PROJECT GUIDE

HiMSEN H35DF

FOR MARINE

2025 1st EDITION

HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY
HYUNDAI HEAVY INDUSTRIES

HiMSEN

DISCLAIMER

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List of updates for H35DF Project Guide

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No.	Section No.	Section name	Description
1	3.1	Rated power for generating-set	Table 3.1 Rated power for generating-set updated
2	3.2	Engine Capacity data	Table 3.2 Engine capacity data (Diesel mode – rated power : 480kW / cylinder at 720 rpm) updated
3	3.2	Engine Capacity data	Table 3.3 Engine capacity data (Gas mode – rated power : 480kW / cylinder at 720 rpm) updated
4	3.2	Engine Capacity data	Table 3.4 Engine capacity data (Diesel mode – rated power : 500kW / cylinder at 720 rpm) updated
5	3.2	Engine Capacity data	Table 3.5 Engine capacity data (Gas mode – rated power : 500kW / cylinder at 720 rpm) updated
6	3.3	Engine performance - 720 rpm	Table 3.7 Engine performance data (Gas mode - rated power : 480 kW / cylinder at 720 rpm) updated
7	3.3	Engine performance - 720 rpm	Table 3.8 Engine performance data (Diesel mode - rated power : 500 kW / cylinder at 720 rpm) updated
8	3.3	Engine performance - 720 rpm	Table 3.9 Engine performance data (Gas mode - rated power : 500 kW / cylinder at 720 rpm) updated
9	5.6	HiEMS	HiEMS updated
10	7.1	Internal lubricating oil system	Diagram for Internal lubricating oil system updated
11	9.5	External exhaust gas system	9.5.1 Exhaust gas back pressure updated

Remark

The above information is the major updates from the previous version, and it doesn't include the minor changes.

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1 General information

1.1 Introduction

This project guide provides necessary information and recommendations for the application of HYUNDAI HiMSEN H35DF (Dual Fuel) generating-set (gen-set). "HiMSEN'® is the licensed brand name of HYUNDAI's own design engine and the abbreviation of '**Hi**-Touch **M**arine & **S**tationary **EN**gine'. The HiMSEN H35DF generating sets are delivered as complete packages, an engine and a generator are mounted on a common base frame together with related auxiliary equipment.

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

Each sheet is identified by the engine type and own 'Sheet Number'. Therefore, please use engine type 'H35DF', and 'Sheet No.' for easier communications

Engine model designation

6 H 35 DF (M/S)

- No. of cylinders (6, 7, 8, 9) — 6
- HYUNDAI's HiMSEN — H
- Cylinder bore in cm — 35
- DF engine — DF
- Marine or Stationary application — (M/S)

