-LM | 1,635 |

### 9.2.3 Compressed air specification

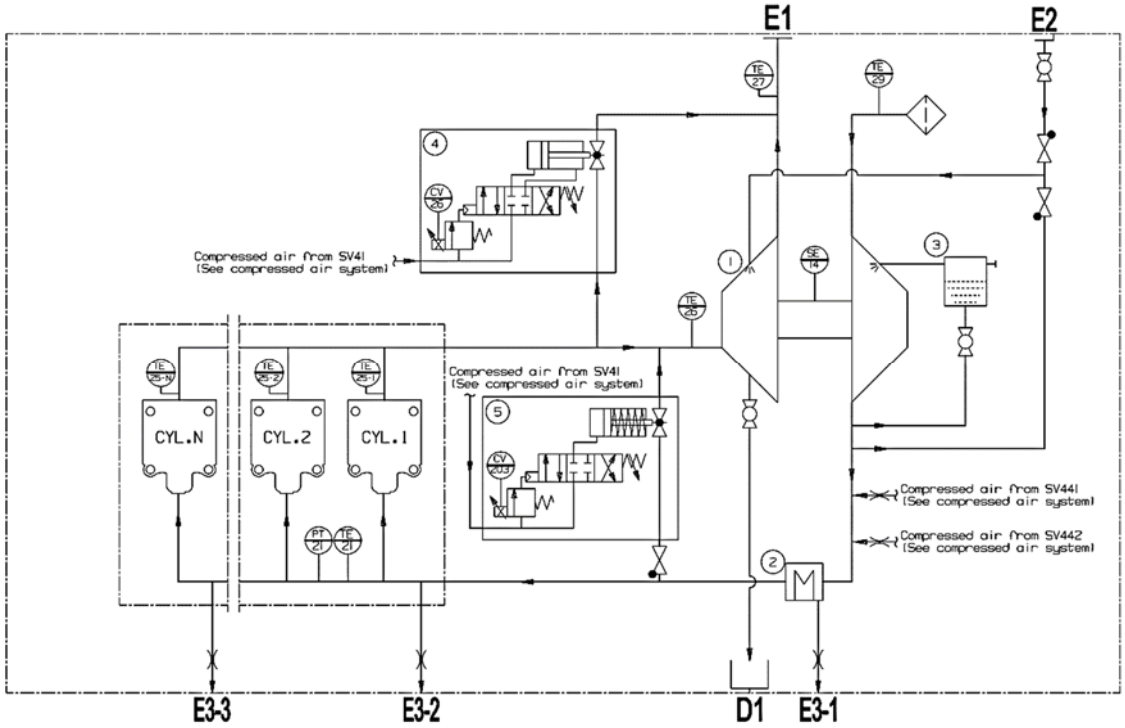
To ensure reliable engine operation and prevent damage to the components in the compressed air system, the compressed air must be free from contaminants such as particles, water, and oil. The required compressed air specification is as follows;

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




*) Supply scope and instrument will be determined by EOD(Extent of Delivery) and engine builder's standard.

Figure 9.3 Diagram for combustion and exhaust gas system [B92-128958-0.1]

Table 9.6 Size of external pipe connection

| Code. | Description | Size | Remark |
|---|---|---|---|
| E1 | Exhaust gas outlet | 1) | Acc. to project |
| E2 | Turbine cleaning water inlet | - | Quick coupler |
| E3 - 1 | Condensate water drain (Water mist catcher) | OD Ø15 | Bite type Conn. |
| E3 - 2 | Condensate water drain (1st cylinder) | OD Ø15 | Bite type Conn. |
| E3 - 3 | Condensate water drain (Last cylinder) | OD Ø15 | Bite type Conn. |
| D1 | Water drain | - | Acc. to project |

1) See "Figure 9.4 External exhaust gas pipe connection".

Table 9.7 System components

| No | Description | Remark |
|---|---|---|
| 1 | Turbocharger | |
| 2 | Charge air cooler | |
| 3 | Compressor washing device (Water vessel) | |
| 4 | EWG (Exh. gas waste gate valve) | |
| 5 | ABP (Air by-pass) valve | |

### 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 and mounted on the feed module of the engine. 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 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 air intake 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. 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 pipe, cleanable waste trap and water drain should be prepared. Therefore air duct should be installed to face the air intake silencer for each turbocharger as close as possible.

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. 1~2m 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 Max. 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, must be kept within 110 mm WC.

Environmental condition of Max.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 pipe, exhaust gas boiler (possibly) and silencer, etc

### Independent exhuast gas system

System should be prepared for each engine even for the case of common boiler system with other engines.

### Back pressure

Back pressure of the exhaust system in total is recommended to be less than 300 mmWC at maximum countious rating. The maximum back pressure should not exceed 500 mm WC at maximum countious rating. Please see the 3.6 correction of fuel consumption for the fuel consumption correction in case of exceeding 300 mmWC at maximum countious rating. The measuring position is approx. 1 ~ 2 m after the turbocharger gas outlet casing not 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 that cover the entire exhaust system should be provided as close as possible to the engine outlet(to prevent the ingress of condensate and other foreign substances into the engine)
- ✓ 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 '9.6 exhaust gas silencer with spark arrestor'

## 9.6 External exhaust gas pipe connection

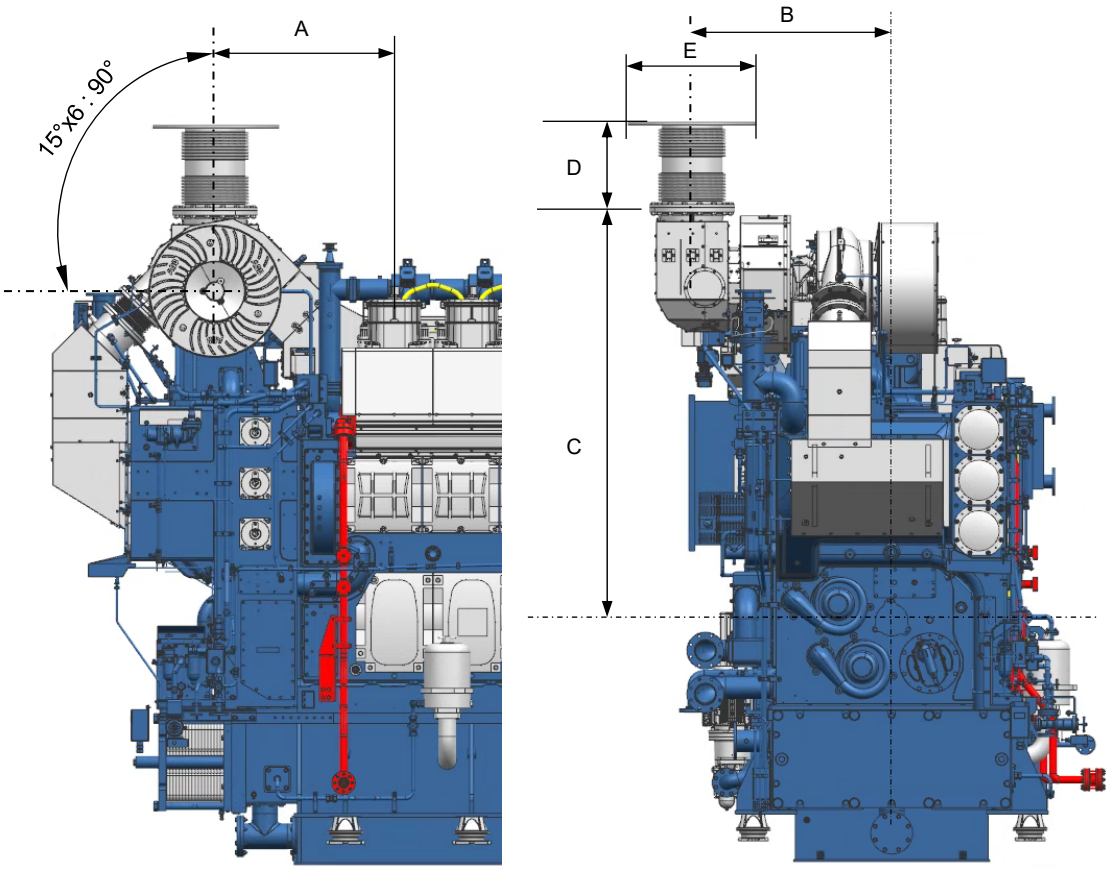



Figure 9.4 External exhaust gas pipe connection.

