# PROJECT GUIDE

## HiMSEN H54GV
FOR STATIONARY

HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY

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.

## General

This project guide provides the necessary information and recommendations for applications of HYUNDAI's HiMSEN H54GV gas generating sets (gen-set).

"HiMSEN'® is the registered brand name of HYUNDAI's own design engine and the abbreviation of '**Hi**-Touch **M**arine & **S**tationary **EN**gine'.

***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 application of the data. Hyundai Heavy Industries Co., Ltd.(HHI) will always provide the data for the installation of the specific project***.

Each sheet is identified by the engine type and own 'Sheet Number'. Therefore, please use engine type 'H54GV' and 'Sheet No.' for easier communications

## Engine model designation

**12 H 54 G V (M/S)**

- No. of cylinders (12,14,16,18)
- HYUNDAI's HiMSEN
- Cylinder bore in cm
- Gas engine
- Vee- type configuration
- Marine or stationary application

## Sheet number

**P . XX . XXX**

- Project guide book
- Section number
- Sub - section with serial number

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**Jul. 2022**

## Cylinder numbering

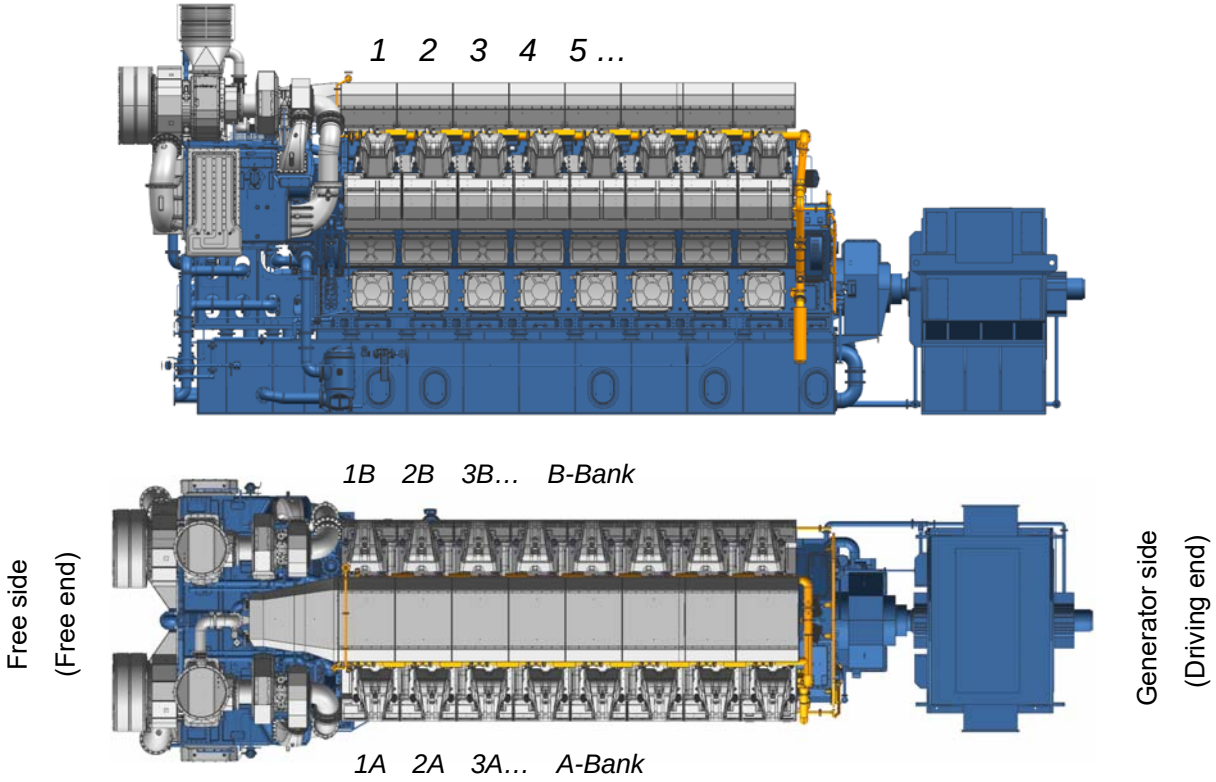
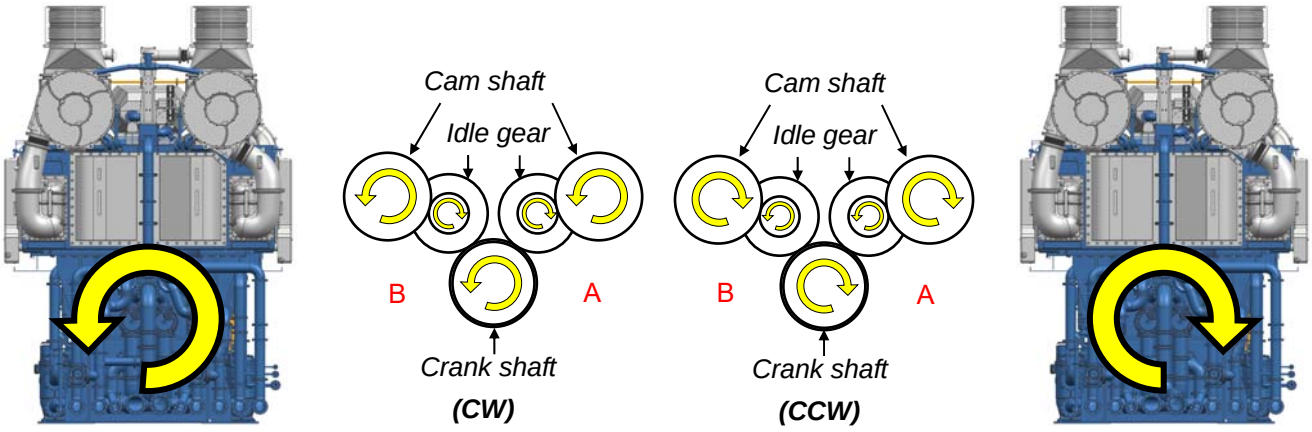



*Figure 0-3-1: Engine definition*

## Direction of engine rotation

Clockwise engine : Clockwise viewed from driving end

Counterclockwise engine : Counterclockwise viewed from driving end




*Clockwise engine (standard) (Viewed from free end)*

*Counterclockwise engine (option) (Viewed from free end)*

*Figure 0-3-2: Direction of the engine rotation*

| | | |
|---|---|---|
| Type of engine | | 4-stroke, Vee-type, trunk piston type gas engine with turbocharger and air cooler |
| Cylinder configuration | | V-type |
| Number of cylinder | | 12, 14, 16, 18 |
| Rated speed | rpm | 600 |
| Power per cylinder | kW | 1,400 |
| Cylinder bore | mm | 540 |
| Piston stroke | mm | 600 |
| Swept volume per cylinder | $dm^3$ | 137.4 |
| Mean piston speed | m/s | 12.0 |
| Mean effective pressure | bar | 20.4 |
| Direction of engine rotation | | Clockwise (Crank-axis)<br>View from generator side<br>(Non-reversible) |
| Cylinder firing order | | |
| | 12H54GV | 1 - 2 - 4 - 6 - 5 - 3 |
| | 14H54GV | 1 - 2 - 4 - 6 - 7 - 5 - 3 |
| | 16H54GV | 1 - 3 - 2 - 5 - 8 - 6 - 7 - 4 |
| | 18H54GV | 1 - 5 - 9 - 4 - 7 - 8 - 2 - 3 - 6 |

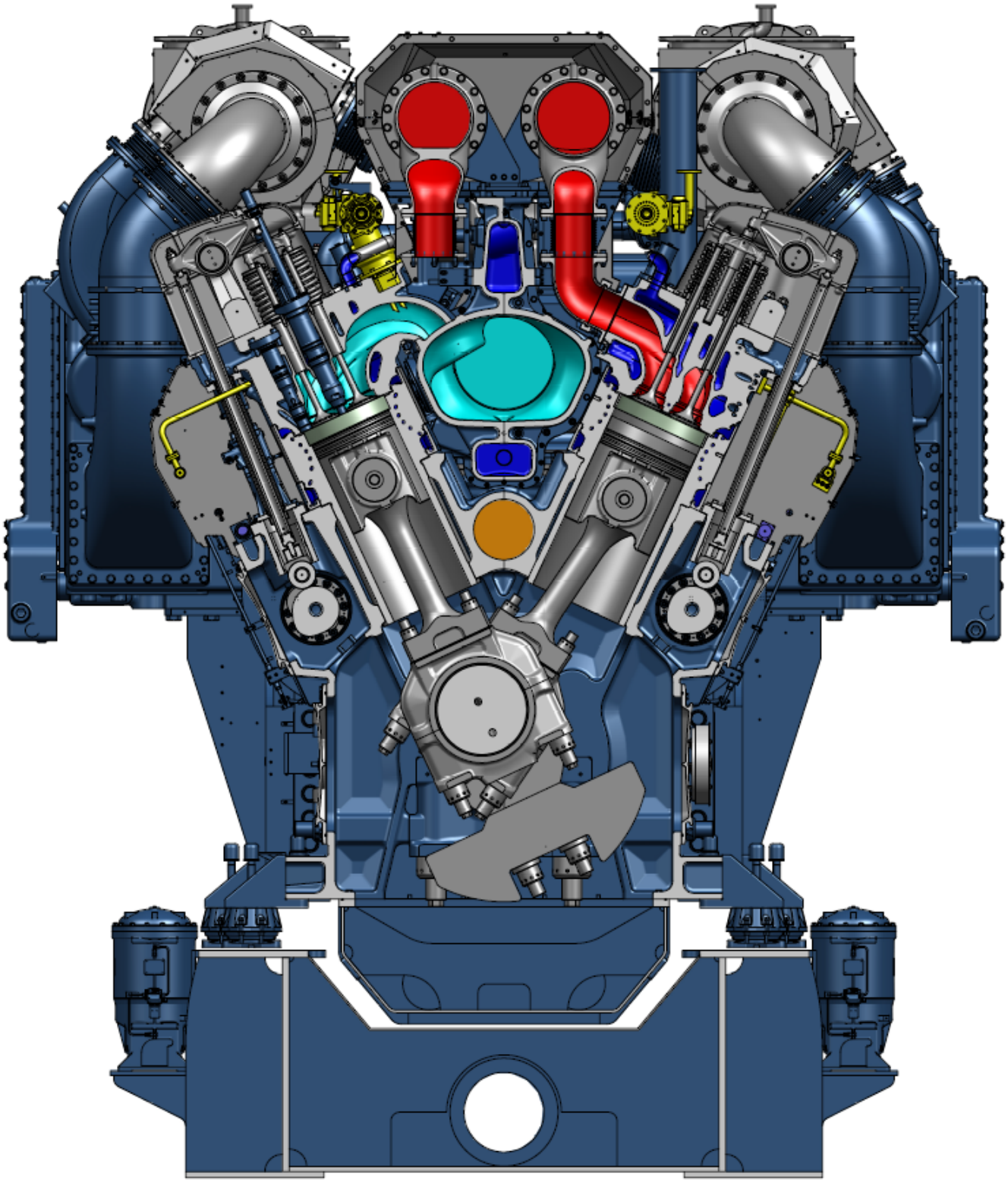


*Figure 1-2-1: Engine cross section [B90-184633-8]*

## General

HiMSEN H54GV family is the most powerful four-stroke engine on the market. And it is designed to generate electricity reliably and highly efficiently by applying the two-stage turbocharging system(TSTC system). Despite the TSTC system, H54GV is compact because all turbochargers and air coolers are mounted on the engine. The key features are summarized as follows:

**HiMSEN H54GV is spark-ignited gas engine. The engine has ported gas admission and a pre-combustion chamber with a spark plug for ignition.**

**An eco-friendly and ecological engine with high efficiency, low NOx emission, low smoke, etc., which is based on the following specific designs:**

- Two-stage turbocharging system (TSTC system)
- Stable combustion, ensured by a high-energy ignition system and pre-combustion chamber
- High compression ratio
- Optimized supercharging with miller cycle
- Optimized air fuel ratio control and combustion parameters

**A reliable and practical engine with simple, smart and robust structure, which is based on the following features:**

- Number of engine components is minimized with pipe-free design.
- Most of the components are directly accessible for easy maintenance.
- Highly integrated control system is applied.
- By mounting the additional turbocharger and air cooler on the engine, the dimension of H54GV is minimized.

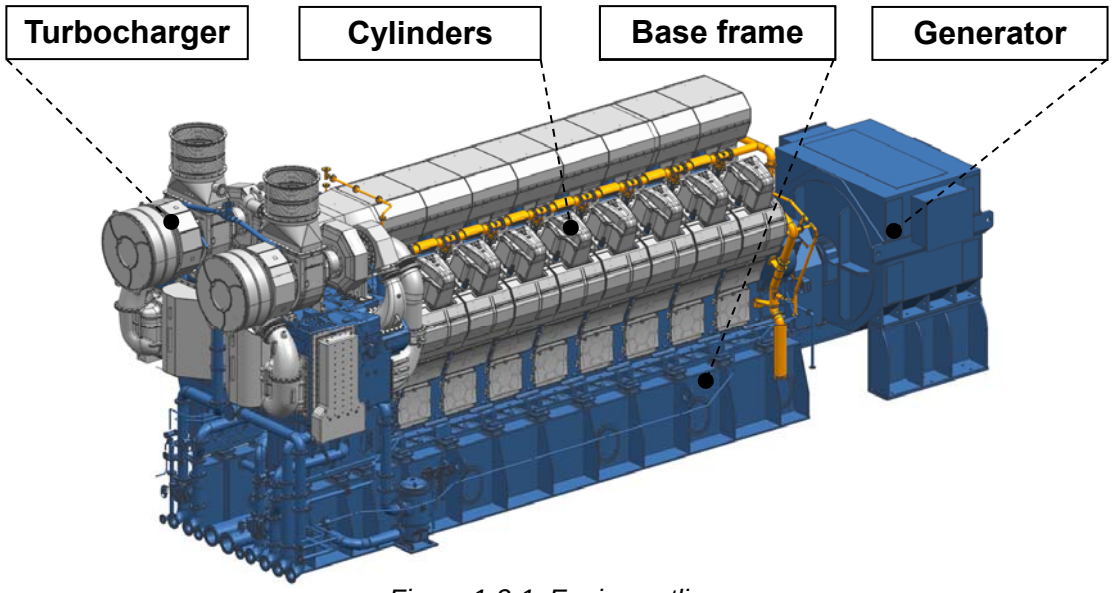



*Figure 1-3-1: Engine outline*

## Design of main components

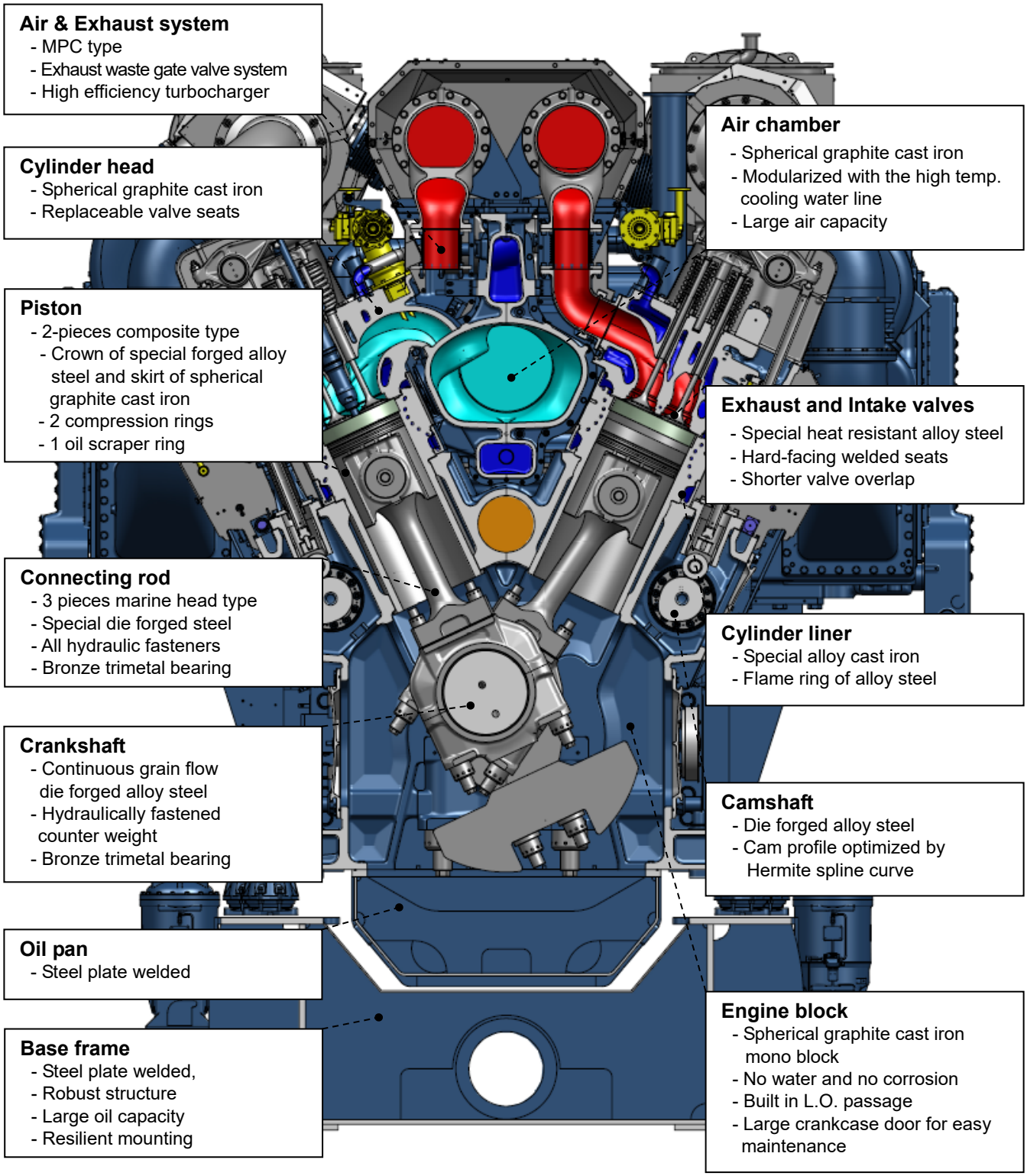



*Figure 1-3-2: Main components of the engine*

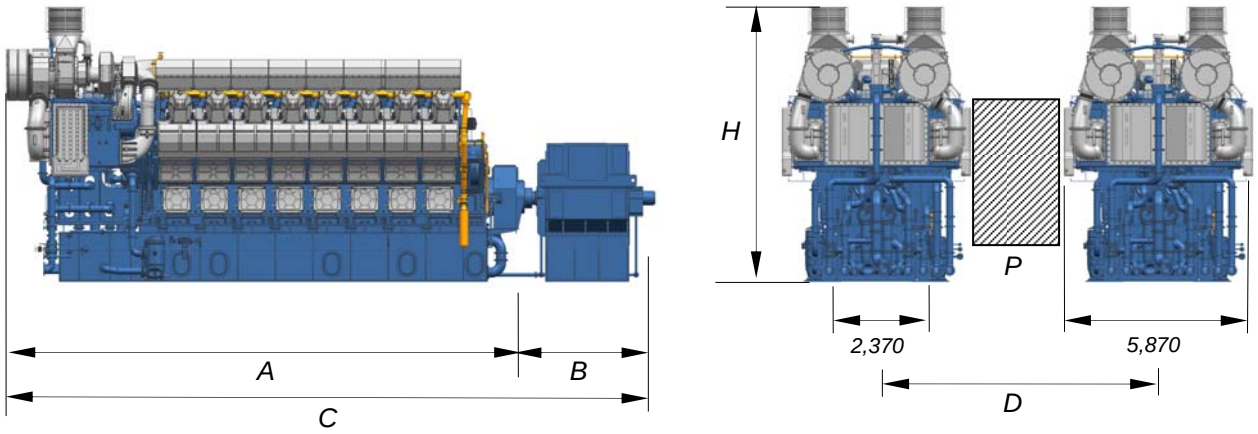



*Figure 1-4-1: Engine outline dimensions*

## Genset

| Engine type | Dimensions [mm] | | | | | Dry weight[ton] | |
|---|---|---|---|---|---|---|---|
| | A | B[1)] | C[1)] | D | H | Engine[3)] | Genset[1),2)] |
| 12H54DFV | 12,511 | 4,638 | 17,149 | 7,000 | 7,994 | 294 | 381 |
| 14H54DFV | 13,661 | 4,582 | 18,243 | 7,000 | 7,994 | 324 | 421 |
| 16H54DFV | 15,086 | 4,757 | 19,843 | 7,000 | 8,383 | 361 | 467 |
| 18H54DFV | 16,236 | 4,927 | 21,163 | 7,000 | 8,383 | 391 | 508 |

1) Depending on a generator

2) Weight included a standard generator (Maker : Hyundai Electric) and base frame

3) Without base frame

D: Min. distance between engine centers

P: Free passage between engines, width 600mm and height 2,000mm

A: Distance between T/C end and flywheel end

B: Distance between flywheel end and generator

*** All dimensions and weights are approximate values and subject to change without prior notice.**

## General

The generating-set consists of engine, baseframe and generator. The generator is mounted on plant separately and connected to the engine with the only flexible coupling in order to isolate the vibrations between the generator and engine.

The engine is mounted on the baseframe by the resilient mount which is made with a number of rubber elements to isolate vibrations between the engine and baseframe.

The baseframe can be rigidily mounted to the foundation either on steel chocks or resin chocks.

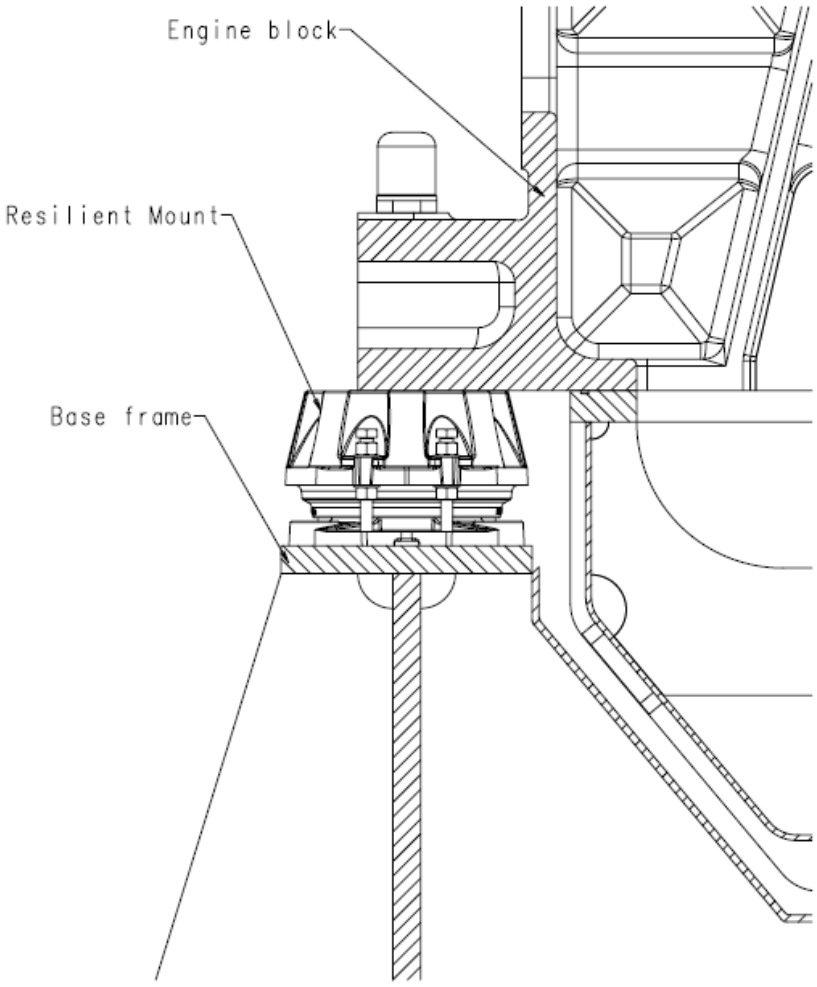



*Figure 1-5-1: Resilient mounting of the generating-set*

## Design of resilient mount

The quantites and position of the resilient mounts are determined by the dynamic characteristics of a vessel or plant. Therefore, the final specification of the mounts shall be decided based on the information from a shipyard or plant case by case.

## Connections to the engine

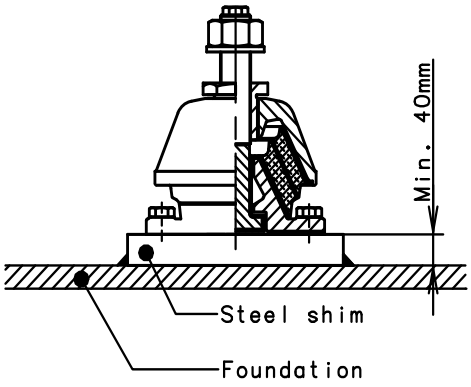
The engine mounted on the resilient mounts is usually influenced by relative motions from the hull/site structure. Due to the reason, any rigid fixing between the engine and hull/site structure causes damages to the engine or hull/site structure. Therefore, all connections, for example, pipes, gratings, ladders, electric wires and etc. should be flexible enough to absorb the relative movements.

## Recommendations for seating design and adjustment

The engine foundation should be rigid enough to support the load from the engine. Thickness of minimum 40mm steel shim plates between the resilient mounts and foundation are required to adjust leveling of each mount (Method 1). Additional shim plate (min. thickness 10mm) can be used for adjustments (Method 2) as shown below.

It is also recommended to check the crankshaft deflection before starting up the vessel to secure the correct adjustments of the shim plate and leveling of the engine.

Method 1




Method 2

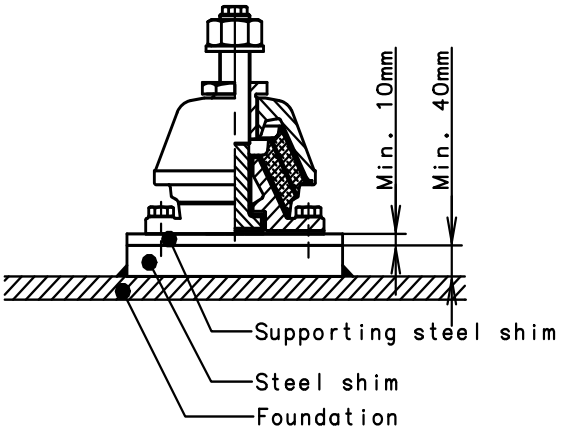
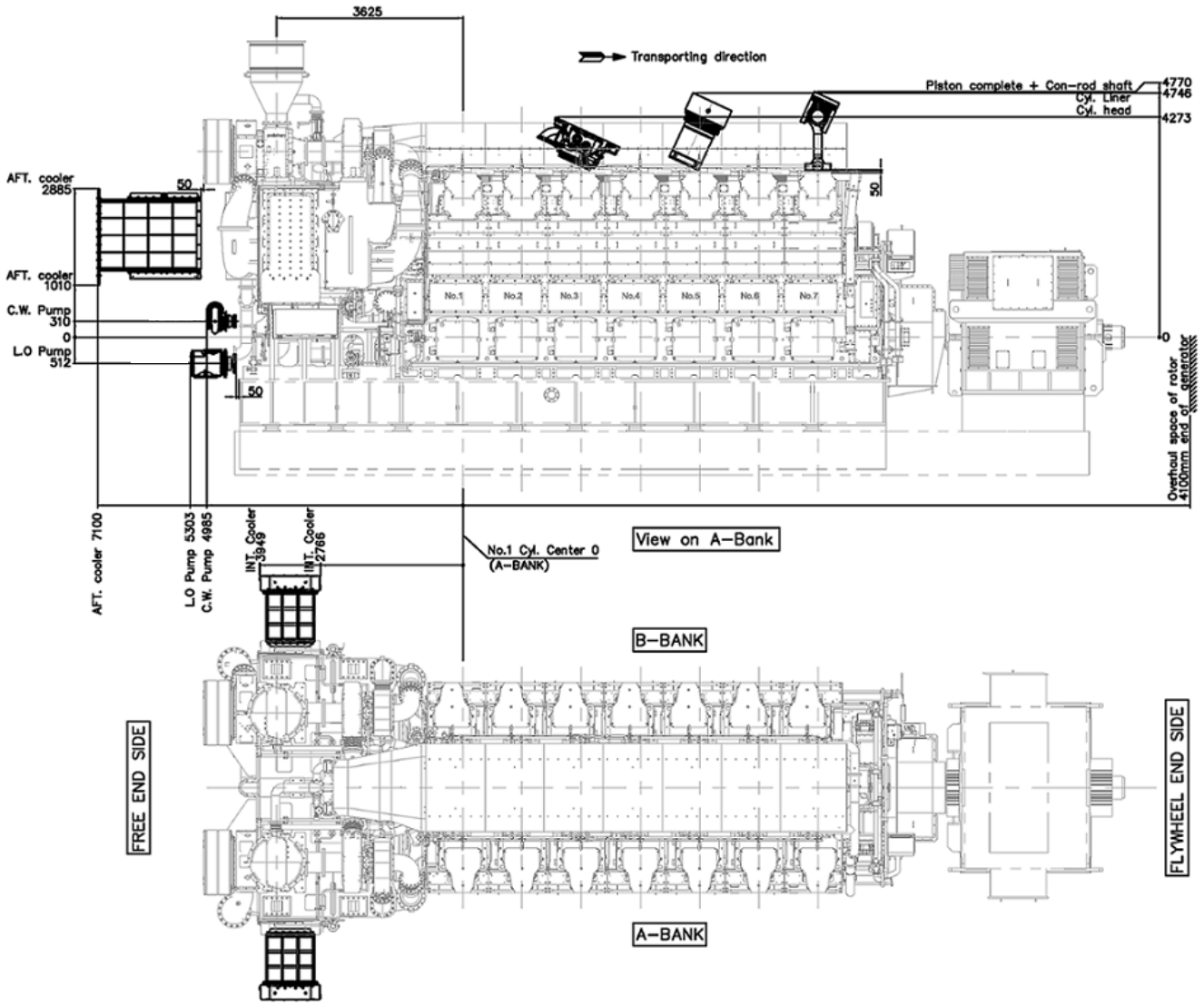
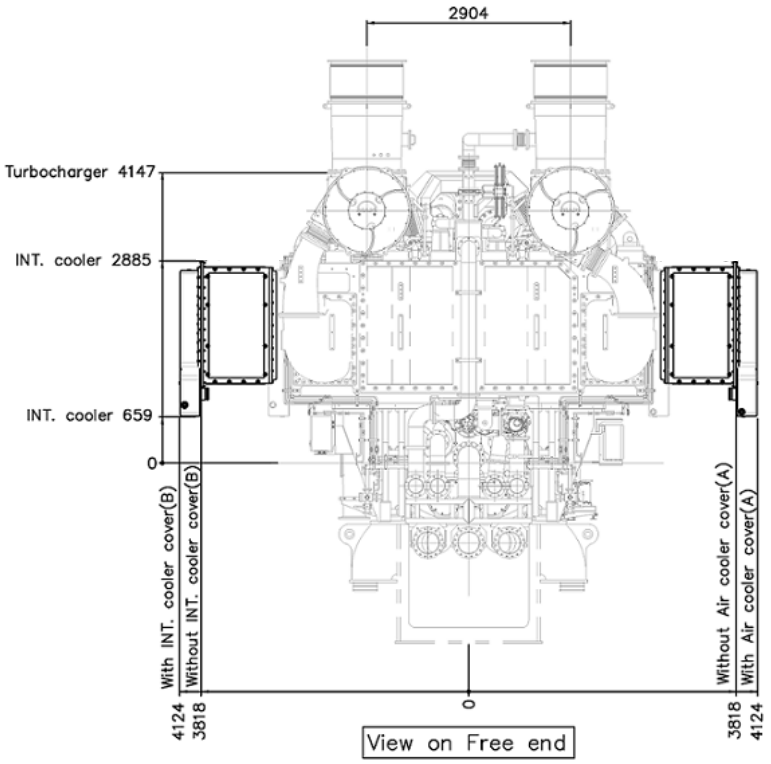



*Figure 1-5-2: Resilient mounting adjustments*


3625
Transporting direction
Piston complete + Con-rod shaft 4770
Cyl. Liner 4746
Cyl. head 4273
AFT. cooler 2885
AFT. cooler 1010
C.W. Pump 310
0
L.O Pump 512
50
50
50
No.1
No.2
No.3
No.4
No.5
No.6
No.7
0
Overhaul space of rotor 4100mm end of generator
AFT. cooler 7100
L.O Pump 5303
C.W. Pump 4985
INT. Cooler 3948
INT. Cooler 2766
No.1 Cyl. Center 0 (A-BANK)
View on A-Bank
B-BANK
FREE END SIDE
FLYWHEEL END SIDE
A-BANK


2904
Turbocharger 4147
INT. cooler 2885
INT. cooler 659
0
With INT. cooler cover(B)
Without INT. cooler cover(B)
Without Air cooler cover(A)
With Air cooler cover(A)
4124
3818
0
3818
4124
View on Free end

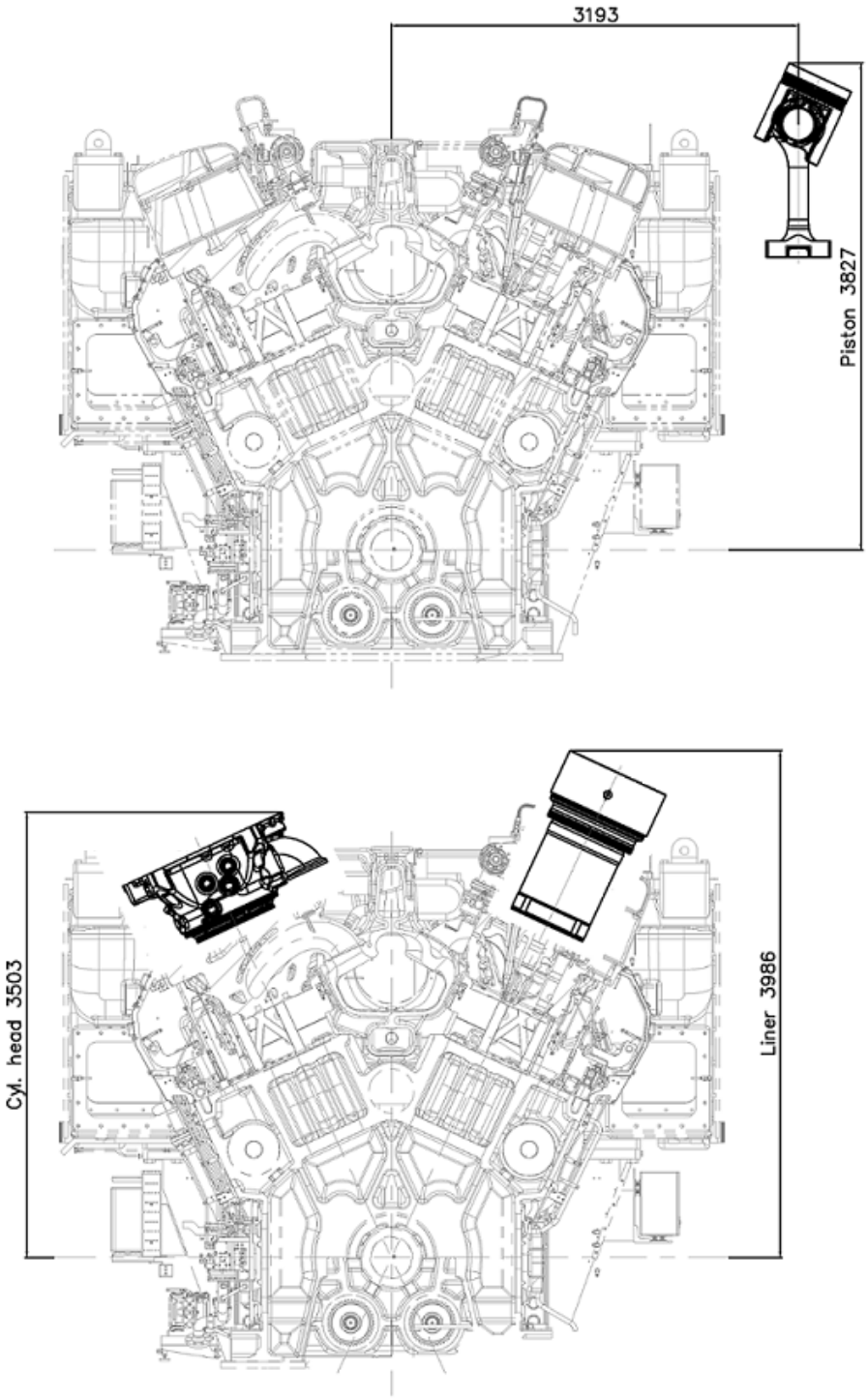



*Figure 1-6-1: Overhaul dimensions for major components [BH0-091922-4]*

## Rated power

| Engine type | Rated output at 600 rpm (60Hz/50Hz) | |
|---|---|---|
| | Engine($kW_m$) | Generator($kW_e$) |
| 12H54GV | 16,800 | 16,296 |
| 14H54GV | 19,600 | 19,012 |
| 16H54GV | 22,400 | 21,728 |
| 18H54GV | 25,200 | 24,444 |

Remark:

1. The generator outputs are calculated for efficiency of 97%, a power factor of 0.85 lagging
2. Power adjusting must be consulted to engine builder.