1.2 Engine nomenclature

1.2.1 Cylinder numbering

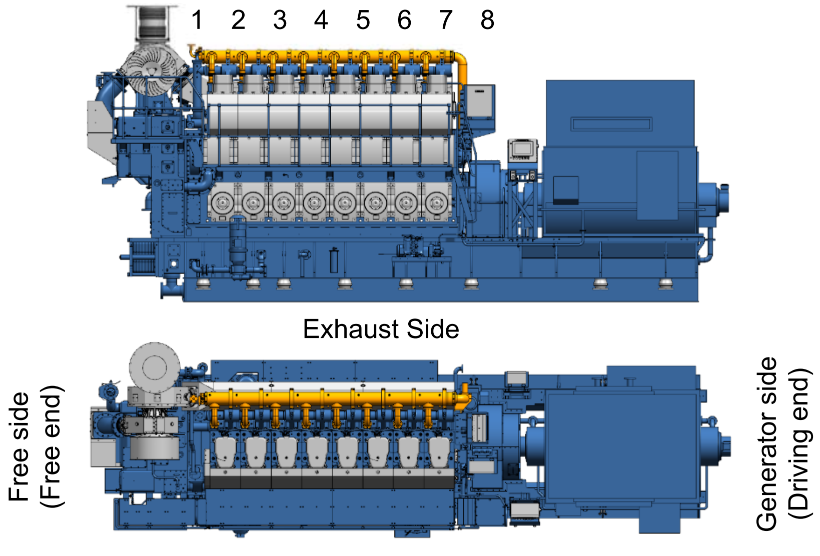


Figure 1.1 Cylinder numbering

1.2.2 Direction of engine rotation

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

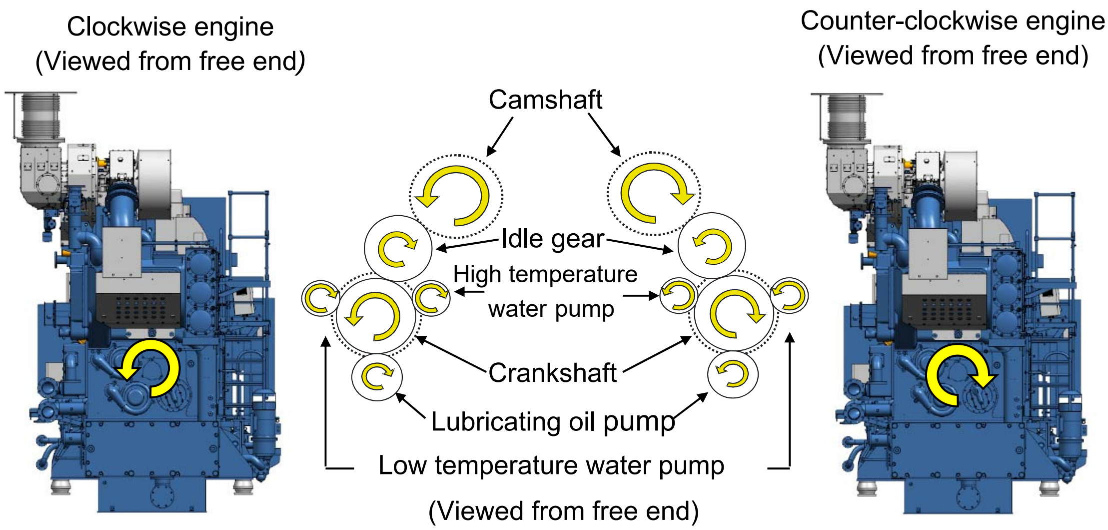


Figure 1.2 Direction of engine rotation

2 Structural design and installation

2.1 Principal data

Table 2.1 Principal data

Type of engine	4-stroke, turbocharged and inter-cooled, dual fuel engine, trunk piston type.	
Cylinder configuration		In-line
Number of cylinder		6 - 7 - 8 - 9
Rated speed	rpm	720 750
Power per cylinder	kW	480
Cylinder bore	mm	350
Piston stroke	mm	400
Swept Volume per cylinder	d㎥	38.5
Mean piston speed	m/s	9.6 10.0
Mean effective pressure	bar	20.8 20.0
Compression ratio		13.5 : 1
Direction of engine rotation		Clockwise viewed from generator side (Non-reversible)
Cylinder firing order	6H35DF	1 - 4 - 2 - 6 - 3 - 5
	7H35DF	1 - 2 - 4 - 6 - 7 - 5 - 3
	8H35DF	1 - 3 - 5 - 7 - 8 - 6 - 4 - 2
	9H35DF	1 - 3 - 5 - 7- 9 - 8 - 6 - 4 - 2