Table 9.8 Exhaust gas connection size for 720 / 750 rpm (500 kW / cylinder)

| Engine type | Exhaust gas outlet position (mm) | | | | E | |
|---|---|---|---|---|---|---|
| | A | B | C | D | Size | Standard |
| 6H32DF-LM | 1143 | 1143 | 2520 | 470 | 600A | JIS F 7805 |
| 7H32DF-LM | 1134 | 1261 | 2612 | 542 | 650A | JIS F 7805 |
| 8H32DF-LM | 1134 | 1261 | 2612 | 542 | 700A | JIS F 7805 |
| 9H32DF-LM | 1134 | 1261 | 2612 | 542 | 750A | 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 :

#### Mode

- ✓ SCR (Selective Catalytic Reduction) operation is allowed in diesel/methanol mode.

#### 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.

- ✓ In some cases exhaust gas temperature is controlled to increase by adjustable waste gate valve automatically for SCR (Selective Catalytic Reduction) active or ready condition

#### Maximum exhaust gas back pressure

- ✓ Allowable back pressure in total of the exhaust system to guarantee fuel consumption see the 9.5.1 "General Description". It is not recommended that the exhaust gas's total back pressure exceeds 500 mmWC 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.

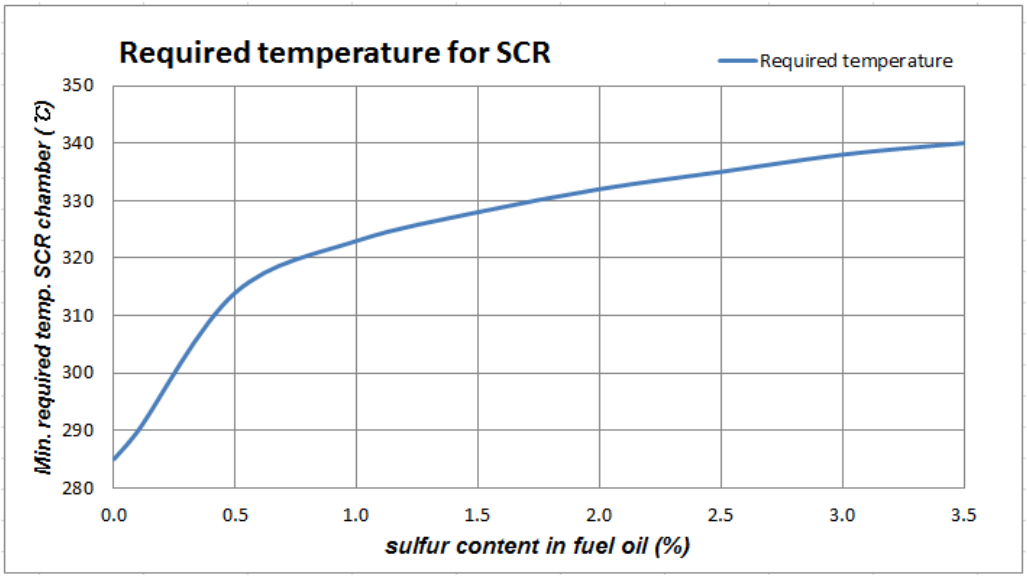



Figure 9.5 Minimum required exhaust gas temperature for SCR operation

1. 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.

### 9.7.3 Operation and performance change

As the SCR (Selective Catalytic Reduction) system is installed, the waste gate valve can be used to increase the exhaust gas temperature in the SCR (Selective Catalytic Reduction) operation at certain loads which is lower exhaust gas temperature.

The waste gate valve is activated when the exhaust temperature is lower than required temperature in SCR (Selective Catalytic Reduction) mode. At this time, the exhaust gas temperature will rise until target temperature and the fuel consumption will be slightly increased in proportion to the valve operation.

### 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 vertically.

The gas flow passes through a straight perforated tube, surrounded with a 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.

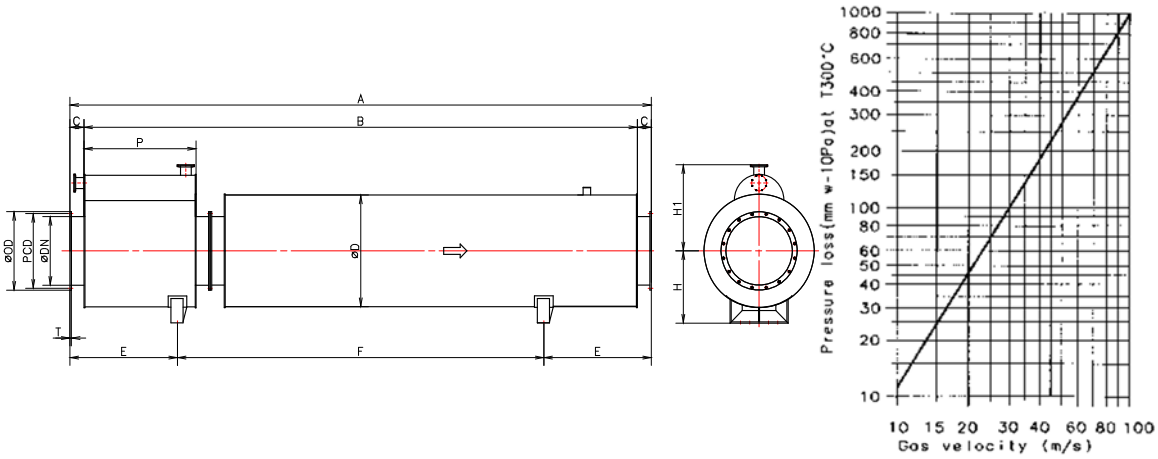



Figure 9.6 Exhaust gas silencer (25 dB type).