## Reference condition

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

## ISO conditions

Turbocharger air inlet pressure : 1 bar

Turbocharger air inlet temperature : 298 K (25°C)

Charge air coolant temperature : 298 K (25°C)

## Tropical conditions

Total barometric pressure : 1 bar

Air temperature : 318 K (45°C)

Charge air coolant temperature* : 309 K (36°C)

## 600 rpm / 50 Hz, 60 Hz (1,400 kW/cyl) – ISO condition

| Engine MCR | Cyl. | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|
| | kW | 16,800 | 19,600 | 22,400 | 25,200 |
| **COOLING CAPACITIES** | | | | | |
| **Inter cooler** | | | | | |
| HT- heat dissipation [1] | kW | 2,110 | 2,460 | 2,815 | 3,165 |
| LT- heat dissipation [1] | kW | 820 | 955 | 1,095 | 1,230 |
| Cooling water flow (HT) | $m^3/h$ | 324 | 380 | 435 | 490 |
| Cooling water flow (LT) | $m^3/h$ | 255 | 300 | 345 | 390 |
| HT-cooling water temperature, cooler (in/out) | °C | 86 / 91 | 86 / 91 | 86 / 91 | 86 / 91 |
| LT-cooling water temperature, cooler (in/out) | °C | 36 / 39 | 36 / 39 | 36 / 39 | 36 / 39 |
| **After cooler** | | | | | |
| HT- heat dissipation [1] | kW | 2160 | 2,525 | 2,885 | 3,245 |
| LT- heat dissipation [1] | kW | 1,035 | 1,205 | 1,380 | 1,550 |
| Cooling water flow (HT) | $m^3/h$ | 324 | 380 | 435 | 490 |
| Cooling water flow (LT) | $m^3/h$ | 255 | 300 | 345 | 390 |
| HT-cooling water temperature, cooler (in/out) | °C | 80 / 86 | 80 / 86 | 80 / 86 | 80 / 86 |
| LT-cooling water temperature, cooler (in/out) | °C | 33 / 36 | 33 / 36 | 33 / 36 | 33 / 36 |
| **Lubricating oil** | | | | | |
| Heat dissipation [1), 3)] | kW | 2,560 | 2,985 | 3,415 | 3,840 |
| LT-cooling water flow | $m^3/h$ | 255 | 300 | 345 | 390 |
| LT-cooling water temperature, cooler (in/out) | °C | 39 / 48 | 39 / 48 | 39 / 48 | 39 / 48 |
| **Cylinder jacket** | | | | | |
| Heat dissipation [1] | kW | 1,390 | 1,620 | 1,850 | 2,085 |
| HT-cooling water flow | $m^3/h$ | 324 | 380 | 435 | 490 |
| HT-cooling water temperature, engine (in/out) | °C | 91 / 95 | 91 / 95 | 91 / 95 | 91 / 95 |
| **HP-turbocharger compressor wheel** | | | | | |
| Heat dissipation [1] | kW | 18 | 20 | 25 | 27 |
| HT-cooling water flow | $m^3/h$ | 9.6 | 11.3 | 12.9 | 14.5 |
| HT-cooling water temperature, T/C (in/out) | °C | 91 / 93 | 91 / 93 | 91 / 93 | 91 / 93 |
| **EXHAUST GAS DATA [2)]** | | | | | |
| Combustion air consumption | kg/h | 101,420 | 118,330 | 135,230 | 152,140 |
| Exhaust gas flow | kg/h | 104,250 | 121,630 | 139,010 | 156,380 |
| Exhaust gas temperature | °C | 280 | 280 | 280 | 280 |
| Allowable exhaust gas back pressure, max. | mbar | 30 | 30 | 30 | 30 |
| **HEAT RADIATION** | | | | | |
| Engine radiation [1] | kW | 515 | 605 | 690 | 775 |
| Generator radiation | kW | (See separate data from generator maker) | | | |

## 600 rpm / 50 Hz, 60 Hz (1,400 kW/cyl) – ISO condition

| Engine MCR | Cyl. | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|
| | kW | 16,800 | 19,600 | 22,400 | 25,200 |
| **STARTING AIR** | | | | | |
| Air consumption per start | $Nm^3$ | 8.0 | 8.9 | 9.8 | 10.7 |
| Air consumption per start with slowturn | $Nm^3$ | 10.3 | 11.4 | 12.6 | 13.7 |
| Starting air source, pressure (20℃) (max/ min) | bar | 30 / 15 | 30 / 15 | 30 / 15 | 30 / 15 |
| **PUMP CAPACITIES, ENGINE DRIVEN PUMP** [4] | | | | | |
| Lubricating oil pump (8 bar) | $m^3/h$ | 220x2 | 250x2 | 280x2 | 310x2 |
| HT-cooling water pump (4.5 bar) | $m^3/h$ | 324 | 380 | 435 | 490 |
| LT-cooling water pump (4.5 bar) | $m^3/h$ | 255 | 300 | 345 | 390 |
| **PUMP CAPACITIES, EXTERNAL PUMP** | | | | | |
| Pre lub. oil pump (3.5 bar) | $m^3/h$ | 120 | 120 | 150 | 150 |

**Remark :**

1) Under ISO condition (Turbocharger inlet air press. 1 bar, intake air temp. 25 ℃, LT-cooling water temp. 25 ℃) with flow tolerance ±10% at 100% load. Heat dissipation tolerance for cooling water ±10% / for heat recovery -15% / for radiation ±30%. A margin and fouling factors to be taken into account when design heat exchangers.

2) Under ISO condition with flow tolerance ±10% and exhaust gas temperature tolerance ±25 ℃

3) Additional heat for purification (30 kJ/kWh) included

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

## 600 rpm / 50 Hz, 60 Hz (1,400 kW/cyl) – Tropical condition

| Engine MCR | Cyl. | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|
| | kW | 16,800 | 19,600 | 22,400 | 25,200 |
| **COOLING CAPACITIES** | | | | | |
| **Inter cooler** | | | | | |
| HT- heat dissipation 1) | kW | 2,665 | 3,110 | 3,550 | 3,995 |
| LT- heat dissipation 1) | kW | 1,035 | 1,210 | 1,380 | 1,555 |
| Cooling water flow (HT) | $m^3/h$ | 324 | 380 | 435 | 490 |
| Cooling water flow (LT) | $m^3/h$ | 255 | 300 | 345 | 390 |
| HT-cooling water temperature, cooler (in/out) | °C | 84 / 91 | 85 / 91 | 85 / 91 | 85 / 91 |
| LT-cooling water temperature, cooler (in/out) | °C | 39 / 43 | 39 / 43 | 39 / 43 | 39 / 43 |
| **After cooler** | | | | | |
| HT- heat dissipation 1) | kW | 2,220 | 2,590 | 2,960 | 3,330 |
| LT- heat dissipation 1) | kW | 1,060 | 1,240 | 1,415 | 1,595 |
| Cooling water flow (HT) | $m^3/h$ | 324 | 380 | 435 | 490 |
| Cooling water flow (LT) | $m^3/h$ | 255 | 300 | 345 | 390 |
| HT-cooling water temperature, cooler(in/out) | °C | 79 / 84 | 79 / 85 | 79 / 85 | 79 / 85 |
| LT-cooling water temperature, cooler (in/out) | °C | 36 / 39 | 36 / 39 | 36 / 39 | 36 / 39 |
| **Lubricating oil** | | | | | |
| Heat dissipation 1), 3) | kW | 2,570 | 3,000 | 3,425 | 3,855 |
| LT-cooling water flow | $m^3/h$ | 255 | 300 | 345 | 390 |
| LT-cooling water temperature, cooler (in/out) | °C | 43 / 52 | 43 / 51 | 43 / 51 | 43 / 51 |
| **Cylinder jacket** | | | | | |
| Heat dissipation 1) | kW | 1,395 | 1,625 | 1,860 | 2,090 |
| HT-cooling water flow | $m^3/h$ | 324 | 380 | 435 | 490 |
| HT-cooling water temperature, engine (in/out) | °C | 91 / 95 | 91 / 95 | 91 / 95 | 91 / 95 |
| **HP-turbocharger compressor wheel** | | | | | |
| Heat dissipation 1) | kW | 18 | 20 | 25 | 27 |
| HT-cooling water flow | $m^3/h$ | 9.6 | 11.3 | 12.9 | 14.5 |
| HT-cooling water temperature, T/C (in/out) | °C | 91 / 93 | 91 / 93 | 91 / 93 | 91 / 93 |
| **EXHAUST GAS DATA** 2) | | | | | |
| Combustion air consumption | kg/h | 101420 | 118330 | 135230 | 152140 |
| Exhaust gas flow | kg/h | 104260 | 121640 | 139020 | 156400 |
| Exhaust gas temperature | °C | 280 | 280 | 280 | 280 |
| Allowable exhaust gas back pressure, max. | mbar | 30 | 30 | 30 | 30 |
| **HEAT RADIATION** | | | | | |
| Engine radiation 1) | kW | 520 | 605 | 690 | 780 |
| Generator radiation | kW | (See separate data from generator maker) | | | |

## 600 rpm / 50 Hz, 60 Hz (1,400 kW/cyl) – Tropical condition

| Engine MCR | Cyl. | 12 | 14 | 16 | 18 |
|---|---|---|---|---|---|
| | kW | 16,800 | 19,600 | 22,400 | 25,200 |
| **STARTING AIR** | | | | | |
| Air consumption per start | $Nm^3$ | 8.0 | 8.9 | 9.8 | 10.7 |
| Air consumption per start with slowturn | $Nm^3$ | 10.3 | 11.4 | 12.6 | 13.7 |
| Starting air source, pressure (20℃) (max/ min) | bar | 30 / 15 | 30 / 15 | 30 / 15 | 30 / 15 |
| **PUMP CAPACITIES, ENGINE DRIVEN PUMP** [4] | | | | | |
| Lubricating oil pump (8 bar) | $m^3/h$ | 220x2 | 250x2 | 280x2 | 310x2 |
| HT-cooling water pump (4.5 bar) | $m^3/h$ | 324 | 380 | 435 | 490 |
| LT-cooling water pump (4.5 bar) | $m^3/h$ | 255 | 300 | 345 | 390 |
| **PUMP CAPACITIES, EXTERNAL PUMP** | | | | | |
| Pre lub. oil pump (3.5 bar) | $m^3/h$ | 120 | 120 | 150 | 150 |

**Remark :**

1) Under Tropical condition (Turbocharger inlet air press. 1 bar, intake air temp. 45 ℃, LT-cooling water temp. 36 ℃) with flow tolerance ±10% at 100% load. Heat dissipation tolerance for cooling water ±10% / for heat recovery -15% / for radiation ±30%. A margin and fouling factors to be taken into account when design heat exchangers.
2) Under Tropical condition with flow tolerance ±10% and exhaust gas temperature tolerance ±25 ℃
3) Additional heat for purification (30 kJ/kWh) included
4) Flow capacity to be within a tolerance of 0% to +10%.

## Engine performance data

**Rated Power: 1,400 kW/Cyl. at 600 rpm**

| Performance data | | | Engine load (%) | | | |
|---|---|---|---|---|---|---|
| | | | 100 | 90 | 75 | 50 |
| **CYLINDER DATA** | | | | | | |
| | Cylinder output | kW/Cyl. | 1,400 | 1,260 | 1,050 | 700 |
| | Mean effective pressure | bar | 20.4 | 18.3 | 15.3 | 10.2 |
| **Gas mode** | **EXHAUST GAS DATA[1)]** | | | | | |
| | Mass flow | kJ/kWh | 6.2 | 6.3 | 6.6 | 6.9 |
| | Gas temperature after turbine | °C | 295 | 315 | 345 | 395 |
| | **GAS MIXTURE DATA [1), 2), 3)]** | | | | | |
| | Air consumption [1)] | kg/kWh | 6.0 | 6.2 | 6.4 | 6.7 |
| | Fuel gas heat rate [3)] | kJ/kWh | 7,060 | 7,200 | 7,425 | 8,000 |
| | Air temperature after cooler | °C | 45 | 45 | 45 | 45 |

Remarks:

1) Reference condition based on ISO 3046-1:2002 (turbocharger inlet air pressure 1 bar, intake air temperature 25°C, relative humidity 30%, LT-cooling water temperature 25°C)
The above values are based on TA-Luft NOx emission level.
Mass flow tolerance ±10%, gas temperature tolerance ±25°C.

2) THR(Total Heat Rate) tolerance for warranty ±5% at 100% load.
Engine driven pumps attached: Lub. oil pumps, HT-pump, LT-pump

3) Fuel gas based on natural gas, LCV 36 MJ/Nm$^3$ (≒50 MJ/kg), min. methane number(MN) 80
Required fuel gas pressure depends on fuel gas LCV and need to be increased for lower LCV's
Pressure drop in external fuel gas supply system to be considered.

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## General

HiMSEN H54GV is designed for environment-friendly engine with lean-burn technology, more air is supplied in the cylinder than is needed for complete combustion, as a result of lean-burn, the maximum temperature in the cylinder is reduced and less NOx is produced.

## Application

HiMSEN H54GV is designed to cover all below NOx emission guideline as applying lean burn concept explained above, therefore HiMSEN H54GV is available for all country of the world as stationary engine.

## NOx guideline for gas enigne

- **World bank guideline**

  - 200 mg/Nm$^3$ @ 15% O2

- **UN-ECE gothenburg protocol**

  - 250 mg/Nm$^3$ @ 5% O2 ( > 1 MWth )

- **Germany - TA Luft**

  - 500 mg/Nm3 @ 5% O2

- **Finland**

  - 1,600 mg/Nm3 @ 15% O2 (Engine internal measures)

  - 750 mg/Nm3 @ 15% O2 (Methods outside the engine)

- **France**

  - 250 mg/Nm3 @ 5% O2 (Operating time > 500 h/year)

  - 625 mg/Nm3 @ 5% O2 (Operating time ≤ 500 h/year)

- **Italy**

  - 100 mg/Nm$^3$ @ 3% O2

- **Switzerland**

  - 400 mg/Nm$^3$ @ 5% O2

- **IMO (for marine)**

  - No regulation for GAS engine

- **Japan**

  - 600 ppm @ 0% O2

## Correction for ambient condition (Gas operation)

The heat rate of the gas operation normally refers to the ISO 3046/1 standard condition. However, for the condition other than ISO 3046-1:2002 standard condition, the heat rate at MCR can be estimated according to the following formula:

First, there is a relationship between the heat rate and the efficiency. The heat rate is the inverse of the efficiency.

**Heat Rate (kJ/kWh) = Thermal Energy Input (kJ/h)*) / Engine Output (kW)**

**Efficiency [%] = 3600 / Heat Rate [kJ/kWh] x 100**

$$\mathbf{Eff_{amb} = Eff_{ISO} \times d_{Eff}}$$

$$d_{Eff} = [100 - (T_{intake} - 25)*0.021 - (1000 - P_{amb})*0.0025 - (T_{charge} - 45)*0.008\ ] / 100$$

*$Eff_{amb}$ [% or kJ/kWh] = Engine efficiency at actual operating condition*

*$Eff_{ISO}$ [% or kJ/kWh] = Engine efficiency at ISO 3046/1 standard condition*

*$d_{Eff}$ [ - ] = Deviation of the efficiency*

*$T_{intake}$ [°C] = Intake air temperature at actual operating condition*

*$P_{amb}$ [mbar] = Ambient air pressure at actual operating condition*

*$T_{Charge}$ [°C] = Charge air temperature after charge air cooler(CAC) at actual operating condition*

**Notice**

1) Maximum value of $d_{Eff}$ is 1.

2) Between ISO and ambient condition, same operating parameters must be used.

3) If there is a change of main component, this correction should be updated.

4) The heat rate is a term commonly used for consumption of thermal energy in gaseous fuels. LCV(Lower Calorific Value) of gaseous fuel is not corrected.

**Example**

- Intake air temperature ($T_{intake}$): 30°C
- Ambient air pressure ($P_{ambient}$): 990 mbar
- Charge air temperature ($T_{charge}$): 47°C
- $Eff_{ISO}$: 48.38% at 720[rpm], MCR (Total Heat rate: 7,441 [kJ/kWh])

then, $d_{Eff}$ = 0.9985 and the efficiency ($Eff_{amb}$) at site condition will be decreased to 48.31[%] for the heat rate at site condition will be increased to 7,452 [kJ/kWh].

***) Remark**

Fuel gas consumption should be measured at the point of stable operation without any leaks on fuel gas line and without any gas ventilation from gas supply - pressure regulation system.

## Calculation of fuel gas flow

Since the heat rate is defined by the amount of thermal energy consumption for gas operation, the calorific value and density of fuel gas are necessary in order to calculate the flow consumption amount.

Volume flow or mass flow of gas consumption are simply calculated by LCV and density of the fuel gas.

**Volume flow of fuel gas [$Nm^3/h$] = Heat rate [kJ/kWh] x Engine output [kW] / LCV [$kJ/Nm^3$]**

**Mass flow of fuel gas [kg/h] = Volume flow of fuel gas [$Nm^3/h$] x Density [$kg/Nm^3$]**

## Correction of additional fuel gas consumption

If additional devices are attached on the engine or operation condition is changed, the heat rate at MCR will increase approximately as follows:

| Item | Additional heat [kJ/kWh] |
|---|---|
| Lubricating oil pump | + 86 |
| L.T cooling water pump | + 43 |
| H.T cooling water pump | + 43 |
| F.O feed pump (DF only) | Please discuss with HHI-EMD |
| 400mmWC> Exhaust gas back pressure after turbine > 240mmWC (Gas mode*) | +120 per 80mmWC of Gas mode |

**Remark)**

*) The maximum back pressure of gas mode is approximately the back pressure of diesel mode x 0.8.

## Correction for exhaust gas temperature after turbine

The exhaust gas temperature after turbine is referred to ISO 3046-1:2002 standard condition normally.

However, for the condition other than ISO 3046-1:2002 standard condition, the exhaust gas temperature after turbine could be estimated according to the following formula:

$$\mathbf{T_{exh.amb} = T_{exh.ISO} + dT_{exh}}$$

$$dT_{exh} = \left(T_{intake} - 25\right) \times 1.5 + \left(T_{cw} - 25\right) \times 0.7$$

*$T_{exh.amb}$ [°C] = Exhaust gas temperature after turbine at actual operating condition*

*$T_{exh.ISO}$ [°C] = Exhaust gas temperature after turbine at ISO 3046-1:2002 standard condition*

*$dT_{exh}$ [°C] = Deviation of the exhaust gas temperature after turbine*

*$T_{intake}$ [°C] = Intake air temperature at actual operating condition*

*$T_{cw}$ [°C] = Cooling water temperature before Charge Air Cooler(CAC) at actual operating condition*

**Example**

- Intake air temperature ($T_{intake}$): 35°C
- Cooling water temperature ($T_{cw}$): 35°C
- $T_{exh.ISO}$: 290°C at 720 rpm, MCR

  then, $dT_{exh}$ = 22°C and the $T_{exh.amb}$ on actual operating condition will be increased to 312°C.

In addition, variable intake pressure before a compressor and the exhaust gas back pressure after a turbocharger are not allowed for the formula above. If the intake pressure before the compressor or the exhaust gas back pressure after the turbocharger is over the following conditions, please contact to HHI-EMD.

For the allowable exhaust gas back pressure after the turbocharger, see P.02.200 / 210 / 220 “Engine Capacity Data”.

## 1. Gas operation

### 1-1. De-rating due to suction air temperature and altitude

Engine output power at MCR shall be reduced depending on the suction air temperature and site altitude.

NOx : dry @5% O2 ≤ 500 mg/Nm3

Cooler out, charged air temperature : 45°C

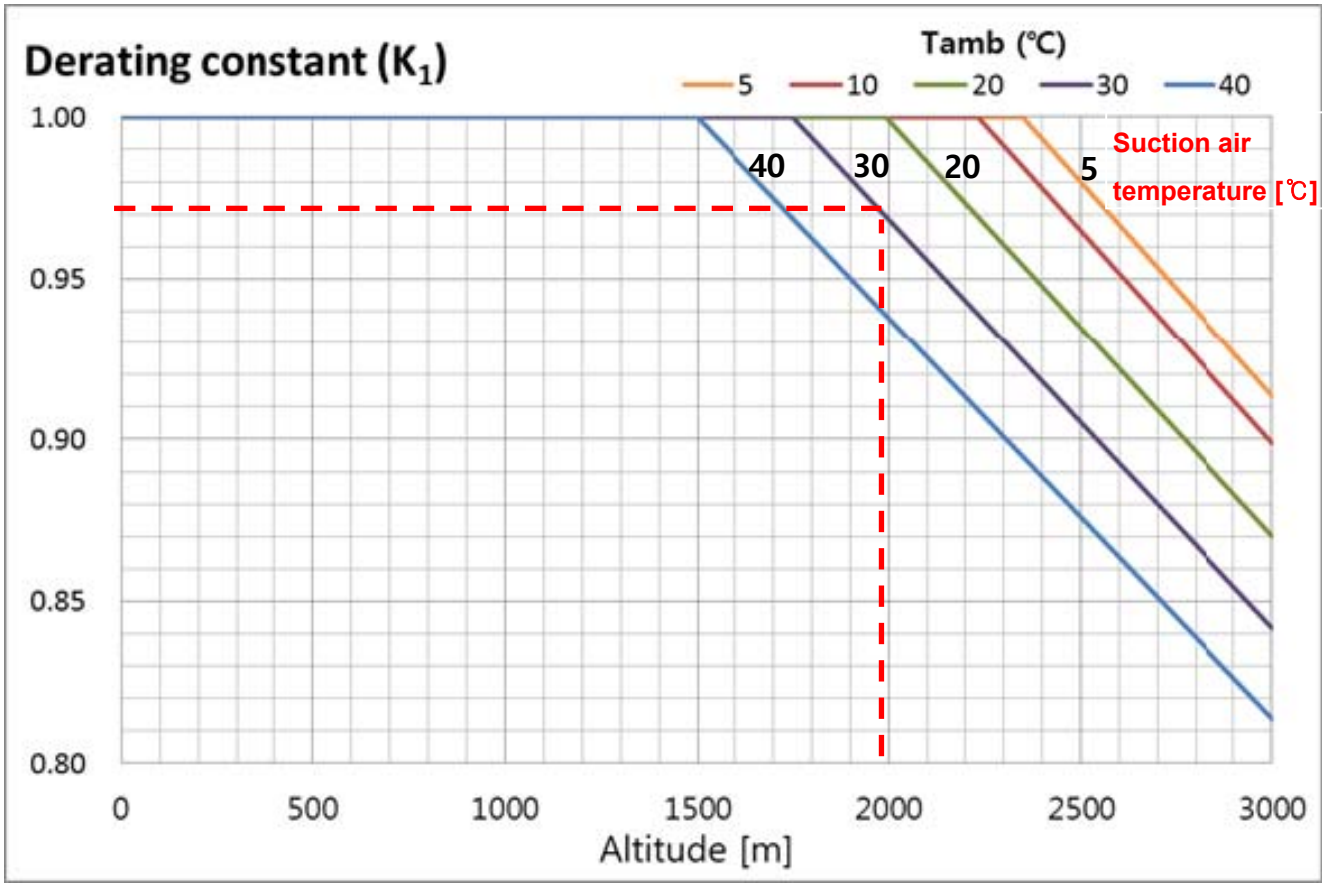



*Figure 2-7-1: De-rating due to suction air temperature and altitude*

**Remark:**

1. Minimum suction air temperature is 5°C
2. The temperatures given above are maximum (continuous) operating temperature on a vessel (or plant).
3. For temperatures above 40°C, please contact to HHI-EMD.
4. All design modifications related to the combustion may change characteristics of de-rating.
   For example, the modifications can be turbocharger specification, compression ratio of cylinder, piston design, etc.
5. Beside the de-rating factors (ambient condition, the gas properties, the gas supply condition, charge air temperature), relative humidity and the glycol content for anti-freezing can reduce the engine maximum power.

**Example**

- Cooler out, charged air temperature : 45°C
- Ambient air temperature: 30°C
- Site altitude: 2000m

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

## 1-2. De-rating due to charge air temperature and methane number(MN)

Engine output power at MCR shall be reduced depending on the charge air temperature and methane number.

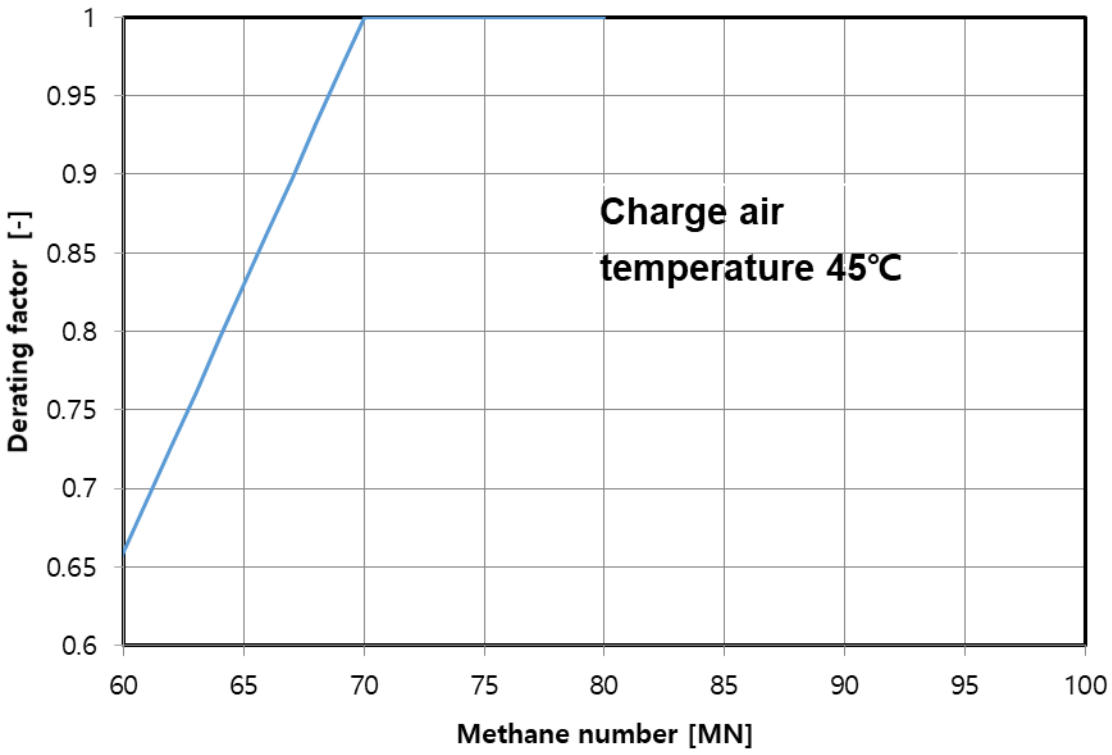



*Figure 2-7-2: De-rating due to charge air temperature and methane number (MN)*

## 1-3. De-rating due to gas lower calorific value(LCV) and gas feed pressure

Engine output power at MCR shall be reduced depending on the gas feed pressure.

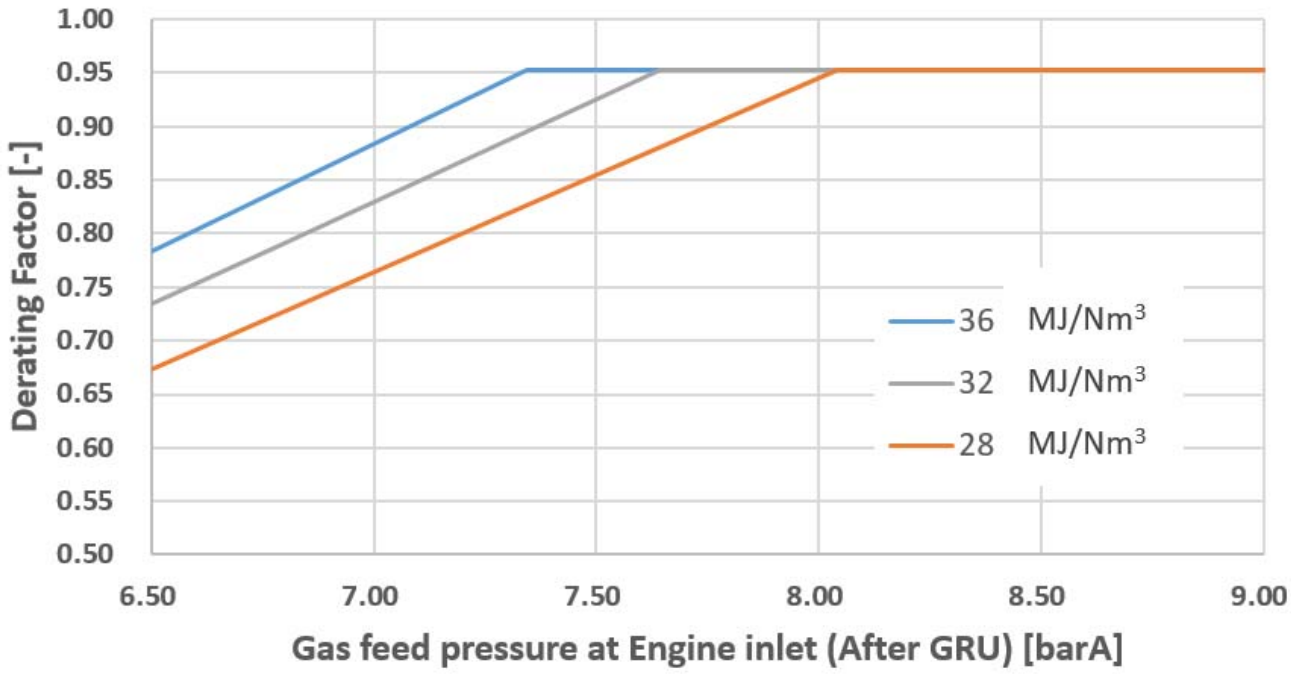



*Figure 2-7-3: De-rating due to gas lower calorific value and gas feed pressure*

## External forces and couples

| Engine type | Speed | External forces and moments | | | | | | Guide force moments | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Order | | Force | | Moment | | Order | | Moment |
| | | | | Horizontal | Vertical | Horizontal | Vertical | | | |
| | [rpm] | No. | [Hz] | [kN] | [kN] | [kNm] | [kNm] | No. | [Hz] | [kNm] |
| 12H54GV | 600 | 1 | 10.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3 | 30.0 | 33.0 |
| | | 2 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6 | 60.0 | 150.8 |
| 14H54GV | | 1 | 10.0 | 11.3 | 1.8 | 339.6 | 53.9 | 3.5 | 35.0 | 23.2 |
| | | 2 | 20.0 | 1.5 | 2.6 | 112.7 | 202.4 | 7 | 70.0 | 137.6 |
| 16H54GV | | 1 | 10.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4 | 40.0 | 79.6 |
| | | 2 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8 | 80.0 | 103.4 |
| 18H54GV | | 1 | 10.0 | 0.0 | 0.0 | 166.9 | 26.2 | 4.5 | 45.0 | 173.8 |
| | | 2 | 20.0 | 0.0 | 0.0 | 183.5 | 330.2 | 9 | 90.0 | 62.7 |

*Table 3-1-1: External forces and couples*

## Moment of inertia

| Engine type | Speed | Hz | Rating | Moments of inertia (MOI), J | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Engine MOI | Flywheel [2] MOI | Flywheel [2] Mass | Generator [1] MOI | Total MOI |
| | [rpm] | | [kW] | [kg m$^2$] | [kg m$^2$] | [kg] | [kg m$^2$] | [kg m$^2$] |
| 12H54GV | 600 | 50 | 16,800 | 6,540.3 | 509.0 | 1,067.1 | 11,200 | 18,249.3 |
| | 600 | 60 | 16,800 | 6,540.3 | 509.0 | 1,067.1 | 12,300 | 19,349.3 |
| 14H54GV | 600 | 50 | 19,600 | 7,532.3 | 500.9 | 1,053.7 | 14,900 | 22,933.2 |
| | 600 | 60 | 19,600 | 7,532.3 | 500.9 | 1,053.7 | 15,600 | 23,633.2 |
| 16H54GV | 600 | 50 | 22,400 | 8,471.9 | 500.9 | 1,053.7 | 17,200 | 26,172.8 |
| | 600 | 60 | 22,400 | 8,471.9 | 500.9 | 1,053.7 | 17,300 | 26,272.8 |
| 18H54GV | 600 | 50 | 25,200 | 9,462.7 | 496.4 | 1,048.6 | 23,100 | 33,059.1 |
| | 600 | 60 | 25,200 | 9,462.7 | 496.4 | 1,048.6 | 24,300 | 34,259.1 |

*[1] The moments of inertia of generators are typical values.*

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

*Table 3-2-1: Moments of inertias*

Remark:

1. The above data is based on 100% load for 1400 kW/cyl. @ 600 rpm
2. The moment of inertia and mass data of the engine flywheel should be dimensioned depending on specific project specifications.

## General

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

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

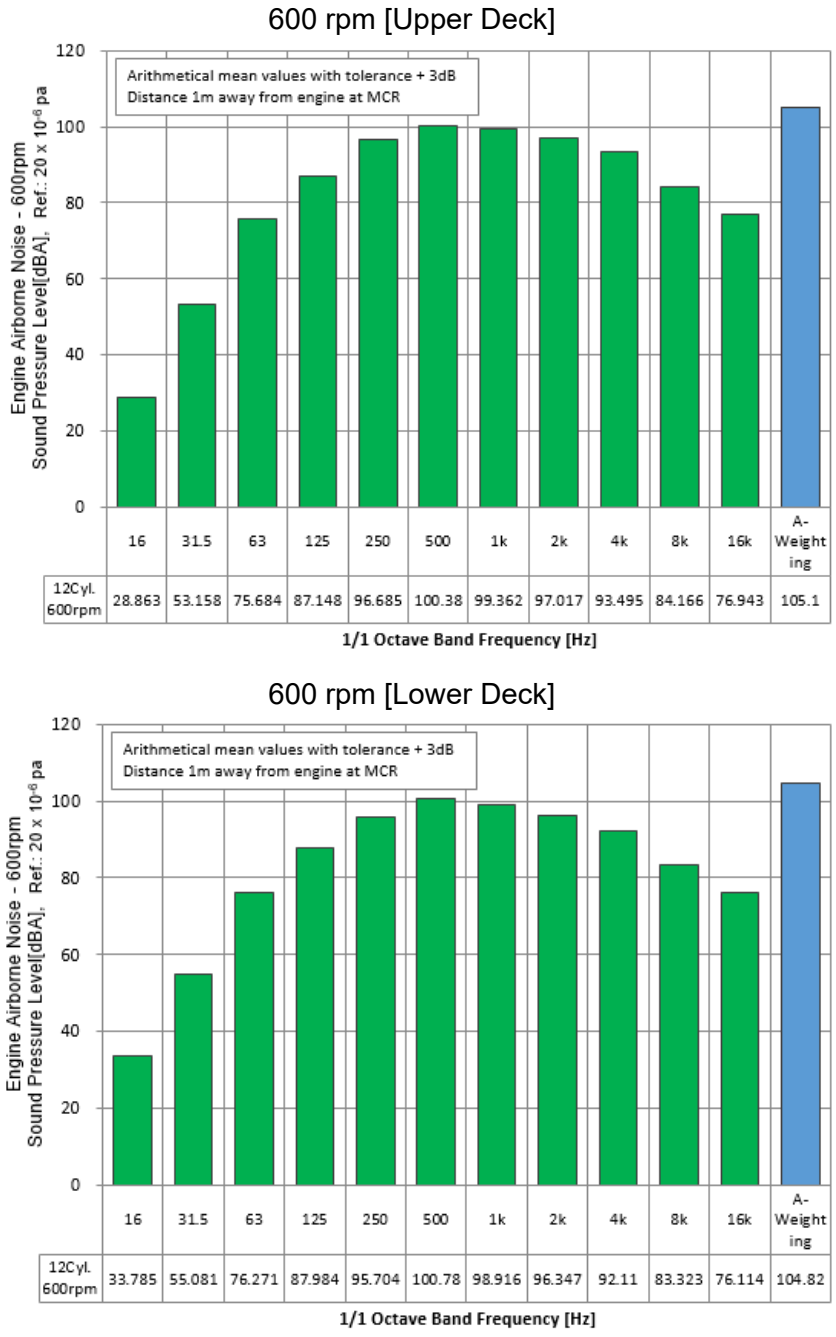



*Figure 3-3-1: Typical noise level of H54GV*

**Remark:**

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

## General

HiMSEN gas engine can be operated in various site conditions. However, there are some recommendations to maintain good performance and reliability consistently.

## Starting condition

### Normal starting condition

- **Lube oil**

  Continuous pre-lubrication is required

  Temperature: over 40 ℃ (Preheated)

- **Cylinder cooling water**

  Starting temp.: over 70 ℃ (Preheated)

- **Combustion air**

  Air temperature: between 0 ℃ and 45 ℃

- **Fuel gas**

  Temperature: 0 ... 50℃

  Refer to Figure 4-1-1 for required fuel gas pressure and allowable variation of pressure.

### Emergency cold starting condition

**Cooling water:** minimum 15℃

**Lube oil:** minimum 10℃, pre-lubricated (approx. 1,000 cSt based on SAE 40)

**Intake air temperature:** minimum 0℃

**Required fuel gas supply pressure**

As the graph below, the required fuel gas pressure is different depending on Engine load. The fuel gas feed pressure at GRU inlet, G11 (see the diagram P.05.500) should be considered as followings;

1) Pressure loss at the GRU including flow-meter (Typically, 1.1 bar can be used.)

2) Pressure loss in the pipe between GRU and engine (Typically, 0.1 bar can be used.)

Also, the fuel gas specification should meet the requirements in the P.05.600.

Admissible fuel gas supply pressure fluctuation: Less than 0.1 bar/sec of pressure fluctuation (peak ± 1 bar) can be absorbed in GRU and no effect on engine operation. The fuel gas feed pressure and the included pressure deviation should be set higher than the required fuel gas pressure at corresponding engine operating condition.

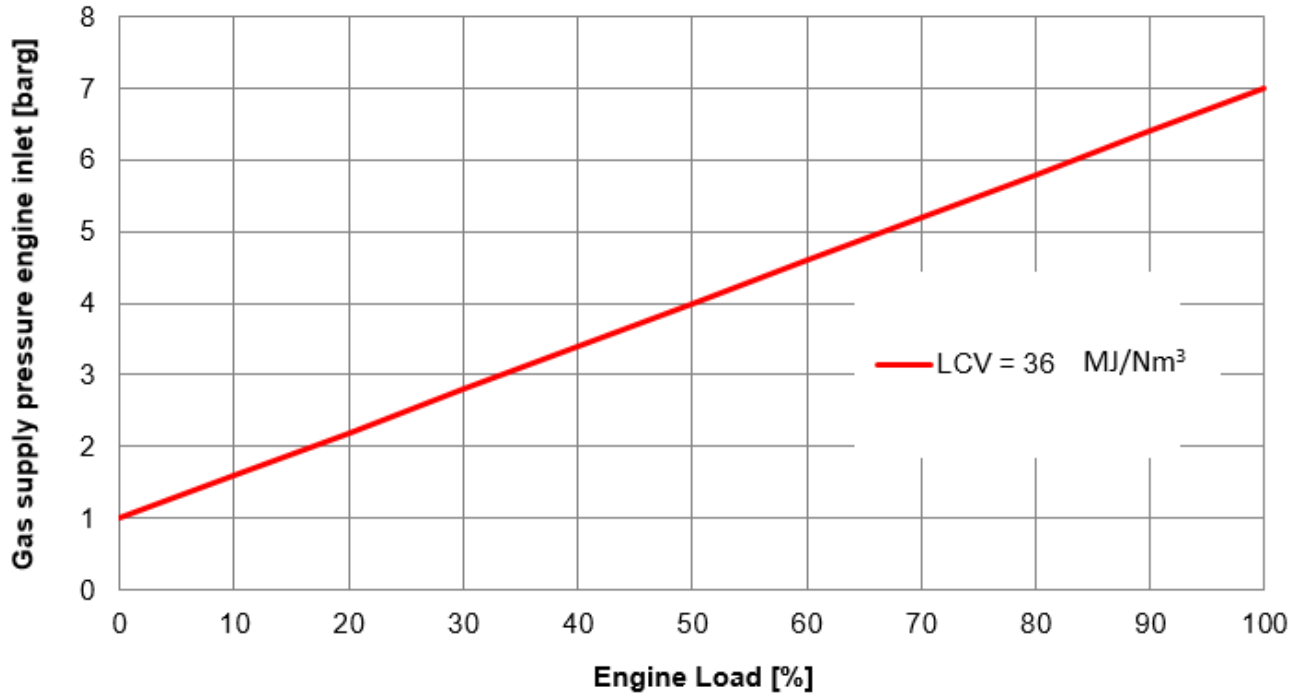



*Figure 4-1-2: Fuel gas supply pressure at Engine inlet (After gas regulating unit)*

Remark:

1. Above graph shows the fuel gas pressure at engine inlet (After gas regulating unit)
2. Required gas supply pressure can be changed by engine load.