2.2 Engine cross section

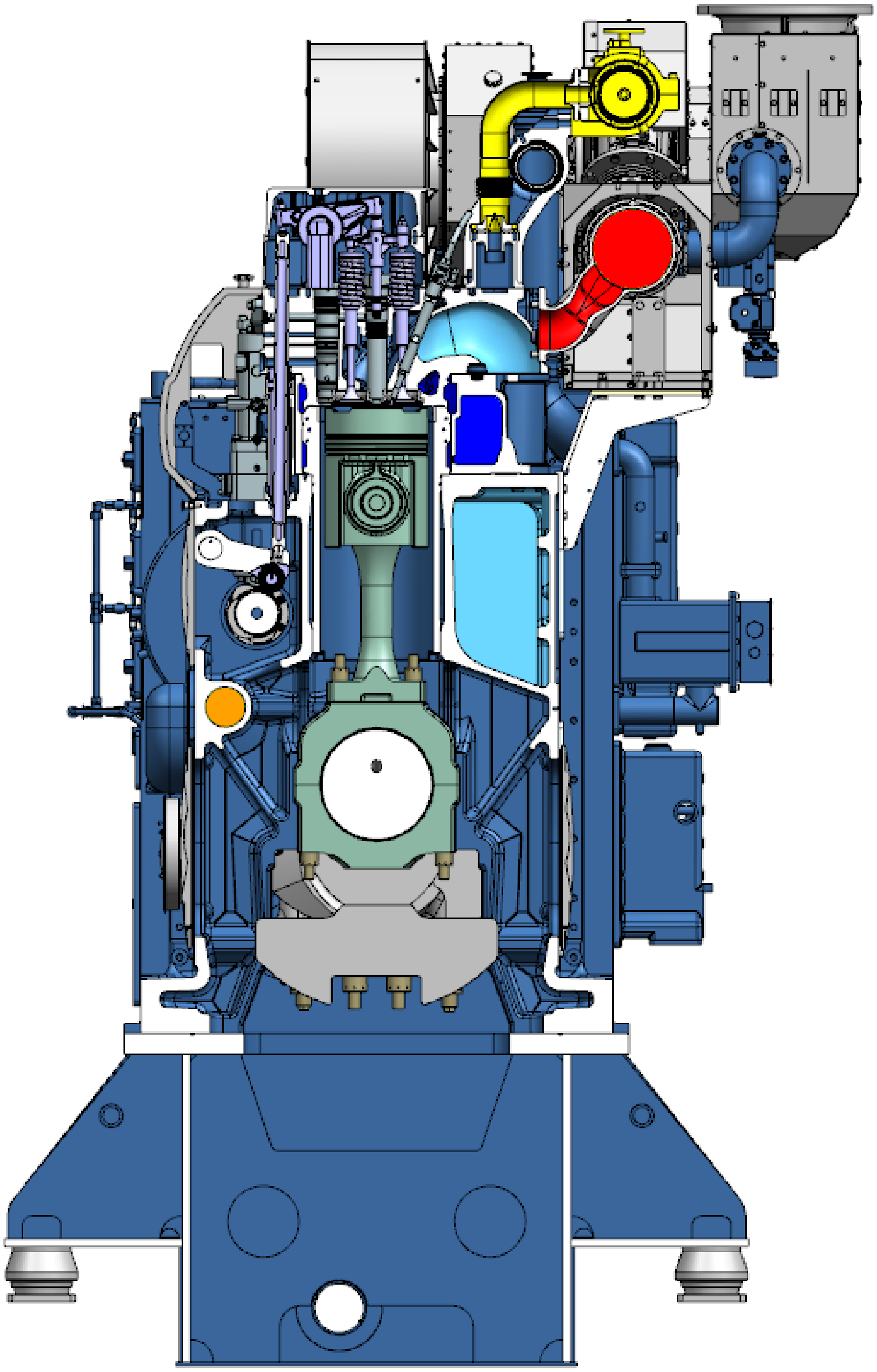


Figure 2.1 Engine cross section

2.3 Engine design outline

2.3.1 General

Hyundai dual fuel engine 'HiMSEN H35DF' family have simple and smart design suitable for marine application with high reliability and performance. The key features are summarized as below :

1. Dual fuel engine can be run with liquid fuel or gaseous fuel alternatively.

2. Eco-friendly and economical engine with the lowest fuel consumption and NO_X emission which are based on the following specific designs :

   - ✓ The best air fuel ratio control
   - ✓ Optimized combustion parameters, i.e. high fuel injection pressure, piston bowl, turbocharger and intake air parts, etc.