Table 9.9 Exhaust gas silencer size (25 dB type)

| Cylinder type | DN | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| 6 (720 rpm) | 600 | 4980 | 4680 | 150 | 1060 | 990 | 3000 |
| 7 (720 rpm) | 650 | 5680 | 5380 | 150 | 1110 | 1090 | 3500 |
| 8 (720 rpm) | 700 | 6220 | 5920 | 150 | 1160 | 1150 | 3920 |
| 9 (720 rpm) | 750 | 6660 | 6360 | 150 | 1210 | 1170 | 4320 |

| Cylinder type | H | H1 | P | PCD | OD | T | N-d | Weight (kg) |
|---|---|---|---|---|---|---|---|---|
| 6 (720 rpm) | 700 | 792 | 1000 | 670 | 710 | 16 | 16- Ø23 | 2065 |
| 7 (720 rpm) | 730 | 819 | 1100 | 720 | 760 | 16 | 16- Ø23 | 2295 |
| 8 (720 rpm) | 750 | 885 | 1200 | 775 | 815 | 16 | 16- Ø23 | 2615 |
| 9 (720 rpm) | 780 | 910 | 1200 | 825 | 865 | 20 | 20- Ø23 | 2910 |

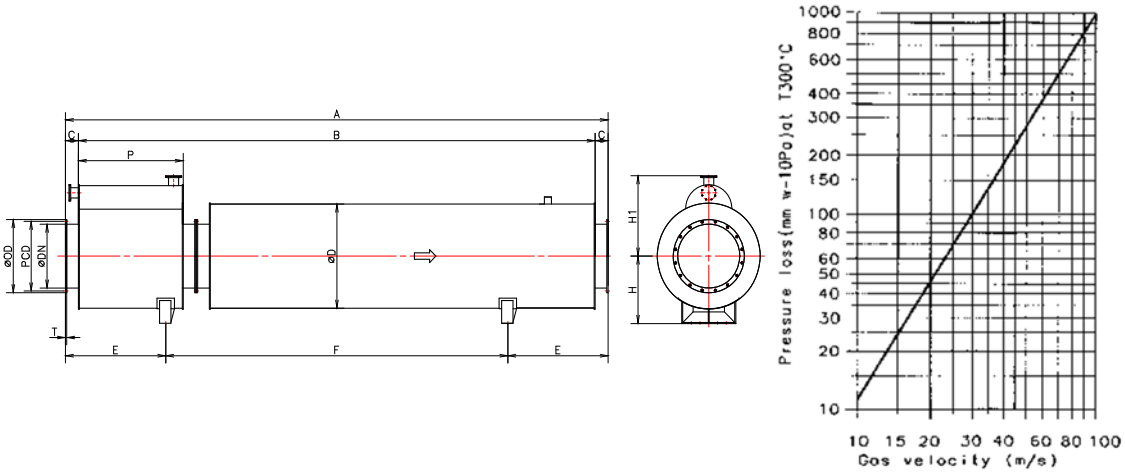



Figure 9.7 Exhaust gas silencer (35 dB type).

Table 9.10 Exhaust gas silencer size (35 dB type).

| Cylinder type | DN | A | B | C | D | E | F |
|---|---|---|---|---|---|---|---|
| 6 (720 rpm) | 600 | 6230 | 5930 | 150 | 1060 | 990 | 4250 |
| 7 (720 rpm) | 650 | 6980 | 6680 | 150 | 1110 | 1090 | 4800 |
| 8 (720 rpm) | 700 | 7570 | 7270 | 150 | 1160 | 1150 | 5270 |
| 9 (720 rpm) | 750 | 8060 | 7760 | 150 | 1210 | 1170 | 5720 |

| Cylinder type | H | H1 | P | PCD | OD | T | N-d | Weight (kg) |
|---|---|---|---|---|---|---|---|---|
| 6 (720 rpm) | 700 | 792 | 1000 | 670 | 710 | 16 | 16- Ø23 | 2065 |
| 7 (720 rpm) | 730 | 819 | 1100 | 720 | 760 | 16 | 16- Ø23 | 2295 |
| 8 (720 rpm) | 750 | 885 | 1200 | 775 | 815 | 16 | 16- Ø23 | 2615 |
| 9 (720 rpm) | 780 | 910 | 1200 | 825 | 865 | 20 | 20- Ø23 | 2910 |

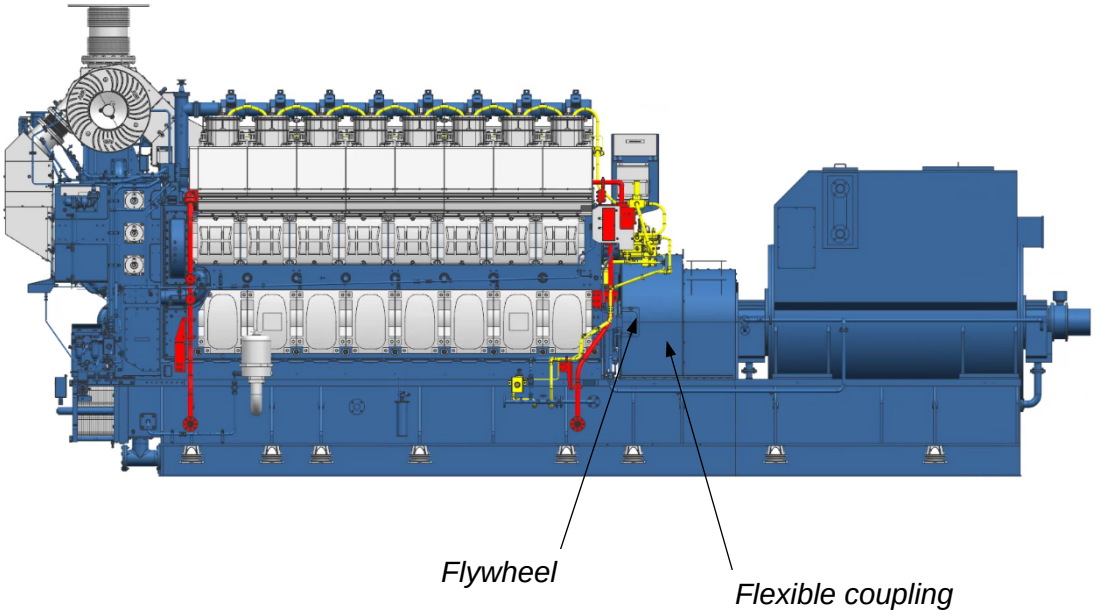
# 9.9 Generator information

## Mounting of generator

As a standard design of H32DF-LM engine, the engine and generator are coupled with flexible coupling and rigidly mounted on common base frame.

## Generator bearing

Type of generator bearing is double sleeves, bearing with forced lubrication.



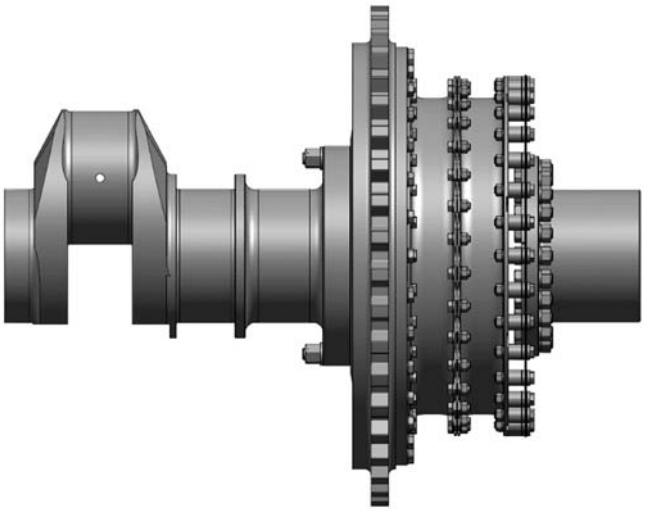



Figure 9.8 Flexible coupling outline

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# 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 | HI1130 | Bolt for base frame and resilient mount | | ▲ | | | ◆ | | | | | | | |
| G1130 | - | Nut for resilient mount and foundation | | ▲ | | | ◆ | | | | | | | |
| - | HI1210 | Hydraulic nut for engine block and base frame | | ◆ | | | ◆ | | | | | | | |
| M3330 | HI1210 | Hydraulic nut for main bearing cap | | ◆ | | | ◆ | | | | | | | |
| M2110 | HI1210 | Hydraulic nut for cylinder head | | ◆ | | | ◆ | | | | | | | |
| M2410 | HI2410 | Bolt and nut for camshaft | | ▲ | | | ◆ | | | | | | | |
| M3100 | HI3210 | Hydraulic nut for connecting rod (Shaft) | | ◆ | | | ◆ | | | | | | | |
| M3100 | HI3210 | Hydraulic nut for connecting rod (big-end) | | ◆ | | | ◆ | | | | | | | |
| M3321 | HI3310 | Hydraulic nut for counter weight | | ◆ | | | ◆ | | | | | | | |
| M3610 | HI3610 | Bolt and nut for timing gear | | ▲ | | | ◆ | | | | | | | |
| - | HI8320 | 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