## Operating modes

### Engine operating mode

HiMSEN Gas engine supports droop mode and fixed kW mode. Droop and Fixed kW mode is activated via the digital input "Droop / Fixed kW operation".

The Fixed kW operation mode is activated when the "Droop / Fixed kW operation" contact is closed and the droop mode is activated when this contact is open.

The switch over between droop mode and fixed kW mode can also be performed while the engine is running.

- **Fixed kW mode**

  The engine is connected to a (public) power grid: changes in engine power do not affect the bus frequency.

  In fixed kW mode HiMSEN Gas engine controls the engine power output, engine speed is determined by the bus frequency.

- **Droop mode**

  The engine is connected to an isolated grid: changes in engine power do affect the grid frequency and therefore the engine speed.

  In droop mode HiMSEN Gas engine controls the engine speed, load is determined by the external load.

### Engine control mode

- **Local mode**

  In local operation mode, the engine can be operated via the touchscreen and other control elements of the LOP (Local operating panel).

- **Remote mode**

  Remote operation is based on a remote / external automation system. In remote control mode the remote automation system is responsible for the operation of the engine.

  Functions cannot be controlled via the LOP. However all states, measured values etc. can be viewed via the touch screen of the LOP.

## Engine start

### Engine start ready

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

### Start block signals

Start blocks are events during engine operation that prevent the engine from starting for safety reasons. The start command triggers the start procedure if no start block is active.

- Lube oil pressure engine inlet low
- Starting air pressure engine inlet low (Option)
- HT water temperature engine inlet low (Option)
- Turning gear engaged
- Slow turning failure
- Low inert gas pressure during engine shutdown sequence (Gas natural ventilation in progress)
- Start block in test mode
- Start block from remote system

### Slow turning

Slow turning is part of cranking the engine. When slow turning is applied, the cranking torque and speed is reduced compared to normal engine cranking. During slow turning, HiMSEN Gas Engine Control System (ECS) checks if the engine turns for a predefined number of revolutions within a predefined time.

This gives information about the availability of the engine. Slow turning can be applied as part of the start sequence or during engine standstill, so called "cyclic slow turning".

- Slow turning during engine start

  Slow turning during engine start is activated in the following cases:

  - Engine start in local operation (control mode = local operation mode)
  - Engine start in remote operation with signal as digital input “Stand-by signal" = inactive.

  If slow turning during engine start fails, a failure is released and the start is aborted. Slow turning during engine start is skipped in case cyclic slow turning has been successfully finished in advance of engine start or time between engine running and engine start is shorter then predefined value.

- Cyclic slow turning

  Cyclic slow turning is applied when all of the following preconditions are fulfilled:

  - Engine in stopped condition (engine state = "READY" or "START DISABLED")
  - Control mode = remote operation mode
  - Signal as digital input “Stand-by signal" = active
  - Cyclic slow turning configured

  During cyclic slow turning, the starter is activated periodically together with the slow turning valve.

  Before activating the starter, the lube-oil pressure is checked. If the lube oil pressure is too low or in case slow turning fails, a failure is released and the engine switches to state "FAILURE".

  In case cyclic slow turning has been successfully performed before engine start, slow turning at engine will be skipped in local operation mode.

**Engine start**

Main starting valve is installed in engine side and operated by compressed air controlled by pneumatic solenoid valve. (See 'Compressed Air System')

For gas engine start, there should not be any start block condition before start. After engine start command is triggered, ECS check start block condition once again for a few second.

Compressed air is directly injected to the combustion chamber. Ignition system is activated and gas shut-off valves are open. Gas injection is activated and chamber is fired.

As soon as combustion chamber is fired, speed is rapidly increased and the starting air cut-off by closing the main starting valve.

At idle speed, warm-up condition is checked and engine run until warm-up condition is satisfied.

After warm-up phase is completed, the speed is ramp up to rated speed automatically. Circuit breaker can be closed after about 1 min. if engine start at warm condition.

## Engine load-up

For load operation of HiMSEN Gas engine, 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.

### Restriction for low load operation

- Idle speed : Max. 10 min.
- Above 30% load : No restriction
- Below 30% load : Max. 1 hour

### Continuous load-up

The continuous load up capacity at each engine condition is referred in Fig. 4-1-2.

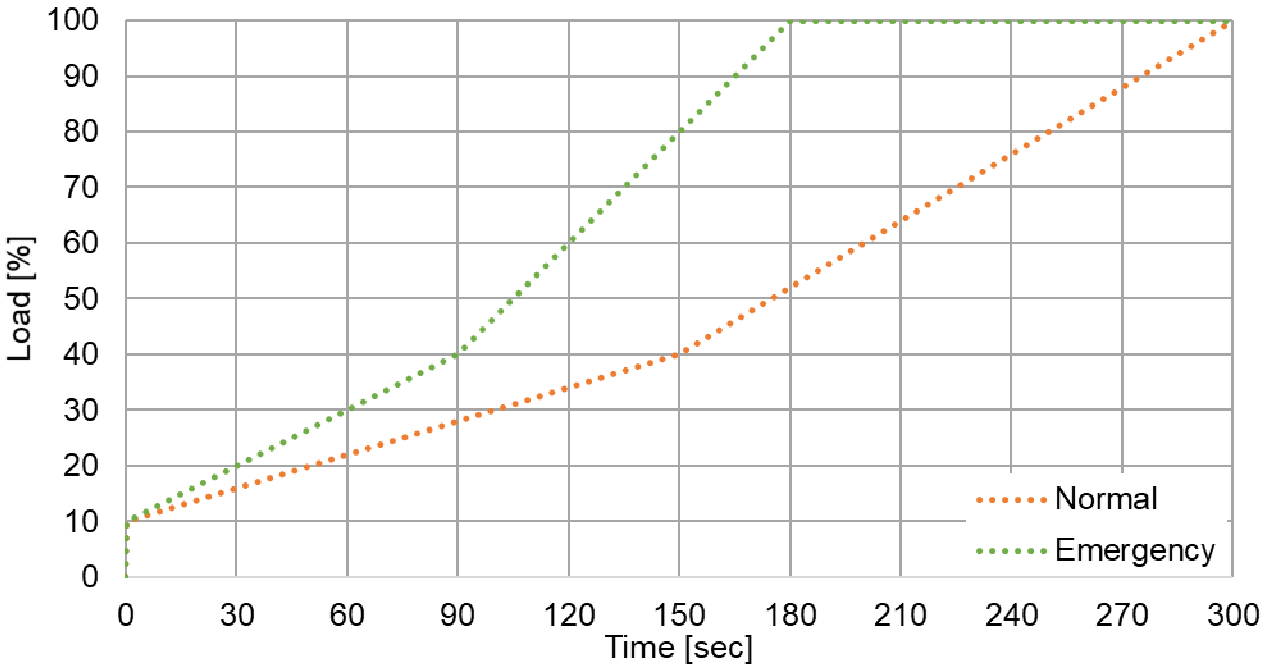



*Figure 4-1-2: Engine load-up capacity in ramp*

- **Normal operation condition**

  At warm condition, gradually increase load up to 50% load within 60 sec. and up to 100% load in another 300 sec. It will require about 6 min. from 0% load to 100% load. Sudden load-up will take a few seconds to achieve stable frequency. The cylinder cooling water temperature should be minimum 40℃ to load-up to 100% load.

  Emergency load up should be only possible when it's really needed. This fast load up shall cause mechanical stress on engine and shall not be repeated too often.

- **Fixed kW operation mode**

  When the genset is connected to the infinite bus, engine run at main parallel operation mode and HiMSEN Gas Enginge Control System (ECS) is able to adjust the power output of engine.

  In this case, 15% of load is applied as soon as synchronization to be protected from reverse power.

  The load ramp up rate is defined in HiMSEN Gas ECS as 15% per min. 100% load can be reached in less than 6 min. and the engine should be in warm condition for this.

  When target load is commanded to HiMSEN Gas ECS, HiMSEN Gas ECS can trace the target load by ramping up the load in defined rate.

  Please see Fig. 4-1-3 engine loading procedure in Fixed kW operation mode.

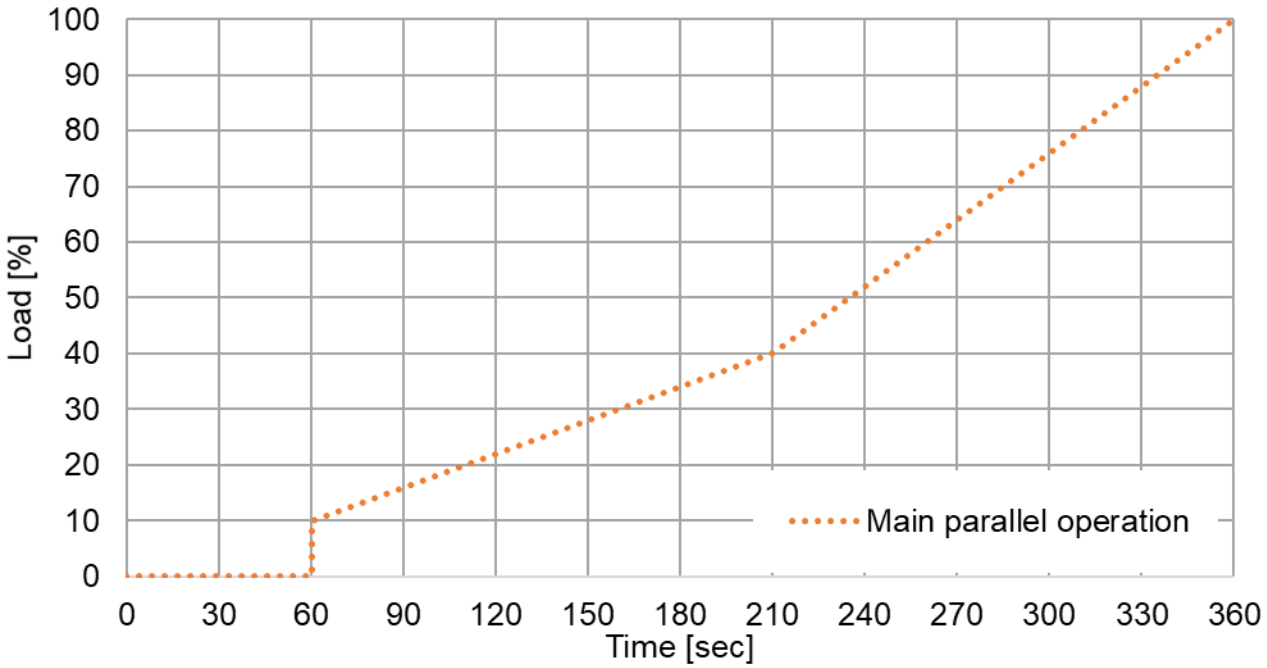



*Figure 4-1-3: Engine load-up in main parallel operation*

**Overload operation**

Normally in gas engine, overload operation is not allowed.

- **Overload operation limit**

  Engine load > rated power + 2 % (more than 5 min): Alarm released

  Engine load > rated power + 2 % (more than 10 min): Engine shutdown

  Engine load > rated power + 5% (more than 5 sec): Engine shutdown

**De-load of engine**

This state is only applied in Fixed kW operation mode. Engine load is ramped down by HiMSEN Gas Engine Control System (ECS). As soon as soon as the engine load is <10 %, digital output "Enable circuit breaker" is deactivated and the external system can open the circuit breaker. Circuit breaker is opened at approx. 10% load to be protected from reverse power.

Recommended engine de-load rate is 25% per min. If engine has run at high load for a long time, cool-down running before engine stop is strongly recommended.

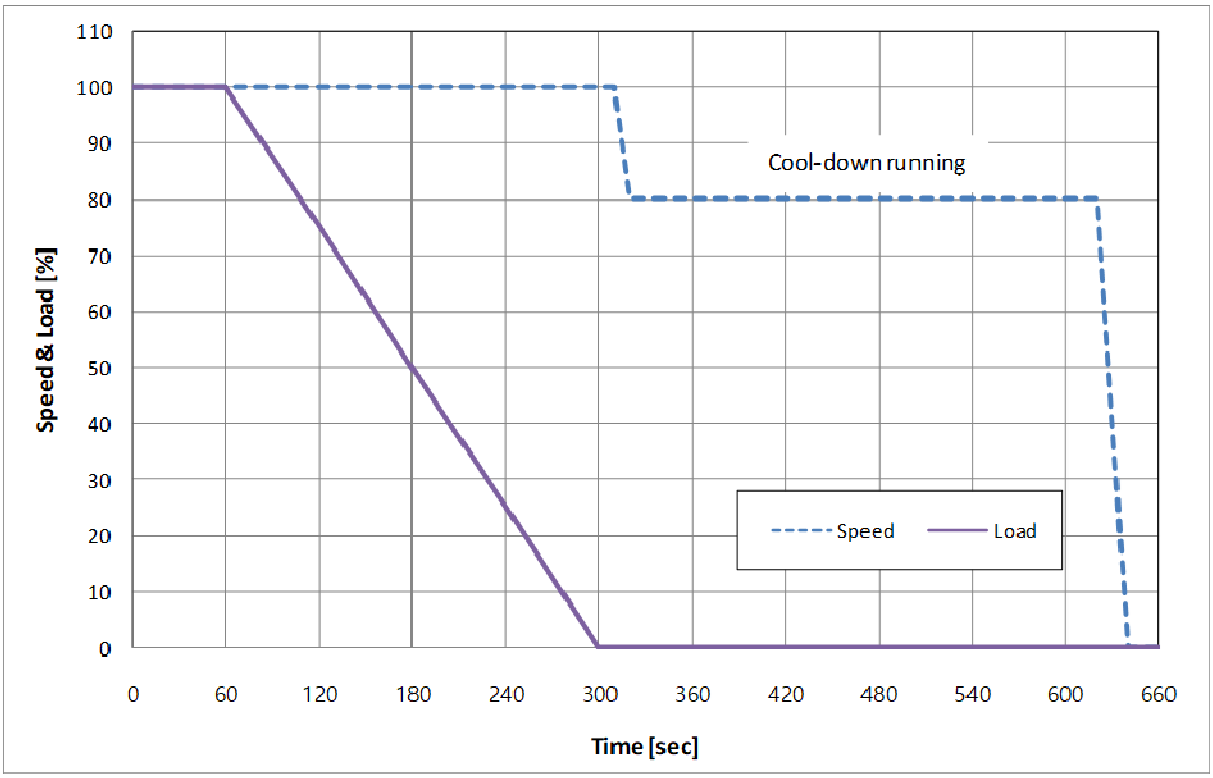



*Figure 4-1-4: Engine de-load and stop sequence including cool-down operation*

**Step by step load-up in Droop mode**

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 six steps. For this operation, the engine should be in warm condition or for an engine which has been operated at above 30% load within the last 30 minutes.

Frequency deviation and recovery time when loading up by step is referred in figure 4-1-5.

In case of gas engine, the amount of load step is decreased at high load due to the higher knock tendency at high load.

This graph is only valid at droop operation mode. In Fixed kW operation mode, load increase/decrease is always in ramp.

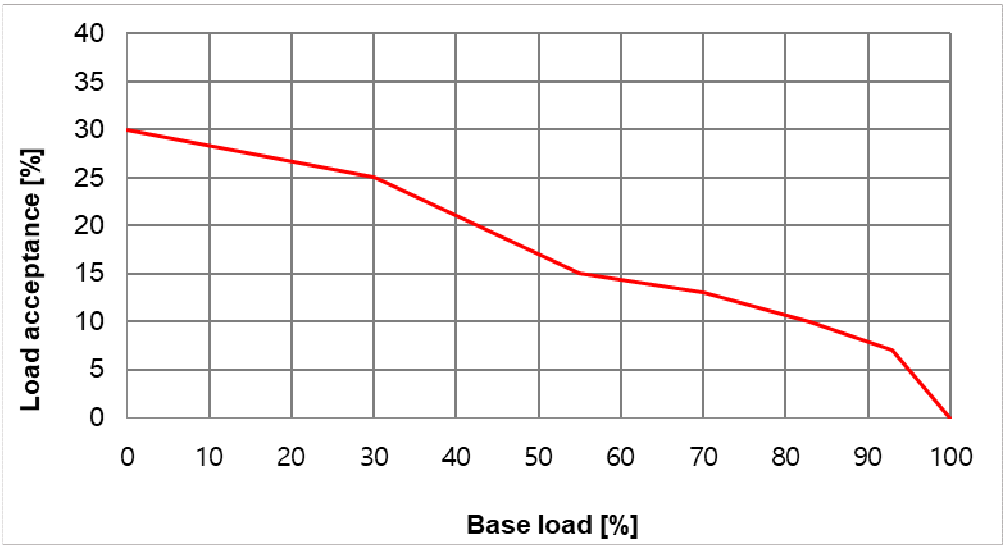



*Figure 4-1-5: Engine de-load and stop sequence including cool-down operation*

**① Max instant load step: 0-30-55-70-83-93-100**
**② Max speed variation ≤ 10%**
**③ Steady-state speed band ≤ 1.5%**
**④ Recovery time ≤ 10 sec**
**⑤ Time between next load step ≥ 20 sec**

**※ Performance depends on fuel gas composition (LCV, MN, etc.)**

## Engine stop

- **Normal stop**

  In island operation mode, the external system should de-load and open the circuit breaker before stop command. In main parallel operation mode, as soon as stop commend is triggered, ECS decreases the load itself and stops the engine.

  It is recommended to cool-down the engine by running the engine at no load state for 5 min. to dissipate the residual heat in engine. Operator can activate this sequence automatically from ECS.

  During engine stop, the gas valves are closed, gas admission and ignition system remains active until predefined speed to burn the rest of gas in the system. After engine stop, pre lub. oil pump is activated for post lubrication.

- **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.

  As soon as shutdown is triggered, the shut-off valves and venting valves at gas regulating unit are activated and gas circuit on engine is purged with inert gas. The ignition is active until predefined speed to burn the rest of gas in chamber.

  After the engine stop, the external exhaust gas system has to be ventilated by exhaust gas ventilation unit by external system (e.g. EGCP).

- **Emergency stop**

  When emergency stop signal is entered from local operating panel and remote system by activating the switch signal, the engine will be stopped immediately.

  The stop procedure is similar with shutdown except that ignition system is deactivated at once.

  After the engine stop, the external exhaust gas system has to be ventilated by exhaust gas ventilation unit by external system (e.g. EGCP).

## Engine safety

The HiMSEN Gas ECS (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 and its delay is predefined in engine control system based on safety function list. HiMSEN Gas ECS fulfills the safety function against critical shutdown conditions.

HiMSEN ECS implements safety functions written in next figure 4-1-6 describes layout of HiMSEN Gas engine safety system.

- **Alarm**

  ECS releases alarm message against abnormal sensor signal or sensor failure. No influence to engine operation but operator has to monitor the value carefully.

- **Start block**

  ECS releases alarm message and engine start is blocked. The start block condition has to be cleared to start the engine.

- **Load reduction**

  ECS releases alarm message and the load is reduced automatically (in Fixed kW mode) or request to reduce the load to its power management system (in Droop mode).

- **Shutdown**

  ECS releases shutdown message and the engine is shut down after predefined delay. Ignition system is alive until a predefined speed is undershoot to burn the rest of gas in engine.

- **Emergency stop**

  ECS releases emergency stop message and the engine is shut down immediately. Emergency stop is applied for ESD condition defined in engine safety function.

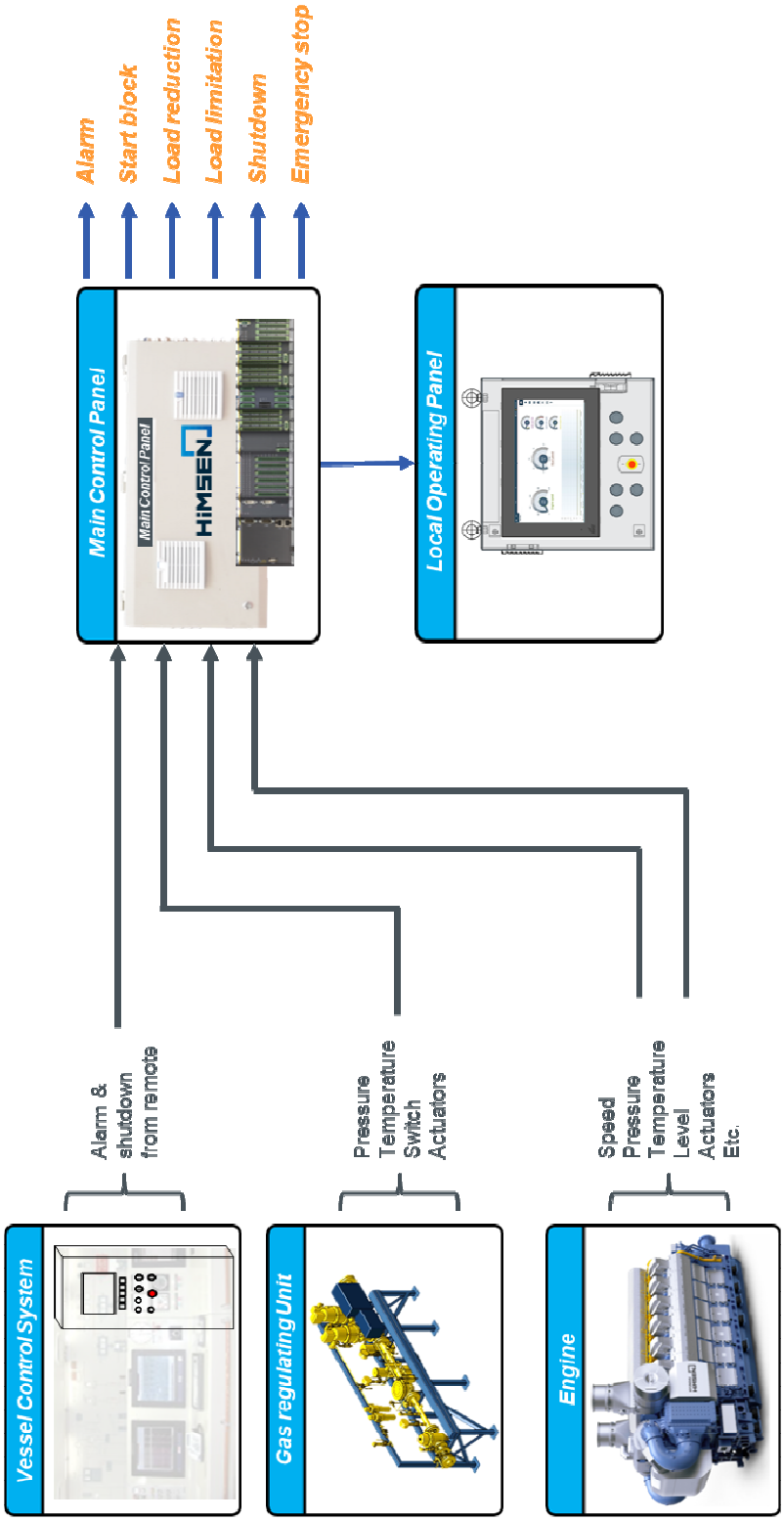



*Figure 4-1-6: H54GV engine safety function layout*

## General

The HiMSEN Gas engine control system (ECS), performs the complete engine management with a stationary application of HiMSEN 4-stroke gas engines. It is also compatible with V-type engine application.

HiMSEN Gas ECS is capable of smart control of sophisticated functions of engine and interfaced with plant system via hardwired signals and bus communication.

The HiMSEN Gas ECS mainly consists of **MCP** (Main control panel), **ICM** (Injection control module), **CMP** (Cylinder monitoring panel), **LOP** (Local operating panel).

HiMSEN Gas 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 configuration provides full operation and monitoring capability to remote system.

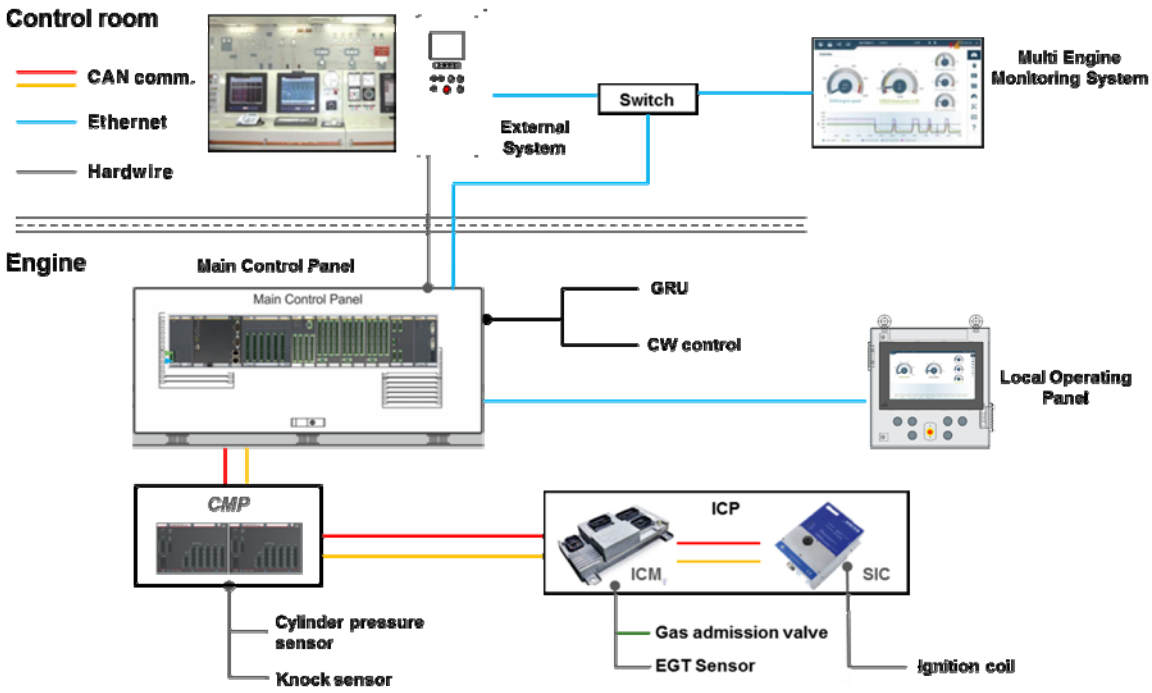



*Figure 4-4-1: HiMSEN Gas ECS Overview*

## Hardware description

- **Main control panel (MCP)**

  MCP is the central control unit of HiMSEN Gas 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 Gas ECS and all instruments on engine for control and monitoring.

  Location : Mounted on engine (1 set per engine)

  Consist of

  - Main control & alarm module
  - I/O modules and terminals
  - Communication switches

  Responsible for

  - Main control and monitoring of Gas engine
  - Engine safety control
  - Engine control and safety parameter tuning

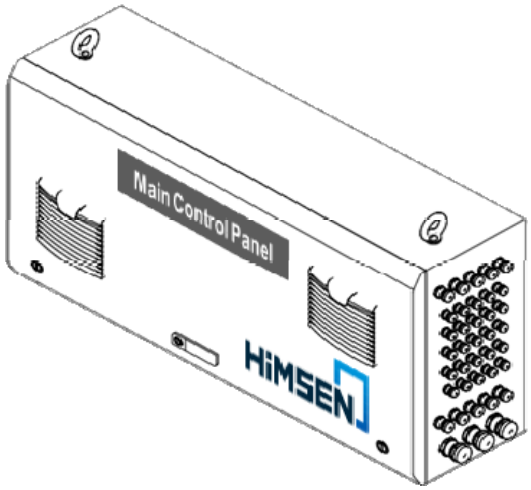



*Figure 4-4-2: Main control panel*

- **Injection control module (ICM)**

  ICM is mounted on an engine and connected to gas admission valves on each cylinder. In order to regulate the timing and duration of each valve, MCP sends the global and individual offset signals to ICM. Also, part of engine signals are connected and processed in ICM. ICM shares processed data with MCP for control.

  Location : Mounted on engine (2 set per engine)

  Responsible for

  - Driving gas admission valve
  - Measurement and process of engine I/O and transmit data to MCP for control
  - Measurement of exhaust gas temperature

*Figure 4-4-3: Injection control module*

- **Spark Ignition Controller(SIC)**

  SIC is mounted on an engine and connected to spark ignition coil on each cylinder. In order to regulate the timing and spark energy of each ignition coil, MCP sends the global and individual offset signals to SIC. Also, part of engine signals are connected and processed in ICM. SIC shares processed data with MCP for control.

  Location : Mounted on engine (1 set per engine)

  Responsible for

  - Spark plug control with ignition coil


*Figure 4-4-5: Spark Ignition Controller*

- **Cylinder monitoring module (CMP)**

  In order to achieve higher thermal efficiency and more stable engine operation, combustion of individual cylinder has to be controlled. For this matter of fact, CMP can be optionally 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 and process of cylinder pressure signal
  - Measurement and process of cylinder knock signal
  - Calculation of combustion characteristics and knock intensity
  - Transmission of data to MCP for control


*Figure 4-4-6: Cylinder monitoring panel*

- **Local operating panel (LOP)**

  LOP 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 / log display and handling
  - Emergency stop button
  - Test of actuators, valves and GRU on engine standstill

*Figure 4-4-7: Local operating panel*

## Local and remote operation of engine

- **Engine operation at local (engine)**

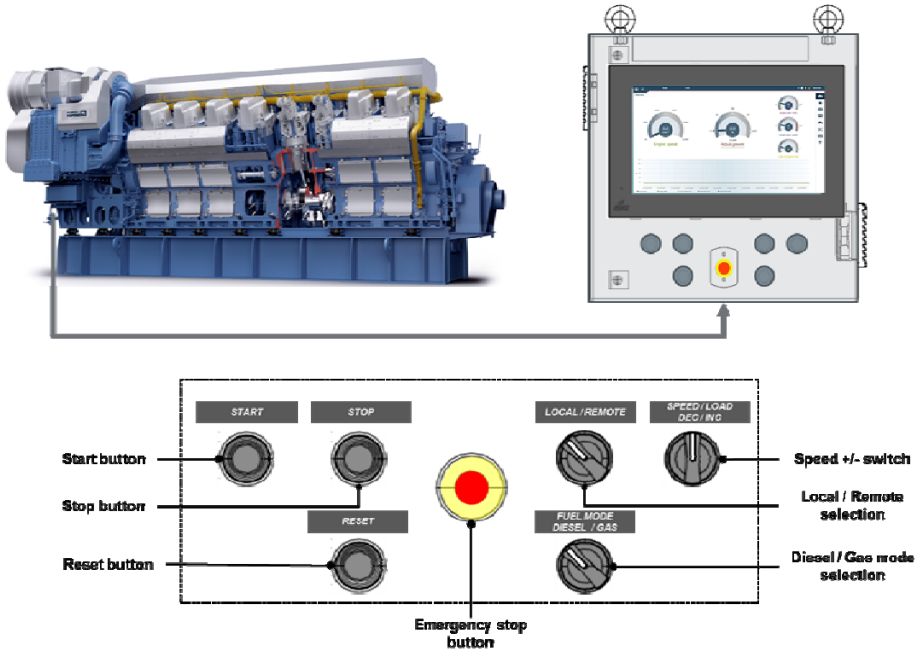



*Figure 4-4-8 Engine operation at local (engine side)*

- **Engine operation at Remote**

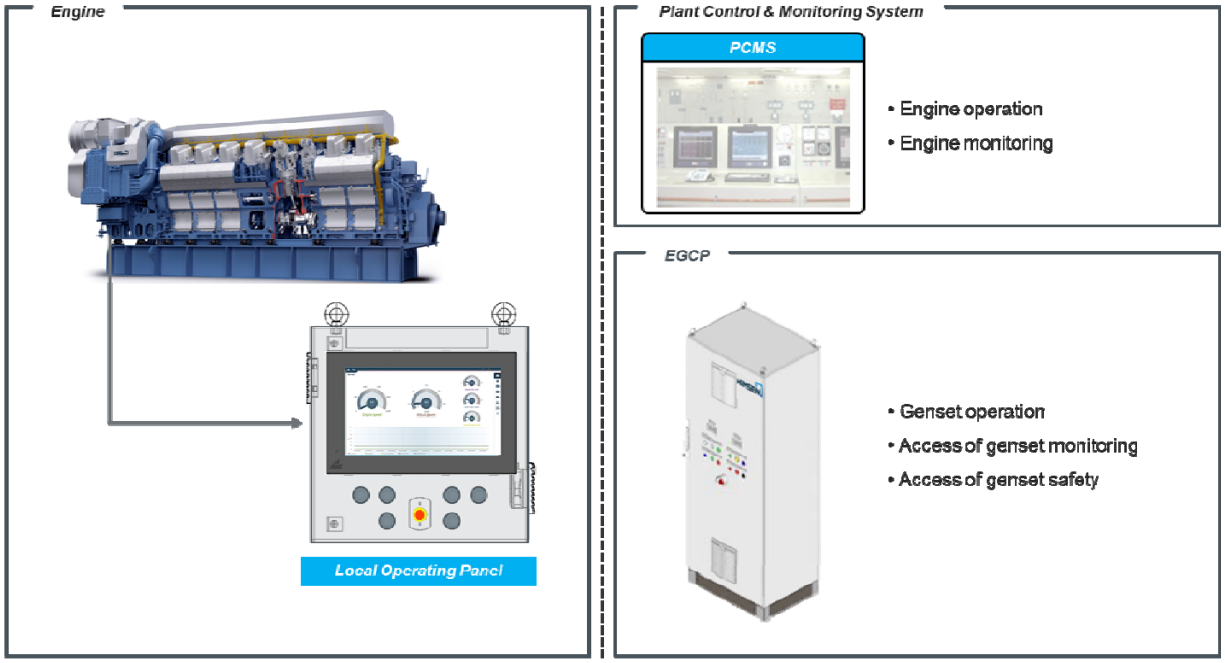



*Figure 4-4-9 Engine operation at remote (ECGP, PCMS)*

**Functional description**

- **Speed Control**

  ECS regulates the duration of gas admission valve for speed & power control.

- **Air Fuel Ratio Control**

  AFR is controlled by adjusting the opening ratio of wastegate. The wastegate controls the amount of bypassed gas of exhaust gas to turbocharger. The operating point shall be defined by charged air pressure at each load point.

- **Ignition System Control**

  In HiMSEN Gas engine, spark plug in pre-chamber is ignition source of combustion. ECS controls precise ignition timing and energy of ignition system.

- **Gas Pressure & Valve Control**

  HiMSEN Gas ECS manages the control of gas pressure regulating, the sequential gas valve operation and the operation of gas admission valve.

- **Knocking and Cylinder Balancing Control**

  Cylinder combustion pressure and knock monitoring function is integrated in HiMSEN Gas ECS. This control function guarantees sophisticated anti-knocking control and cylinder combustion balancing control.

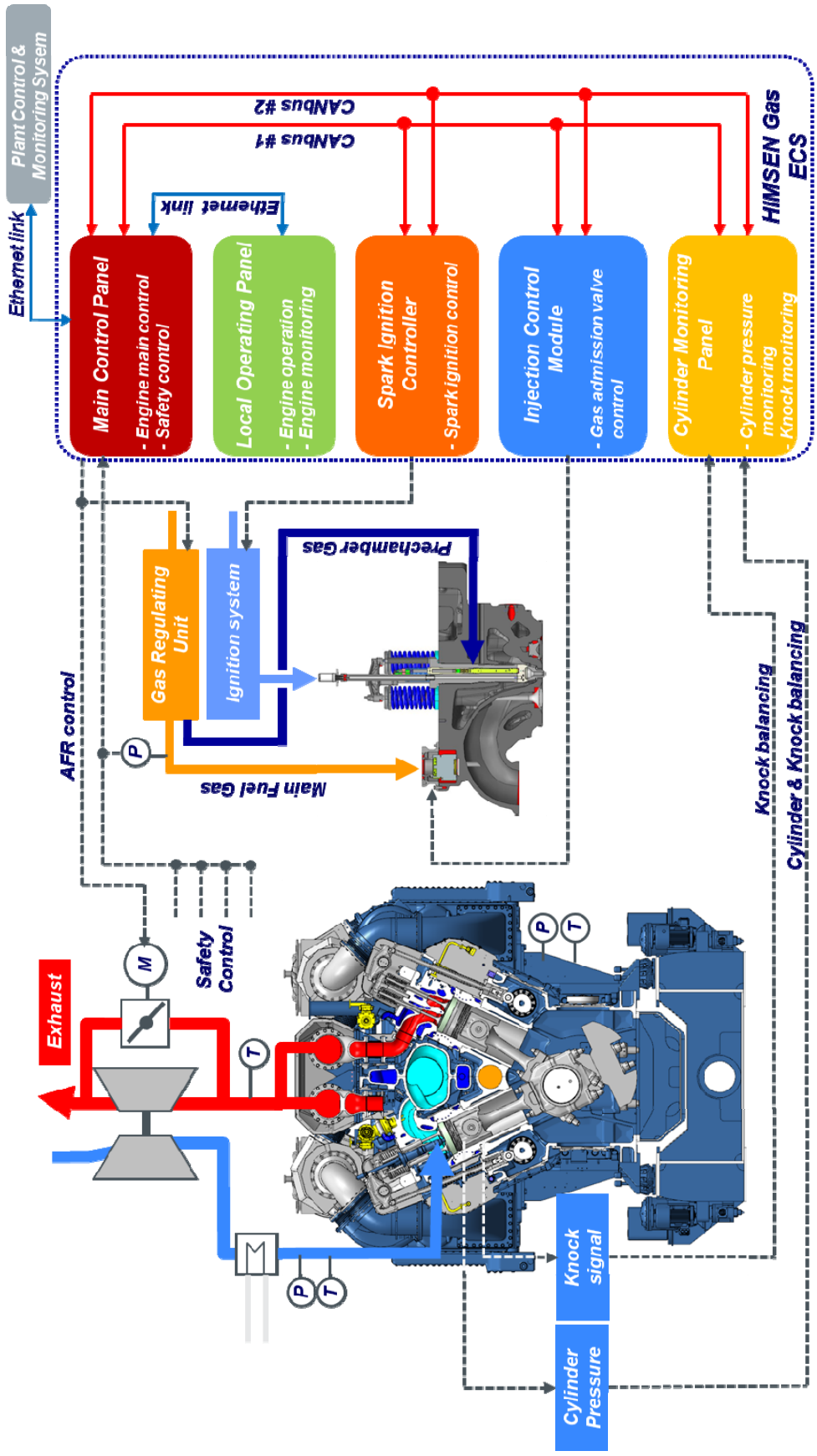



*Figure 4-4-10: Functional description of HiMSEN Gas Engine*

## General

HiMSEN Gas ECS is closely interfaced with external system and provides full capability for optimum operation. Refer to figure 4-6-1 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.