3. Reliable and practical engine with simple, smart and robust structure.

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

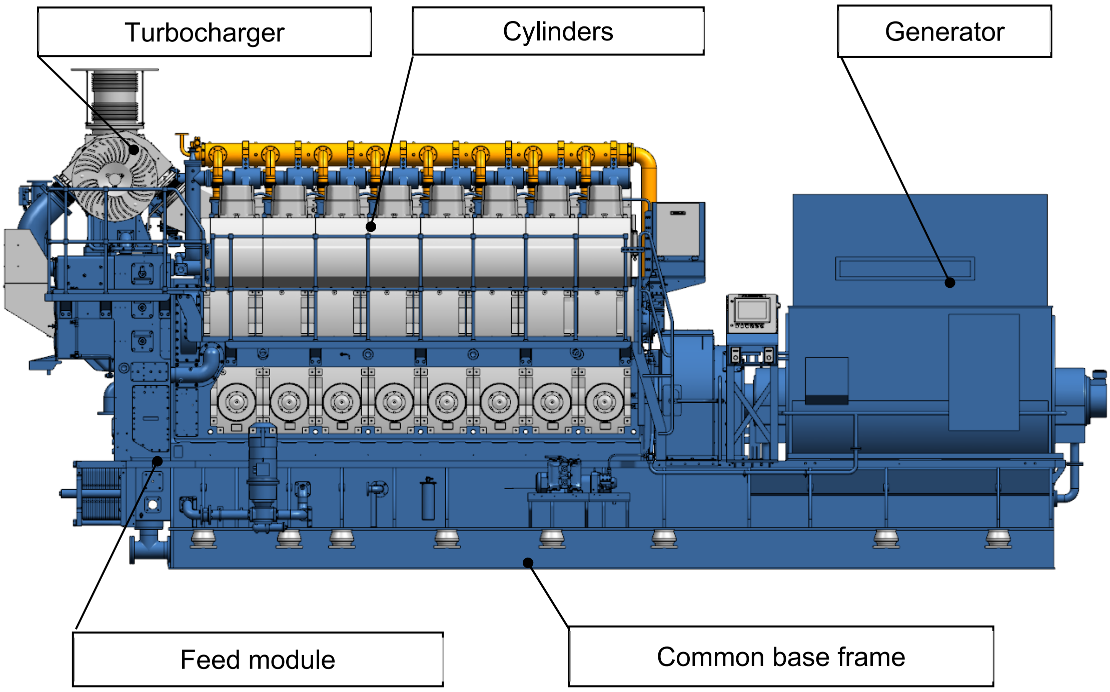


Figure 2.2 Engine design outline

2.3.2 Design of main components

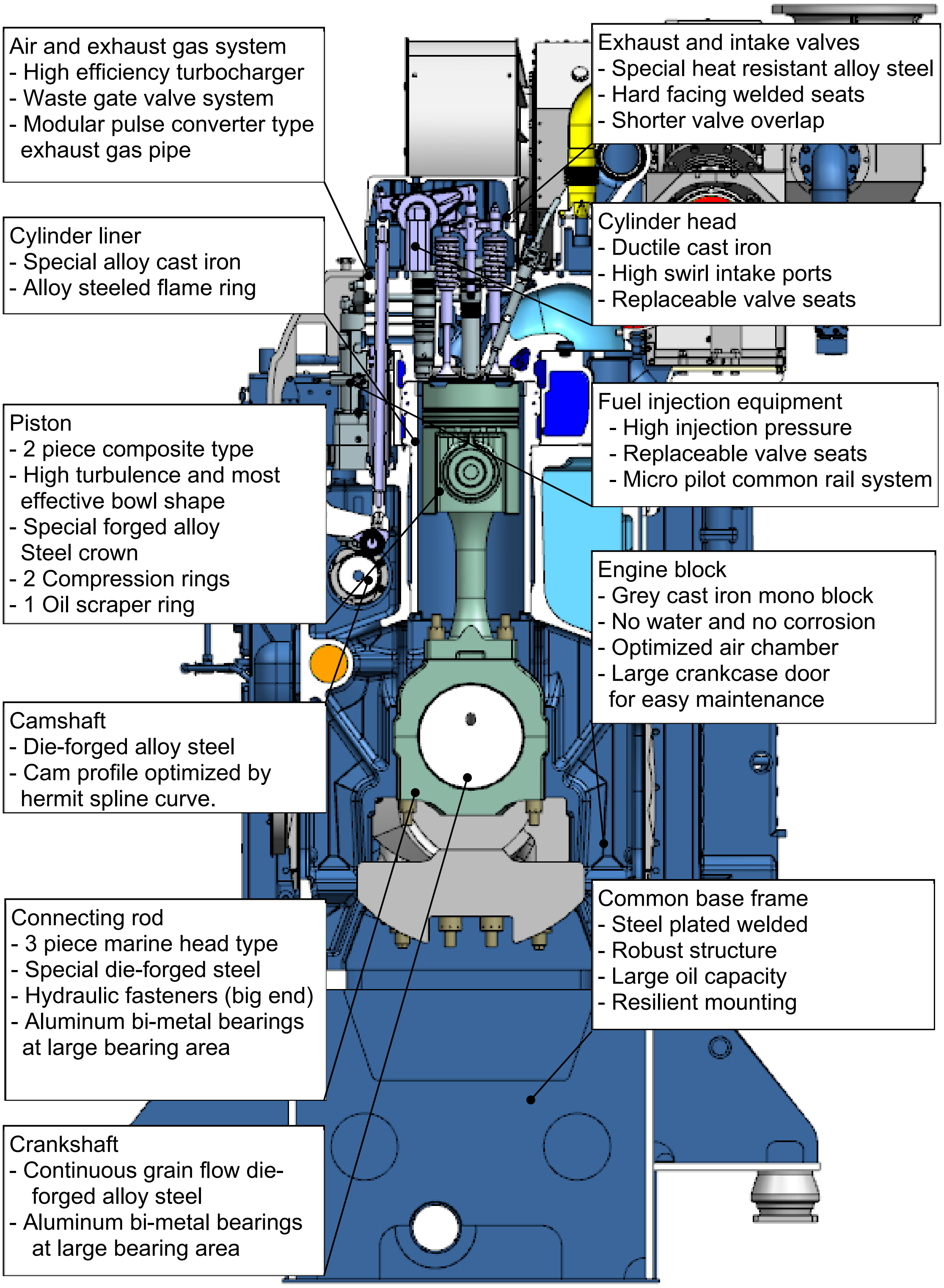


Figure 2.3 Cross section drawing

2.3.3 Description of feed module

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

- ✓ All the components of the system, for example, pumps, valves, filters and coolers are mounted on feed block without any pipe connection, which provides direct accessibility with fewer parts for easy maintenance as shown below Figure 2.4
- ✓ Feed block has cast-in flow channels for cooling water and lubricating oil circuits, which are arranged to secure water-tight to oil space and simplified in combination with pumps and valve housings for better flow characteristics to avoid any risk of corrosion due to cavitation.