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 | HI1130 | Resilient mount | | ● | | | ● | | | | | | | **) |
| **Major bearing** | | | | | | | | | | | | | | |
| M3330 | HI3330 | Main bearing | | | | | √ | | | | ▣ | | | |
| M3330 | HI3330 | Thrust washer : axial clearance | | | | | ◎ | | | | | | ▣ | |
| M2410 M2430 | HI2430 | Camshaft bearing : clearance | | | | | √ | | ◎ | | | | ▣ | |
| M3100 M3212 | HI3210 | Connecting rod bearing (big-end) | | | | | √ | | ■ | | ▣ | | | |
| M3213 | HI3210 | Connecting rod bearing (small-end) | | | | | √ | | ■ | | | | ▣ | |
| M3610 | HI3610 | 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

**) During on board (site) commissioning, inspection is caried 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 | HI2210 | Cylinder liner | | | | | √ | | ■ | | | | | |
| M2210 | HI2210 | Flame ring | | | | | √ | | ▣ | | | | | |
| M2110 | HI2110<br>HI2210 | Cylinder head and water jacket cooling water space | | | | | √ | | ■ | | | | | |
| M2112<br>M2113<br>M2310 | HI2110<br>HI2310 | Intake/exhaust valve spindle, seat ring and valve guide : overhaul and reconditioning | | | | | √ | | ■ | | ▣ | | | |
| M2310 | HI2310 | Intake/exhaust valve : clearance | | ● | ● | | | | | | | | | **) |
| M2311 | HI2310 | Rocker arm shaft and bush | | | | | √ | | ■ | | | | | |
| M2312 | HI2310 | Rotocap | | | ○ | | | | ■ | | | | | |
| M2140 | HI2140 | Starting valve | | | | | √ | | ■ | | | | | |
| M2330 | HI2330 | Dual valve timing | | | | | √ | | | | | | | |
| M3110 | HI3110 | Piston rings | | | | | √ | | ▣ | | | | | |
| M3110 | HI3110 | Piston and piston pin | | | | | √ | | ■ | | | | | |
| M3100<br>M3211 | HI3210 | Connecting rod bore (big-end) | | | | | √ | | ■ | | | | | |

▣ 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

**) During on board (site) commissioning, inspection is caried 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** | | | | | | | | | | | | | | |
| M3110<br>M3213 | HI3110<br>HI3210 | Piston pin and connecting rod (small-end) : clearance | | | | | √ | | ■ | | | | | |
| M3100 | HI3210 | Shim plate for connecting rod | | | | | √ | | ▣ | | | | | |
| M3100 | HI3210 | Studs for connecting rod | | | | | | | | | | | ▣ | |
| **Crankshaft and gears** | | | | | | | | | | | | | | |
| M3320 | HI3310 | Crankshaft : deflection | | | | | ◎ | | | | | | | |
| - | HI3340<br>HI3510 | Gear teeth on flywheel and turning gear | | | | | ▲ | | | | | | | |
| - | HI3350 | Torsional vibration damper : fluid sampling (only for viscous damper) | | | | | | | ◎ | | | | | ***) |
| - | HI3360 | Flexible coupling | ▲ | | | | | | | | | | | ***) |
| M3610 | HI3610 | Timing gear and pump driving gear : clearance and backlash | | | | | | | ◎ | | | | | |

▣ 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

***) 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 | |
| **Valve operating mechanism** | | | | | | | | | | | | | | |
| M2320 | HI2320 | Swing arm roller shaft and bush | | | | | | | ■ | | | | ▣ | |
| M2320<br>M2430 | HI2320<br>HI2430 | Contact faces of cam and swing arm roller camshaft bearing | | ▲ | | | ▲ | | | | | | | |
| **Control system** | | | | | | | | | | | | | | |
| G4001 | - | Safety device : function check | ○ | | | | | | | | | | | Monthly |
| - | HI4110 | Engine RPM pick-up sensor : clearance | | | | | ● | | | | | | | |
| M4100 | HI4100<br>HI4200 | 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

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 oil & Methanol system** | | | | | | | | | | | | | | |
| G0510<br>G0511<br>G0520 | - | Analyze fuel oil/Methanol properties : sampling | ◎ | | | | | | | | | | | Every bunkering |
| M5111 | HI5110 | **Fuel injection pump** | | | | | | | | | | | | |
| | | Plunger assembly | | | | | ■ | | ▣ | | | | | |
| | | Delivery valve assembly (except case) | | | | | ■ | | ▣ | | | | | |
| | | Delivery valve case | | | | | ■ | | | | | | ▣ | |
| | | Roller bush for tappet | | | | | | | ■ | | | | ▣ | |
| | | Control valve for control valve ass'y | | | | ● | ▣ | | | | | | | |
| M5120<br>M5121<br>M5122<br>M5123 | HI5120 | Fuel injection valve : opening pressure | | ● | ● | ▣ | | | | | | | | ****)<br>▣ :Atomizer life time |
| | HI5120 | Electric Regulating valve | | | | | | | | | | | ▣ | |
| - | HI5410 | O-rings for feed block | | | | | ▣ | | | | | | | |
| - | HI5510 | Fuel oil shock absorber | | | | ■ | | | | | | | | |
| M5310 | HI5310 | Fuel oil filter | ■ | | | | | | | | | | | If pressure drop reaches limit(See G0140) |
| M5630 | HI5630 | Methanol pipe | | | | | | | ■ | | | | | |

▣ 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

***) 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 M5120.

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 oil & Methanol system** | | | | | | | | | | | | | | |
| - | HI5630 | Support for Methanol pipe | | | | ■ | ▣ | | | | | | | |
| - | HI6130 | LO high pressure pump | ■ | | | | | | | | | | | ***) |
| M6580 | HI6580 | LO high pressure pipe | | | | | | | ■ | | | | | |
| **Lubricating oil system** | | | | | | | | | | | | | | |
| G0610 | - | Analyze lubricating oil properties : sampling | ◎ | | | | | | | | | | | Every 3 month |
| M6110 | HI6110 | Lubricating oil pump | | | | | | | ■ | | | | | |
| M6210 | HI6210 | Lubricating oil cooler | | | | | | | ■ | | | | | ***) |
| M6310 | HI6310 | Lubricating oil filter (cartridge type) | ■ | | ▣ | | | | | | | | | If pressure drop reaches limit(See G0140) |
| - | HI6310 | Auto backwashing filter (If applied) | ■ | | | | | | | | | | | ***) |
| - | HI6410 | Thermostatic valve : clean and check the elements | | | | | | | ■ | | | | | ***) |
| - | HI6320 | 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

***) 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 | HI7110 | Cooling water pump | | | | | | | ■ | | | | | |
| - | HI7210 | Thermostatic valve : clean and check the elements | | | | | | | ■ | | | | | ***) |
| **Compressed air system** | | | | | | | | | | | | | | |
| O0230 | - | Air running | ○ | | | | | | | | | | | Monthly |
| G4000 | - | Check starting & stop system | ○ | | | | | | | | | | | Weekly (over a week stand-still condition) |
| **Combustion air system** | | | | | | | | | | | | | | |
| G8001 | HI7510 | Charge air condensate drain pipe | ● | | | | | | | | | | | Weekly |
| M8000 | - | 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 |
| - | HI8360 | Exhaust gas waste gate | ○ | | | | | | | | | | | Weekly |
| M8410 | HI8410 | 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

*) It is not a part of normal overhaul interval, but confirmations or visual inspections of the specified components should be carried out after overhaul and renew.