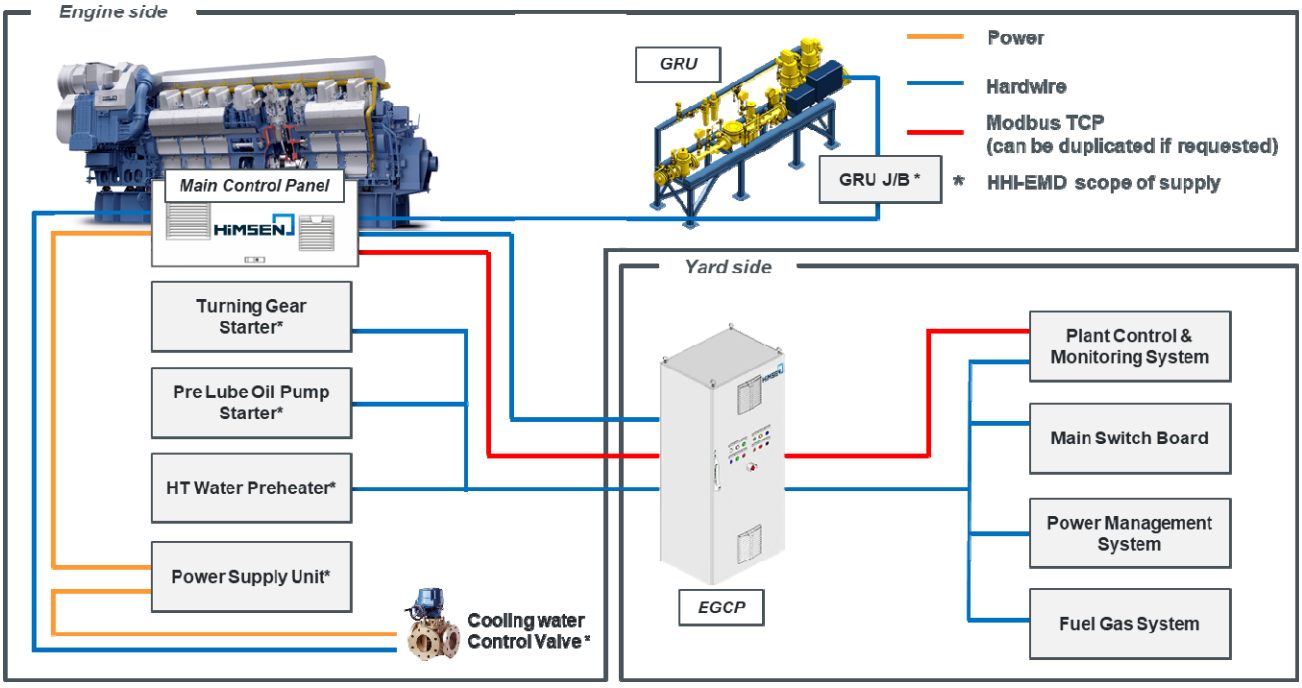



*Figure 4-6-1: HiMSEN Gas ECS external interface (system schematic)*

## Communication interface

HiMSEN Gas ECS provides all information including status of engine, monitored value and operation condition through Ethernet (Modbus TCP) to external system.

The external system is Modbus master and HiMSEN Gas ECS is always Modbus slave.

Refer to figure 4-6-2 for concept of system bus.

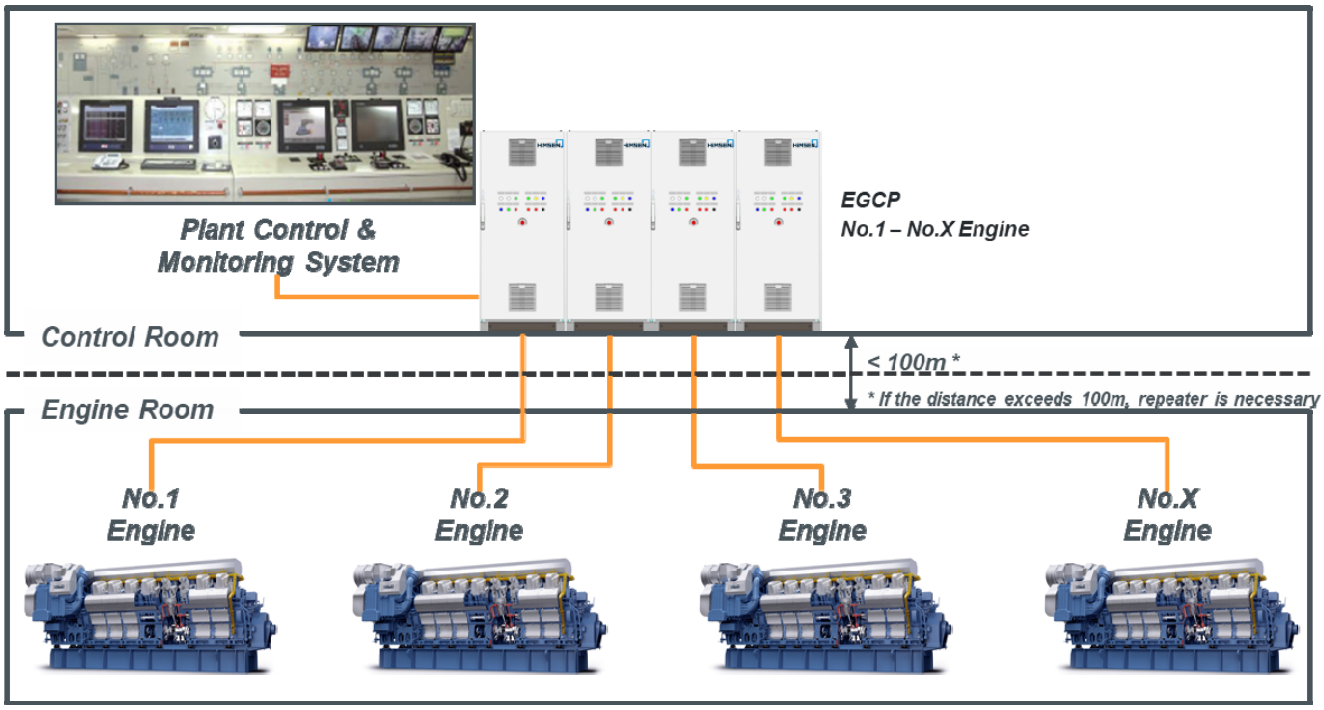



*Figure 4-6-2: HiMSEN Gas ECS communication interface*

Operation data of the engine is listed below.

The data may be subject to change and shall be informed separately for specific project.

| System | Descriptions | Normal operation range at rated power | | Alarm set points | | Autostop set points | |
|---|---|---|---|---|---|---|---|
| Speed control | Engine speed | SE11 | 600 rpm | AL High | 105% MCR | SD High | 108% MCR |
| | Engine speed & TDC | SE12 | 600 rpm | | | | |
| | Turbocharger HP speed | SE14 | (A) | AL High | (A) | | |
| | Turbocharger LP speed 2) | SE14L | (A) | AL High | (A) | | |
| Fuel gas system | Gas supply filter differential pressure | PT80-81 | | AL High | 0.5 bar | | |
| | Gas supply pressure filter inlet | PT80 | 9.5 ~ 11.5 bar | | | | |
| | Gas supply pressure filter outlet | PT81 | 9.0 ~ 11.0 bar | AL High | 12 bar | | |
| | | | | AL Low | 2.5 bar from C.A | | |
| | | | | GT Low | 2.0 bar from C.A | | |
| | Gas supply temperature filter outlet | TE81 | 15 ~ 35 °C | GT Low | 0 °C | | |
| | | | | GT High | 55 °C | | |
| | Gas supply pressure regulator outlet | PT82 | Depends on load | AL High | 0.5 bar from ref. | | |
| | | | | GT High | 1.0 bar from ref. | | |
| | (At gas leak test) | | | GT High | 2.0 bar | | |
| | Control air pressure gas regulating unit | PT83 | 8 ~ 10 bar | GT Low | 7.5 bar | | |
| | Main gas pressure engine inlet | PT87 | Depends on load | AL High | 0.5 bar from ref. | | |
| | | | | GT High | 1.0 bar from ref. | | |
| | Inert gas pressure (Please contact HHI-EMD) | PT89 | 8.5 ~ 10.5 bar | AL Low | 8.0 bar | | |
| Lube oil system | Lube oil filter differential pressure 3) | PT61-62 | | AL High | 1.5 bar | | |
| | Lube oil pressure engine inlet | PT62 | 4.0 ~ 5.0 bar | AL Low | 3.5 bar | SD Low | 3.0 bar |
| | Lube oil temperature engine inlet | TE62 | 51 ~ 60 °C | AL High | 70 °C | | |
| | Lube oil pressure TC inlet | PT63 | 1.3 ~ 2.2 | AL Low | 1.0 | | |
| | Lube oil pressure TC LP inlet 2) | PT63L | 1.3 ~ 2.2 | AL Low | 1.3 | | |
| | Lube oil temperature TC outlet | TE64 | 65 ~ 75 °C | AL High | (A) | | |
| | Lube oil temperature TC LP outlet 2) | TE64L 2) | 65 ~ 90 °C | AL High | (A) | | |
| | Lube oil pressure HP pump inlet | PT66 | 7.0 ~ 8.0 bar | AL Low | 6.3 bar | | |
| | | | | PT Low | 6 bar | | |
| | Lube oil sump tank level 2) | LS68 2) | | AL High | High level | | |
| | | | | AL Low | Low level | | |
| Cooling water system | LT water pressure after cooler inlet | PT71 | 2.0 ~ 4.5 bar | AL Low | 0.4 + (B) bar | | |
| | LT water temperature after cooler inlet | TE71 | 25 ~ 36 °C | AL High | 50 °C | | |
| | LT water pressure inter cooler inlet | PT72 | 2.0 ~ 4.5 bar | AL Low | 0.4 + (B) bar | | |
| | LT water temperature inter cooler inlet | TE72 | 29 ~ 38 °C | AL High | 55 °C | | |
| | HT water pressure engine inlet | PT75 | 2.0 ~ 4.5 bar | AL Low | 0.6 + (B) bar | | |
| | | | | LR Low | (Option) | | |
| | HT water temperature engine inlet | TE75 | 65 ~ 75 °C | AL Low | 50 °C | | |
| | | | | SB Low | 40 °C | | |
| | HT water temperature engine outlet | TE76 | 75 ~ 85 °C | AL High | 92 °C | SD High | 95 °C |

| System | Descriptions | Normal operation range at rated power | | Alarm set points | | Action points | |
|---|---|---|---|---|---|---|---|
| Combustion gas / air system | Exhaust gas temperature cylinder outlet | TE25 | 350 ~ 530 °C | AL High | 590 °C | | |
| | | | | GT High | 600 °C | | |
| | | | | LR High | 610 °C | | |
| | | | | GT High | Mapped ± (C) | | |
| | | | | LR High | 100 °C ± (C) | | |
| | Exhaust gas temperature TC inlet | TE26 | 480 ~ 560°C | AL High | 600 °C | SD High | 620 °C |
| | | | | GT High | 610 °C | | |
| | Exhaust gas temperature TC LP Inlet 2) | TE26L 2) | 350 ~ 500 °C | AL High | 500 °C | | |
| | Exhaust gas temperature TC outlet | TE27 | 300 ~ 500°C | AL High | 450 °C | | |
| | Intake air temperature before TC compressor | TE29 | | AL High | 50 °C | | |
| | Charge air pressure air cooler outlet | PT21 | depends on load | | | | |
| | (At gas mode) | | | GT High | 8.0 bar | | |
| | (At gas mode) | | | GT High | 0.5 bar | | |
| | Charge air pressure LP air cooler outlet 2) | PT21L 2) | | | | | |
| | Charge air temperature air cooler outlet | TE21 | 43-50 °C | | | | |
| | (At gas mode) | | | AL High | 55 °C | | |
| | (At gas mode) | | | GT High | 60 °C | | |
| | Charge air temperature LP air cooler outlet 2) | TE21L 2) | | | | | |
| Compressed air system | Starting air pressure engine inlet | PT40 | 30 bar | AL Low | 18 bar | | |
| | Control air pressure engine inlet | PT41 | 4.5~8.0 bar | AL Low | 4 bar | | |
| | | | | GT Low | 3.5 bar | | |
| | Control air pressure DVT inlet | PT43 | | AL Low | 3 bar (D) | | |
| | | | | LL High | 3 bar (D) | | |
| Cylinder monitoring system | Cylinder knocking | LT94 | | AL High | (E) > 5 °CA | | |
| | | | | GT High | (E) > 10 °CA | | |
| | Cylinder combustion pressure | PT24 | | | | | |
| | (At gas mode) | | | AL High | 225 bar (F) | | |
| | (At gas mode) | | | GT High | 235 bar (F) | | |
| Liner & bearing | Main bearing temperature | TE05 | | AL High | 95 °C | SD High | 100 °C |
| | Con. rod bearing temperature 2) | TE06 | | AL High | 85 °C | SD High | 90 °C |
| | Cylinder liner temperature 2) | TE07 | | AL High | 175 °C | SD High | 185 °C |
| Miscellaneous system | Oil mist detector | LS92 | | AL High | High level | SD High | High level |
| | Crankcase pressure | PT03 | 1 ~ 4 mbar | | | | |
| | (At gas mode) | | | AL High | 8 mbar | | |
| | (At gas mode) | | | GT High | 12 mbar | | |

1) The pressure inlet T/C should be in the recommended range by turbocharger maker.
The admissible pressure range and the detailed specification are based on the turbocharger manual in those days of each project
With written agreement between HHI and a turbocharger maker, it can be changed.
For more detailed information, please see turbocharger manual.

2) Can be applied as an option.

3) See P.02.200 engine capacity data.

*Table 4-7-1: Operation data of an engine*

Remark:

1. These data of table 4-7-1 is only for guide.
   The data can be subjected to change and shall be informed separately for the specific project.
2. (A) depends on cylinder No. and T/C maker.
3. (B) depends on the height of expansion tank (static pressure).
4. (C) Average of exhaust gas temperature.
5. (D) depends on DVT on / off condition.
6. (E) is total retardation of ignition timing in order to avoid knocking.
7. (F) when predefined times of last 10 cycle exceed this value.

| Code | Description | Code | Description |
|---|---|---|---|
| AL | Alarm | SB | Start block |
| GT | Gas trip | PT | Pilot trip |
| LR | Load reduction | LL | Load limitation |
| SD | Shutdown | ESD | Emergency shutdown |

*Table 4-7-2: Code for alarm and action*

| Description | | Instrument no. | Measuring range |
|---|---|---|---|
| Pressure | Fuel oil pressure engine inlet for only DF engine | PI 52 | 0 ... 16 bar |
| | Gas supply pressure filter outlet | PI 81 | 0 ... 16 bar |
| | Gas supply pressure regulator outlet | PI 82 | 0 ... 10 bar |
| | Lube oil pressure engine inlet | PI 62 | 0 ... 10 bar |
| Temperature | Fuel oil temperature engine inlet for only DF engine | TI 52 | 0 … 200 °C |
| | LT water temperature air cooler inlet | TI 71 | 0 … 120 °C |
| | LT water temperature air cooler outlet | TI 72 | 0 … 120 °C |
| | Gas supply temperature | TI 80 | 0 … 50 °C |

*Table 4-8-1: Local instruments*

**All measurements can be monitored on local operating panel.**

## 1. Introduction

Hyundai intelligent Equipment Management Solution

- HiEMS offers a real-time engine status monitoring, troubleshooting guidance to marine engineers and provides connectivity between engines and on shore monitoring center.
- With HiEMS, HiMSEN customers can get our experts of engine and service close to you.
- With intuitive UI, engine operators can figure out the root cause of a certain alarm and get the technical advice and troubleshooting guide.
- When detecting the abnormalities in engine, HiEMS transfers alarm/fault information and sensor data to onshore for the detail analysis.
- Also, HiEMS keeps long term data for fleet and engine managements and reporting service.

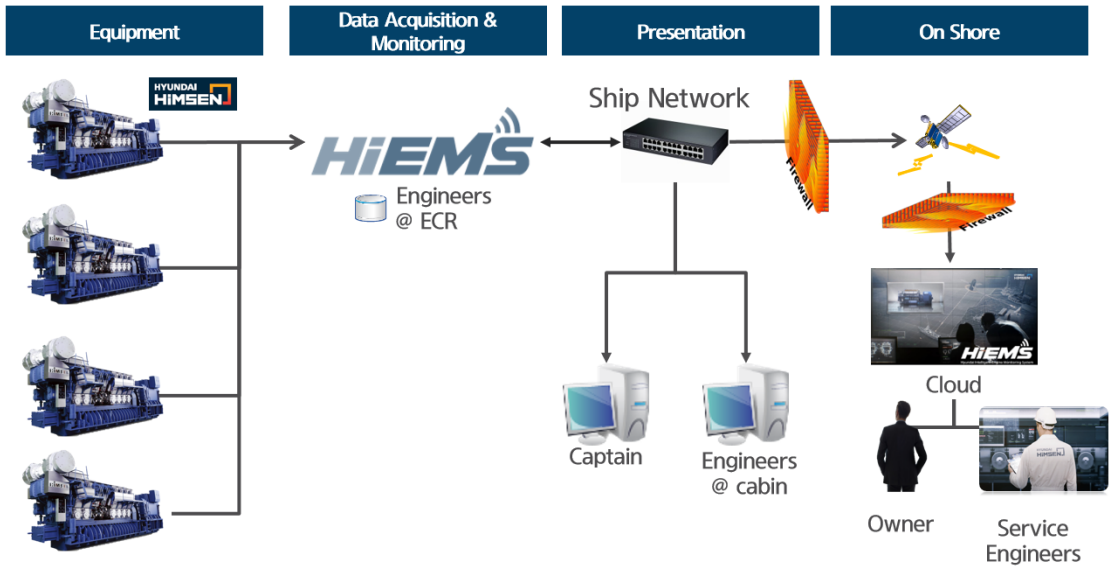



*Fig. 4-6-1 HiEMS Configuration and Network*

## 2. Main features

2.1 On Ship,

Real-time Status Monitoring of the HiMSEN engine

- Status of the engine, indicator of sub systems, trend and surveillance with FAT

Analysis tools for engine data

- Performance, Deviation, Correlation Analysis and Statistics

Maintenance and Guidance based on the instruction guide

- Alarm Manager, Maintenance Manager, Wearing Parts Manager

2.2 On Shore,

Status monitoring of the Fleet of HiMSEN engines

- Overall status of alarm and running hour
- Long Term Data management and reporting service

## 3. Benefits

3.1 On ship

- HiEMS provides guidance for the engine operator, maintenance function with engineering based instruction guide and integrated trouble shooting guide, which enables engine operators to run and maintain HiMSEN Engine at optimal condition.

3.2 On shore

- Ship managers can manage the Fleet of HiMSEN engines with HiEMS, accessible 24*7 through the Digital Innovation (DI) Center of HGS (Hyundai Global Service)
- Ship managers can get real-time remote diagnostics, qualified advices and services from our engineers and service experts (on reporting service version)

## 4. License Policy

4.1 Standard version

- All main features for “On ship” is available, data of a specific time interval is sent to on shore, such as alarm, statistics and operational data.

4.2 Reporting service version

- Including “Standard version” features, regular reporting service is available through HGS.
- contact HGS service manager.

## 5. Features

5.1 Monitoring

Real-time Status Monitoring of the HiMSEN engine

- Indicators of sub systems, running information.
- Status information by location through P&ID (DF only)

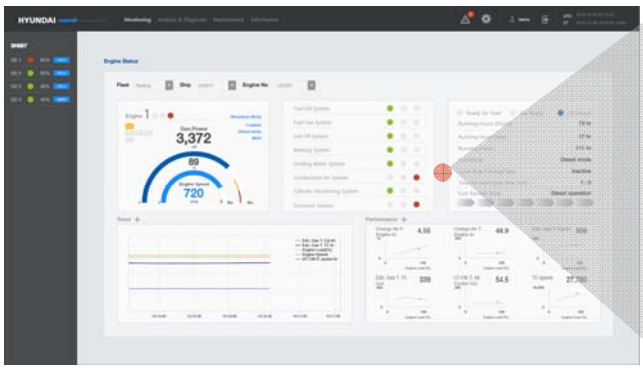


*Fig. 4-6-2 Engine Status (Indicators of subsystem)*

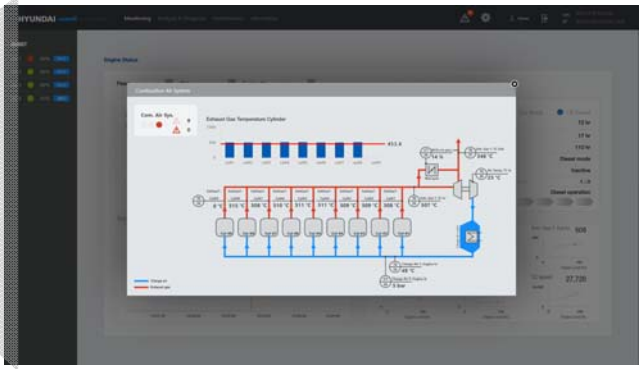


*Fig. 4-6-3 Status with P&ID*

5.2 Analysis & Diagnosis

Analysis tools for engine performance and correlation data

- Performance, Deviation, Correlation Analysis and Statistics.
- Compare FAT data with Current State.

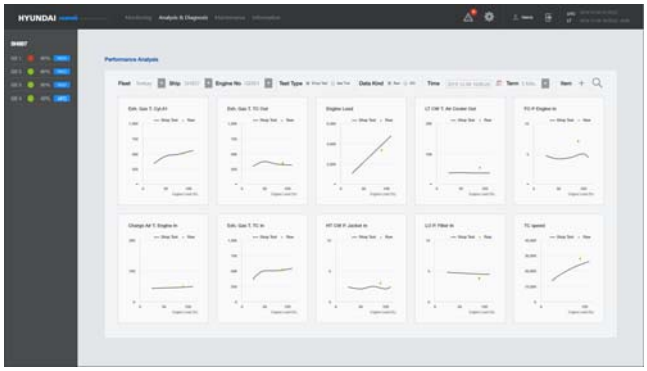


*Fig. 4-6-4 Performance Analysis*

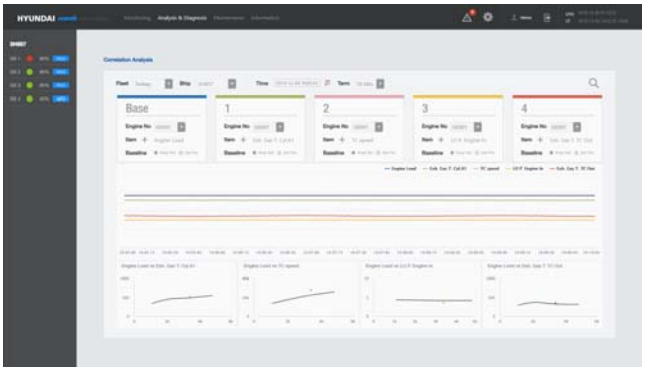


*Fig. 4-6-5 Correlation Analysis*

5.3 Maintenance

Maintenance and Guidance based on the Instruction Guide

- Alarm/Event, Maintenance, Wearing Parts Manager.

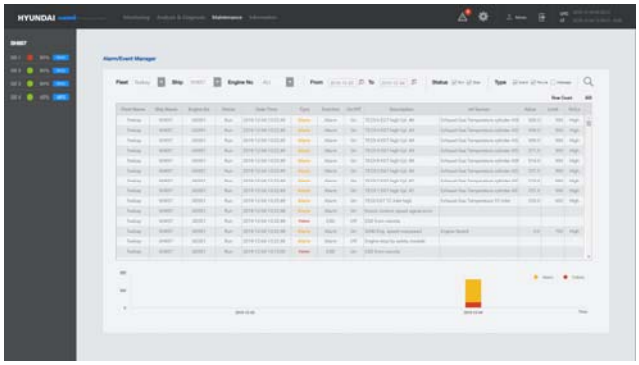


*Fig. 4-6-6 Alarm/Event Manager*

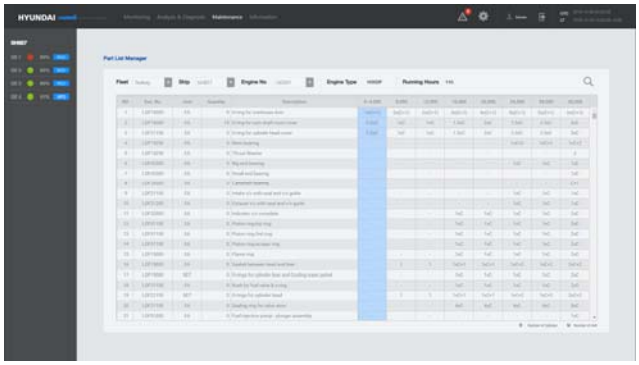


*Fig. 4-6-7 Wearing Parts Manager*

5.4 Fleet Management (Option)

On Shore, Status Monitoring of the Fleet of HiMSEN engines

- Overall status of alarm, running hour and reporting service.

*Fig. 4-6-8 Digital Innovation Center*

*Fig. 4-6-9 DI Report*

## Diagram for the internal fuel gas system

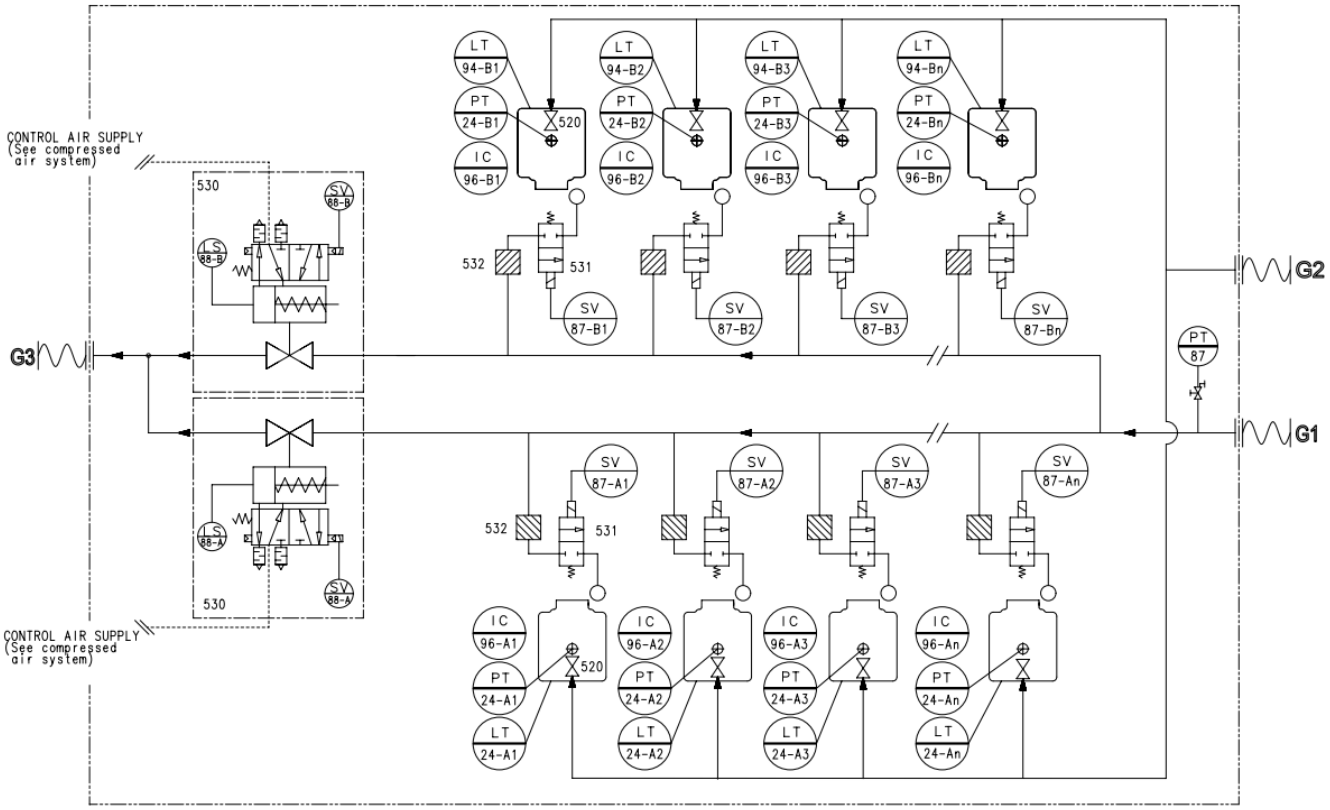



*Figure 5-4-1: Internal fuel gas system, single walled pipe [BH2-101790-7]*

## System components

| No. | Description | Remark |
|---|---|---|
| 520 | Check valve assembly | |
| 530 | Fuel gas venting valve | Normal open |
| 531 | Gas admission valve | |
| 532 | Fuel gas safety filter | 80㎛ |

## Sizes of the external pipe connections

| Code | Description | Size | Standard | Remark |
|---|---|---|---|---|
| G1 | Fuel gas inlet to main chamber | 16K-100A | JIS B 2220 | |
| G2 | Fuel gas inlet to pre-chamber | 16K-50A | JIS B 2220 | |
| G3 | Fuel gas ventilation | 10K-65A | JIS B 2220 | |

Remark:

1. Scope of instrumentation will be followed according to the extent of delivery and the engine builder's standard.

## General

The fuel gas regulated by the external fuel gas system is supplied to the two gas rails connected to the main chamber and the prechamber of each cylinder.

The fuel gas for main chambers is supplied to the intake port of each cylinder through a gas admission valve. The mixture of air and gas is injected to the main combustion chamber through an intake valve and ignited by flames from prechamber

The rich gas is injected into the prechamber via the check valve wihich is actuated by the cam mechanism and the injected gas is burned by the high voltage spark in prechamber. Flames in the prechamber efficiently causes combustion in cylinder with main gas.

At the time of engine shut down, emergency stop or maintenance work of gas supply line, fuel gas should be purged out with inert gas with dry & clean, which is supplied from the gas regulating unit.

## Gas admission valve

Fuel gas for main chamber is injected by gas admission valves into the intake port of each cylinder with suitable timing and duration. To regulate the power and speed of engine, the amount of fuel gas fed into each cylinder is individually controlled by the gas admission valves which receive signals from ECS(engine control system).

The gas admission valves are inserted on the molded-cases.

## Safety filter

To protect the gas admission valves, a safety filter with a fineness of approx. 80㎛ is installed at the entrance of each gas admission valve.

## Gas ventilation valve

In case of engine stop(including emergency stop) or shut down, the gas venting valve is to be operated according to the specific sequence in order to vent out the fuel gas in gas pipe on engine.

Fuel gas vent line does not common with any other pipes to prevent unintended gas flowing to the other engine due to risk for backflow of gas and it should be led to open space with non-hazardous area where there are no any ignition sources.

The pressure drop in fuel gas vent line is to be designed as minimum as possible.

## Check valve

The check valve in prechamber is controlled by the spring loaded linkage via camshaft moving. So, rich fuel gas can be injected into the prechamber of each cylinder through a check valve with suitable timing and duration according to the firing order.

Also the check valve prevents the combustion air/exhaust gas entering the fuel gas supply system. It is sealed closely with several O-rings

## Purging with inert gas

In order to secure safety, the crankcase or gas pipe of engine should be purged with inert gas in case of engine shut down, emergency stop or maintenance work. The inert gas for purging of fuel gas piping is supplied from gas regulating unit according to purging sequence controlled by ECS (Engine control system). In case of purging to crankcase, it would be only conducted by manually before maintenance such as opening the crankcase door.

- Connection code
  - Crank chamber: L6 (See the Lube oil system P.06.100)
  - Gas piping: G18 (See the External Fuel Gas System P.05.500)

Remark :

1. Do not supply inert gas to crankcase during engine operation.

## Volume of gas pipe and crank chamber (Unit: L)

| Engine type | Gas pipe | Crank chamber |
|---|---|---|
| 12H54GV | 483.6 | 50,150 |
| 14H54GV | 562.7 | 56,465 |
| 16H54GV | 641.7 | 62,780 |
| 18H54GV | 720.8 | 69,094 |

## General

In order to supply fuel gas to the engine, fuel gas passes through the external fuel gas system in order to ensure stable operation with correct pressure and temperature.

## Gas Supply Pressure

The gas supply pressure to HiMSEN engine system depends on the minimum lower heating value of the fuel gas and pressure drop. Also, the gas supply pressure should be constantly supplied for stable operation.

Please refer to the P.04.100 sheet (Engine Operation) for further information.

## Master fuel gas valve

To shut off the gas inlet, the master fuel gas valve is required to install in the fuel gas system. Generally, the valves are located outside the engine room

## Gas Regulating Unit

The fuel gas is supplied to the engine through the gas regulating unit. It adjusts the pressure of the fuel gas through pressure regulator with I/P convertor, which is controlled by ECS(engine control system).

The gas regulating unit is required for each engine and it should be applied with the ventilation fan and gas detection system in the engine room.

- **Installation**

  The Gas Regulating Unit shall be located as close to engine as possible for stable engine operation. Therefore, the distance between the fuel gas inlet of HiMSEN engine and Gas Regulating unit is recommended to be within 10m (Max. 20m).

- **The main function of Gas Regulating Unit as follows :**

  - Filtering fuel gas
  - Measuring gas consumption (Optional)
  - Control of the fuel gas pressure supplied to HiMSEN Engine
  - Stopping fuel gas supply to engine in case of emergency stop or shut down
  - Purging fuel gas line

- **The Gas Regulating Unit comprises as follows :**
  - Manual shut-off valve
  - Gas filter
  - Flow meter (Option)
  - Gas pressure regulator for main gas feed
  - I/P converter for main gas feed
  - Gas ventilation valve for main gas feed
  - Double block & bleed valve for main gas feed
  - Gas pressure regulator for prechamber gas feed
  - I/P converter for prechamber gas feed
  - Gas ventilation valve for prechamber gas feed
  - Double block & bleed valve for prechamber gas feed
  - Block valve for inert gas line
  - Instruments (Pressure indicator, sensor, Temperature indicator, transmitter)

## Typical drawing of Open Type Gas Regulating Unit

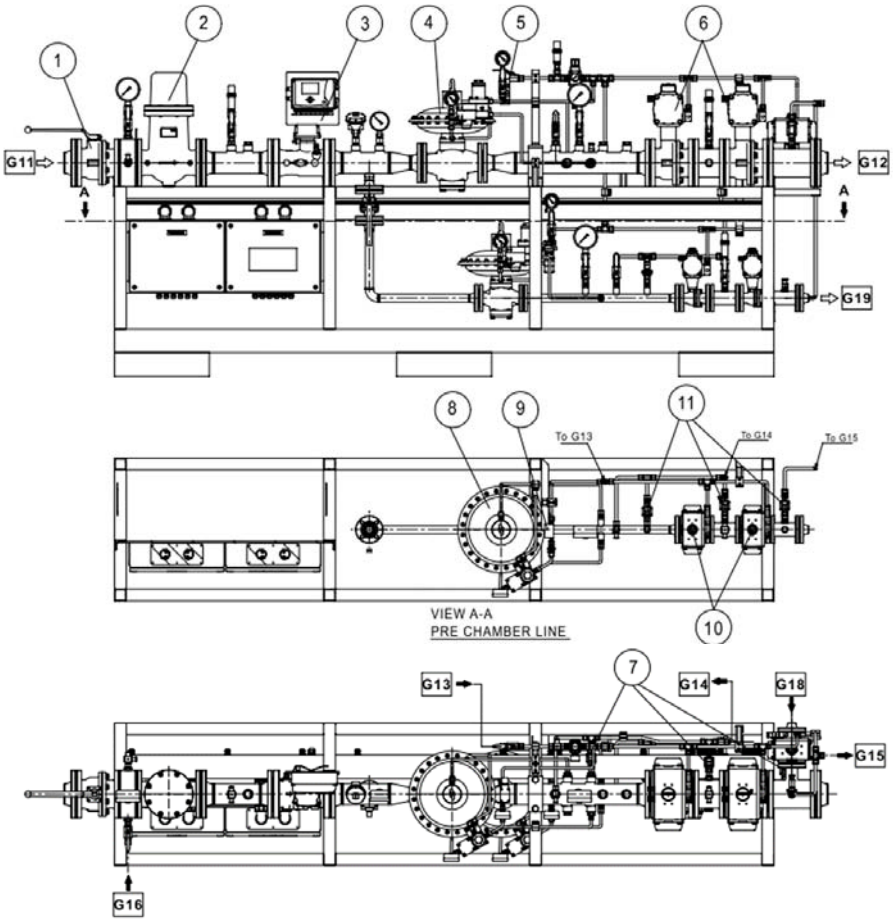



*Figure 5-5-1: Typical drawing of OpenType Gas Regulating Unit*

| No. | Description | Remark |
|---|---|---|
| 1 | Manual shut off valve | |
| 2 | Fuel gas filter | 5㎛ |
| 3 | Flow meter | Option |
| 4 | Gas pressure regulator for main gas feed | |
| 5 | I/P converter for main gas feed | |
| 6 | Double block valve for main gas feed | |
| 7 | Gas ventilation valves for main gas feed | |
| 8 | Gas pressure regulator for prechamber gas feed | |
| 9 | I/P converter for prechamber gas feed | |
| 10 | Double block valve for prechamber gas feed | |
| 11 | Gas ventilation valves for prechamber gas feed | |

Remark:

1. This drawing is only for reference in order to show the GRU figure.
2. Scope of supply will be followed according to extent of delivery for each project and engine builder's standard.