Outline of feed module

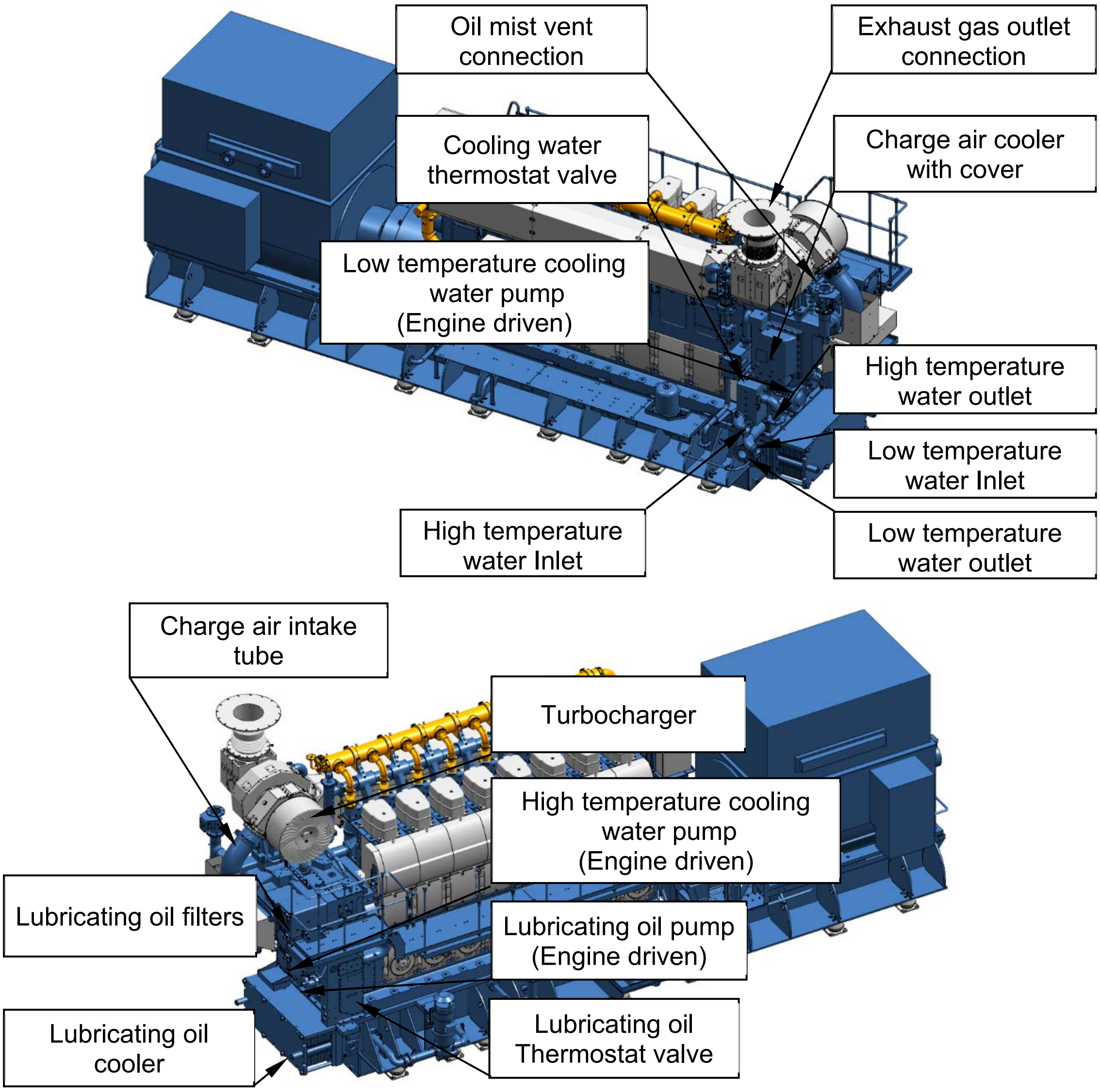


Figure 2.4 Outline of feed module

2.4 Generating-set dimension and weight

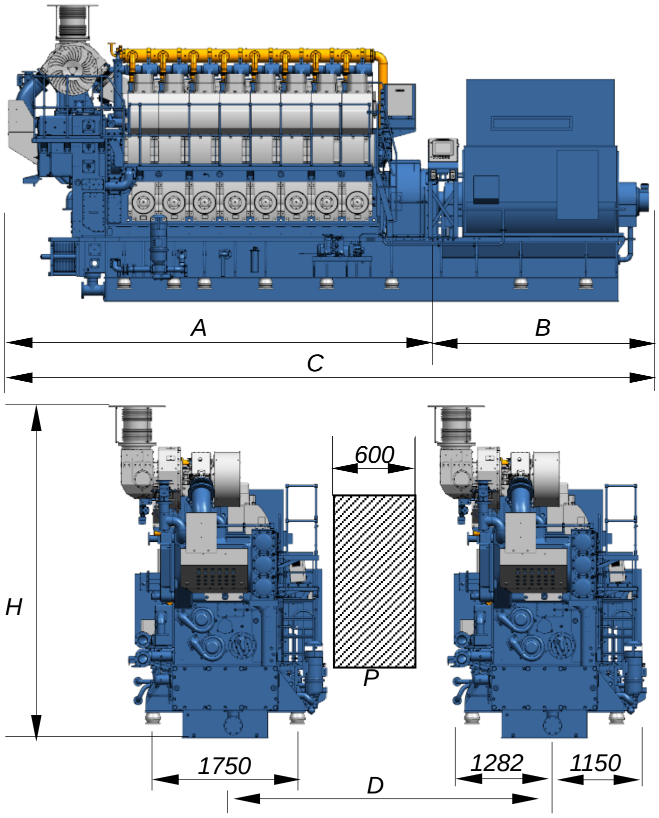


Table 2.2 Generating-set dimension and weight

Engine type	Dimensions (mm)					Dry weight (ton) 2)	
	A	B 1)	C 1)	D	H	Engine 3)	Generating-set 4)
6H35DF	5,760	3,130	8,890	3,408	4,367	34.7	69.6
7H35DF	6,112	3,374	9,486	3,408	4,538	39.6	78.1
8H35DF	6,602	3,594	10,196	3,408	4,538	42.5	83.0
9H35DF	7,092	4,097	11,189	3,408	4,538	45.6	90.1

1. All dimensions and weight are approximate value and subject to change without prior notice.
1) : Depending on alternator.
2) : Weight including a standard alternator (Maker : HHI-EES)
3) : Without common base frame
4) : With common base frame and generator
D : Min. distance between engines
P : Free passage between the engines, width 600 mm and height 2,000 mm.