***) 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** | | | | | | | | | | |
| HI1210 | Gaskets for gear case cover | set | - | 1 | 1 | 2 | 2 | 3 | 3 | 4 |
| HI1220 | 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 |
| HI1230 | 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** | | | | | | | | | | |
| HI3330 | Main bearing (upper & lower) | set | - | - | - | - | - | 1xC+1 | 1xC+1 | 1xC+1 |
| HI3330 | Thrust washer | ea | - | - | - | - | - | - | - | 2 |
| HI2430 | Camshaft bearing | ea | - | - | - | - | - | - | - | 1xC+1 |
| HI3210 | Big-end bearing (upper & lower) | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HI3210 | Small-end bearing | ea | - | - | - | - | - | - | - | 1 x C |
| HI3610 | Bearing bush for idle gear | ea | - | - | - | - | - | - | - | 1 |
| **Cylinder unit and connecting rod** | | | | | | | | | | |
| HI2210 | Flame ring | ea | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HI2210 | O-rings and gasket for cylinder liner / cooling water jacket | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 1xC+2 | 1xC+2 | 2xC+2 |
| HI2110 | O-rings for cylinder head cover | set | 0.5xC | 1 x C | 1.5xC | 2 x C | 2.5xC | 3 x C | 3.5xC | 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** | | | | | | | | | | |
| HI2110 | O-ring for cylinder head | ea | - | 1 | 1 | 1xC+1 | 1xC+1 | 1xC+2 | 1xC+2 | 2xC+2 |
| HI2110 | Bush and O-ring for fuel valve | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HI2110 | O-rings for valve guide and exhaust valve seat ring | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 1xC+2 | 1xC+2 | 2xC+2 |
| HI2110 HI2310 | Intake valve spindle, seat ring and valve guide | set | - | - | - | - | - | 1 x C | 1 x C | 2 x C |
| HI2110 HI2310 | Exhaust valve spindle, seat ring and valve guide | set | - | - | - | - | - | 1 x C | 1 x C | 2 x C |
| HI2140 | O-rings for starting valve | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 1xC+2 | 1xC+2 | 2xC+2 |
| HI2320 | Roller bush for swing arm | ea | - | - | - | - | - | - | - | 1 x C |
| HI2330 | O-rings for dual valve timing | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 1xC+2 | 1xC+2 | 2xC+2 |
| HI3110 | Piston ring-top ring / 2nd ring / scraper ring | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HI3210 | Shim plate for connecting rod | ea | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HI3210 | Stud for connecting rod shaft | ea | - | - | - | - | - | - | - | 4 x C |
| **Fuel & Methanol system** | | | | | | | | | | |
| HI5110 | Plunger assembly for fuel pump | ea | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HI5110 | 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 |
| HI5110 | Gaskets and seal ring for fuel pump | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HI5110 | Delivery valve assembly (except case) | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HI5110 | Delivery valve case | ea | - | - | - | - | - | - | - | 1 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 & Methanol system** | | | | | | | | | | |
| HI5110 | 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 |
| HI5110 | Roller bush for tappet | ea | - | - | - | - | - | - | - | 1 x C |
| HI5110 | O-ring for fuel pump drive | ea | - | - | - | - | - | - | - | 1 x C |
| HI5110 | 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 |
| HI5110 | Solenoid valve unit | set | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C |
| HI5120 | 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 |
| HI5120 | O-rings and gasket for fuel injection valve | set | 2 x C | 4 x C | 6 x C | 8 x C | 10xC | 12xC | 14xC | 16xC |
| HI5120 | Electric regulating valve for fuel injection valve | set | - | - | - | - | - | - | - | 1 x C |
| HI5130 | O-rings for fuel injection pipe block | set | 2xC | 4xC | 6xC | 8xC | 10xC | 12xC | 14xC | 16xC |
| HI5630 | Sealing rings for methanol branch pipe | set | 2xC | 4xC | 6xC | 8xC | 10xC | 12xC | 14xC | 16xC |
| HI5630 | Sealing ring for methanol main pipe | ea | - | 3 | - | 6 | - | 9 | - | 12 |
| HI5630 | Sealing ring for methanol helix pipe | ea | - | 3 | - | 6 | - | 9 | - | 12 |
| HI5410 | O-rings for fuel feed pipe connection | set | - | 1 | 1 | 2 | 2 | 3 | 3 | 4 |
| HI5310 | Spare parts for fuel oil filter | set | (See manual for fuel oil filter filter) | | | | | | | |
| HI5630 | Sealing rings For methanol pipe | set | | | | | 1 x U | 1 x U | 1 x U | 2 x U |
| HI5630 | Support for Methanol pipe | set | | 1 x U | 1 x U | 2 x U | 2 x U | 3 x U | 3 x U | 4 x U |
| HI5510 | Wearing ring and sealing ring for F.O 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 |
| HI5630 | Spare parts for safety valve unit | set | (See manual for safety valve unit) | | | | | | | |
| HI6130 | Spare parts for lubricating oil high pressure pump | set | (See manual for lubricating oil high pressure pump) | | | | | | | |

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** | | | | | | | | | | |
| HI6110 | Bushes for lubricating oil pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HI6110 | O-rings for lubricating oil pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HI6210 | O-ring for lubricating oil cooler connection (installation on engine side) | ea | - | - | - | 4 | 4 | 4 | 4 | 8 |
| HI6310 | Lubricating oil filter cartridge (paper cartridge type) | ea | 2xU | 4xU | 6xU | 8xU | 10xU | 12xU | 14xU | 16xU |
| HI6310 | O-rings for lubricating oil filter assembly (paper cartridge type) | set | 2xU | 4xU | 6xU | 8xU | 10xU | 12xU | 14xU | 16xU |
| HI6310 | Spare parts for auto backwashing filter | set | (See manual for auto backwashing filter) | | | | | | | |
| HI6310 | Packing for auto backwashing filter (see manual for auto backwashing filter) | ea | - | - | - | 1 | 1 | 1 | 1 | 2 |
| HI6410 | O-ring for lubricating oil thermostat valve | ea | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HI6410 | Gasket for thermostatic valve cover (No installation of auto backwashing filter) | ea | - | - | - | 1 | 1 | 1 | 1 | 2 |
| HI6320 | Spare parts for centrifugal filter | set | (See manual for centrifugal filter) | | | | | | | |
| HI6580 | Gasket for sealing lubricating oil connection pipe | ea | 2xC | 4xC | 6xC | 8xC | 10xC | 12xC | 14xC | 16xC |
| HI6580 | O-ring for lo high pressure pipe | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| **Cooling water system** | | | | | | | | | | |
| HI7110 | 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 |
| HI7210 | 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 |