## Diagram for Open Type Gas Regulating Unit

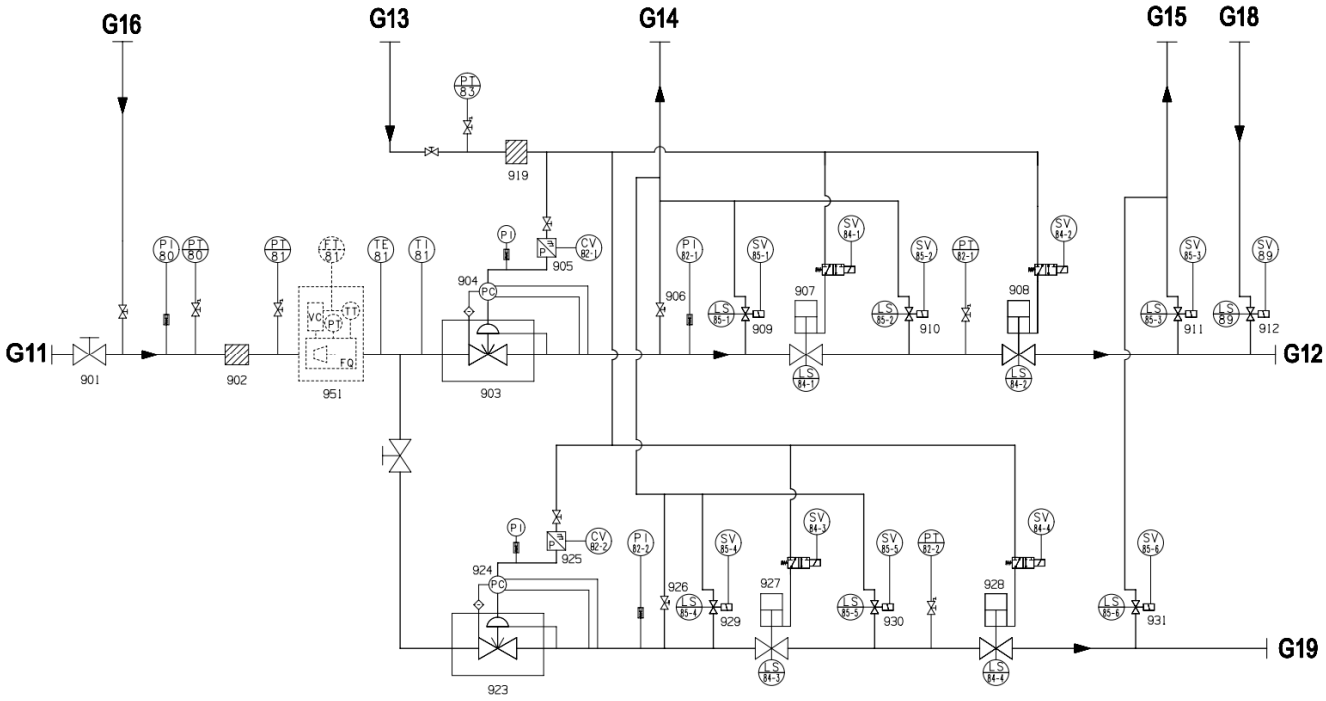



*Figure 5-5-2: Diagram for Open Type Gas Regulating Unit [BH2-109127-3]*

## System components

| No. | Description | Remark |
|---|---|---|
| 901 | Manual shut off valve | |
| 902 | Fuel gas filter | 5㎛ |
| 903 | Gas pressure regulator | |
| 904 | Pilot regulator | |
| 905 | I/P converter | |
| 906 | Manual vent valve | |
| 907 | First block valve | Normal close |
| 908 | Second block valve | Normal close |
| 909 | Vent valve | Normal close |
| 910 | Vent valve | Normal open |
| 911 | Vent valve | Normal open |
| 912 | Inert gas block valve | Normal close |
| 919 | Air filter | 5㎛ |
| 923 | Gas pressure regulator | |
| 924 | Pilot regulator | |
| 925 | I/P converter | |
| 926 | Manual vent valve | |
| 927 | First block valve | Normal close |
| 928 | Second block valve | Normal close |

| No. | Description | Remark |
|---|---|---|
| 929 | Vent valve | Normal close |
| 930 | Vent valve | Normal open |
| 931 | Vent valve | Normal open |
| 951 | (Option) Flow meter | Turbine type |

## Sizes of the external pipe connections

| Code | Description | Size | Standard |
|---|---|---|---|
| G11 | Fuel gas inlet to GRU | DN150 PN16[1)] | DIN 2501 |
| G12 | Fuel gas outlet to engine | DN100 PN16 | DIN 2501 |
| G13 | Control air to GRU | OD 12 | |
| G14 | Fuel gas ventilation | 16K-25A | JIS B 2220 |
| G15 | Fuel gas ventilation | 16K-25A | JIS B 2220 |
| G16 | Inert gas inlet | 16K-25A | JIS B 2220 |
| G18 | Inert gas inlet | 16K-25A | JIS B 2220 |
| G19 | Fuel gas outlet to pre-chamber | DN50 PN16 | DIN 2501 |

- **Gas filter**

  The Gas filter protects the downstream equipment of the pressure regulators from impurities such as dust, rust, and other solid particles. It filters out the particles of 5 ㎛ (abs.) and over, and the filtration degree is 99 %.

  Remark

  1. The pressure loss at this filter is monitored by the front and the rear of pressure transmitter.

- **Flow meter (option)**

  Flow meter can measure the flow rate directly by the measured values.

- **Double block valve**

  The double block and bleed valve (DBB valve) is composed with two shut off valves (block valves) and ventilation valve (bleed valve) between the shut off valves. The two shut off valves cut off the fuel gas supply to the engine according to specific sequence controlled by ECS. And the ventilation valve will be opened to release the trapped fuel gas between shut off valve at the same time. The block valves are designed for normal close (fail to close) and bleed valve is designed for normal open (fail to open) for fuel gas system's safety.

  The double block and bleed valves are arranged in main fuel gas line and prechamber fuel gas line.

Remark

1. To check for any leakage from the double block valves, close the valves and check the pressure right in front of the valves. If there is any pressure drop, it means that the gas is leaking from these valves.

- **Gas pressure regulating valve**

  The gas pressure regulating valve adjusts the gas pressure fed into the engine. It is controlled by the ECS through the I/P converter which transforms the electronic signals into the control air pressure.

  Gas pressure regulating valves are arranged in main fuel gas line and prechamber fuel gas line

- **Purging with inert gas of the fuel gas pipe**

  In case of engine shut down, emergency stop or maintenance work of gas supply line, fuel gas in gas pipings should be purged out with inert gas(Nitrogen) with dry & clean. The inert gas for purging of fuel gas piping is supplied through gas regulating unit according to purging sequence controlled by ECS (Engine control system).

  The pressure of the inert gas is recommended to be minimum 0.5 bars higher than the maximum operating fuel gas pressure. Also, the volume of inert gas has to be minimum 5.8 $Nm^3$.

- **Gas vent line**

  Fuel gas vent line does not common with any other pipes to prevent unintended gas flowing to the other engine due to risk for backflow of gas and it should be led to open space with non-hazardous area where there are no any ignition sources.

## Diagram for the external fuel gas system

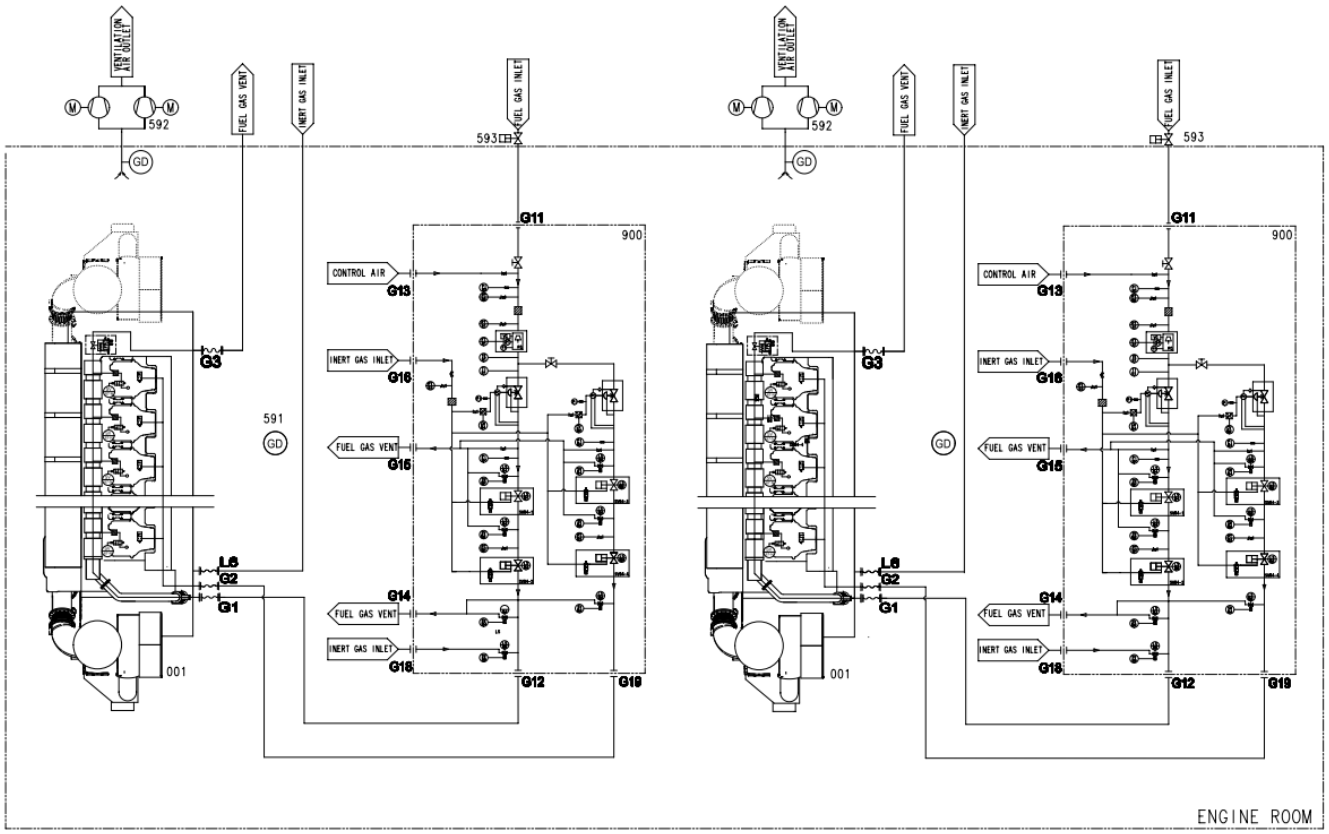



*Figure 5-5-3: External fuel gas system [BH1-109129-7]*

## System components

| No. | Description | Remark |
|---|---|---|
| 001 | HiMSEN GAS Engine | |
| 591 | Gas detector | |
| 592 | Ventilation fan | |
| 593 | Master fuel gas valve | |
| 900 | Gas regulating unit | |

## Fuel gas characteristics

For continuous operation without a reduction in the rated output, fuel gas has to fulfill the below mentioned quality requirements. In order to avoid operational problems like de-rating, corrosion, wear, lubricating oil contamination etc., the fuel gas composition must be provided to HHI-EMD.

| Property | Unit | Value |
|---|---|---|
| Lower calorific value (LCV), minimum [3] | MJ/Nm$^3$ [1] | 28 |
| Methane number (MN), minimum [2] | - | 70 |
| Methane (CH4) content, minimum | Vol % | 75 |
| Total content of C3, C4, C5, C6, Heavier, maximum (Propane, Butane, Pentane, Hexane, Heptane, Octane, Cetane …) | Vol % | 3 |
| Particles or solids at engine inlet, maximum | ㎛ | 5 |
| Particles or solids at engine inlet | mg/Nm$^3$ | 50 |
| Hydrogen sulfide content ($H_2S$), maximum | mg/Nm$^3$ | 30 |
| Gas inlet temperature | °C | 0 ~ 50 |
| Oil content, maximum | mg/Nm$^3$ | 0.01 |
| Water or liquids | Condensate not allowed at engine inlet | |

[1] Reference condition for the volume designation Nm$^3$ (Temp. 0℃, Atmospheric press. 1.013 bar)

[2] The MN of the fuel gas is to be calculated by using "AVL Methane version 3.20" of AVL's software

[3] HHI-EMD has to be contacted for further evaluation, in case the lower calorific value is in the range of 28 ~ 36MJ/Nm$^3$ or the MN is in the range of 70 ~ 80.

*Table 5-6-1: Fuel gas quality requirement for HiMSEN Dual fuel / Gas engine*

## Diagram for the internal lubricating oil system

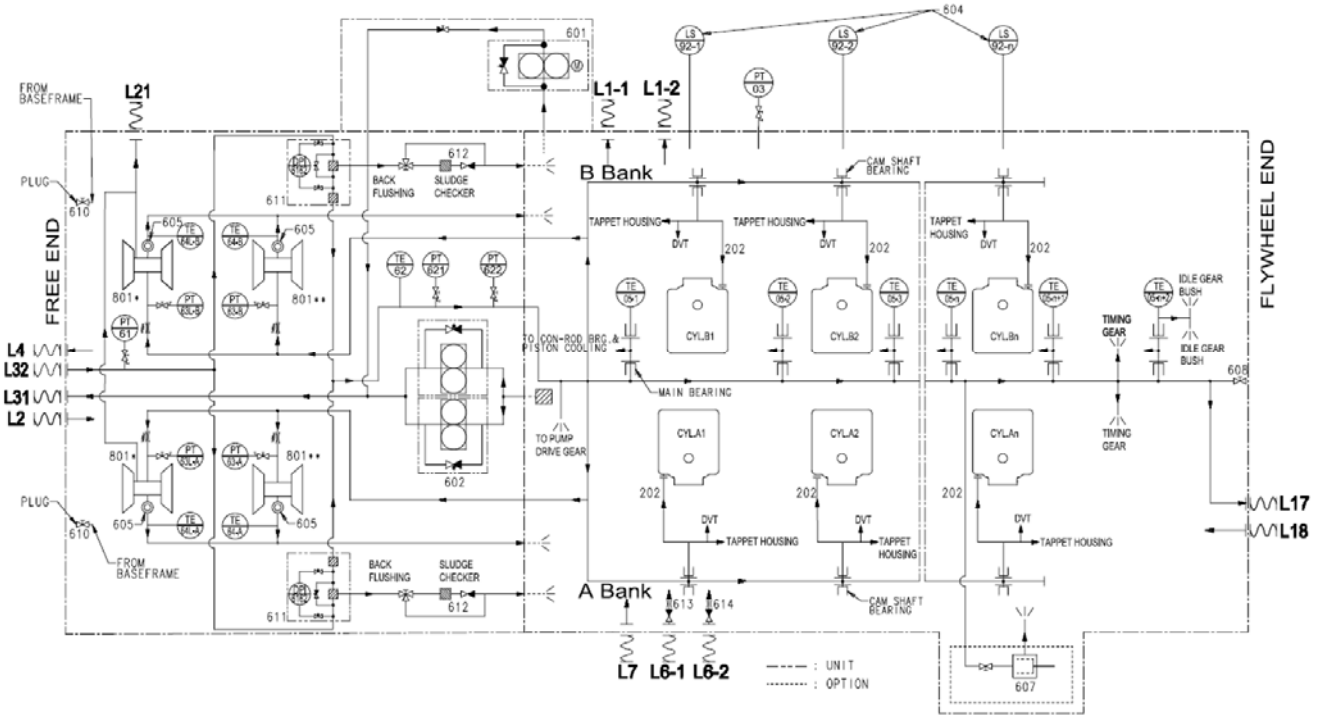



*Figure 6-1-1: Internal lubricating oil system [BH2-110373-2]*

## System components

| No. | Description | Remark |
|---|---|---|
| 202 | Rocker arm | |
| 602 | Engine driven lubricating oil pump | |
| 604 | Oil mist detector | SPECS |
| 605 | Sight glass | |
| 607 | Centrifugal filter | For indication |
| 608 | Lubricating oil sampling valve | |
| 610 | Lubricating oil drain valve | From baseframe |
| 611 | Lubricating oil automatic filter | 34㎛+80㎛ |
| 612 | Sludge checker | 70㎛ |
| 613 | Orifice | Ø17 |
| 801 * | Low pressure turbocharger | |
| 801 ** | High pressure turbocharger | |

## Sizes of the external pipe connections

| Code | Description | Size | Standard |
|---|---|---|---|
| L1-1 | Oil mist gas outlet from crank chamber | 5K-250A | JIS B 2220 |
| L1-2 | Oil mist gas outlet from baseframe | 5K-200A | JIS B 2220 |
| L2 | Lubricating oil inlet from separator | 10K-150A | JIS B 2220 |
| L4 | Lubricating oil outlet to separator | 10K-150A | JIS B 2220 |
| L6-1 | Inert gas supply to crank chamber | 5K-50A | JIS B 2220 |

| Code | Description | Size | Standard |
|---|---|---|---|
| L6-2 | Inert gas supply to baseframe | 5K-25A | JIS B 2220 |
| L7 | Lubricating oil filling | 5K-150A | JIS B 2220 |
| L17 | Lubricating oil outlet to generator | 10K-32A | JIS B 2220 |
| L18 | Lubricating oil inlet from generator | 5K-100A | JIS B 2220 |
| L21 | Oil mist gas outlet from low pressure turbocharger | 12/14H:5K-100A<br>16/18H:5K-125A | JIS B 2220 |
| L31 | Lubricating oil outlet to lub. oil cooler | 10K-300A | JIS B 2220 |
| L32 | Lubricating oil inlet from lub. oil cooler | 10K-300A | JIS B 2220 |

Remark:

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

## General

The engine has its own Internal lubricating oil system, which supplies lubricating oil pressurized by lubricating oil pump into all moving parts for lubricating as well as for cooling.

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

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

- Pre lubricating oil pump
- Lubricating oil pump (with relief valve), engine driven
- Oil mist detector
- Lubricating oil automatic filter (34㎛+80㎛, absolute)
- Sludge chekcer (70㎛, absolute)

## Quantity of lubricating oil (wet sump)

Total quantity of lubricating oil inside an engine is as follows;

| Engine type | Oil quantities in liter | |
|---|---|---|
| | 600rpm | |
| | min. | max. |
| 12H54GV | 12,348 | 15,876 |
| 14H54GV | 14,406 | 18,522 |
| 16H54GV | 16,464 | 21,168 |
| 18H54GV | 18,522 | 23,814 |

## Lubricating oil consumption

The specific lubricating oil consumption in the engine can be estimated as follows:

SLOC = approx. 0.5

*SLOC [g/kWh] = specific lubricating oil consumption at MCR*

Remark:

1. +25% tolerance should be considered depending on the operating conditions.
2. Only MCR should be used to evaluate the lubricating oil consumption.

## General

The external lubricating oil system is required for not only cleaning but also heating the oil so that the *engine is warmed up and starts* quickly. The system can be in common with other engines or independent.

For the external lubricating oil system, the requirements are as follows:

- Even though the automatic back-flushing or the cartridge duplex manual type filter is built on the engines to remove particles by filtration, a centrifugal purification is commonly required for the engines in order to remove water, carbon residues and particles by separation.
- The solid particles and water in the lubricating oil can cause wear and frequent maintenance for the engine itself as well as the external lubricating oil system. Therefore, qualified separation equipment should be included in the external system.
- In order to prevent excessive pressure loss in the piping system, it is recommended that the flow velocity of the lubricating oil should be the following values:
  - Suction pipe: 0.5 ~ 1.5 m/s
  - Pressure pipe: 1.0 ~ 2.5 m/s
- The actual required quantity of the lubricating oil should depend on the tank geometry and total volume of the system including pipes.

The external lubricating oil system normally comprises a lubricating oil treatment and a feed system. The general requirements are described as follows and more detailed information can be provided for the specific projects if needed.

## 1. Lubricating oil treatment system

In order to remove water, combustion residues and other mechanical contaminations from the lubricating oil, the treatment system for the lubricating oil is required. It is recommended to install a suitable separator for the engine to ensure the required oil quality. The separator unit shall be dimensioned for continuous service while the engine is in operation. If the engine is operated with only MDO, the intermittent separation might provide sufficient capacity.

The system mainly consists of a feed pump, a preheater, a separator, etc.

- **Separator (SP-601)**

  The separator should be dimensioned for continuous operation. It is recommended to be a centrifuge and of a self- cleaning type.

  The required flow for the separation can be estimated as following formula:

$$Q = \frac{1.4 \times P \times n}{t}$$

  *Q [liter/h] = required flowrate for the separation*
  *P [kW] = maximum continuous output of the engine(s)*

*n [-] = number of oil circulation per day (6 for HFO, 4 for MDO/MGO and GAS)*
*t [h] = actual separation time per day (23 hours for normal operation)*

Remark:

1. The actual capacity of the separator should be considered with the throughput (%) additionally.

- **Feed pump for the separator (PP-602)**

The feed pump shall be either directly driven by the separator or driven by an independent motor. The feed pump should be dimensioned for the required flowrate for the separation. It is recommended to be of a screw type and it should be protected by a suction strainer with a mesh size of approx. 0.5…1.0 mm with a magnet.

The specifications of the pump should be in accordance with the recommendation of the separator manufacturer. To dimension the motor for the feed pump, the lowest temperature in the system oil tank or the Base frame (if wet sump type is applied) should be taken into account.

- **Preheater for the separator (HE-601)**

The lubricating oil in the system oil tank or the Base frame (if wet sump type is applied) shall be warmed up to 40°C before engine starting and heated up to approx. 65°C during engine running.

The preheater for the separator is designed to heat the lubricating oil to a recommended temperature after the preheater for efficient separation. The recommended temperature is typically 95…98°C and the specific temperature is according to separator maker's recommendation. However, the temperature of heater surface must not exceed 150°C in order to avoid cooking the lubricating oil.

In addition, the heater is to have a sufficient capacity to maintain the separation temperature when the engine is stopped and the lubricating oil is not heated by the engine.

If the separation temperature is reduced, the separator throughput has to be reduced to maintain the same separation efficiency.

- **Separator installation**

The separator should be in continuous operation as the engine is running in order to remove contaminants as quickly as possible. If possible, the separator should be also in operation when the engine is shut down to further reduce the level of contamination.

In the latter case, oil temperature for efficient separation needs to be maintained through heaters. Those installations with their separation unit shut down during engine stop, should consider re-starting the separator prior to engine start-up because the contaminations (engine leaks, condensation) could have occurred during engine stop.

With multi-engine applications, the best installation would be to have one separator per engine. (Figure 6-2-1, on the next page)

The cleaning system of auxiliary engines are often designed such that the separator intermittently serves on the engine at a time. If only one separator is in operation, the following lay-outs can be used. (Figure. 6-2-2, on the next page)

Depending on the operating time between two periods of oil cleaning and 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. An appropriate discharge interval has to be found by trial and error.

It is important that the maintenance and operation of the separator is done according to the recommendations of the manufacturer.

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.

With only one engine in operation there is no problem 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.

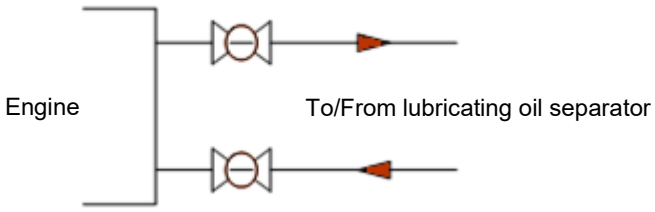



Figure 6-2-1: Principle lay-out for direct separating on a single plant

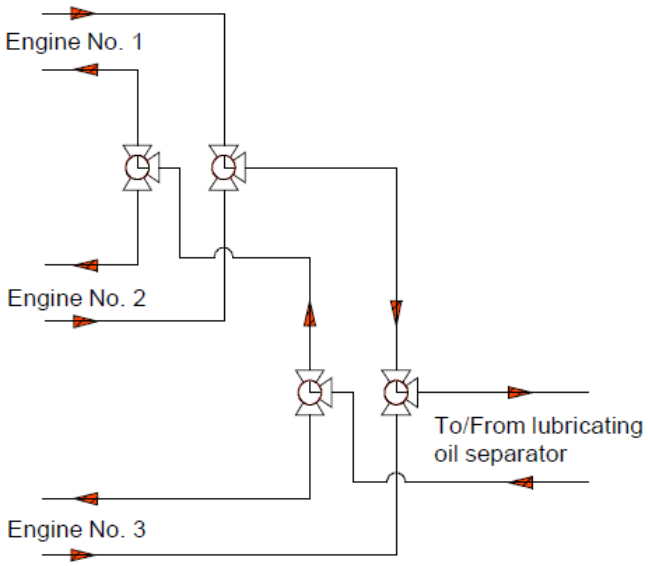



Figure 6-2-2: Principle lay-out for direct separating on a multi plant

- **Sludge tank (TK-603)**

  The sludge tank should be located as close as possible below the separator foundation. The sludge oil pipes from the separator should be suitable to continuously drain.

- **Overflow system**

  In some cases, the overflow system can be applied as an alternative for continuous purification (Figure. 6-2-3).

  In order to have better siphon effects, the overflow pipes from the sump to the overflow tank should have continuous downward gradients of minimum 10 degrees without high and low points.

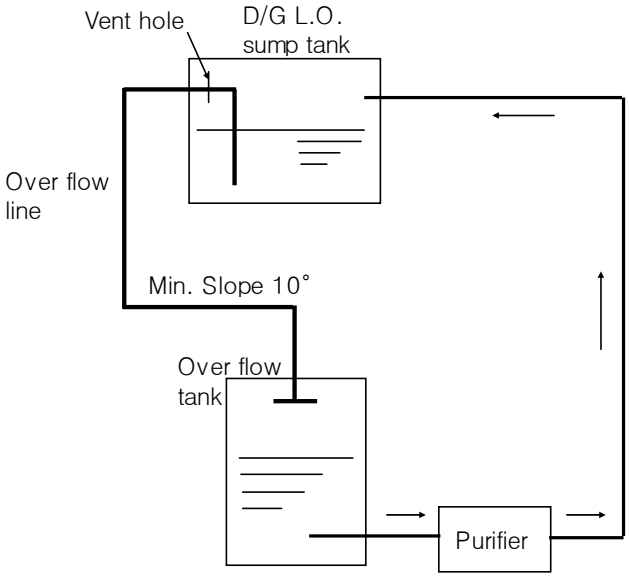



*Figure 6-2-3: Principle lay-out for overflow system*

- **Suction strainer**

  0.5~1.0mm mesh size of suction strainer should be inserted before the separator pump.

## 2. Lubricating oil feed system

The system mainly consists of a storage tank, a sludge tank, a pressure regulating valve, etc.

- **Storage tank (TK-602)**

  The lubricating oil shall be stored in the storage tank for long voyage operation or long term bunkering frequency beyond system oil tank capacity.

- **Suction strainer**

  In order to protect the lubricating oil pump against large dirty particles, 0.5…1.0 mm mesh size of the suction strainer should be applied before all lubricating pumps. The mesh size of the suction strainer should be dimensioned to minimize pressure losses. It is advisable to provide the local indicator of differential pressure in order to recognize the abnormal condition of strainer and the necessity of cleaning strainer manually.

- **Separated oil tank for wet sump (TK-604)**

  The separated oil tank contains the lubricating oil which is cleaned by the separator when a wet sump is applied.

- **Lubricating oil cooler (HE-602)**

  The Lubricating oil cooler shall be installed in the external system and a plate heat exchanger type (PHE). The L.T cooling water is typically used as a cooling medium. If the sea water that is not treated is directly used as a cooling medium, it is required to add a fouling margin based on the cooler manufacturer's recommendation.

  The specifications of the cooler should be as follows:

| | | |
|---|---|---|
| Required heat dissipation | : | See P.02.200 "Engine Capacity Data"<br>(It should include the margin of 15% for a fouling) |
| Temperature of the lubricating oil after cooler | : | Max. 60°C |
| Flow rate of the lubricating oil | : | Lubricating oil flow in the engine(s) at MCR,<br>(See P.02.200 "Engine Capacity Data") |
| Flow rate of the fresh water | : | Fresh water flow in the engine(s) at MCR,<br>(See P.02.200 "Engine Capacity Data") |
| Pressure drop<br>on the lubricating oil side | : | Max. 0.8bar |
| Pressure drop<br>on the fresh water side | : | Max. 0.6bar |

- **Thermostatic valve (TV-601)**

  In order to control the temperature of the lubricating oil before the engine(s), the thermostatic valve should be provided and shall be installed in the external system after the lubricating oil cooler. It is required to be as a mixing three-way valve and can be of a motor-operated type, an electric-pneumatic or a wax thermostat.

  Set temperature : 60°C

## 3. Crankcase and tank ventilation

Ventilations on the engine and tanks must be provided with sufficient ventilation. The crankcase ventilation of the engine must not be connected to other ventilations such as tanks.

The arrangement should be as follows:

- When two or more engines are installed, the crankcase vent pipes shall be kept independently.
- The crankcase vent pipes from each engine shall be led independently to a safe location outside of engine room which is distant place from any source of ignition. The pipes should not be connected to any other branch such as a tank vent, etc.
- Corrosion resistant flame screens shall be applied to each vent pipe.
- The vent pipes should have a continuous upward gradient of minimum 10 degrees without high or low points.
- A condensate trap with draining facilities shall be applied to each vent pipe.

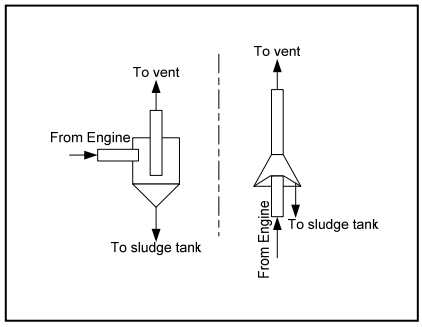



*Figure 6-2-4: an example of condensation trap*

- The connection between the engine and the vent pipes of the external system should be flexible if a resilient mounting is applied.
- The size of the crankcase vent pipes shall be equal or larger than engine side vent pipes.
  (See the P.06.100 “Internal Lubricating Oil System”, L1 connection.)
- The ventilation pipe on the tank should be arranged at the corners of the tank or at the ends of the tank to secure venting at any trim of the vessel (or plant).
- The oil mist should not be flowed into suction air from outside intake duct (for outdoor type) or engine room (for indoor type)
- Inert gas purging in the crankcase is required manually before crankcase door open through L6 connection.
- The lube oil mist with gas and air would be vent out from crankcase lube oil mist vent line during the gas mode operation.

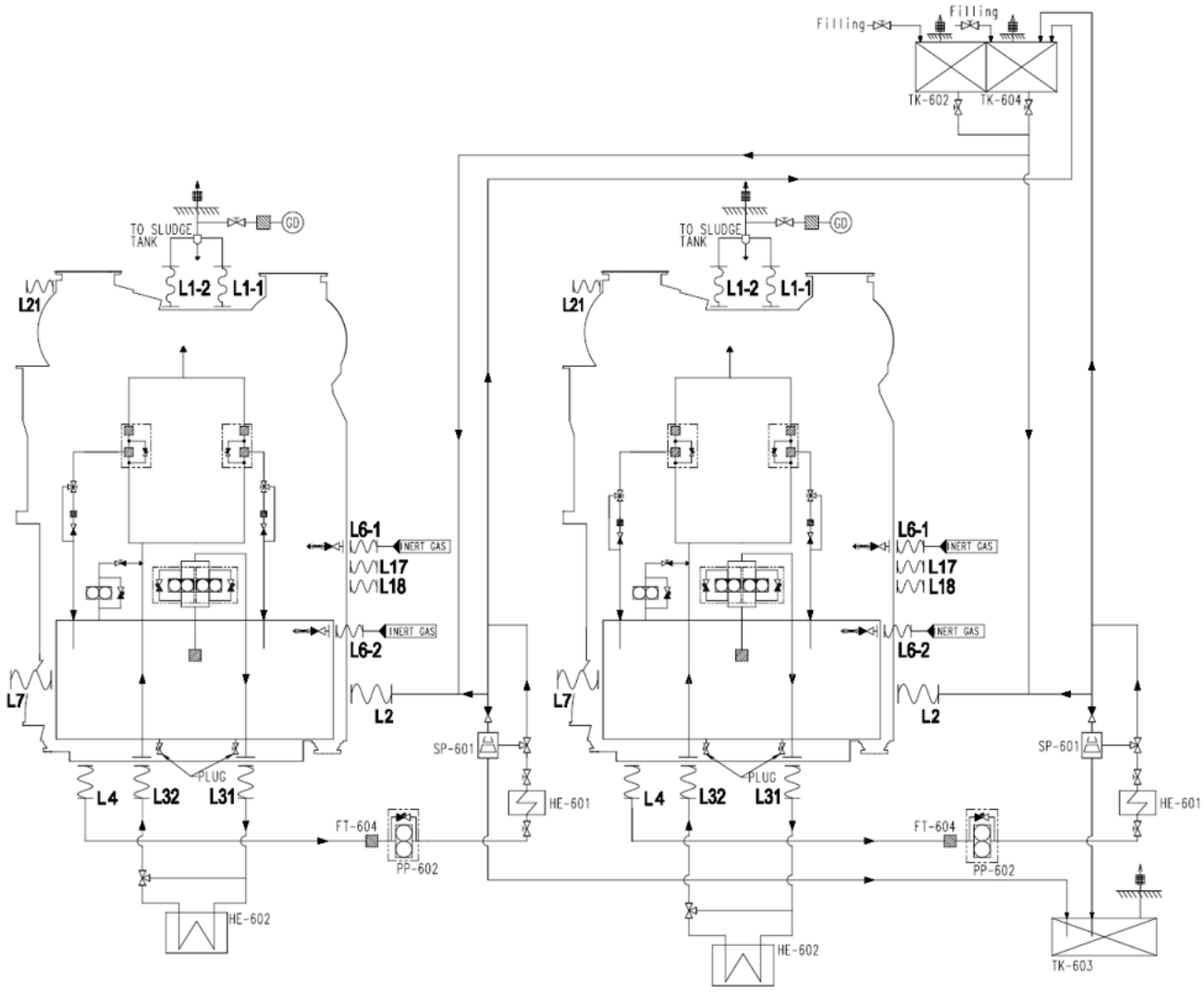



*Figure 6-2-5: External lubricating oil system (Wet sump) for multi-engine installation [BH1-107311-9]*

## Diagram for the external lubricating oil system(wet oil sump), multi engine installation

### System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-602 | Storage tank | HE-602 | Cooler for lubricating oil |
| TK-603 | Sludge tank | PP-602 | Feed pump for separator |
| TK-604 | Separated oil tank for wet sump | FT-604 | Suction strainer (Feed pump for separator) |
| SP-601 | Separator | GD | Gas detector |
| HE-601 | Preheater for the separator | | |

### External pipe connections

| Code | Description | Code | Description |
|---|---|---|---|
| L1-1 | Oil mist gas outlet from crank chamber | L7 | Lubricating oil filling |

| Code | Description | Code | Description |
|---|---|---|---|
| L1-2 | Oil mist gas outlet from baseframe | L17 | Lubricating oil outlet to generator |
| L2 | Lubricating oil inlet from separator | L18 | Lubricating oil inlet from generator |
| L4 | Lubricating oil outlet to separator | L21 | Oil mist gas outlet from low pressure turbo charger |
| L6-1 | Inert gas supply to crank chamber | L31 | Lubricating oil outlet to lub. oil cooler |
| L6-2 | Inert gas supply to baseframe | L32 | Lubricating oil inlet from lub. oil cooler |

## Oil grade

A medium-alkaline, heavy duty (HD) oils in API-CD class has to be used for HiMSEN engine including turbocharger lubrication.

## Oil viscosity

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

Initial oil heating to 40℃ is necessary prior to engine starting.

## Governor oil grade

In case of the hydraulic governor, an independent oil system is required. For further information, please refer to the sheet 'List of Lubricants'.

## 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).

## Approved lubricating oils

The approved lubricating oils are as shown in the table below:

| Oil brand | Engine system lubricating oil | | | Governor oil |
|---|---|---|---|---|
| Oil company | Brand name | SAE | BN*) | |
| Shell | Mysella S3 N40 | 40 | 5 | 1) Same as Engine system L.O<br>2) Refer to the governor manual for detailed L.O specification, volume of governor.<br>3) Initial filling: Oil filled<br>4) Electrical (Digital) Governor: Not applied |
| | Mysella S5 N40 | | 4.5 | |
| | Shell Gadinia S3 40 | | 12 | |
| | Shell Argina S2 40 | | 20 | |
| | Shell Argina S3 40 | | 30 | |
| | Shell Argina S4 40 | | 40 | |
| | Shell Argina S5 40 2) | | 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 2) | | 55 | |
| Chevron (Taxaco, Caltex) | Geotex LA | 40 | 5.2 | |
| | 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) 2) | | 50 | |
| ExxonMobil | Pegasus 705 | 40 | 5.3 | |
| | Pegasus 805 | | 6.2 | |
| | Pegasus 905 | | 6.2 | |
| | Pegasus 1 | | 6.5 | |
| | Mobilgard ADL 40, Mobil Delvac 1640 | | 12 | |
| | Mobilgard 412 | | 15 | |
| | Mobilgard M420 | | 20 | |
| | Mobilgard M430 | | 30 | |
| | Mobilgard M440 | | 40 | |
| BP | CASTROL Duratex L | 40 | 4.5 | |
| | CASTROL MLC 40 | | 12 | |

| Oil brand<br>Oil company | Engine system lubricating oil<br>Brand name | SAE | BN*) | Governor oil |
|---|---|---|---|---|
| BP | CASTROL MHP 154 | 40 | 15 | 1) Same as Engine system L.O<br>2) Refer to the governor manual for detailed L.O specification, volume of governor.<br>3) Initial filling: Oil filled<br>4) Electrical (Digital) Governor: Not applied |
| | CASTROL TLX Xtra 204 | | 20 | |
| | CASTROL TLX Xtra 304 | | 30 | |
| | CASTROL TLX Xtra 404 | | 40 | |
| | CASTROL TLX Xtra 504 | | 50 | |
| | CASTROL TLX Xtra 554 | | 55 | |
| SK Lubricants | SUPERMAR 13TP 40 | 40 | 13 | |
| | SUPERMAR 24TP 40 | | 24 | |
| | SUPERMAR 30TP 40 | | 30 | |
| | SUPERMAR 40TP 40 | | 40 | |
| LUKOIL | Navigo TPEO 12/40 | 40 | 12 | |
| | Navigo TPEO 15/40 | | 15 | |
| | Navigo TPEO 20/40 | | 20 | |
| | Navigo TPEO 30/40 | | 30 | |
| | Navigo TPEO 40/40 | | 40 | |
| | Navigo TPEO 50/40 2) | | 50 | |
| | Navigo TPEO 55/40 2) | | 55 | |
| Gulf Oil Marine | GulfSea Power MDO 4012, SeaLub Power MDO 4012 | 40 | 12 | |
| | 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 2) | | 55 | |
| ENI S.p.A. | AGIP CLADIUM 120 | 40 | 12 | |
| | AGIP CLADIUM 300 | | 30 | |
| | AGIP CLADIUM 400 | | 40 | |
| | AGIP CLADIUM 500S 2) | | 50 | |
| Petronas | PETRONAS Disrol 50 | 40 | 6 | |
| | PETRONAS Disrol 120 | | 12 | |
| | PETRONAS Disrol 300 | | 32 | |
| | PETRONAS Disrol 400 | | 42 | |
| | PETRONAS Disrol 500 | | 51 | |
| AEGEAN | ALFAMAR 430 | 40 | 30 | |
| | ALFAMAR 440 | | 40 | |
| | ALFAMAR 450 2) | | 50 | |
| | ALFAMAR 455 2) | | 55 | |

| Oil brand<br>Oil company | Engine system lubricating oil<br>Brand name | SAE | BN*) | Governor oil |
|---|---|---|---|---|
| SINOPEC TPEO | SINOPEC TPEO 4012 | 40 | 12 | 1) Same as Engine system L.O<br>2) Refer to the governor manual for detailed L.O specification, volume of governor.<br>3) Initial filling: Oil filled<br>4) Electrical (Digital) Governor: Not applied |
| | SINOPEC TPEO 4015 | | 15 | |
| | SINOPEC TPEO 4020 | | 20 | |
| | SINOPEC TPEO 4030 | | 30 | |
| | SINOPEC TPEO 4040 | | 40 | |
| | SINOPEC TPEO 4050 2) | | 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 2) | | 50 | |
| 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) See P.06.300 “Lubricating Oil Specification” when selecting the BN value.