2.5 Mounting

2.5.1 General

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

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

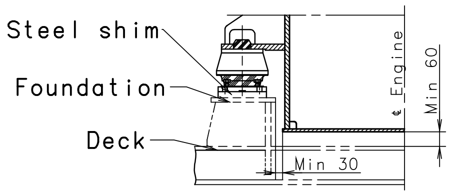


Figure 2.5 Resilient mounting

2.5.2 Design of resilient mount

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

2.5.3 Connections to the generating-set

Generating-set mounted on resilient mount is usually influenced by a relative motions from the hull structure. Due to the reason, any rigid fixing between generating-set and hull structure causes damages to generating-set or hull. Therefore, all connections, for example, pipes, gratings, ladders, electric wires, etc., should be flexible enough to absorb the relative movements.

2.5.4 Recommendations for seating design and adjustment

The foundation for common base frame mounting should be rigid enough to support the load from generating-set. Steel shim plates with thickness of minimum 25mm between rubber elements and foundation are required to adjust leveling of each mount (Method 1). Additional shim plate (Minimum thickness 10 mm) can be used for adjustments (Method 2) as shown below Figure 2.6. It is also recommended to check the crankshaft deflection before starting up the engine to secure the correct adjustments of the shim plate and leveling of the generating-set.

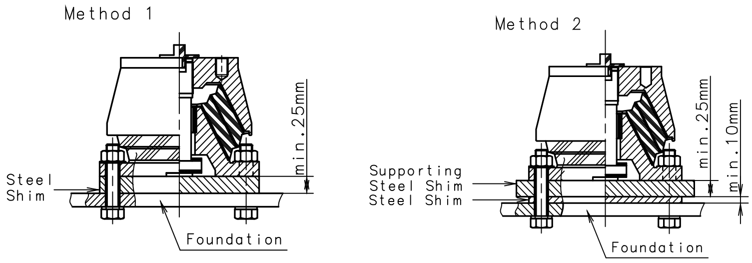


Figure 2.6 Recommendations for seating design

2.6 Overhaul dimension

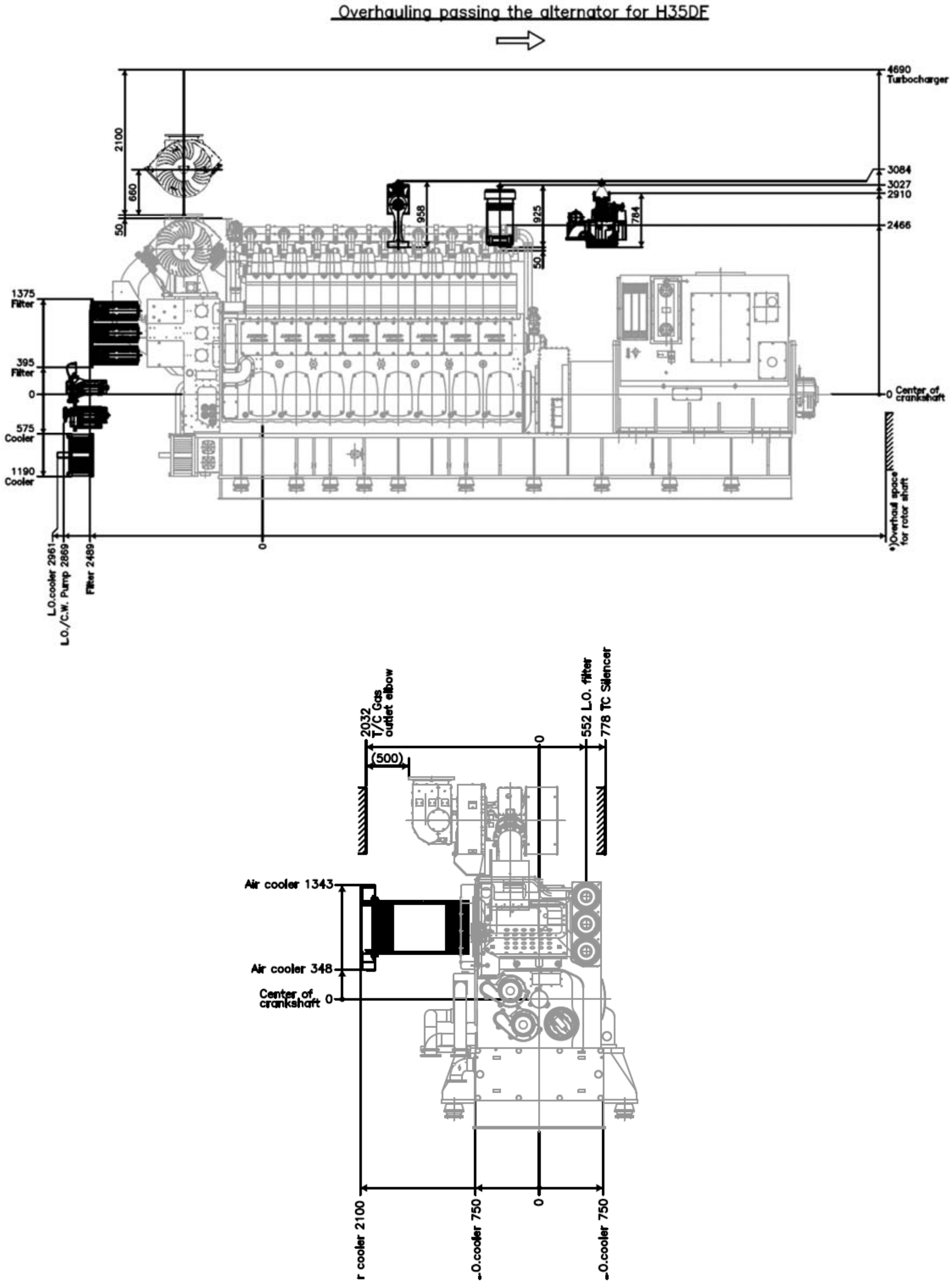


Figure 2.7 Overhaul dimension

3 Performance data

3.1 Rated power for generating-set

Table 3.1 Rated power for generating-set

Engine type	Rated output at					
	720 rpm / 60 Hz		720 rpm / 60 Hz (Up-rated)		750 rpm / 50 Hz	
	Engine (kWm)	Generator (kWe)	Engine (kWm)	Generator (kWe)	Engine (kWm)	Generator (kWe)
6H35DF	2,880	2,779	3,000	2,895	2,880	2,779
7H35DF	3,360	3,242	3,500	3,378	3,360	3,242
8H35DF	3,840	3,706	4,000	3,860	3,840	3,706
9H35DF	4,320	4,169	4,500	4,343	4,320	4,169

1. No overload operation is permissible except 10 % overload of diesel mode during official factory test only.
2. The alternator outputs are calculated for an efficiency of 96.5 % and a power factor of 0.8 lagging.
3. Power adjusting of dual fuel engines must be consulted to engine builder.

Reference condition

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

ISO condition

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

Tropical condition

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

3.2 Engine capacity data

Table 3.2 Engine capacity data (Diesel mode – rated power : 480kW / cylinder at 720 rpm)

Engine MCR	Cyl.	6	7	8	9