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 |
| **Cooling water system** | | | | | | | | | | |
| HI7210 | 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 |
| HI7310 | O-ring for cooling water connection | ea | - | 2 | 2 | 4 | 4 | 6 | 6 | 8 |
| HI7320 | O-ring for cylinder head cooling water connection | ea | - | 8 | 8 | (4xC)+6 | (4xC)+6 | (4xC)+14 | (4xC)+14 | (8xC)+12 |
| HI7320 | O-ring for cylinder head outlet connection | ea | - | 1 | 1 | (1xC)+1 | (1xC)+1 | (1xC)+2 | (1xC)+2 | (2xC)+2 |
| **Supercharging system** | | | | | | | | | | |
| HI8110 | Gaskets for compressor out | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| HI8210 | Gasket for connection flange | ea | - | 1 | 1 | 1xC+1 | 1xC+1 | 1xC+2 | 1xC+2 | 2xC+2 |
| HI8320 | O-rings for Turbocharger connection | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| **Charge air cooler** | | | | | | | | | | |
| HI8410 | O-rings and gaskets for air cooler | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| **Turbocharger** | | | | | | | | | | |
| | Spare parts for turbocharger | set | (See manual for turbocharger) | | | | | | | |
| | 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 minimum spare parts for each plant or each ship (valid for all classification societies)

Table 10.3 List of standard spare parts

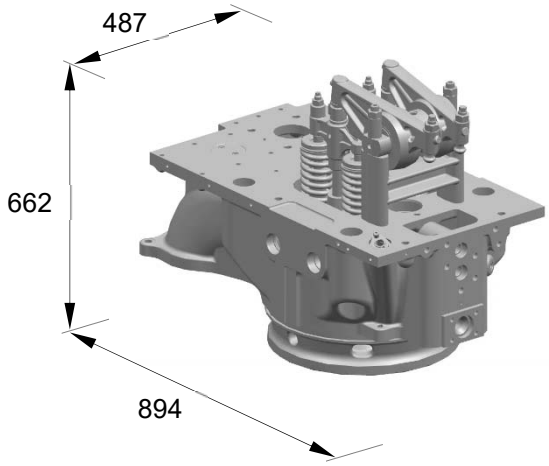
| Parts description | Q'ty | Section No. | Item No. | Remark |
|---|---|---|---|---|
| **Engine block and covers** | | | | |
| Main bearing, upper | 1 | LDFM13250 | 251 | |
| Main bearing, lower | 1 | LDFM13250 | 251 | |
| Thrust washer | 2 | LDFM13250 | 252 | |
| Main bearing stud | 2 | LDFM13000 | 231 | |
| Nut for main bearing stud | 2 | LDFM13000 | 232 | |
| Oil sealing ring for crankcase door | 1 | LDFM19300 | 390 | |
| **Cylinder head and cylinder liner** | | | | |
| O-ring for cooling water jacket | 1 | LDFM15000 | 901 | |
| O-ring for cooling water jacket | 1 | LDFM15000 | 902 | |
| O-ring for cylinder liner | 1 | LDFM15000 | 192 | |
| O-ring for cylinder liner | 2 | LDFM15000 | 193 | |
| Sealing ring for cylinder liner | 1 | LDFM15000 | 191 | |
| O-ring for cooling water jacket | 1 | LDFM15000 | 922 | |
| O-ring for cooling water jacket | 1 | LDFM15000 | 923 | |

| Parts description | Q'ty | Section No. | Item No. | Remark |
|---|---|---|---|---|
| **Cylinder head and cylinder liner** | | | | |
| Valve seat, inlet | 2 | LDFM21100 | 111 | |
| Valve seat, exhaust | 4 | LDFM21100 | 112 | |
| Valve guide | 4 | LDFM21100 | 113 | |
| O-ring for exhaust valve seat ring | 4 | LDFM21100 | 118 | |
| O-ring for valve guide | 4 | LDFM21100 | 291 | |
| Valve stem seal | 2 | LDFM21100 | 292 | |
| Valve guide for valve stem seal | 2 | LDFM21100 | 293 | |
| O-ring for cylinder head cover, lower | 1 | LDFM21100 | 805 | |
| O-ring for cylinder head cover, upper | 2 | LDFM21100 | 806 | |
| O-ring for cylinder head | 2 | LDFM21100 | 901 | |
| Valve spindle, intake | 2 | LDFM21200 | 201 | |
| Valve spindle, exhaust | 4 | LDFM21200 | 202 | |
| Rotocap | 6 | LDFM21200 | 204 | |
| Conical piece | 6 | LDFM21200 | 206 | |
| Valve spring | 6 | LDFM21200 | 207 | |
| O-ring for dual valve timing | N | LDFM24100 | 340 | N : maximum. cylinder No. |
| O-ring for dual valve timing | N x 2 | LDFM24100 | 420 | N : maximum. cylinder No. |

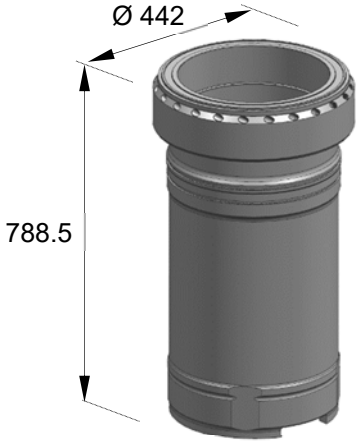
| Parts description | Q'ty | Section No. | Item No. | Remark |
|---|---|---|---|---|
| **Cylinder head and cylinder liner** | | | | |
| Air start valve | 1 | LDFM21400 | 400 | |
| O-ring for starting valve | 1 | LDFM21400 | 409 | |
| O-ring for starting valve | 1 | LDFM21400 | 410 | |
| O-ring for starting valve | 1 | LDFM21400 | 411 | |
| O-ring for starting valve | 1 | LDFM21400 | 412 | |
| O-ring for starting valve | 1 | LDFM21400 | 413 | |
| O-ring for starting valve | 1 | LDFM21400 | 415 | |
| O-ring for starting valve | 1 | LDFM21400 | 416 | |
| O-ring for starting valve | 1 | LDFM21400 | 417 | |
| O-ring for cooling water connection | 4 | LDFM78000 | 630 | |
| **Piston, connecting rod** | | | | |
| Piston pin | 1 | LDFM31100 | 120 | |
| Piston ring, top | 1 | LDFM31100 | 151 | |
| Piston ring, 2nd | 1 | LDFM31100 | 152 | |
| Piston ring, scraper | 1 | LDFM31100 | 153 | |
| Big end bearing, upper and lower | 1 | LDFM32000 | 113 | |
| Small end bush | 1 | LDFM32000 | 114 | |
| Connecting rod big end stud | 4 | LDFM32000 | 191 | |
| Nut for connecting rod | 8 | LDFM32000 | 192 | |
| Cylindrical pin | 4 | LDFM32000 | 193 | |
| Stud for connecting rod shaft | 1 | LDFM32000 | 194 | |
| Shim plate for connecting rod | 2 | LDFM32000 | 195 | |