2) For the dual fuel engine with alternating fuel gas and heavy fuel oil operation, please contact to HHI-EMD.

Remark:

1. This list is for guidance only.
2. Especially, base number (BN value) must be carefully selected for dual fuel engine depending on main fuel.

## Diagram for the internal cooling water system

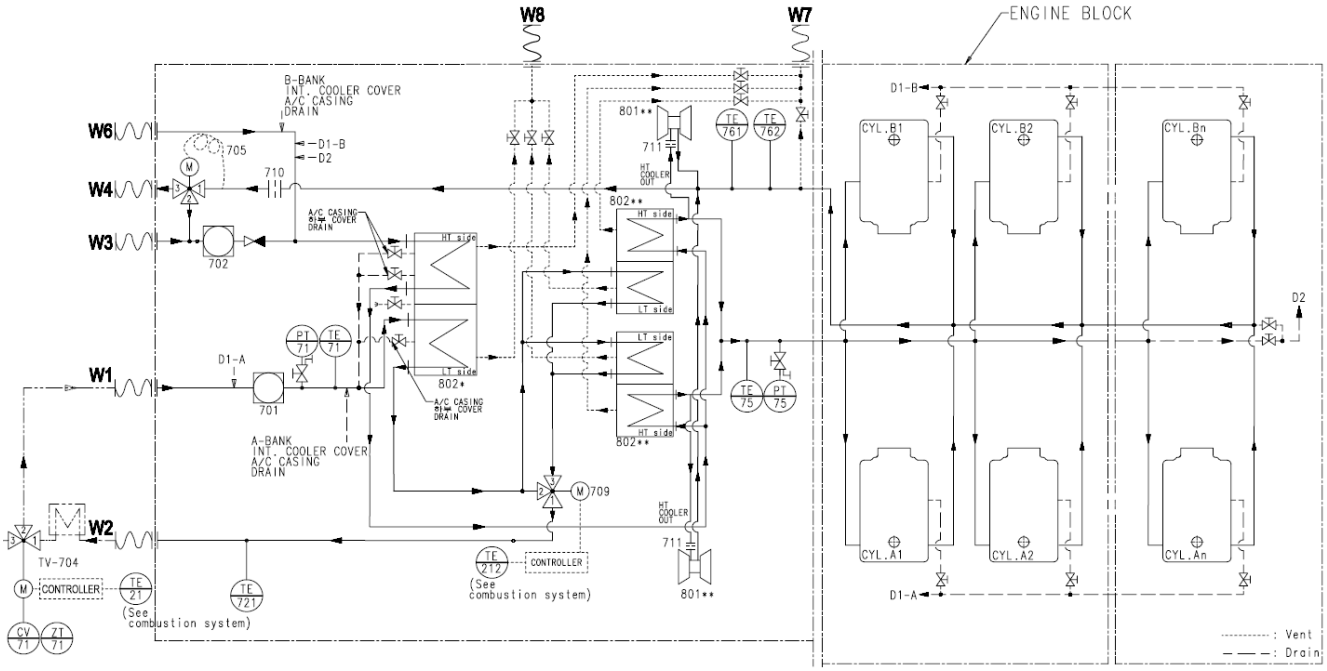



*Figure 7-1-1: Internal cooling water system [BH2-107312-0]*

## System components

| No. | Description | Remark |
|---|---|---|
| 603 | Lubricating oil cooler | |
| 701 | Low temperature cooling water pump | |
| 702 | High temperature cooling water pump | |
| 705 | High temperature thermostatic valve | MOV |
| 706 | Orifice | Ø3.0 |
| 709 | Low temperature thermostatic valve for charge air inter cooler | MOV |
| 710 | Adjustable orifice | |
| 801** | High pressure turbo charger | |
| 802* | Charge air after cooler | |
| 802** | Charge air inter cooler | |
| TV-704 | Low temperature thermostatic valve | MOV |

## Sizes of the external pipe connections

| Code | Description | Size | Standard |
|---|---|---|---|
| W1 | Low temperature fresh water inlet | 5K - 200A | JIS B 2220 |
| W2 | Low temperature fresh water outlet | 5K - 200A | JIS B 2220 |
| W3 | High temperature fresh water inlet | 5K - 200A | JIS B 2220 |
| W4 | High temperature fresh water outlet | 5K - 200A | JIS B 2220 |
| W6 | High temperature fresh water inlet from jacket water preheating unit | 5K - 80A | JIS B 2220 |
| W7 | High temperature fresh water venting from jacket & air cooler | 5K – 25A | JIS B 2220 |
| W8 | Low temperature fresh water venting | 5K -25A | JIS B 2220 |

| Code | Description | Size | Standard |
|---|---|---|---|
| | from air cooler | | |
| D1 | Water drain | 5K – 20A | JIS B 2220 |

**Remark:**

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

## General

The engine has two cooling water circuits internally and externally, which are low temperature (L.T) and high temperature (H.T) cooling water circuits.

The L.T cooling water circulates through the L.T stage of the air cooler and lub. oil coolers built on the engine by the engine driven L.T cooling water pump. The temperature of the L.T cooling water circulation in the engine can be regulated by the thermostatic valves mounted on the engine in order to control the temperature of the charge air.

The H.T cooling water circulates through the engine water jacket, cylinder head and the H.T stage of the air cooler by the engine driven H.T cooling water pump. The temperature of the H.T cooling water circulation in the engine should be regulated by the thermostatic valve mounted on the engine.

For the pump flow rate at MCR, see P.02.200 “Engine Capacity Data”.

The internal cooling water system is mainly comprised of the following equipment:

- L.T cooling water pump, engine driven
- H.T cooling water pump, engine driven
- H.T temperature control valve, motor driven
- L.T temperature control valve for Inter cooler , motor driven
- Aft. air cooler with two stage (L.T and H.T)
- Int. air cooler with two stage (L.T and H.T)

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

Note: If sea water or other coolant system is required, please contact engine maker in advance.

## Pressure drops

The pressure drops over the engine are as follows:

H.T circuit: approx. 1.8 bar

L.T circuit: approx. 1.0 bar

## General

The external cooling water system should be designed for cooling the engine(s) with the required temperature considering the pressure losses in the system. It can be in common with other engines or separate for each one. In case of a common system, the system should be able to ensure the sufficient cooling of every engine.

For the external cooling water system, the requirements are as follows:

- The freshwater in the system is required to be treated with chemical products to prevent the corrosion and fouling.
- In order to avoid the erosion and excessive pressure loss in the piping system, the flow velocity of the cooling water should be in the following range:
  - Fresh water suction: 1.5…2.0 m/s
  - Fresh water discharge: 2.0…2.5 m/s
  - Sea water suction: 1.0…1.5 m/s
  - Sea water discharge: 1.5…2.5 m/s
- The cooling water pressure at the engine inlet shall be kept in the range of 0.5… 2.5 bar.

## 1. Cooling water circulation system

- **Expansion tank (TK-701 / TK-702)**

  The expansion tank is required to compensate for the changes of the cooling water volume in the system due to the thermal expansion and/or leakages. And the air or gases in the system should be vented through this tank.

  In order to avoid cavitation, the tank should provide the positive static pressure of minimum 0.7 bar (7 meters above the crankshaft of the engine) on the suction side of the pump(s).

  For dual fuel and gas engines, some fuel gas may infiltrate to the expansion tank through the cooling water system. Therefore, it is recommended that the expansion tank is of a closed type and fitted with the ventilation pipes on the top of the tank in order to naturally emit gas (due to the fact that fuel gas is lighter than air). In addition, the extracted gas shall be vented to a safe location in open air.

  For dual fuel and gas engines, the arrangement and structure of the expansion tank and vent system should meet the requirements of the classification societies, or other applicable standards.

  Concerning the total volume of the cooling water system, please see P.07.100 Internal cooling water system.

  Capacity of the tank : min. 10% of the total volume of the cooling water system

## Water volumes

The total water volumes in the engine are approximately as shown in the table below:

| Engine type | H.T cooling water [L] | L.T cooling water [L] |
|---|---|---|
| 12H54GV | 4,800 | 1,500 |
| 14H54GV | 5,200 | 1,500 |
| 16H54GV | 5,500 | 1,600 |
| 18H54GV | 5,800 | 1,600 |

- **L.T.C.W central cooler (HE-701 / HE-702)**

  The L.T.C.W central cooler can be of shell & tube or plate type. It can be in common with other engines.

  The capacity of other equipment such as lube oil cooler, fuel oil cooler, lube oil cooler of reduction gear, etc. should be considered, if commonly used in one system.

  The specifications of each cooler should be as follows:

  | | | |
  |---|---|---|
  | Required heat dissipation | : | See P.02.200 “Engine Capacity Data”.<br>(It should include the margin of 15% for a fouling.) |
  | Temperature of the fresh water after the cooler | : | max. 36°C<br>(See P.02.200 “Engine Capacity Data”) |
  | Flow rate of the fresh water | : | required engine flow rate including the other equipment |
  | Flow rate of the sea water | : | Acc. to cooler manufacturer,<br>normally 1.1…1.5 x the fresh water flow<br>(It should be recommended by the manufacturer of the cooler.) |
  | Pressure drop on the fresh water side | : | max. 0.5 bar |
  | Pressure drop on the sea water side | : | typically 1.0…1.5 bar<br>(It should depend on the specifications of the sea water pump.) |

- **H.T.C.W central cooler (HE-703)**

  The H.T.C.W cooler can be of shell & tube or plate type. .

  The cooler is recommended to be redundant so that the one can be overhauled while the other one is in service, which should depend on the requirements of classification societies.

  The specifications of each cooler should be as follows:

  | | | |
  |---|---|---|
  | Required heat dissipation | : | See P.02.200 “Engine Capacity Data”.<br>(It should include the margin of 15% for a fouling.) |

| | | |
|---|---|---|
| Temperature of the fresh water after the cooler | : | max. 75°C<br>(See P.02.200 “Engine Capacity Data”) |
| Flow rate of the fresh water | : | required engine flow rate including the other equipment |
| Flow rate of the sea water | : | Acc. to cooler manufacturer,<br>normally 1.1…1.5 x the fresh water flow<br>(It should be recommended by the manufacturer of the cooler.) |
| Pressure drop on the fresh water side | : | max. 0.5 bar |
| Pressure drop on the sea water side | : | typically 1.0…1.5 bar<br>(It should depend on the specifications of the sea water pump.) |

- **Thermostatic valve for heat recovery (TV-702)**

  The thermostatic valve controls the maximum temperature of the cooling water which is led before the H.T pump. It can be either self-actuated or electrically actuated.

  Set temperature : 77°C

- **Thermostatic valve for L.T cooling water (TV-704)**

  The temperature of the charge air is maintained on desired level with an electrically actuated temperature control valve in the external LT circuit. The control valve regulates the recirculating water flow after the lubricating oil cooler through to the LT-stage of the charge air cooler in order to maintain the proper charge air temperature.

## 2. Preheating system

In order to ensure the engine initial starting and load-up quickly, the H.T cooling water in the engine is required to be preheated up to the minimum required temperature. The heating source for the preheating is recommended to be supplied by the separate preheating unit which mainly consists of the heater, circulating pump, etc.

The unit should be always running when the engine(s) is positioned at an initial starting. After running the engine(s), it should be switched off to the stop mode.

- **Preheater for H.T cooling water (HE-705)**

  The H.T cooling water in the engine should be able to be heated up to minimum 40…60°C within 10…15 hours by the preheater. The heating source can be steam or electric power.

  The specification of the preheater should be as follows:

| | | |
|---|---|---|
| Heat capacity | : | min. 21 kW per cylinder<br>(depending on the initial temperature of H.T cooling water and heater's operation hours) |
| Temperature of the cooling water after the heater | : | min. 70°C |
| Flow rate of the cooling water | : | same as the delivery capacity of the circulation pump for the preheater |
| Pressure drop on the cooling water side | : | max. 0.5 bar |

- **Circulation pump for preheating (PP-706)**

  The circulation pump is required to circulate the H.T cooling water in the engine during preheating. It should be of a centrifugal type and electrically driven.

  The specification of the pump should be as follows:

| | | |
|---|---|---|
| Delivery capacity | : | min. 2.8 $m^3$/h per cylinder |
| Delivery head | : | 1 bar |

## Diagram for the external cooling water system with combined LT/HT cooling system

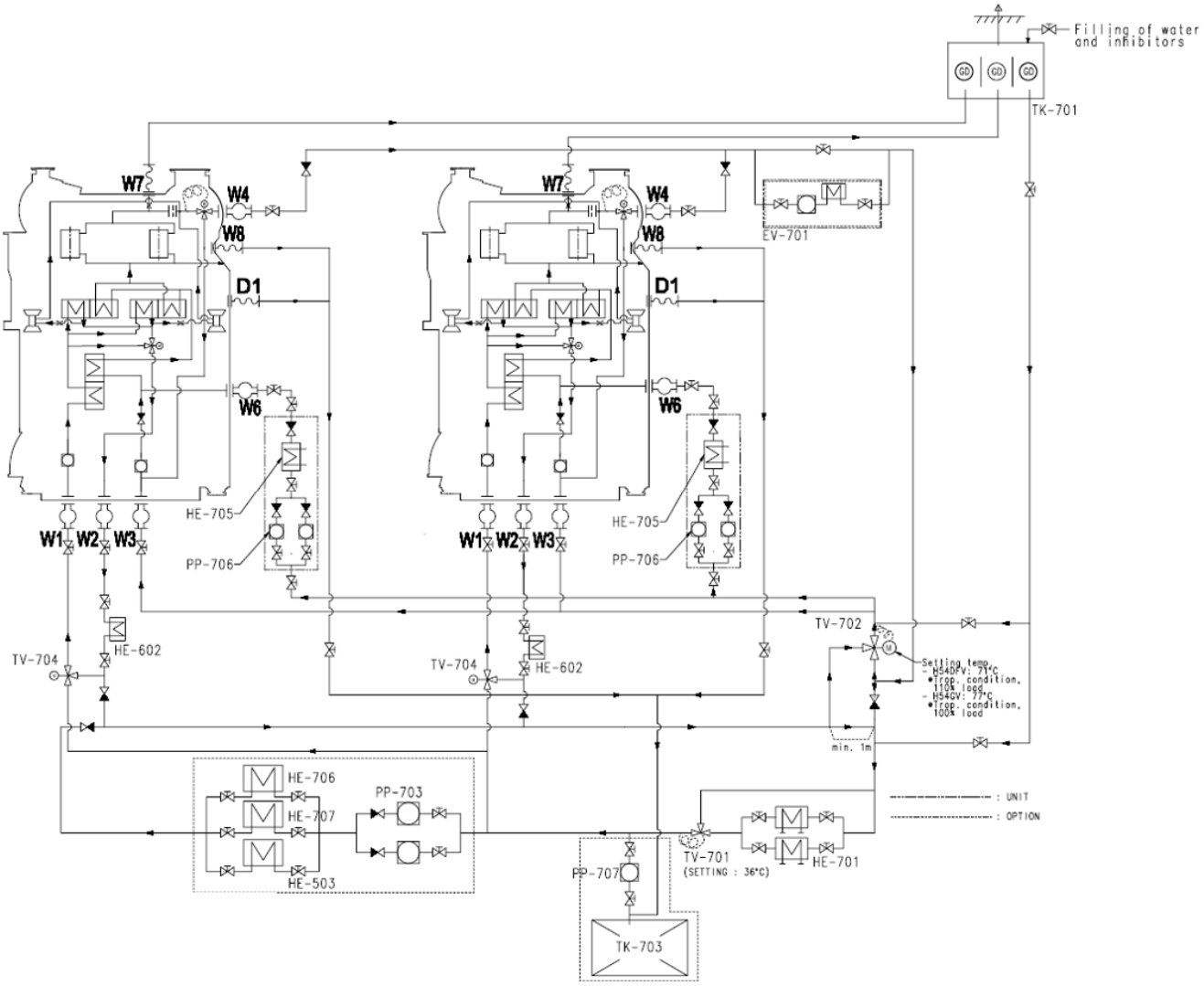



*Figure 7-2-1: External cooling water system with combined LT/HT cooling system [BH1-107313-2]*

## System components

| Code | Description | Code | Description |
|---|---|---|---|
| TK-701 | Expansion tank | HE-706 | Cooler for generator |
| TK-703 | Drain tank | HE-707 | Cooler for consumer |
| PP-703 | Circulating pump for fresh water | TV-701 | Thermostatic valve for central cooling |
| PP-706 | Circulating pump for preheating | TV-702 | Thermostatic valve for heat recovery |
| PP-707 | Transfer pump | TV-704 | Thermostatic valve for LTCW inlet |
| HE-503 | Cooler for MDO/MGO for only DF engine | EV-701 | Evaporator unit |
| HE-701 | Central cooler | GD | Gas detector |
| HE-705 | Preheater for high temperature cooling water | | |

## External pipe connections

| Code | Description | Code | Description |
|---|---|---|---|
| W1 | Low temperature fresh water inlet | W7 | High temperature fresh water venting from jacket & air cooler |
| W2 | Low temperature fresh water outlet | W8 | Low temperature fresh water venting from air cooler |
| W3 | High temperature fresh water inlet | D1 | Water drain |
| W4 | High temperature fresh water outlet | | |
| W6 | High temperature fresh water inlet from jacket water preheating unit | | |

## Quality of cooling water

Only distilled and demineralized fresh water should be used as cooling medium for an engine. It is required to be checked and treated to meet the following requirements shown in Table 7-3-1 below before being added with corrosion-inhibitor.

It is important to maintain effective cooling and prevent the system corrosion. Though the distilled water perfectly matches the requirements for cooling water, it should be added with the corrosion-inhibitor before being applied to the engine because the untreated cooling water can absorb carbon dioxide from air and then, it becomes corrosive.

| Property | Recommended values |
|---|---|
| pH | 7…9 |
| Total hardness as $CaCO_3$ | max. 75 ppm (mg/l) |
| Chlorides Cl- | max. 80 ppm (mg/l) |
| Sulfates as $SO_4^{2-}$ | max. 100 ppm (mg/l) |
| Silica as $SiO_2$ | max. 60 ppm (mg/l) |
| Residue after evaporation | max. 400 ppm (mg/l) |

*Table 7-3-1: Quality specifications for cooling water*

Remark:

1. Chloride and sulfate can be corrosive even in the presence of an inhibitor.

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

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

Tap water (drinking water) is not recommended as cooling water due to the risk of forming chalk-deposits in the cooling system. However, if the distilled water is not available, tap water may be used as cooling water after being softened and treated according to the ingredients.

## Treatment of cooling water

Cooling water should be treated properly and added with corrosion-inhibitor. The analysis and the treatment of the cooling water are recommended to be carried out by the qualified specialists. The treatment procedures should be kept strictly according to the instructions of the suppliers.
The recommended products are as shown in Table 7-3-2 below:

| Manufacturer | Brand name |
|---|---|
| Chevron (FAMM) | DELO XLI(Havoline XLI) |
| Vecom | Cooltreat NCLT |
| Wilhelmsen Chemicals | Rocor NB |
| Nalco | NALCOOL2000 |
| | TRAC100 |
| | TRAC108 |
| GE Water & Process Technologies | CorrShield NT4200 |
| Shell | Shipcare Cooling Water Treat |
| Drew marine | LIQUIDEWT |
| | MAXIGARD |

*Table 7-3-2: List of the inhibitor products*

Remark:

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

## Diagram for the internal compressed air system

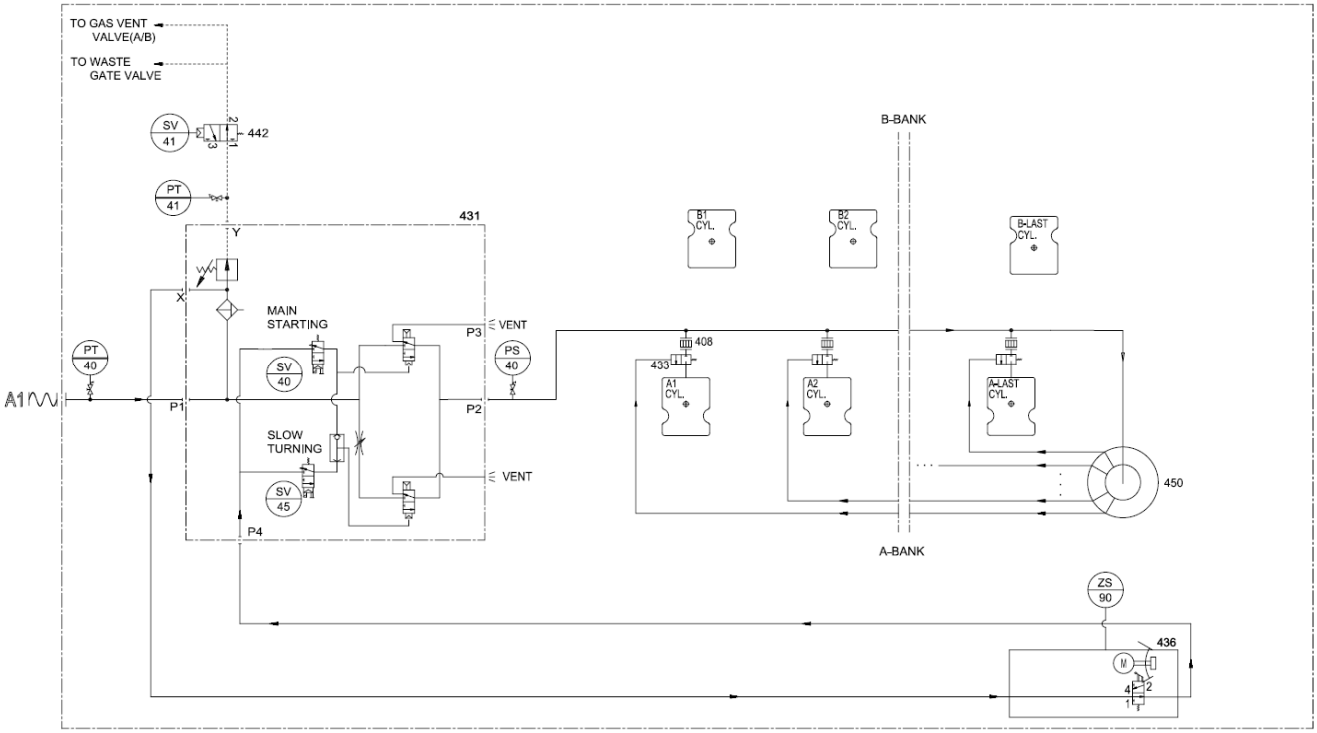



*Figure 8-1-1: Internal compressed air system [BH2-101789-8]*

## System components

| No. | Description | Remark |
|---|---|---|
| 408 | Flame trap | |
| 431 | Main starting valve module | |
| 433 | Starting valve | |
| 436 | Turning gear | |
| 442 | Solenoid valve for control valves | |
| 450 | Pilot air timing controller | |

## Size of external pipe connections

| Code | Description | Size | Standard |
|---|---|---|---|
| A1 | Compressed air inlet | 30K - 65A | JIS B 2220 |

Remark:

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

## General

The compressed air is supplied to start the engine and actuate some pneumatic devices such as the gas vent valves and exhaust waste gate valves. When the built-on turning gear is engaged, the compressed air for the engine starting is cut-off and the engine cannot be started.

The internal compressed air system mainly consists of the following equipment:

- Main starting valve module (including air filter & pressure reducing valve)
- Turning gear, electrically driven

## Engine start

The starting system comprises a main starting valve module and starting valves located in each cylinder. When the engine is started, compressed air with the pressure of maximum 30 bar flows through a main starting valve module and is directly injected into the combustion chambers while being distributed to each cylinder according to the firing order by means of pilot air timing controller.

## Slow turn

Slow turning solenoid valve is incorporated into a main starting valve module. Slow turn 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 30 minutes before start. On the contrary, slow turn will be skipped when engine has been operated 30 minutes earlier.

## General

The external compressed air system should be properly designed for nominal pressure of 30 bar and also fulfill the requirement of the corresponding classification societies. The system can be in common with other engines or independent. In case of common system, it should be able to ensure the sufficient air supply to each engine with the required flow and pressure. In general, classification society requires total capacity to be divided into at least two equal size starting air vessels and starting air compressors.

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 5.5.3. 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.

The external compressed air system mainly comprises air vessels, compressors, etc. The general requirements are described as follows:

## External compressed air system

- **Compressed air quality**

  Starting air (According to ISO 8573-1 : 2010)

  - Humidity and liquid water classes : Cw ≤ 0.5 g/m$^3$ [Class 7]
  - Particle classes : Maximum particle size 40 μm
  - Oil classes : Concentration ≤ 5 mg/m$^3$ [Class 4]

  Control air (According to ISO 8573-1 : 2010) – 100% Dry air

  - Humidity and liquid water classes : Class 4
  - Particle classes : Class 5
  - Oil classes : Class 3

- **Air vessels (AR-801)**

  At least two air vessels of the equal size are required in the external compressed air system. The total capacity of air vessels should be sufficient to provide not less than the required number of consecutive starts without recharging the air vessels. The required numbers of consecutive starts can be variable depending on the classification societies and propulsion / auxiliary system arrangement such as the number of engines, the number of screws, and reduction gears, etc.

In generally, the required total volume of starting air vessels for only reference is derived as follows:

$$V_r = \frac{V_{st} \times (N_{st} + N_{margin}) + t_{Jet} / 5_{sec.} \times N_{Jet} \times V_{Jet}}{P_{max} - P_{min}}$$

*$V_r$ [L] = total volume of starting air vessels for the number of starts required by classification societies*
*$V_{st}$ [L] = air consumption per start with slow turn*
*$N_{st}$ [-] = number of starts required by classification societies*
*$N_{margin}$ [-] = starts margin (typically 1 start)*
*$V_{Jet}$ [L] = air consumption per jet assist*
*$N_{Jet}$ [-] = number of jet assist (typically 3 times)*
*$t_{Jet}$ [s] = duration of jet assist (typically 5 seconds)*
*$P_{max}$ [bar] = maximum starting air pressure*
*$P_{min}$ [bar] = minimum starting air pressure*

Volume values on the formula are based on 1000 mbar, 0°C.
In order to fit the condition of vessel, the volume can be increased depending on ambient condition such as tropical condition.

If an engine is started while being engaged with a propeller shaft, the each capacity of air vessels should be increased accordingly to supply enough air to jet assist system or an additional air vessel may be required.

If other consumers (i. e. auxiliary engines, SCR system, ship air etc.) which are not listed in the formula are connected to the starting air vessel, the capacity of starting air vessel must be increased accordingly, or an additional separate air vessel has to be installed.

The air vessels must be designed for a nominal pressure of 30 bar with a valve for condensate drain. Typically, the vertical installation of the air vessel is preferred. In case it is mounted horizontally, the air vessel is recommended to have an inclination of 3…5 degree to ensure a good drainage of condensate.

- **Air compressor (AC-801)**

  At least two air compressors are required in the external compressed air system and should be arranged to be able to charge each air vessel. At least one of the air compressors shall be driven from emergency power source in case that the subject engine is used for the propulsion engine.

  A total capacity of the air compressors should be sufficient for charging the air vessels from atmospheric pressure to maximum pressure within one hour. Each compressor is to have sufficient capacity to supply minimum 50% of the required total capacity. If the engine is started while being engaged with a propeller shaft or jet air assist is applied on the engine, the capacity is required to be increased.

  The exact specifications for the air compressors shall meet the requirement of classification societies for each project. If there is requirement of special operation condition, the capacity of the compressor has to be adjusted to such requirement.

Generally, a total capacity of compressors is stated as follows:

$$V_c = \frac{V_r \times P_{max.}}{t}$$

*$V_c$ [$m^3/h$] = total capacity of compressors*
*$P_{max}$ [bar] = maximum starting air pressure*
*t [h] = air vessel filing time from empty*
*$V_r$ [$m^3$] =total volume of starting air vessels for the number of starts required by classification societies*

If the engine is started while being engaged with a propeller shaft, the each capacity of air vessels should be increased accordingly to supply enough air to jet assist system. Otherwise an additional air vessel may be required. At that time, a total capacity of compressors shall be increased and classification society approves the design. Otherwise, an additional compressor may be required. Please contact to HHI for this case.

- **Oil and water separator (WS-801)**

  The oil and water separator should be installed in the line between the compressors and the starting air vessels in order to ensure the drainage of the oil and water from the compressors

- **Filter with water trap (FT-801)**

  It is recommended to install the filter with water trap as close as possible to the engine air inlet pipe.

## Diagram for the external compressed air system, a multi- engine installation

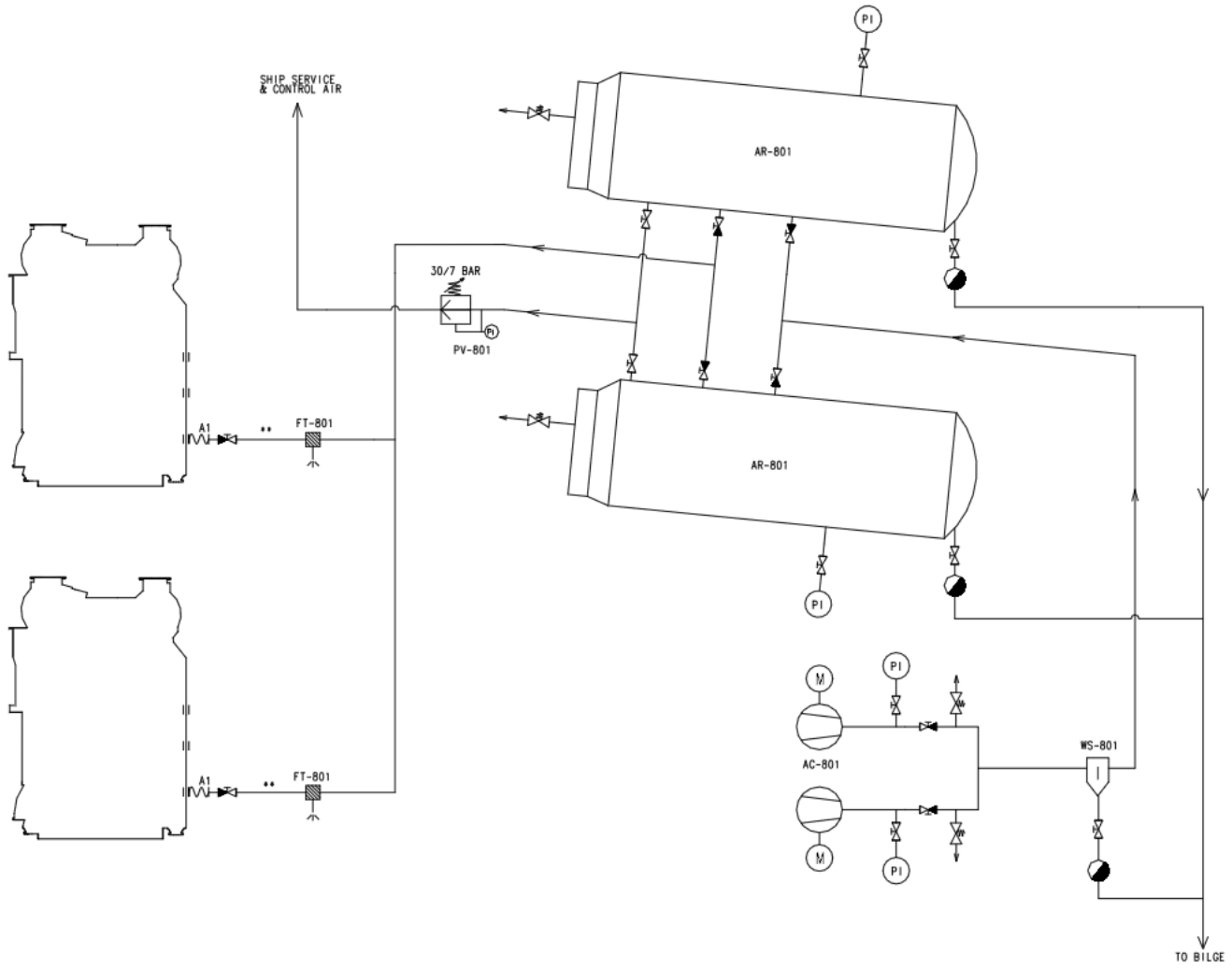



*Figure 8-2-2: External compressed air system for a multi-engine installation [BH1-100014-5]*

## System components

| Code | Description | Code | Description |
|---|---|---|---|
| AR-801 | Air vessel | FT-801 | Filter with water trap |
| AC-801 | Air compressor | WS-801 | Oil and water separator |
| PV-801 | Pressure regulating valve | | |

## External pipe connections

| Code | Description | Code | Description |
|---|---|---|---|
| A1 | Compressed air inlet | | |

## Diagram for the combustion air and exhaust gas system

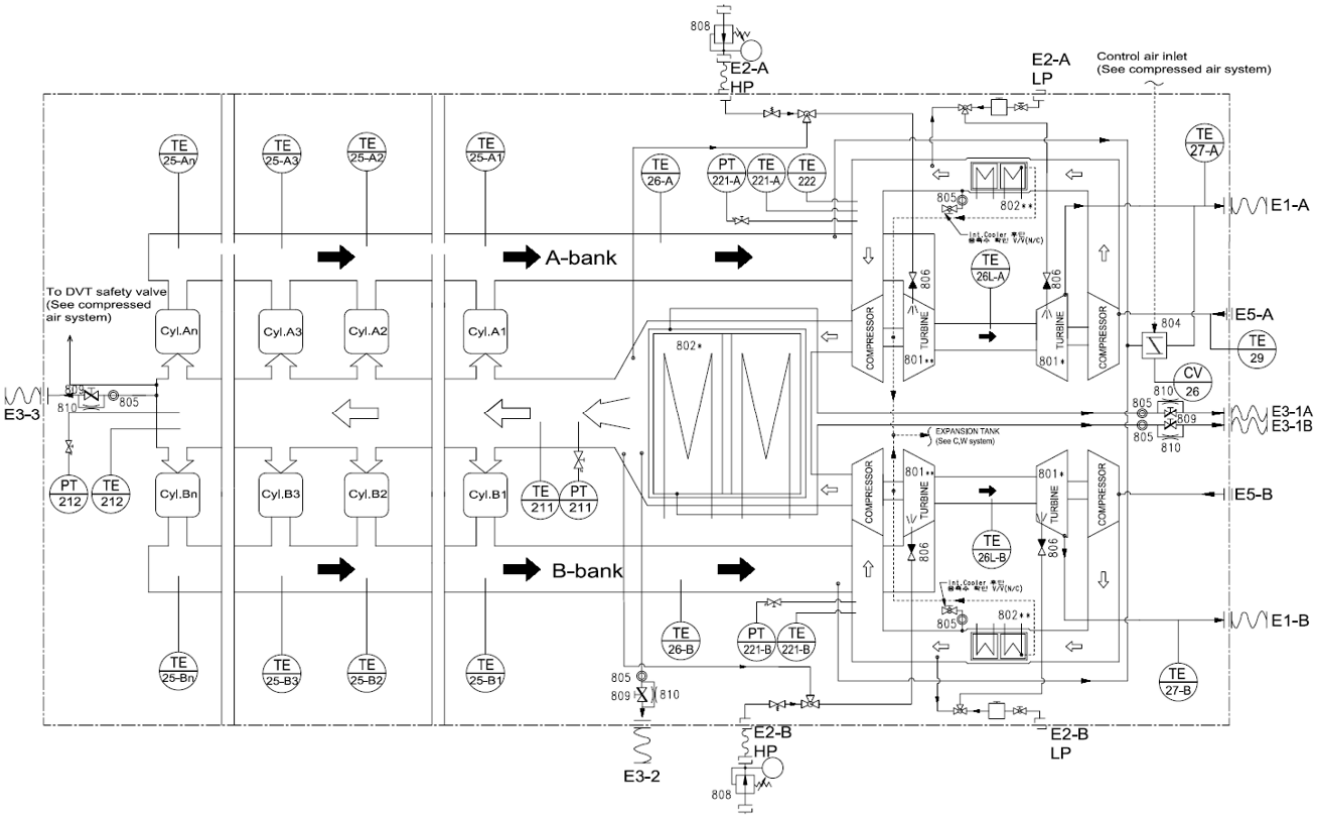



*Figure 8-3-1: Internal combustion air and exhaust gas system [B92-190916-4]*

## System components

| No. | Description | Remark |
|---|---|---|
| 801* | Low pressure turbocharger | |
| 801** | High pressure turbocharger | |
| 802* | Charge air after cooler (2-stage) | |
| 802** | Charge air inter cooler (2-stage) | |
| 804 | Exhaust waste gate valve | |
| 805 | Sight glass | |
| 806 | Non return valve | 0.05 kg/cm$^2$ |
| 808 | Turbocharger cleaning hose | |
| 809 | Drain valve with orifice (Ø 3) | |

## Size of the external pipe connections

| Code | Description | Size | Standard |
|---|---|---|---|
| E1-A/B | Exhaust gas outlet from A/B bank | 12/14H : 2K-800A[1)]<br>16/18H : 2K-1000A[1)] | JIS F 7805 |
| E2-A/B HP | Water washing inlet for turbine | OD 20 | |
| E2-A/B LP | Compressed air to turbine side (Cleaning) | OD 15 | |
| E3-1A/B | Condensate water from air cooler | 10K-40A | JIS B 2220 |

| Code | Description | Size | Standard |
|---|---|---|---|
| | (WMC) | | |
| E3-2 | Condensate water from air cooler housing | 10K-40A | JIS B 2220 |
| E3-3 | Condensate water from last cylinder | 10K-40A | JIS B 2220 |
| E5-A/B | Charging air inlet | 12/14H : 2K-700A[1)]<br>16/18H : 2K-1000A[1)] | JIS F 7805 |

1) Depending on the project, the pipe sizes could be changed.

Remark:

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

## General

Air required for the combustion is taken from the engine room through filters fitted on the turbochargers. The combustion air should be free from sea water, dust, fumes, etc.