	KW	2880	3360	3840	4320
1. Cooling capacities					
Charge air					
High temperature cooling water - heat dissipation [1)]	kW	760	887	1013	1140
Low temperature cooling water - heat dissipation [1)]	kW	225	262	300	337
Cooling water flow (High temperature and low temperature)	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	36 / 39	36 / 39	36 / 39	36 / 39
Lubricating oil					
Heat dissipation [1) 3)]	kW	491	573	654	736
Low temperature cooling water flow	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	39 / 46	39 / 46	39 / 46	39 / 47
Cylinder jacket					
Heat dissipation [1)]	kW	455	531	607	683
High temperature cooling water flow	㎥/h	70	70	85	85
High cooling water temperature, engine in / out	℃	76 / 82	75 / 82	76 / 82	75 / 82
2. Gas data [2)]					
Combustion air consumption	kg/h	18130	21151	24173	27194
Exhaust gas flow	kg/h	18685	21800	24914	28028
Exhaust gas temperature	℃	340	340	340	340
Allowable exhaust gas back pressure, max.	mbar	30	30	30	30

Engine MCR	Cyl.	6	7	8	9
	KW	2880	3360	3840	4320
3. Heat radiation					
Engine radiation [1)]	kW	120	137	157	177
Alternator radiation	kW	(See separate data from alternator maker)			
Starting air					
Air consumption per start [7)]	N㎥	4.8	5.0	5.45	5.55
Starting air source, pressure (20 ℃) max. / min.	bar	30 / 15	30 / 15	30 / 15	30 / 15
4. Pump capacities					
Engine driven pumps [4)]					
Lubricating oil pump (6 bar)	㎥/h	95	95	120	140
High temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
Low temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
External pumps [5)]					
Marin diesel oil pump (head) - (8 bar)	㎥/h	2.13	2.48	2.84	3.19
Heavy fuel oil supply pump (head) - (4 bar)	㎥/h	1.06	1.24	1.42	1.60
Heavy fuel oil booster pump (8 bar at Engine inlet, F1) [6)]	㎥/h	2.13	2.48	2.84	3.19
Pilot supply pump (6 bar at Engine inlet, F9)	㎥/h	0.3	0.3	0.3	0.3

Remark

1) Under tropical condition (turbocharger air inlet pressure 1 bar, intake air temperature 45℃, L.T cooling water temperature 36℃) flow tolerance ± 5 % at 100 % load. Heat dissipation tolerance for cooling water ± 10 %, heat dissipation tolerance for radiation ± 30 %. A margin and fouling factors to be taken into account when design heat exchangers.
2) Exhaust gas mass flow tolerance ± 5 %, Exhaust gas temperature tolerance ± 25℃.
3) Additional heat for lube oil purification should be included. (30 kJ/kWh).
4) Flow capacity to be within a tolerance of 0 % to + 10 %.
5) Flushing oil quantity of automatic filter is included.
6) Heavy fuel booster pump head to be designed by external system designer considering pressure loss of external system.
7) This value includes slow turn consumption.