| Parts description | Q'ty | Section No. | Item No. | Remark |
|---|---|---|---|---|
| **Ignition system** | | | | |
| Fuel injection pump | 1 | LDFM51000 | 100 | |
| Fuel injection valve | N / 2 | LDFM52000 | 100 | N : maximum. cylinder No. |
| Gasket for fuel injection valve | 15 x Cyl. | LDFM52000 | 110 | |
| Fuel high pressure block | 1 | LDFM52300 | 100 | |
| Methanol high pressure block | 1 | LDFM52300 | 200 | |
| Sealing ring for methanol branch | 2 | LDFM57000 | 630 | |
| Sealing ring for methanol main | 4 | LDFM57000 | 631 | |
| O-ring for methanol branch | 6 | LDFM57000 | 633 | |
| O-ring for methanol main | 4 | LDFM57000 | 634 | |
| Sealing ring for methanol helix | 6 | LDFM57000 | 983 | |
| O-ring for methanol helix | 6 | LDFM57000 | 984 | |
| O-ring for level switch cover | 1 | LDFM57000 | 985 | |
| O-ring for level switch cover | 1 | LDFM57000 | 986 | |
| **Piping system** | | | | |
| Flexible connecting pipe, each type | 1 set | LDFM98370 | | |
| Lube oil filter cartridge (primary) | 1 set | LDFM63000 | 701 | |
| Paper insert (centrifugal filter) | 1 set (25ea) | LDFM67000 | 702 | |
| **Etc.** | | | | |
| Turning gear spare kit | 1 set | Maker | - | |
| Air cooler spare kit | 1 set | Maker | - | |
| Plug for connection block | 2 | LDFM57000 | 990 | |
| Gasket for air cooler cover | 1 | LDFM84000 | 111 | |
| Gasket for air cooler cover | 1 | LDFM84000 | 131 | |

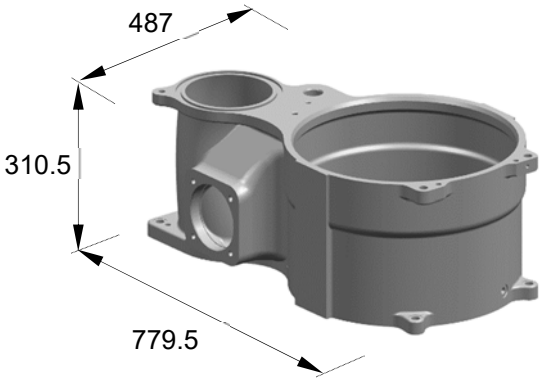
## 10.4 Heavy parts for maintenance




Cylinder head and rocker arms assembly
(Weight : approx. 468.11 kg)

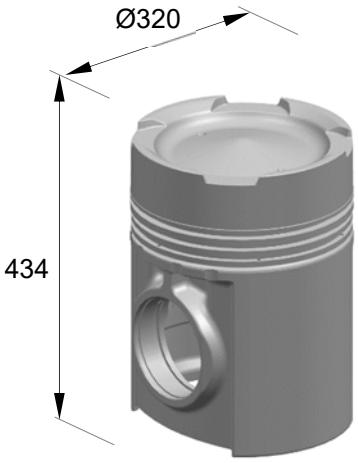



Cylinder liner
(Weight : approx. 189.96 kg)

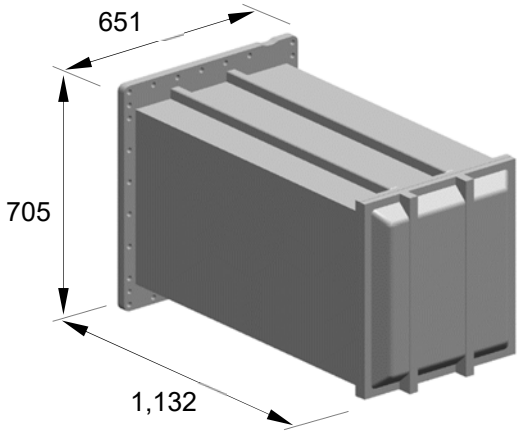



Water jacket
(Weight : approx. 114.98 kg)

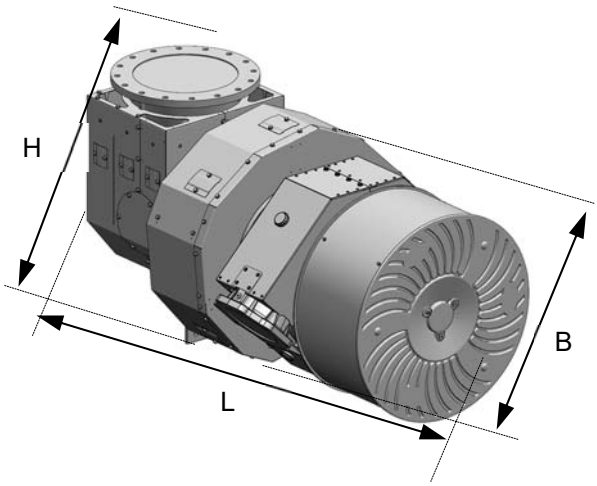
Connecting rod shaft
(Weight : approx. 71.36 kg)



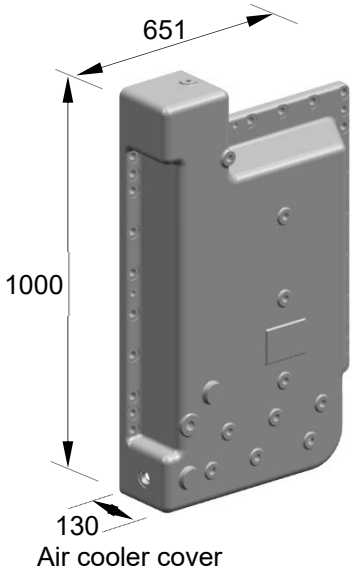

Piston
(Weight : approx. 81.2 kg)




Air cooler
(Weight : approx. 560 kg)




Turbocharger
(Refer to following table)




Air cooler cover
(Weight : approx. 154.44 kg)

Figure 10.1 Heavy parts dimension and weight.

Table 10.4 List of turbocharger outline dimension and weight

| Turbocharger type | B | H | L | Weight (kg) | Remarks |
|---|---|---|---|---|---|
| A145 | 801 | 902 | 1436 | 850 | Without insulation |
| A150-M58 | 839 | 930 | 1823 | 1200 | 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 liner | 1 | |
| Extract/suspension device for cylinder liner | 1 | |
| Cylinder bore gauge | 1 | |
| Removing device for flame ring | 1 | |
| Removal device for intake and exhaust valve seat | 1 | |
| Lapping device for inlet and exhaust valve seat | 1 | |
| Air gun | 1 | |
| Feeler gauge for inlet and exhaust valve. | 1 | |
| Plier for locking ring | 1 | |
| **Piston and connecting rod** | | |
| Guide bush for piston | 1 | |
| Lifting tool for piston | 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 | |

| 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 | |
| Test tool for fuel valve driver | 1 | |
| Separator for methanol adaptor | 4 | |
| Separator for methanol branch | N | N : maximum. cylinder No. |
| Removal device for fuel injection valve | 1 | |
| Lapping device for fuel injection valve bush | 1 | |
| Removal tool for atomizer nut | 1 | |
| Cleaning tool for fuel injection valve nozzle | 1 | |
| Methanol drain tank unit | 1 | |
| Removal device for fuel injection valve bush | 1 | |
| Spanner for fuel high pressure block | 1 | |
| **General tools** | | |
| Removal device for cooling water connection | 1 | |
| Torque wrench 22.5 Nm | 1 | |
| Torque wrench spanner head 8 | 1 | |
| Torque wrench spanner head 16 | 1 | |
| Crowfoot wrench head 41 | 1 | |
| Turbocharger cleaning hose | 1 | |