The engine is equipped with axial and radial type turbochargers with a high efficiency. The turbochargers can be mounted on a free end of the engine. In order to maintain a reliable engine performance, it is strongly recommended to wash compressor and turbine wheels of the turbocharger periodically by the water washing systems. (excluding the compressor of low pressure turbocharger. It is not allowed to wash it.)

The charger air coolers are built on the engine and of a two stage cooled type by high temperature and low temperature fresh water. The charge air cooler of sea water cooled type is not recommended because of the corrosions of the engine parts.

The condensate can occur during the charge air cooling and it causes the corrosions of the engine parts. Therefore, a water mist catcher is installed right after each charge air cooler and it removes the condensate from the cooled air. The collected condensate will be drained via pipes.

The internal combustion air and exhaust gas system mainly comprises the following equipment:

- Low pressure turbocharger
- High pressure turbocharger
- Inter charge air cooler (2-stage)
- After charge air cooler (2-stage)
- Water mist catcher
- Exhaust waste gate valve for DF/GAS engine, or some special case
- Exhaust pipe system

## General

As the engine(s) is consuming a considerable amount of air in the engine room directly, the air conditions of the engine room are important not only for man-working but also for the engine operating condition.

It is recommended to see applicable standards, such as ISO 8861:1998 for the minimum requirements concerning the engine room ventilation and more details.

Various requirements are applicable depending on the plant, but the minimum requirements and recommendations for the marine propulsion engines are described as follows:

## Combustion air

- **Arrangement of air intake pipes**

  The arrangement of air intake pipes should be made to supply fresh air for the reliable 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.

  In case of indoor intake air system, a sufficient volume of air should be supplied to the turbocharger(s). Therefore, an air duct should be installed to face an air intake silencer for each turbocharger. The pressure of air is needed to be slightly positive during the engine running. Approximately 5mm WC is recommended.

  The temperature of air shall be controlled for a reliable engine operation. The highest permissible level is 45°C based on the tropical conditions. The lowest level should depend on the engine operating conditions as follows:

  - For cold starting: 0°C
  - For continuous idle load running: -5°C
  - For continuous full load running: -20°C.

  If a cold starting is necessary for arctic conditions, the air preheating unit must be provided before the turbocharger intake.

- **Air velocity**

  The air velocity in combustion air intake pipe system should be less than approx. 15m/s during the engine running. Prior to commissioning, the pressure loss must be checked nearby compressor side whether the depression of compressor air inlet must not exceed 200mmWC. The measuring point is approx. 1…2m before from the turbocharger air inlet casing.

- **Air consumption volume**

  The air consumption volume should be designed in accordance with "Engine capacity data" (P.02.200).

- **Air filtration**

  The air filtration should be provided to prevent engine combustion air system from the outdoor sand, cement, dust, and other particles. All particles whose size is larger than 5μm should not to be entered the engine room.

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

- **Maximum size of a dust particle for environmental condition**

  The maximum size of a dust particle is typically applied depending on site.

  - Non-industrial 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 the engine room

To determine the air amount for the ventilation of the engine room, all heat sources of machineries in the engine room should be considered. The required amount can be estimated as following formula:

$$Q = Q_c + \frac{Q_e}{Q_a} + Q_v$$

*$Q$ [$m^3/h$] = required air amount for the ventilation of the engine room*
*$Q_c$ [$m^3/h$] = required air flow for the engine combustion*
*$Q_e$ [kJ/h] = engine radiation heat*
*$Q_a$ [$kJ/m^3$] = air conditioning factor (typically 12)*
*$Q_v$ [$m^3/h$] = required air ventilation for other heat sources such as generator, exhaust gas pipes, etc.*

Remark

1. In case an outdoor intake air and/or intake air shut off system are necessary, special provisions are required as an option.

## General

The external exhaust gas system should be designed so that the exhaust gas of the engine(s) flows out smoothly from the turbocharger to an atmosphere.

For the external exhaust system, the requirements are as follows:

- Where two or more engines are installed, the independent exhaust gas system should be provided for each engine even for the case of the common boiler system with other engines.
- Back Pressure of the exhaust system in total is recommended to be less than 300mmWC at MCR of Diesel mode. The maximum back pressure should not exceed 500mmWC at MCR of Diesel mode (400mmWC at MCR of Gas mode). Please see the P.02.500/510 for the fuel consumption correction in case of exceeding 300mmWC at MCR of Diesel mode. The measuring position is approx. 1~2m after the turbocharger gas outlet casing not turbocharger gas outlet casing.
- External exhaust gas piping is recommended to be designed that velocity of exhaust gas through pipes should not exceed approximately 40 m/sec at MCR.
- The insulation of the whole exhaust system is required for the safety and to reduce thermal losses and noise. It should comply with the requirements of classification societies and other related authorities.

The external exhaust gas system is typically comprised of expansion joints, exhaust gas boilers, silencers, etc. The general requirements are described as follows and more detail information can be provided for the specific projects if needed.

The external exhaust system can have applicable requirements according to the rules of classification societies or other related authorities. The exhaust system should meet the applicable requirements of appropriate authorities for each project.

## External exhaust gas system

- **Expansion joint**

  The expansion joint should be mounted between a turbocharger outlet and an external exhaust gas pipe in order to compensate thermal expansion and mechanical vibration.

  The expansion joint required for a turbocharger outlet is supplied separately as a standard. Otherwise, it can be supplied attached to the engine, but the expansion joint can be damaged during the delivery period.

  Additional expansion joints may be required depending on the actual length and layout of the external exhaust pipes.

  The general requirements are as follows:

  - The external exhaust pipes must not exert any force against the gas outlet on the engine.
  - The external exhaust pipes just on expansion joints should be fixed rigidly so that the turbocharger can be free from any forces from the external exhaust pipes.

- The rigid support must be provided for the expansion joint on the turbocharger. It should be positioned directly above the expansion joint in order to prevent the transmission of forces due to weight, thermal expansion and lateral displacement of the exhaust piping to the turbocharger.
- The exhaust pipes should be 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.

▪ **Exhaust gas boiler**

The thermal energy of the exhaust gas can be utilized by an exhaust gas boiler which may be in common with other engines or an independent system. In any cases, the exhaust gas pipes for each engine should be separated from each other.

The back pressure through the boiler is required to be minimized and the total back pressure of the external exhaust gas system including the boiler should be within 300mmWC.

For the exhaust gas data to design the boiler, see P.02.200 “Engine capacity data”.

▪ **Silencer**

The silencer with or without the spark arrestor can be supplied as an option to reduce the exhaust noise. The noise attenuation of the silencer shall be either 25 dB(A) or 35 dB(A).

For more information, see P.08.600 “Silencer with spark arrestor”, and P.08.610 “Silencer without spark arrestor”.

▪ **Exhaust gas ventilation unit for DF/Gas engine**

The exhaust gas ventilation system is required to purge unburned gas through the exhaust gas system after stopping engine in gas operating mode. The ventilation unit consists of a centrifugal fan, a pressure switch and a butterfly valve which can endure the high temperature of the exhaust gas system and should be designed to be gas-tight.

It is recommended to install the ventilation unit near the engine side, but the distance between the main stream of exhaust gas pipe and the ventilation unit should be kept over 2 meter. Also, the branch pipe connection from the ventilation unit is not heading to the engine direction. The ventilation unit is controlled by engine control system automatically.

▪ **Relief valve or rupture disc for DF/Gas engine**

The relief valve or rupture disc is to be installed in the external exhaust gas system to discharge the over pressure caused by potential explosion effectively. The rupture disc outlet has to be located in the gas safe place far from ignition source.

## Piping design for the exhaust gas system

In order to have the lower back pressure and thermal losses, the pipe arrangement should be as short and straight as possible. The pipe bending shall be minimized and made with the largest possible radius.

The piping system is required to be equipped with the water-separating pocket and drain system. And the rigid and movable supports must be provided considering the thermal expansions and vibrations of the pipe system.

For DF/Gas engine, in order to prevent from any accumulation of explosive gas, the exhaust gas system has to be designed to be gradually ascending.

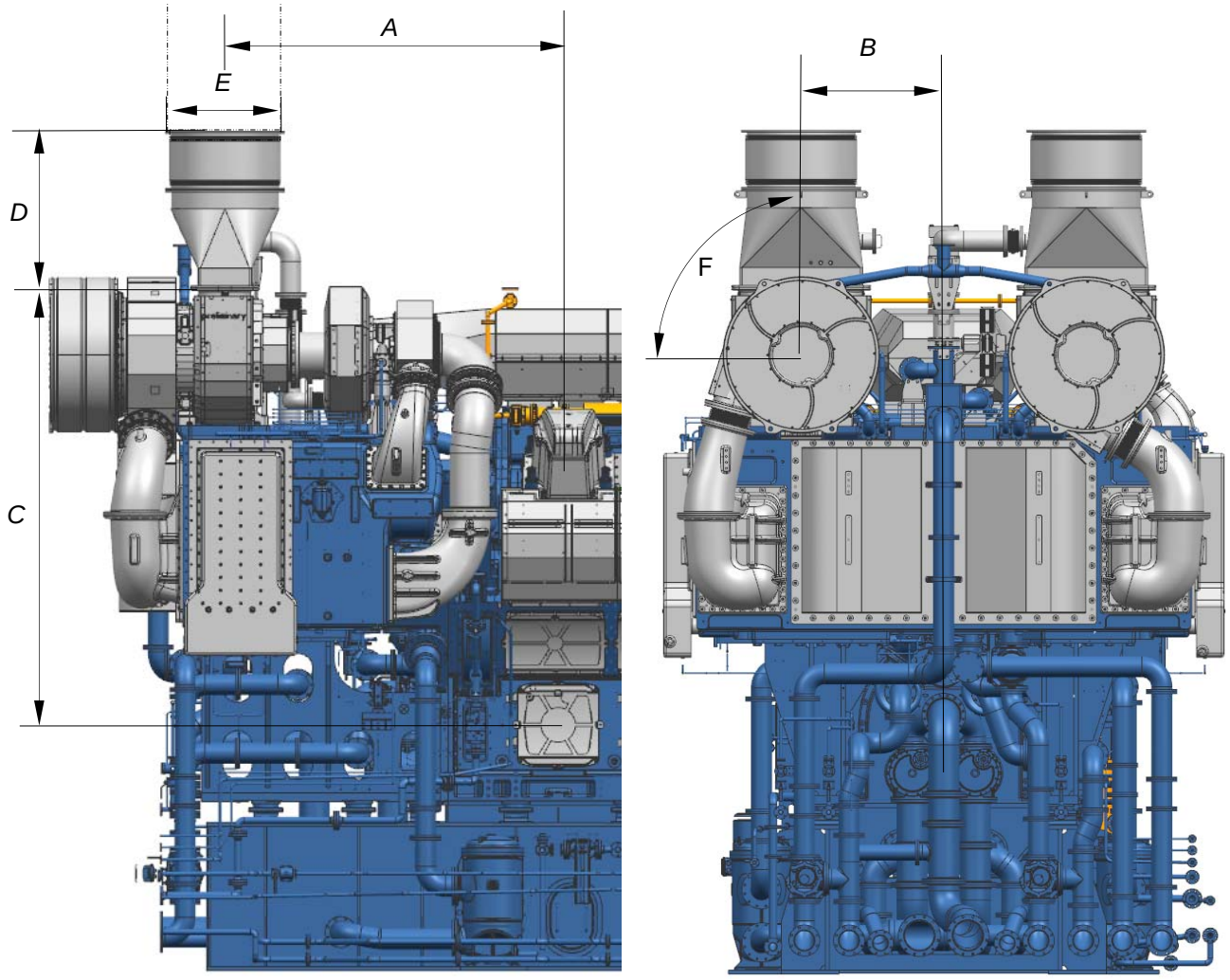



*Table 8-5-1: Position and size of the exhaust gas pipe connections*

| Cyl. No. | Rotation angle of turbine outlet (F) | Exh. gas outlet position [mm] | | | | Exh. gas connection flange (E) | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | Size | Standard |
| 12 | 5x15°=75° | 3,620 | 1,452 | 4,147 | 1,284 | 2K - 800A | JIS F 7805 |
| 14 | 5x15°=75° | 3,620 | 1,452 | 4,147 | 1,284 | 2K - 800A | JIS F 7805 |
| 16 | 5x15°=75° | 3,519 | 1,452 | 4,443 | 1,377 | 2K - 1000A | JIS F 7805 |
| 18 | 5x15°=75° | 3,519 | 1,452 | 4,443 | 1,377 | 2K - 1000A | JIS F 7805 |

## General

In order to reduce the exhaust noise, the silencer equipped with the spark arrestor can be provided as an option. The silencer is of an absorption type with mounting brackets and not applied with insulations.

The silencer can be mounted horizontally or vertically for a diesel engine generally.

However, the silencer must not be mounted horizontally for a DF(Dual Fuel)/Gas engine. In order to prevent accumulation of unburned fuel gas in the silencer, the vertical layout is strongly recommended.

The exhaust gas passes through a straight perforated tube which is surrounded with efficient sound-absorbing materials. The silencer gives whereby an excellent sound attenuation suitable for even a wide operating range.

The gas pressure after the silencer will be dropped to an approximate value as shown on the graph below.

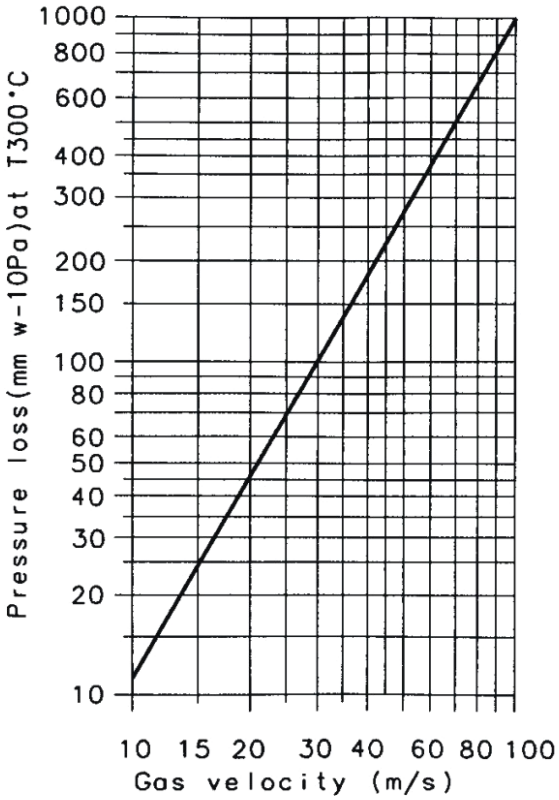



*Figure 8-6-1: Pressure loss in the silencer with the spark arrestor depending on the gas velocity*

## Silencer with the spark arrestor

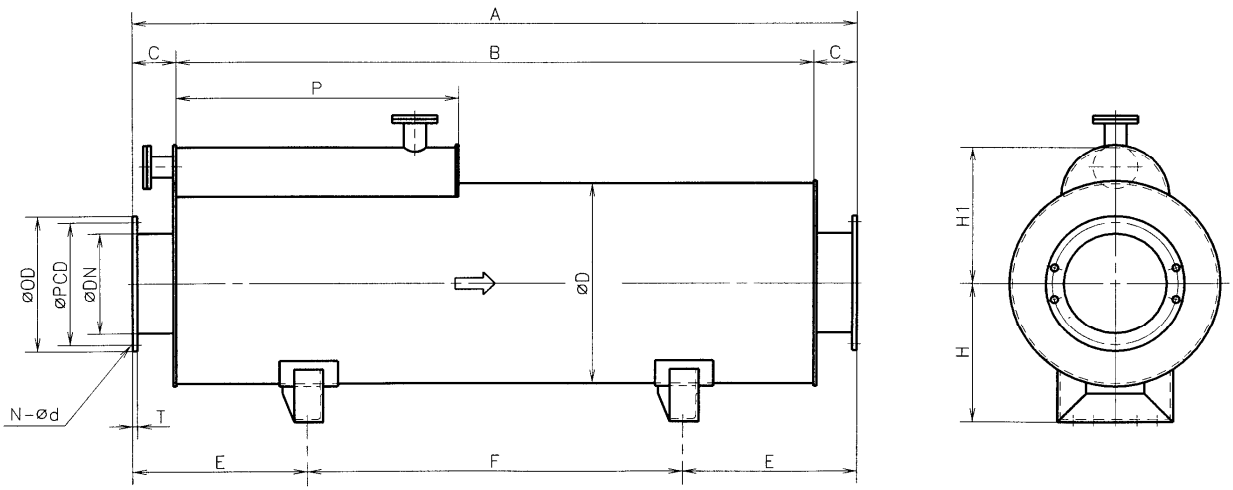



*Figure 8-6-2: Layout of the silencer with the spark arrestor*

### Silencer of 25dB type

| Engine type | A | B | C | D | E | F | H | H1 | P | Flange | | | | | | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DN | OD | PCD | T | N | d | |
| | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [A] | [mm] | [mm] | [mm] | [-] | [mm] | [kg] |
| 12H54DFV(GV) | 9,640 | 9,300 | 170 | 2,100 | 2,000 | 5,640 | 1,230 | 1,385 | 2,300 | 1,400 | 1,525 | 1,480 | 20 | 28 | 25 | 5,235 |
| 14H54DFV(GV) | 10,640 | 10,240 | 200 | 2,200 | 2,400 | 5,840 | 1,300 | 1,440 | 2,400 | 1,400 | 1,525 | 1,480 | 20 | 28 | 25 | 5,915 |
| 16H54DFV(GV) | 11,520 | 11,120 | 200 | 2,300 | 2,500 | 6,520 | 1,350 | 1,510 | 2,500 | 1,500 | 1,645 | 1,590 | 20 | 28 | 27 | 6,710 |
| 18H54DFV(GV) | 13,100 | 12,600 | 250 | 2,400 | 2,600 | 7,900 | 1,400 | 1,565 | 2,600 | 1,500 | 1,645 | 1,590 | 20 | 28 | 27 | 7,770 |

*Table 8-6-1: Size and weight of silencers with the spark arrestor (25dB type)*

### Silencer of 35dB Type

| Engine type | A | B | C | D | E | F | H | H1 | P | Flange | | | | | | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | DN | OD | PCD | T | N | d | |
| | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [A] | [mm] | [mm] | [mm] | [-] | [mm] | [kg] |
| 12H54DFV(GV) | 11740 | 11400 | 170 | 2100 | 2050 | 7300 | 1280 | 1440 | 2300 | 1400 | 1525 | 1480 | 20 | 28 | 25 | 6255 |
| 14H54DFV(GV) | 13400 | 13000 | 200 | 2300 | 2400 | 8700 | 1350 | 1495 | 2400 | 1400 | 1525 | 1480 | 20 | 28 | 25 | 7590 |
| 16H54DFV(GV) | 15000 | 14600 | 200 | 2400 | 2700 | 9600 | 1400 | 1565 | 2500 | 1500 | 1645 | 1590 | 20 | 28 | 27 | 8890 |
| 18H54DFV(GV) | 16450 | 15950 | 250 | 2500 | 2800 | 10850 | 1450 | 1620 | 2600 | 1500 | 1645 | 1590 | 20 | 28 | 27 | 9870 |

*Table 8-6-2: Size and weight of silencers with the spark arrestor (35dB type)*

## General

In order to reduce the exhaust noise, the silencer without the spark arrestor can be provided as an option. The silencer is of an absorption type with mounting brackets and not applied with insulations.

The silencer can be mounted horizontally or vertically for a diesel engine generally.

However, the silencer must not be mounted horizontally for a DF(Dual fuel)/Gas engine. In order to prevent accumulation of unburned fuel gas in the silencer, the vertical layout is strongly recommended.

The exhaust gas passes through a straight perforated tube which is surrounded with efficient sound-absorbing materials. The silencer gives whereby an excellent sound attenuation suitable for even a wide operating range.

The gas pressure after the silencer will be dropped to an approximate value as shown on the graph below.

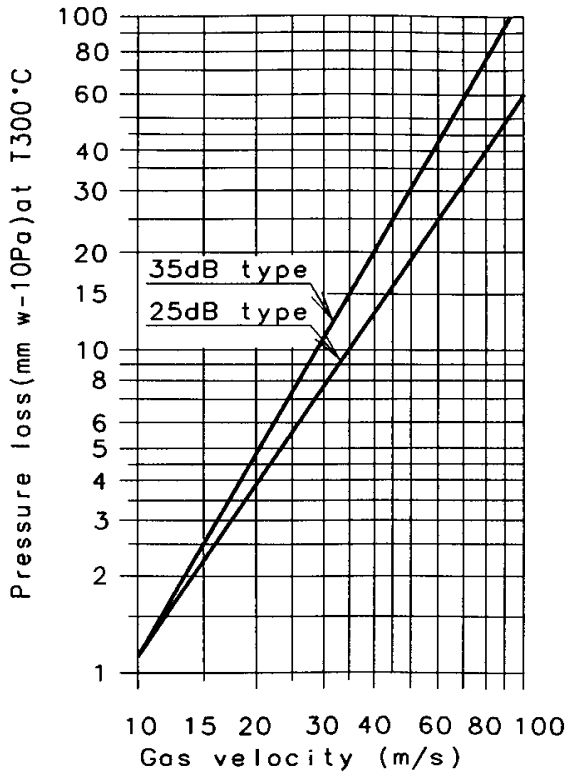



*Figure 8-6-3: Pressure loss in the silencer without the spark arrestor depending on the gas velocity*

## Silencer without the spark arrestor

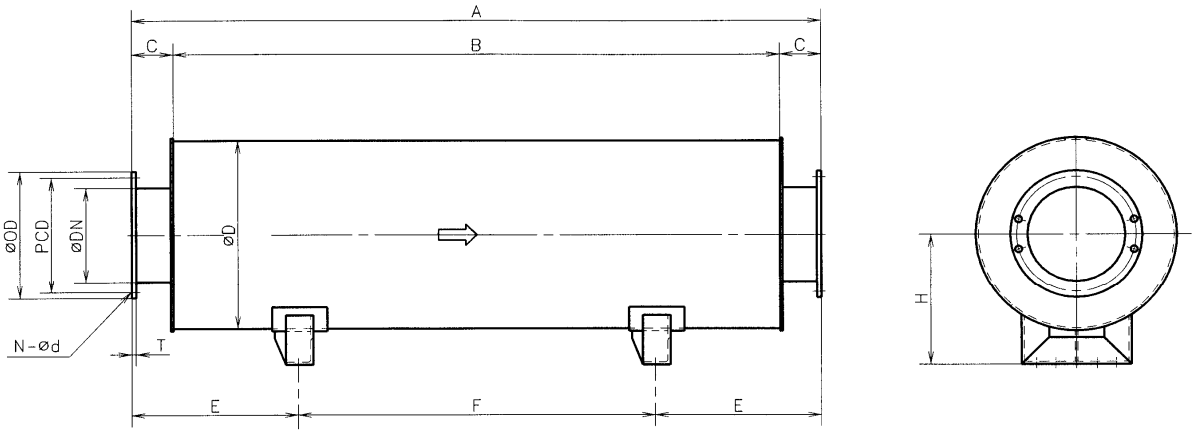



*Figure 8-6-4: Layout of the silencer without the spark arrestor*

### Silencer of 25dB type

| Engine type | A | B | C | D | E | F | H | Flange | | | | | | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DN | OD | PCD | T | N | d | |
| | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [A] | [mm] | [mm] | [mm] | [-] | [mm] | [kg] |
| 12H54DFV(GV) | 8,340 | 8,000 | 170 | 2,100 | 1,500 | 5,340 | 1,230 | 1,400 | 1,525 | 1,480 | 20 | 28 | 25 | 4,380 |
| 14H54DFV(GV) | 9,240 | 8,840 | 200 | 2,200 | 1,700 | 5,840 | 1,300 | 1,400 | 1,525 | 1,480 | 20 | 28 | 25 | 4,380 |
| 16H54DFV(GV) | 10,020 | 9,620 | 200 | 2,300 | 2,000 | 6,020 | 1,350 | 1,500 | 1,645 | 1,590 | 20 | 28 | 27 | 5,660 |
| 18H54DFV(GV) | 11,500 | 11,000 | 250 | 2,400 | 2,200 | 7,100 | 1,400 | 1,500 | 1,645 | 1,590 | 20 | 28 | 27 | 6,615 |

*Table 8-6-3: Size and weight of silencers without the spark arrestor (25dB type)*

### Silencer of 35dB Type

| Engine type | A | B | C | D | E | F | H | Flange | | | | | | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DN | OD | PCD | T | N | d | |
| | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [mm] | [A] | [mm] | [mm] | [mm] | [-] | [mm] | [kg] |
| 12H54DFV(GV) | 10,440 | 9,100 | 170 | 2,100 | 2,000 | 6,440 | 1,280 | 1,400 | 1,525 | 1,480 | 20 | 28 | 25 | 4,890 |
| 14H54DFV(GV) | 12,000 | 11,600 | 200 | 2,300 | 2,200 | 7,600 | 1,350 | 1,400 | 1,525 | 1,480 | 20 | 28 | 25 | 6,560 |
| 16H54DFV(GV) | 13,500 | 13,100 | 200 | 2,400 | 2,400 | 8,700 | 1,400 | 1,500 | 1,645 | 1,590 | 20 | 28 | 27 | 7,720 |
| 18H54DFV(GV) | 15,850 | 14,350 | 250 | 2,500 | 2,600 | 10,650 | 1,450 | 1,500 | 1,645 | 1,590 | 20 | 28 | 27 | 8,610 |

*Table 8-6-4: Size and weight of silencers without the spark arrestor (35dB type)*

## Major overhaul guidance

| Section No. | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2,000 | 4,000 | 8,000 | 12,000 | 16,000 | 20,000 | 24,000 | 28,000 | 32,000 | |
| | | **Major fasteners - Confirmation** | | | | | | | | | | | | |
| M11100 | HGV11100 | Bolt for base frame and resilient mount | | ▲ | | | ◆ | | | | | | | |
| G11100 | - | Nut for resilient mount and foundation | | ▲ | | | ◆ | | | | | | | |
| - | HGV13000 | Nut for engine block and base frame | | ◆ | | | ◆ | | | | | | | |
| M13250 | HGV13000 | Hyd. Nut for main bearing cap | | ◆ | | | ◆ | | | | | | | |
| M21100 | HGV13000 | Hyd. Nut for cylinder head | | ◆ | | | ◆ | | | | | | | |
| M25000 | HGV25000 | Bolt and nut for camshaft | | ▲ | | | ◆ | | | | | | | |
| M31000 | HGV32000 | Hyd. Nut for con-rod (shaft) | | ◆ | | | ◆ | | | | | | | |
| M31000 | HGV32000 | Hyd. Nut for con-rod (big-end) | | ◆ | | | ◆ | | | | | | | |
| M33200 | HGV33000 | Hyd. Nut for counter weight | | ◆ | | | ◆ | | | | | | | |
| M35300 | HGV35000 | Bolt and nut for timing gear | | ▲ | | | ◆ | | | | | | | |
| - | HGV83000 | Bolt and nut for turbocharger mounting | | ▲ | | | ◆ | | | | | | | |
| | | **Major bearing** | | | | | | | | | | | | |
| M13250 | HGV13250 | Main bearing | | | | | √ | | | | ▣ | | | |
| M13250 | HGV13250 | Thrust washer : Axial clearance | | | | | ◎ | | | | | | ▣ | |
| M25000/M25300 | HGV25300 | Camshaft bearing : Clearance | | | | | √ | | ◎ | | | | ▣ | Replacement based on visual inspection |
| M31000/M32120 | HGV32000 | Con-rod bearing (big-end) | | | | | √ | | ■ | | ▣ | | | |
| M32130 | HGV32000 | Con-rod bearing (small-end) | | | | | √ | | ■ | | | | ▣ | |
| M35300 | HGV35000 | Bearing bush for idle gear : Clearance | | | | | | | ◎ | | | | ▣ | |
| | | **Resilient mount** | | | | | | | | | | | | |
| M11100 | HGV11100 | Resilient mount | | ● | | | ● | | | | | | | |
| | | **Cylinder unit and con. rod** | | | | | | | | | | | | |
| M15100 | HGV15000 | Cylinder liner | | | | | √ | | ■ | | | | | |
| M15100 | HGV15000 | Flame ring | | | | | √ | | ▣ | | | | | |
| M21100 | HGV15000<br>HGV21100 | Cylinder head &<br>water jacket cooling water space | | | | | √ | | ■ | | | | | |
| M21120/M21130<br>/M21200 | HGV21100<br>HGV21200 | Intake/Exhaust v/v spindle, Seat ring and<br>v/v guide: Overhaul and reconditioning | | | | | √ | | ■ | | ▣ | | | |
| M21210 | HGV21200 | Intake/Exhaust v/v : Clearance | | ● | ● | | | | | | | | | |
| M21210 | HGV21200 | Rocker Arm Shaft and Bush | | | | | √ | | ■ | | | | | |
| M21220 | HGV21200 | Rotocap | | | ○ | | | | ■ | | | | | |
| M21400 | HGV21400 | Starting valve | | | | | √ | | ■ | | | | | |
| M24100 | HGV24100 | Duel valve timing | | | | | √ | | ■ | | | | | |
| M31100 | HGV31100 | Piston rings | | | | | √ | | ▣ | | | | | |
| M31100 | HGV31100 | Piston and piston pin | | | | | √ | | ■ | | | | | |
| M31000/M31101 | HGV32000 | Con-rod bore (big-end) | | | | | √ | | ■ | | | | | |
| M31100/M32130 | HGV31100<br>HGV32000 | Piston pin & Con-rod (small-end) :<br>Clearance | | | | | √ | | ■ | | | | | |
| M31000 | HGV32000 | Shim plate for con-rod | | | | | √ | | ▣ | | | | | |

▣ Expected life time
■ Overhaul inspection
● Check & adjustment
○ Function test
√ 1 Cylinder overhaul. If not good, check all cylinders.
◆ Confirm tightening: Tighten with specified torque or hyd. pressure. Do not loosen!
◎ Measuring or sampling without dismantling
▲ Visual Inspection

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

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

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

## Major overhaul guidance

| Section No. | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2,000 | 4,000 | 8,000 | 12,000 | 16,000 | 20,000 | 24,000 | 28,000 | 32,000 | |
| M31000 | HGV32000 | Stud for con-rod shaft | | | | | | | | | | | ▣ | |
| | | **Crankshaft and gears** | | | | | | | | | | | | |
| M33100 | HGV33000 | Crankshaft : Deflection | | | | | ◎ | | | | | | | |
| - | HGV33300<br>HGV42300 | Gear teeth on flywheel & turning gear | | | | | ▲ | | | | | | | |
| - | HGV33400 | Torsional vibration damper : Fluid sampling (Only for viscous damper) | | | | | | | ◎ | | | | | (See manual for T/V damper) |
| - | HGV33500 | Flexible coupling | ▲ | | | | | | | | | | | (See manual for flex. coupling) |
| M35300 | HGV35000 | Timing gear and pump driving gear : Clearance and backlash | | | | | | | ◎ | | | | | |
| | | **Valve operating mechanism** | | | | | | | | | | | | |
| M23000 | HGV23000 | Tappet roller shaft and bush | | | | | | | ■ | | | | ▣ | |
| M25000 | HGV23000<br>HGV25000 | Contact faces of cam and tappet roller<br>Camshaft bearing | | ▲ | | | ▲ | | | | | | | |
| | | **Control system** | | | | | | | | | | | | |
| G40001 | - | Safety device : Function check | ○ | | | | | | | | | | | Monthly |
| - | HGV45000 | Engine RPM pick-up sensor : Clearance | | | | | ● | | | | | | | |
| - | HGV45000 | Knock sensor : Tightening torque check | | | | | | | ◆ | | | | | |
| M45200 | HGV45000 | Temperature / pressure sensor | ○ | | | | | | | | | | | In case of necessity |
| - | HGV45275 | Cylinder pressure sensor (if applied) | | | | | | ▣ | | | | | | |
| | | **Ignition system** | | | | | | | | | | | | |
| M46102 | HGV46102 | Spark Plug | | | ■ | ▣ | | | | | | | | |
| M46102 | HGV46102 | Ignition Coil | | | | | ■ | | | | | | ▣ | |
| M52000 | HGV52000 | O-rings for check Valve Assembly | | | | | | | ▣ | | | | | |
| M52000 | HGV52000 | Check Valve Assembly: Clearance | | ● | ● | | | | | | ▣ | | | |
| | | **Fuel gas supply system** | | | | | | | | | | | | |
| G05201 | - | Analyze fuel gas properties : Sampling | ◎ | | | | | | | | | | | Weekly during the first 3 months operation |
| - | HGV53002 | Gas admission valve | | | | | | | ▣ | | | | | |
| - | HGV53001 | Main gas feed pipe | | | | | | | ■ | | | | | |
| | | **Lubricating oil system** | | | | | | | | | | | | |
| G06100 | - | Analyze lub. oil properties : Sampling | ◎ | | | | | | | | | | | Every 3 month |
| M61000 | HGV61000 | Lubricating oil pump | | | | | | | ■ | | | | | |
| M62000 | HGV62000 | Lubricating oil cooler | | | | | | | ■ | | | | | (See manual for LO cooler) |
| M63000 | HGV63000 | Lubricating oil filter | ■ | | ▣ | | | | | | | | | If pressure drop reaches limit (See G01400) |
| - | HGV63000 | Auto backwashing filter | ■ | | | | | | | | | | | (See manual for auto filter) |
| - | HGV64000 | Thermostatic valve : Clean & check the elements | | | | | | | ■ | | | | | (See manual for thermo.v/v) |

▣ Expected life time
■ Overhaul inspection
● Check & adjustment
○ Function test
√ 1 Cylinder overhaul. If not good, check all cylinders.
◆ Confirm tightening: Tighten with specified torque or hyd. pressure. Do not loosen!
◎ Measuring or sampling without dismantling
▲ Visual Inspection

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

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

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.

## Major overhaul guidance

| Section No. | | Description | Overhaul interval (hours) | | | | | | | | | | | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Others | 500 *) | 2,000 | 4,000 | 8,000 | 12,000 | 16,000 | 20,000 | 24,000 | 28,000 | 32,000 | |
| **Cooling water system** | | | | | | | | | | | | | | |
| G07100 | - | Analyze cooling water properties : Sampling | ◎ | | | | | | | | | | | Weekly : Test kit<br>Every 3 month : Lab. test |
| M70000 | HGV71000 | Cooling water pump | | | | | | | ■ | | | | | |
| - | HGV76000 | 3-way valve : Clean & check the elements | | | | | | | ■ | | | | | (See manual for thermo.V/V) |
| **Compressed air system** | | | | | | | | | | | | | | |
| O02300 | - | Air running | ○ | | | | | | | | | | | Monthly |
| G40000 | - | Check starting & stop system | ○ | | | | | | | | | | | Weekly<br>(Over a week stand-still condition) |
| M42100 | HGV42100 | Safety stop system (Acc. to each application) | ■ | | | | | | | | | | | |
| **Supercharging system** | | | | | | | | | | | | | | |
| M80000 | - | Turbocharger | ■ | | | | | | | | | | | (See manual for turbocharger) |
| | | - Clean air filter (Only for filter silencer type) | ■ | | ▣ | | | | | | | | | Every 500hrs running |
| | | - Turbine | ● | | | | | | | | | | | Every 200hrs running |
| | | - Compressor | ● | | | | | | | | | | | Every 24~50hrs running |
| M83200 | - | Exhaust gas waste gate | ○ | | | | | | | | | | | Weekly |
| M84000 | HGV84000 | Charge air cooler | | | | | | | ■ | | | | | |

▣ Expected life time
■ Overhaul inspection
● Check & adjustment
○ Function test
√ 1 Cylinder overhaul. If not good, check all cylinders.
◆ Confirm tightening: Tighten with specified torque or hyd. pressure. Do not loosen!
◎ Measuring or sampling without dismantling
▲ Visual Inspection

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

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

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.

## List of consumable parts for one engine

(C=Number of cylinder / U=Number of unit)

| Section No. | Parts description | set/ea | Quantity for the operating hours | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0-4,000 | 0-8,000 | 0-12,000 | 0-16,000 | 0-20,000 | 0-24,000 | 0-28,000 | 0-32,000 |
| | **Covers for engine** | | | | | | | | | |
| HGV13000 | Gaskets for gear case cover | set | - | 1 | 1 | 2 | 2 | 3 | 3 | 4 |
| HGV19300 | O-ring for crankcase cover | ea | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C |
| HGV21100 | O-ring for cylinder head cover upper | ea | 0.5 x C | 1 x C | 1.5x C | 2 x C | 2.5 x C | 3 x C | 3.5 x C | 4 x C |
| HGV21100 | O-ring for cylinder head cover lower | ea | 0.5 x C | 1 x C | 1.5x C | 2 x C | 2.5 x C | 3 x C | 3.5 x C | 4 x C |
| | **Bearings** | | | | | | | | | |
| HGV13250 | Main bearings (upper & lower) | set | - | - | - | - | - | 0.5xC+2 | 0.5xC+2 | 0.5xC+2 |
| HGV13250 | Thrust washer | ea | - | - | - | - | - | - | - | 4 |
| HGV25300 | Camshaft bearing | ea | - | - | - | - | - | - | - | C+4 |
| HGV32000 | Big-end bearings (upper & lower) | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HGV32000 | Small-end bearing | ea | - | - | - | - | - | - | - | 1 x C |
| HGV35000 | Bearing bush for idle gear | ea | - | - | - | - | - | - | - | 2 |
| HGV35000 | Thrust disc for idle gear | ea | - | - | - | - | - | - | - | 4 |
| | **Cylinder unit and con-rod** | | | | | | | | | |
| HGV15000 | Flame ring | ea | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HGV15000 | O-rings & gasket for cylinder liner / cooling water jacket | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| HGV21100 | O-rings for cylinder head | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| HGV21100 | O-rings for valve guide & exh. valve seat ring | set | - | - | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C |
| HGV21100 HGV21200 | Intake v/v spindle,seat ring and v/v guide | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HGV21100 HGV21200 | Exhaust v/v spindle, seat ring and v/v guide | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HGV21400 | O-rings for starting valve | set | - | - | - | 0.5 x C | 0.5 x C | 0.5 x C | 0.5 x C | 0.5 x C |
| HGV23000 | O-rings for pushrod cover | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| HGV23000 | Roller bush for tappet | ea | - | - | - | - | - | - | - | 1 x C |
| HGV31100 | Piston ring-top rings / 2nd rings / scraper rings | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HGV32000 | Shim plate for con-rod | ea | - | - | - | 2 x C | 2 x C | 2 x C | 2 x C | 4 x C |
| HGV32000 | Stud for con-rod shaft | ea | - | - | - | - | - | - | - | 4 x C |
| | **Control system** | | | | | | | | | |
| HGV45275 | Cylinder pressure sensors | set | - | - | 1 x C | 1 x C | 1 x C | 2 x C | 2 x C | 2 x C |

* 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.

## List of consumable parts for one engine

(C=Number of cylinder / U=Number of unit)

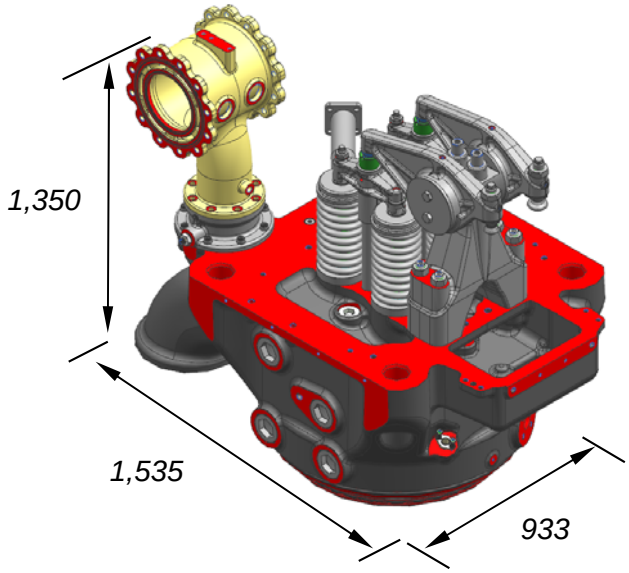
| Section No. | Parts description | set/ea | Quantity for the operating hours | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0-4,000 | 0-8,000 | 0-12,000 | 0-16,000 | 0-20,000 | 0-24,000 | 0-28,000 | 0-32,000 |
| | **Fuel gas supply system** | | | | | | | | | |
| HGV46101 | Gas admission valve | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HGV46102 | Spark plug | 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 |
| HGV46102 | Ignition coil | set | - | - | - | - | - | - | - | 1 x C |
| HGV46102 | Spark plug extension | set | - | - | - | - | - | - | - | 1 x C |
| HGV52001 | Seal for spark plug extension | set | - | 1 x C | 1 x C | 2 x C | 2 x C | 3 x C | 3 x C | 4 x C |
| HGV52001 | O-ring for prechamber | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HGV52001 | Prechamber tip | ea | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HGV52001 | Washer for prechamber | ea | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| HGV52001 | Check valve assembly for prechamber | set | - | - | - | - | - | 1 x C | 1 x C | 1 x C |
| HGV53001 | O-rings for gas feed pipe to each cylinder | set | - | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| HGV53001 | O-rings & gaskets for main gas feed pipe | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| HGV53002 | O-rings for gas admission valve | set | - | - | - | 1 x C | 1 x C | 1 x C | 1 x C | 2 x C |
| | **Lubricating oil system** | | | | | | | | | |
| HGV61000 | Bushes for lub. oil pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HGV61000 | O-rings for lub. oil pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HGV62000 | O-ring for lub. oil cooler connection (Installation on engine side) | ea | - | - | - | 4 | 4 | 4 | 4 | 8 |
| HGV63000 | Spare parts for auto backwashing filter (See manual for auto backwashing filter) | set | - | - | - | - | - | - | - | - |
| | **Cooling water system** | | | | | | | | | |
| HGV71000 | Oil seals, mechanical seals & O-rings for HT and LT-pump | set | - | - | - | 1 x U | 1 x U | 1 x U | 1 x U | 2 x U |
| HGV77000 | Gasket for cooling water connection | ea | - | 4 | 4 | 8 | 8 | 12 | 12 | 16 |
| HGV78000 | Gasket for cyl.head cooling water connection | ea | - | 8 | 8 | (4xC)+4 | (4xC)+4 | (4xC)+12 | (4xC)+12 | (8xC)+8 |
| | **Supercharging system** | | | | | | | | | |
| HGV81000 | Gaskets for compressor out | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| HGV82000 | Gasket for connection flange | ea | - | 1 | 1 | 1xC+1 | 1xC+1 | 2xC+1 | 2xC+1 | 3xC+1 |
| | **Charge air cooler** | | | | | | | | | |
| HGV84000 | O-rings and gaskets for air cooler | set | - | - | - | 1 | 1 | 1 | 1 | 2 |
| | | | | | | | | | | |
| - | Spare parts for turbocharger (See manual for turbocharger) | set | - | - | - | - | - | - | - | - |
| - | Air filter mat (Engine room air suction) | ea | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |

* 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.

## List of standard spare parts for each vessel (or plant)

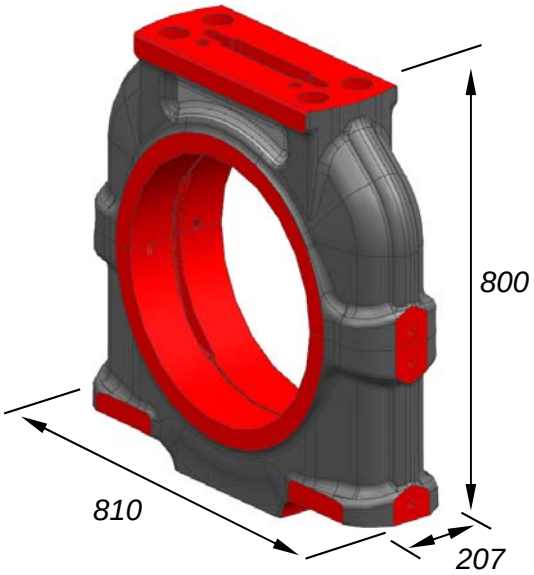
| Description | Section No. | Item No. | Quantity |
|---|---|---|---|
| **Engine block and cover** | | | |
| Main bearing stud (M90) | HGV13000 | 311 | 2 |
| Nut for main bearing stud (M90) | HGV13000 | 312 | 2 |
| Main bearing, upper & lower | HGV13250 | 251 | 1 |
| Thrust washer | HGV13250 | 252 | 4 |
| O-ring for crankcase door | HGV19300 | 390 | 1 |
| **Cylinder liner** | | | |
| Metal gasket for cylinder liner | HGV15000 | 191 | 1 |
| O-ring for cool. water jacket (P760) | HGV15000 | 192 | 1 |
| O-ring for cool. water jacket (P685) | HGV15000 | 193 | 1 |
| Compensation ring | HGV15000 | 194 | 1 |
| **Cylinder head** | | | |
| O-ring for Air chamber/head ø 16 x 273 | HGV16000 | 801 | 1 |
| O-ring for exh. valve seat ring ø 3.53 x156 | HGV21100 | 117 | 4 |
| O-ring for valve guide ø 3.53 x 36.09 | HGV21100 | 118 | 6 |
| O-ring for cylinder head ø 8.4 x 760 | HGV21100 | 123 | 1 |
| O-ring for cylinder head ø 8.4 x 630 | HGV21100 | 124 | 1 |
| O-ring for cylinder head cover lower | HGV21100 | 171 | 1 |
| O-ring for cylinder head cover upper | HGV21100 | 172 | 1 |
| O-ring for push rod cover | HGV23000 | 906 | 1 |
| O-ring for cover flange (P150) | HGV24100 | 037 | 1 |
| **Valve train** | | | |
| Intake valve seat | HGV21100 | 111 | 2 |
| Exhaust valve seat | HGV21100 | 112 | 4 |
| Intake valve spindle | HGV21200 | 201 | 2 |
| Exhaust valve spindle | HGV21200 | 202 | 4 |
| Rotocap | HGV21200 | 203 | 6 |
| Conical piece | HGV21200 | 206 | 6 |
| Intake spring, outer | HGV21200 | 211 | 2 |
| Exhaust spring, outer | HGV21200 | 213 | 4 |
| Spring, inner | HGV21200 | 214 | 6 |
| **Starting valve** | | | |
| Air start valve | HGV21400 | 100 | 1 |
| O-ring for air start valve ø 3.53 x 74.79 | HGV21400 | 409 | 1 |
| O-ring for air start valve ø 3.53 x 83.32 | HGV21400 | 410 | 1 |
| O-ring for air start valve ø 3.53 x 85.32 | HGV21400 | 411 | 1 |

| Description | Section No. | Item No. | Quantity |
|---|---|---|---|
| O-ring for pusher (G90) | HGV21400 | 502 | 2 |
| **Piston** | | | |
| Piston pin | HGV31100 | 120 | 1 |
| Piston ring, top | HGV31100 | 151 | 1 |
| Piston ring, 2nd | HGV31100 | 152 | 1 |
| Oil scraper ring | HGV31100 | 153 | 1 |
| **Connecting rod** | | | |
| Big end bearing, upper & lower | HGV32000 | 120 | 1 |
| Small end bearing | HGV32000 | 130 | 1 |
| Stud M80 | HGV32000 | 191 | 2 |
| Nut M80 | HGV32000 | 192 | 2 |
| Pin | HGV32000 | 193 | 4 |
| Stud M56 x 3 | HGV32000 | 194 | 4 |
| Nut M56 x 3 | HGV32000 | 195 | 4 |
| **Ignition system** | | | |
| Gas admission valve | HGV46101 | | 2 |
| Spark plug | HGV46102 | | N/2 (N: Max. Cyl.No) |
| Ignition Coil | HGV46102 | | 2 |
| Check valve ass'y | HGV52001 | | 4 |
| Gasket for Spark plug | HGV52001 | | 1 |
| O-ring for SOGAV ø 2.62 x 120.32 | HGV53002 | 105 | 1 |
| O-ring for SOGAV ø 2.62 x 101.27 | HGV53002 | 106 | 1 |
| O-ring for SOGAV ø 3.53 x 98.02 | HGV53002 | 113 | 2 |
| O-ring for SOGAV (P105) | HGV53002 | 114 | 1 |
| O-ring for SOGAV (G165) | HGV53002 | 115 | 1 |
| **Spare for charge air cooler** | | | |
| Gasket for air duct middle | HGV81000 | 200 | 1 |
| Gasket for inter cooler | HGV84000 | 141 | 2 |
| Gasket for inter cooler cover | HGV84000 | 142 | 2 |
| Gasket for after cooler | HGV84000 | 150 | 1 |
| **Piping system** | | | |
| Flexible connecting pipe, each type | HGV98370 | - | 1 set |

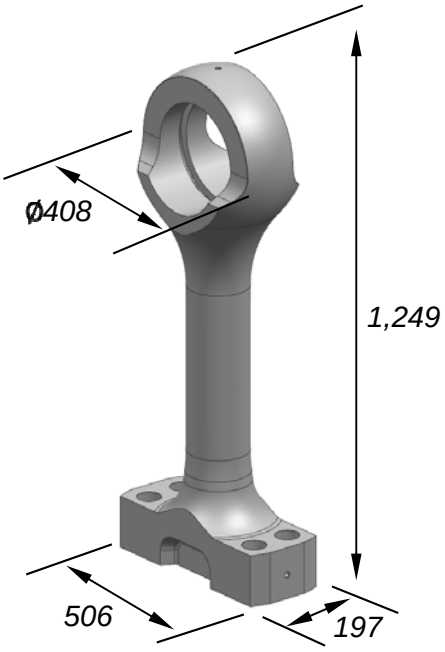



*Cylinder head complete + others*
*(Weight : approx. 2,485 kg)*

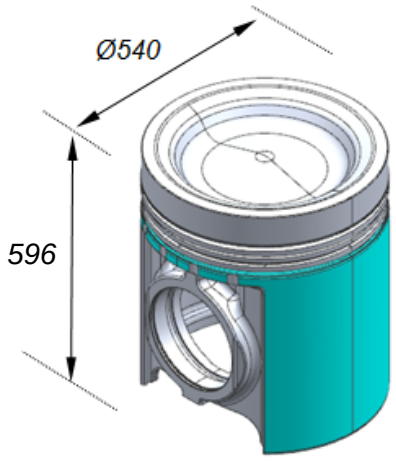
| Component | Weight [kg] |
|---|---|
| Cylinder head complete | 1,730 |
| Valve train (without push rod) | 400 |
| Main Gas pipe | 125 |
| Gas admission valve | 45 |
| Prechamber assembly | 60 |
| Starting valve | 25 |
| HT outlet pipe, etc. | 100 |



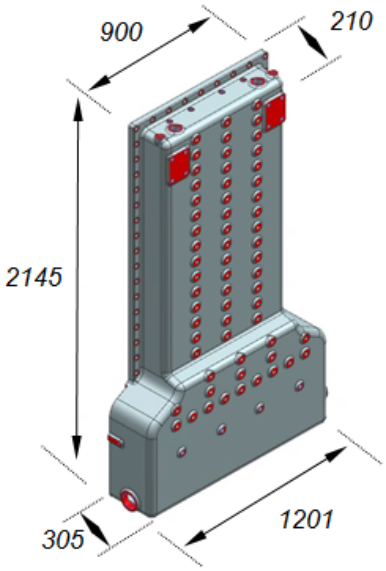

*Con-rod big end*
*(Weight : approx. 455 kg)*



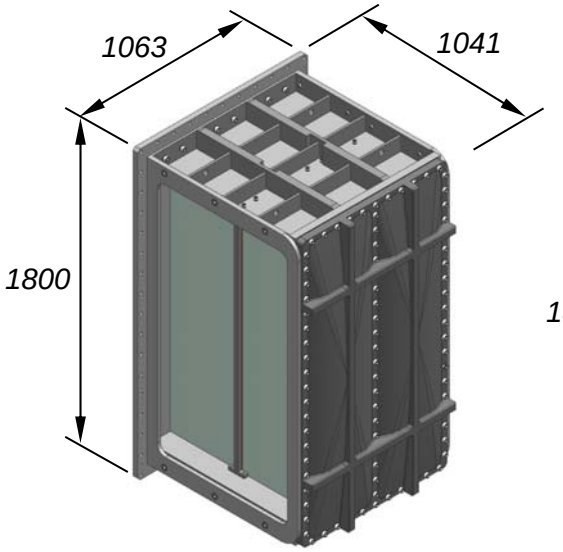

*Connecting rod shaft*
*(Weight : approx. 290 kg)*



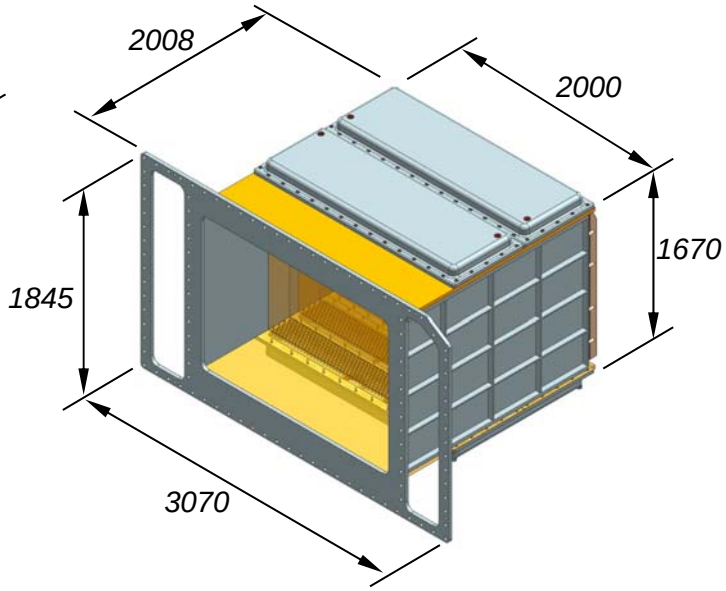

*Piston*
*(Weight : approx. 294 kg)*



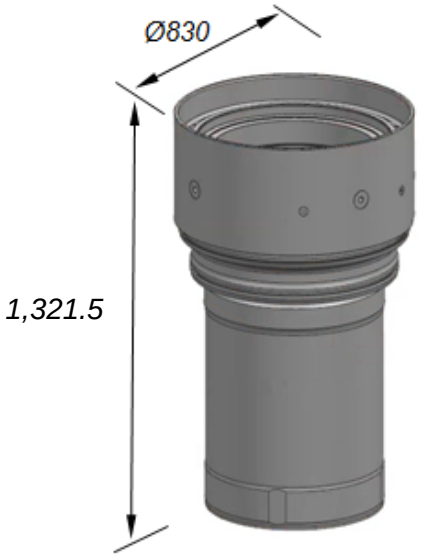

*Inter air cooler cover*
*(Weight : approx. 975 kg)*



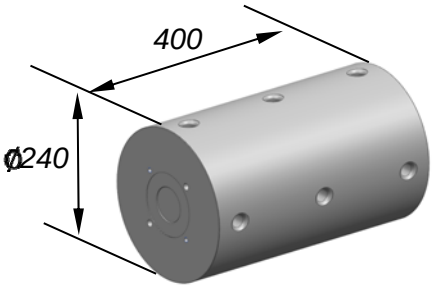

*Charge air inter cooler*
*(Weight : approx. 2,100 kg)*



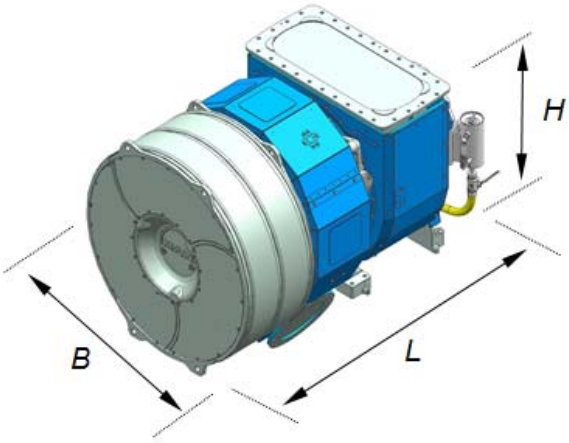

*Charge air after cooler*
*(Weight : approx. 7,200 kg)*



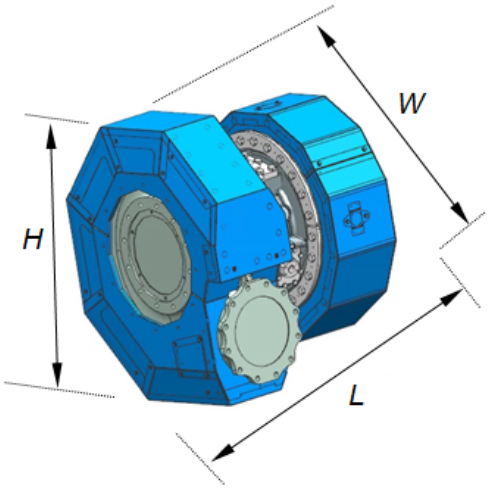

*Cylinder liner*
*(Weight : approx. 1,245kg)*




*Piston pin*
*(Weight : approx. 133 kg)*




*Turbocharger - Low pressure*
*(See the following table)*




*Turbocharger - High pressure*
*(See the following table)*

| Cyl. No. | Turbocharger type | Dimensions [mm] | | | Weight [kg] |
|---|---|---|---|---|---|
| | | B or W | H | L | |
| 12, 14 Cyl. | PBST TCT 40 (LP) | Ø 1,250 | 1,119 | 1,985 | 2,418 |
| | PBST TCX 21(HP) | 1,033 | 1,131 | 939 | 1,800 |
| 16, 18 Cyl. | PBST TCT 60 (LP) | Ø 1,593 | 1,415 | 2,515 | 4,545 |
| | PBST TCX 23 (HP) | 1,222 | 1,336 | 1,118 | 2,657 |

| Description | Quantity |
|---|---|
| **Cylinder head and liner** | |
| Installation for cylinder pressure sensor | 1 |
| Lifting tool for cylinder head | 1 |
| Fitting/Removal device for valve conical clamping piece | 1 |
| Cylinder bore gauge | 1 |
| Removing device for flame ring | 1 |
| Air gun for roto cap & engine clean | 1 |
| Plier for locking ring | 1 |
| Lapping device for inlet exh. valve seat | 1 |
| Removing device for valve seat (int.) | 1 |
| Removing device for valve seat (exh.) | 1 |
| Socket for yoke adj. nut | 1 |
| Socket for R/A S/T stud nut | 1 |
| Socket for R/A adj. nut | 1 |
| Lifting device for cylinder liner | 1 |
| Lifting device for tappet body | 1 |
| Lifting device for push rod | 1 |
| Lifting device for tappet housing | 1 |
| **Piston and connecting rod** | |
| Guide for piston | 1 |
| Lifting device for piston | 1 |
| Protection cover for big end lower | 1 |
| Lifting device for big end lower | 1 |
| Lifting device for big end upper | 1 |
| Guide for con-rod shaft | 1 |
| Plier 125 for retaining ring (piston) | 1 |
| Piston ring expander for piston | 1 |
| **Crankshaft and main bearing** | |
| Lifting device for main bearing cap | 1 |
| Fitting device for main bearing | 1 |
| Deflection gauge for crankshaft | 1 |
| **Fuel injection valve (For only DF)** | |
| Removing device for fuel valve | 1 |
| Lifting device for fuel injection valve | 1 |
| Nozzle tester & removing device for fuel injection v/v | 1 |
| Cleaning tool for fuel injection nozzle | 1 |
| Lapping device for fuel injection valve bush | 1 |
| Fit/Removing device for fuel valve bush | 1 |

| Description | Quantity |
|---|---|
| Lifting device for fuel injection pump | 1 |
| Lifting device for FIP drive | 1 |
| **Fuel injection pump & Pilot fuel oil injector (For only DF)** | |
| Long socket 41 for FIP drive | 1 |
| Long socket 41 for FIP | 1 |
| Cut-off device for fuel injection pump | 2 |
| Plunger Stopper | 2 |
| Fitting device for pilot fuel oil injector bush | 1 |
| Removal device for pilot fuel oil injector bush | 1 |
| Pilot fuel oil injector test jig parts | 1 |
| Test tool for Pilot fuel oil drive | 1 |
| **Gas engine component** | |
| Extract/suspension device for prechamber | 4 |
| Fitting/Removal tool for check valve | 1 |
| Fitting/Removal tool for spark plug | 1 |
| **Other tools** | |
| Feeler gauge | 1 |
| Lifting device for cylinder head hydraulic tool with 4 port | 1 |
| Fit/removal device for cam | 1 |
| Lifting device for air starting valve | 1 |
| Lapping device for air starting valve bush | 1 |
| Fit/removal device for air starting valve bush | 1 |
| Turbocharger cleaning hose | 1 |
| **Hydraulic tools** | |
| Hydraulic tightening devices for MBC M90 | 2 |
| Hydraulic tightening devices for cyl. head/big-end/c-weight M80 | 4 |
| Hydraulic tightening devices for side bolt/con-rod shaft M56x3 | 2 |
| Hydraulic tightening devices for flywheel/damper M48x3 | 2 |
| Hydraulic tightening devices for rocker arm shaft M39x2 | 2 |
| Set of spare parts for hydraulic tools M90 | 1 |
| Set of spare parts for hydraulic tools M80 | 1 |
| Set of spare parts for hydraulic tools M56x3 | 1 |
| Set of spare parts for hydraulic tools M48x3 | 1 |
| Set of spare parts for hydraulic tools M39x2 | 1 |
| Support for MBC M90 | 2 |
| Support for cyl. head/big-end/c-weight M80 | 4 |
| Support for side bolt/con-rod shaft M56x3 | 2 |
| Support for flywheel/damper M48x3 | 2 |

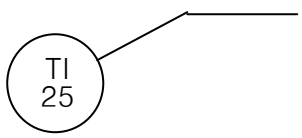
| Description | Quantity |
|---|---|
| Support for rocker arm shaft M39x2 | 2 |
| Extension screw for con-rod shaft M56x3 | 2 |
| Extension screw for flywheel M48x3 | 2 |
| Angle union for connection rod shaft | 2 |
| Distribution pieces 2-POT | 1 |
| Distribution pieces 4-POT | 1 |
| High pressure hose (L=800) | 4 |
| High pressure hose (L=4000) | 1 |
| Pneumatic high press. Pump | 1 |
| Turning pin (Φ16) | 2 |
| Turning pin (Φ10.2) | 2 |
| Turning pin (Φ10) | 2 |
| Turning pin (Φ9) | 2 |
| Turning pin (Φ6.2) | 2 |
| **Standard tool box** | |
| Spare & tool box | 1 |

| NO. | SYMBOL | SYMBOL DESIGNATION | NO. | SYMBOL | SYMBOL DESIGNATION |
|---|---|---|---|---|---|
| 1. GENERAL CONVENTIONAL SYMBOLS | | | | | |
| 1.1 |  | PIPE | 1.6 |  | HIGH PRESSURED PIPE |
| 1.2 |  | PIPE WITH INDICATION OF DIRECTION OF FLOW | 1.7 |  | TRACING |
| 1.3 |  | VALVES,GATE VALVES,COCKS AND FLAPS | 1.8 |  | ENCLOSURE FOR SEVERAL COMPONENTS ASSEMBLED IN ONE UNIT |
| 1.4 |  | APPLIANCES | | | |
| 1.5 |  | INDICATING AND MEASURING INSTRUMENTS | | | |
| 2. 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-WATERTIGHT |
| 2.5 |  | EXPANSION PIPE (CORRUGATED) GENERAL | 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 & 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 | | | |
| 3. VALVES,GATE VALVES,COCKS AND FLAPS | | | | | |
| 3.1 |  | VALVE, STRAIGHT THROUGH | 3.10 |  | FLAP, ANGLE |
| 3.2 |  | VALVE, ANGLE | 3.11 |  | REDUCING VALVE |
| 3.3 |  | STOP VALVE (SCREW ENDED) | 3.12 |  | SAFETY VALVE |
| 3.4 |  | VALVE, THREE-WAY | 3.13 |  | ANGLE SAFETY VALVE |
| 3.5 |  | NON-RETURN VALVE(FLAP) STRAIGHT | 3.14 |  | SELF-CLOSING VALVE |
| 3.6 |  | NON-RETURN VALVE(FLAP) ANGLE | 3.15 |  | QUICK-OPENING VALVE |
| 3.7 |  | NON-RETURN VALVE(FLAP) STRAIGHT, SCREW DOWN | 3.16 |  | QUICK-CLOSING VALVE |
| 3.8 |  | NON-RETURN VALVE(FLAP) ANGLE, SCREW DOWN | 3.17 |  | REGULATING VALVE |
| 3.9 |  | FLAP, STRAIGHT THROUGH | 3.18 |  | ANGLE VALVE |

| NO. | SYMBOL | SYMBOL DESIGNATION | NO. | SYMBOL | SYMBOL DESIGNATION |
|---|---|---|---|---|---|
| 3.19 |  | BALL VALVE(-COCK) | 3.34 |  | COCK,ANGLE,WITH BOTTOM CONNECTION |
| 3.20 |  | BUTTERFLY VALVE | 3.35 |  | COCK,THREE-WAY,WITH BOTTOM CONNECTION |
| 3.21 |  | GATE VALVE | 3.36 |  | SOLENOID VALVE |
| 3.22 |  | DOUBLE-SEATED CHANGEOVER VALVE | 3.37 |  | 3-WAY TEST VALVE |
| 3.23 |  | SUCTION VALVE CHEST | 3.38 |  | THERMOSTATIC VALVE |
| 3.24 |  | SUCTION VALVE CHEST WITH NON RETURN VALVES | 3.39 |  | VALVE WITH TEST FLANGE |
| 3.25 |  | DOUBLE-SEATED CHANGEOVER VALVE,STRAIGHT | 3.40 |  | 3-WAY VALVE WITH REMOTE CONTROL(ACTUATOR) |
| 3.26 |  | DOUBLE-SEATED CHANGEOVER VALVE,ANGLE | 3.41 |  | NON-RETURN VALVE(AIR) |
| 3.27 |  | COCK,STRAIGHT THROUGH | 3.42 |  | 3/2 SPRING RETURN VALVE, NORMALLY CLOSED |
| 3.28 |  | COCK,ANGLE | 3.43 |  | 2/2 SPRING RETURN VALVE, NORMALLY CLOSED |
| 3.29 |  | COCK,THREE-WAY,L-PORT IN PLUG | 3.44 |  | 3/2 SPRING RETURN VALVE CONTR. BY SOLENOID |
| 3.30 |  | COCK,THREE-WAY,T-PORT IN PLUG | 3.45 |  | ON/OFF VALVE CONTROLED BY SOLENOID AND PILOT DIRECTIONAL VALVE AND WITH SPRING RETURN |
| 3.31 |  | COCK,FOUR-WAY,STRAIGHT THROUGH IN PLUG | | | |
| 3.32 |  | COCK,WITH BOTTOM CONNECTION | | | |
| 3.33 |  | COCK,STRAIGHT THROUGH WITH BOTTOM CONNECTION | | | |
| 4. CONTROL AND REGULATION PART | | | | | |
| 4.1 |  | HAND-OPERATED | 4.11 |  | AIR MOTOR DRIVEN |
| 4.2 |  | REMOTE CONTROL | 4.12 |  | MANUAL(AT PNEUMATIC VALVE) |
| 4.3 |  | SPRING | 4.13 |  | PUSH BUTTON |
| 4.4 |  | MASS | 4.14 |  | SPRING |
| 4.5 |  | FLOAT | 4.15 |  | SOLENOID |
| 4.6 |  | PISTON | 4.16 |  | SOLENOID AND PILOT DIRECTIONAL VALVE |
| 4.7 |  | MEMBRANE | 4.17 |  | BY PLUNGER OR TRACER |
| 4.8 |  | ELECTRO-MAGNETIC | | | |
| 4.9 |  | FLAME TRAP | | | |
| 4.10 |  | ELECTRIC MOTOR DRIVEN | | | |
| 5. APPLIANCES | | | | | |
| 5.1 |  | MUDBOX | 5.3 |  | DUPLEX STRAINER |
| 5.2 |  | SIMPLEX STRAINER | 5.4 |  | MAGNETIC FILTER |

| NO. | SYMBOL | SYMBOL DESIGNATION | NO. | SYMBOL | SYMBOL DESIGNATION |
|---|---|---|---|---|---|
| 5.5 |  | SEPARATOR | 5.16 |  | AIR FILTER WITH MANUAL CONTROL |
| 5.6 |  | STEAM TRAP | 5.17 |  | AIR FILTER WITH AUTOMATIC DRAIN |
| 5.7 |  | CENTRIFUGAL PUMP | 5.18 |  | WATER TRAP WITH MANUAL CONTROL |
| 5.8 |  | GEAR-OR SCREW PUMP | 5.19 |  | AIR LUBRICATOR |
| 5.9 |  | HAND PUMP(BUCKET) | 5.20 |  | SILENCER |
| 5.10 |  | EJECTOR | 5.21 |  | FIXED CAPACITY PNEUMATIC MOTOR WITH DIRECTION OF FLOW |
| 5.11 |  | VARIOUS ACCESSRIES (TEXT TO BE ADDED) | 5.22 |  | SINGLE ACTING CYLINDER WITH SPRING RETURNED |
| 5.12 |  | PISTON PUMP | 5.23 |  | DOUBLE ACTING CYLINDER WITH SPRING RETURNED |
| 5.13 |  | HEAT EXCHANGER | 5.24 |  | AUTO DRAIN TRAP |
| 5.14 |  | ELECTRIC PRE-HEATER | | | |
| 5.15 |  | AIR FILTER | | | |
| 6. FITTINGS | | | | | |
| 6.1 |  | FUNNEL | 6.10 |  | SHORT SOUNDING PIPE WITH SELFCLOSING COCK |
| 6.2 |  | BELL-MOUTHED PIPE END | 6.11 |  | STOP FOR SOUNDING ROD |
| 6.3 |  | AIR PIPE | 6.12 |  | OIL TRAY COAMING |
| 6.4 |  | AIR PIPE WITH NET | 6.13 |  | BEARING |
| 6.5 |  | AIR PIPE WITH COVER | 6.14 |  | WATER JACKET |
| 6.6 |  | AIR PIPE WITH COVER AND NET | | | |
| 6.7 |  | AIR PIPE WITH PRESSURE-VACUUM VALVE | | | |
| 6.8 |  | AIR PIPE WITH PRESSURE-VACUUM VALVE | | | |
| 6.9 |  | DECK FITTINGS FOR SOUND'G OR FILLING PIPE | | | |
| 7.READING INSTRUMENTS WITH ORDINARY SYMBOL DESIGNATIONS | | | | | |
| 7.1 |  | SIGHT FLOW INDICATOR | 7.5 |  | COUNTER (INDICATE FUNCTION) |
| 7.2 |  | OBSERVATION GLASS | 7.6 |  | RECORDER |
| 7.3 |  | LEVEL INDICATOR | | | |
| 7.4 |  | DISTANCE LEVEL INDICATOR | | | |

## Symbol explanation

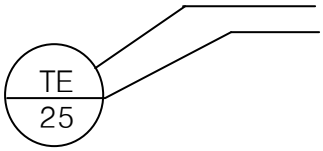



Measuring device

Locally reading

Temperature Indicator

No. 25*



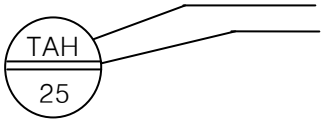

Measuring device

Sensor mounted on engine/unit

Reading/identification mounted in a panel on the engine/unit

Temperature element

No. 25*




Measuring device

Sensor mounted on engine/unit

Reading/identification outside the engine/unit

Temperature Alarm High

No. 25*

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

| Specification of letter code for measuring devices | | | |
|---|---|---|---|
| 1st letters | | Following letters | |
| F | Flow | A | Alarm |
| L | Level | D | Differential |
| P | Pressure | E | Element |
| S | Speed, Solenoid, Spark | H | High |
| T | Temperature | I | Indicating |
| U | Voltage | L | Low |
| V | Viscosity, Vibration | S | Switching, Stop |
| Z | Position | T | Transmitting, Trip |
| M | Motor | X | Failure |
| H | Heater | V | Valve, Device |
| I | Ignition | P | Plug, Pilot |
| C | Control | O | Operation |
| | | F | Feedback |
| | | G | Gas |
| | | C | Coil |

## General

Standard text for instruments - Dual Fuel engine / generator

| Cat' | MS Group | Instrument Group | Code | Text description | | Remark |
|---|---|---|---|---|---|---|
| 0 | Plant Outline | Engine structure | 03 | Crankcase | | |
| | | | 05 | Main bearing | | |
| | | | 06 | Conrod | | |
| | | | 07 | Cylinder liner | | |
| 1 | Engine structure | Operation | 11 | Engine speed & Position (Flywheel) | | |
| | | | 12 | Engine speed & Position (CAM) | | |
| | | | 13 | Overspeed (Mechanical) | | |
| | | | 14 | Turbocharger speed | | |
| | | | 14L | Turbocharger(LP) speed | | 2stage T.C |
| 2 | Combustion gas system | Combustion gas system | 20 | Charge air | air cooler inlet | |
| | | | 21 | | air cooler outlet | |
| | | | 21 | | air cooler(LP) outlet | 2stage T.C |
| | | | 22 | | inter air cooler outlet | 2stage T.C |
| | | | 24 | Cylinder combustion | | |
| | | | 25 | Exhaust gas | cylinder outlet | |
| | | | 26 | | turbocharger inlet | EWG |
| | | | 26A | | turbocharger A inlet | Pulse type |
| | | | 26B | | turbocharger B inlet | Pulse type |
| | | | 26C | | turbocharger C inlet | Pulse type |
| | | | 26L | | turbocharger(LP) inlet | 2stage T.C |
| | | | 27 | | turbocharger outlet | |
| | | | 29 | Intake air before turbocharger compressor | | |
| 3 | Moving system | Pilot fuel oil system | 30 | Pilot fuel oil | filter inlet | |
| | | | 31 | | HP pump inlet | |
| | | | 32 | | engine inlet | |
| | | | 34 | Dirty pilot fuel oil leakage tank | | |
| | | | 35 | Pilot fuel oil engine outlet | | Return |
| 4 | Control system Compressed air system | Control system Compressed air system | 40 | Starting air engine inlet | | |
| | | | 41 | Control air engine inlet | | |
| | | | 43 | Control air | DVT inlet | Intake |
| | | | 43E | | DVT(EXH) inlet | Exhaust |
| | | | 44 | Jet assist air | | |
| | | | 45 | Slow turn | | |
| | | | 49 | Emergency stop | | |
| 5 | Fuel Inj. system | Fuel Inj. system | 50 | Fuel rack position | | |
| | | | 51 | Fuel oil | filter inlet | |
| | | | 52 | | engine inlet | |
| | | | 54 | Clean fuel oil Leakage tank | | |
| | | | 55 | Waste oil leakage tank | | |
| | | | 57 | Nozzle cooling oil | engine inlet | |
| | | | 58 | | engine outlet | |

| Cat' | MS Group | Instrument Group | Code | Text description | | Remark |
|---|---|---|---|---|---|---|
| 6 | Lube Oil system | Lube Oil system | 61 | Lube oil | filter inlet | |
| | | | 62 | | engine inlet | |
| | | | 63 | | turbocharger inlet | |
| | | | 63L | | turbocharger(LP) inlet | 2stage T.C |
| | | | 64 | | turbocharger outlet | |
| | | | 64L | | turbocharger (LP) outlet | 2stage T.C |
| | | | 65 | Pre lube oil | | |
| | | | 66 | Lube oil HP pump inlet | | |
| | | | 67 | Splash oil | | |
| | | | 68 | Lube oil sump tank | | |
| 7 | Cooling water system | Cooling water system | 70 | LT water | LT pump inlet | Seawater applicable |
| | | | 71 | | air cooler inlet | |
| | | | 72 | | air cooler outlet | |
| | | | 72I | | air cooler(in) outlet | Inter cooler |
| | | | 73 | | Lub. oil cooler outlet | |
| | | | 74 | HT water | air cooler inlet | Fresh water applicable |
| | | | 75 | | engine inlet | |
| | | | 76 | | engine outlet | |
| | | | 77 | | air cooler outlet | |
| 8 | Supercharge system | Gas system | 80 | Gas supply | filter inlet | |
| | | | 81 | | filter outlet | |
| | | | 82 | | regulator outlet | |
| | | | 83 | Control air gas regulating unit | | |
| | | | 84 | Gas shutoff valve | | |
| | | | 85 | Gas venting valve | | |
| | | | 86 | Prechamber gas engine inlet | | |
| | | | 87 | Main gas engine inlet | | |
| | | | 88 | Degassing | | |
| | | | 89 | Inert gas engine inlet | | |
| 9 | Maintenance | Maintenance Miscellaneous device | 90 | Turning gear | | |
| | | | 92 | Oil mist detector | | |
| | | | 93 | Vibration sensor | | |
| | | | 94 | Knock sensor | | |
| | | | 95 | Rupture disc | | |
| | | | 96 | Ignition coil | | |
| | | | 97 | Water in oil | | |
| | | | 98 | Oil in water | | |
| | | | 99 | GRU enclosure | | |
| - | | Special note | | 201 Air recirculation valve<br>202 Air waste gate valve<br>203 Air by pass valve<br>204 Charge air shut off valve | | Multiple equip. in the same location |

# NOTES

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