| Tool description | Q'ty | Remark |
|---|---|---|
| **Hydraulic tools** | | |
| Hydraulic tightening devices M48 (cylinder head, main bearing cap) | 4 | |
| Hydraulic tightening devices M39 (side stud, count weight) | 2 | |
| Hydraulic tightening devices M33 (connecting rod shaft, big end) | 2 | |
| 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 | |
| Insert screw for hydraulic jack M33 | 2 | |
| Angle piece | 2 | |
| Support for hydraulic tools M48 (main bearing cap) | 2 | |
| Support for hydraulic tools M48 (cylinder head) | 4 | |
| Support for hydraulic tools M39 (side stud, count weight) | 2 | |
| Support for hydraulic tools M33 (connecting rod shaft, big end) | 2 | |
| Extension screw for hydraulic tools M48 (cylinder head) | 4 | |
| Distribution pieces 2-POT | 1 | |
| Distribution pieces 4-POT | 1 | |
| High pressure hose (L=800) | 4 | |
| High pressure hose (L=4000) | 2 | |
| Adapter for hydraulic handing pump | 1 | |

| Tool description | Q'ty | Remark |
|---|---|---|
| Hydraulic tools | | |
| Turning pin (Φ10) | 2 | |
| Turning pin (Φ6) | 2 | |
| Cylinder pressure sensor tools | | |
| Fitting/removal device for cylinder pressure sensor | 1 | |
| Dual valve timing tools | | |
| Assembly tool for dual valve timing | 1 | |
| Standard tool box | | |
| Spare and tool box | 5 | |
| Air starting valve tools | | |
| Lapping device for air starting valve | 1 | |
| Tool for air starting valve | 1 | |
| Supercharging system | | |
| Air cooler tool kit | 1 set | Maker |
| Turning equipment | | |
| Turing gear tool kit | 1 set | Maker |

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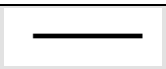
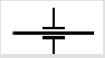
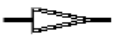
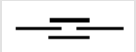
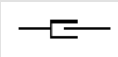
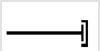
# 11 Appendix 1 (Piping symbols)

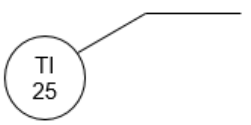
| No. | Symbol | Symbol designation | No. | Symbol | Symbol designation |
|---|---|---|---|---|---|
| **General conventional symbols** | | | | | |
| 1.1 |  | Pipe | 1.5 | | Indicating and measuring instruments |
| 1.2 |  | Pipe with indication of direction of flow | 1.6 | | High pressure pipe |
| 1.3 | | 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 | | Cock, three-way, L-port in plug |
| 3.2 | | Stop valve (needle valve) | 3.25 | | Cock, three-way, T-port in plug |
| 3.3 | | Shuttle valve | 3.26 | | Cock, four-way, straight through in plug |
| 3.4 | | Valve, Three-way | 3.27 | | Cock, with bottom connection |
| 3.5 | | Non-return valve | 3.28 | | Cock, straight through with bottom connection |
| 3.6 | | Flap, straight through | 3.29 | | Cock, angle with bottom connection |
| 3.7 | | Flap, angle | 3.30 | | Cock, three-way, with bottom connection |
| 3.8 | | Safety valve | 3.31 | | Solenoid valve |
| 3.9 | | Self-closing valve | 3.32 | | 3-way test valve |
| 3.10 | | Quick-opening valve | 3.33 | | Thermostatic valve |
| 3.11 | | Quick-closing valve | 3.34 | | Valve with test flange |
| 3.12 | | Regulating valve | 3.35 | | 3-way valve with remote control (Actuator) |
| 3.13 | | Angle valve | 3.36 | | Non-return valve (Air) |
| 3.14 | | Ball valve | 3.37 | | Reducing valve |
| 3.15 | | Butterfly valve | 3.38 | | 3/2 way valve, normally open |
| 3.16 | | Gate valve | 3.39 | | 3/2 way valve, normally closed |
| 3.17 | | Double-seated changeover valve | 3.40 | | 2/2 way valve, normally open |
| 3.18 | | Suction valve chest | 3.41 | | 2/2 way valve, normally closed |
| 3.19 | | Suction valve chest with non-return valves | 3.42 | | |
| 3.20 | | Double-seated changeover valve, straight | 3.43 | | |
| 3.21 | | Double-seated changeover valve, angle | 3.44 | | |
| 3.22 | | Ball valve, angle | 3.45 | | |

| 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 override (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 directional valve |
| 4.8 | | Electro-magnetic | 4.17 | | By plunger or tracer |
| 4.9 | | Flame arrestor | | | Pneumatic |
| **Appliances** | | | | | |
| 5.1 | | Mudbox | 5.13 | | Heat exchanger |
| 5.2 | | Filter | 5.14 | | Strainer |
| 5.3 | | Duplex filter | 5.15 | | Air filter |
| 5.4 | | Magnetic filter | 5.16 | | Air filter with manual control |
| 5.5 | | Separator | 5.17 | | Air filter with automatic drain |
| 5.6 | | Steam trap | 5.18 | | Water trap with manual 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 motor with spring returned |
| 5.10 | | Ejector | 5.22 | | Single acting cylinder with spring returned |
| 5.11 | | Various accessories (Text to be added) | 5.23 | | Double acting cylinder with spring returned |
| 5.12 |  | Piston pump | 5.24 |  | Auto drain trap |

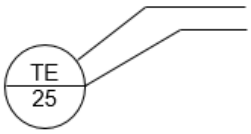
| No. | Symbol | Symbol designation | No. | Symbol | Symbol designation |
|---|---|---|---|---|---|
| **Fittings** | | | | | |
| 6.1 | | Funnel | 6.8 | | Air pipe with pressure-vacuum valve |
| 6.2 | | Bell-mouthed pipe end | 6.9 | | Deck fittings for sound's or filling pipe |
| 6.3 | | Air pipe | 6.10 | | 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)



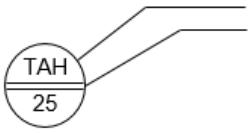

Measuring device Locally reading

Temperature Indicator No. 25*



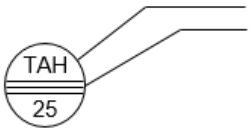

Measuring device
Sensor mounted on engine/unit
Reading/identification mounted in a panel on the engine/unit

Temperature element No. 25*




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

Temperature Alarm High No. 25*




Measuring device
Sensor mounted on engine/unit
Reading/identification mounted in a panel on the engine
& 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 | | 2nd letter | | 3rd letter | |
| C | Control | A | Alarm | L | Low |
| F | Flow | D | Differential | H | High |
| L | Level, Limit | E | Element | | |
| P | Pressure | I | Indicating | | |
| S | Speed, Solenoid | S | Switching, Stop | | |
| T | Temperature | T | Transmitting | | |
| U | Voltage | X | Failure | | |
| V | Viscosity | V | Valve | | |
| Z | Position | | | | |

## Speed system

11 Engine speed
12 Engine speed & position

## Combustion gas system

21 Charge air at cooler outlet
25 Exhaust gas at cylinder outlet
26 Exhaust gas at TC inlet
27 Exhaust gas at TC 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 v/v 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 TC 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

## Second fuel system

67 Control & sealing oil
80 Methanol at FVT filter inlet
81 Methanol at FVT filter outlet
82 Methanol at methanol double block and bleed valve
83 Control air at FVT
84 Methanol shutoff valve
85 Methanol drain valve
87 Methanol at methanol high pressure pump inlet and engine outlet
89 Inert gas valve

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# 13 Note

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