Table 3.3 Engine capacity data (Gas mode – rated power : 480kW / cylinder at 720 rpm)

Engine MCR	Cyl.	6	7	8	9
	KW	2880	3360	3840	4320
1. Cooling capacities					
Charge air					
High temperature cooling water - heat dissipation [1]	kW	555	650	740	835
Low temperature cooling water - heat dissipation [1]	kW	190	221	253	284
Cooling water flow (High temperature and low temperature)	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	36 / 38	36 / 38	36 / 38	36 / 39
Lubricating oil					
Heat dissipation [1] [3]	kW	430	500	575	645
Low temperature cooling water flow	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	38 / 44	38 / 45	38 / 44	39 / 45
Cylinder jacket					
Heat dissipation [1]	kW	405	475	540	610
High temperature cooling water flow	㎥/h	70	70	85	85
High cooling water temperature, engine in / out	℃	74 / 80	74 / 80	77 / 82	76 / 82
2. Gas data [2]					
Combustion air consumption	kg/h	14564	16992	19419	21846
Exhaust gas flow	kg/h	15002	17502	20003	22503
Exhaust gas temperature	℃	390	390	390	390
Allowable exhaust gas back pressure, max. [6]	mbar	(24)	(24)	(24)	(24)

Engine MCR	Cyl.	6	7	8	9
	KW	2880	3360	3840	4320
3. Heat radiation					
Engine radiation [1)]	kW	110	125	145	160
Alternator radiation	kW	(See separate data from alternator maker)			
4. Pump capacities					
Engine driven pumps [4)]					
Lubricating oil pump (6 bar)	㎥/h	95	95	120	140
High temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
Low temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
External pumps [5)]					
Pilot supply pump (6 bar at engine inlet, F9)	㎥/h	0.3	0.3	0.3	0.3

Remark

1) Under tropical condition (turbocharger air inlet pressure 1 bar, intake air temperature 45℃, L.T cooling water temperature 36℃) flow tolerance ± 5 % at 100 % load. Heat dissipation tolerance for cooling water ± 10 %, heat dissipation tolerance for radiation ± 30 %. A margin and fouling factors to be taken into account when design heat exchangers.
2) Exhaust gas mass flow tolerance ± 5 %, Exhaust gas temperature tolerance ± 25℃.
3) Additional heat for lube oil purification should be included. (30 kJ/kWh).
4) Flow capacity to be within a tolerance of 0 % to + 10 %.
5) Flushing oil quantity of automatic filter is included.
6) The maximum exhaust gas back pressure of gas mode is defined depending on allowable exhaust gas back pressure of diesel mode.

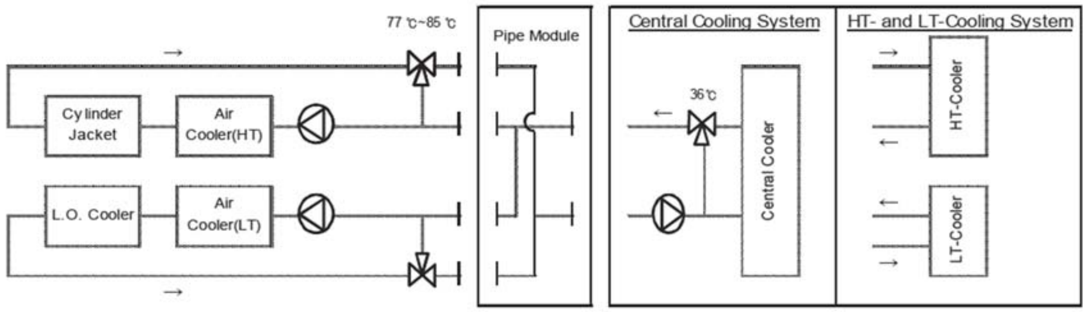


Figure 3.1 Cooling system arrangement

Table 3.4 Engine capacity data (Diesel mode – rated power : 500kW / cylinder at 720 rpm)

Engine MCR	Cyl. KW	6 3000	7 3360	8 3840	9 4320
1. Cooling capacities					
Charge air					
High temperature cooling water - heat dissipation [1)]	kW	795	928	1060	1193
Low temperature cooling water - heat dissipation [1)]	kW	235	274	314	353
Cooling water flow (High temperature and low temperature)	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	36 / 39	36 / 39	36 / 39	36 / 39
Lubricating oil					
Heat dissipation [1) 3)]	kW	514	600	685	771
Low temperature cooling water flow	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	39 / 46	39 / 46	39 / 46	39 / 47
Cylinder jacket					
Heat dissipation [1)]	kW	477	556	635	715
High temperature cooling water flow	㎥/h	70	70	70	70
High cooling water temperature, engine in / out	℃	76 / 82	75 / 82	76 / 82	75 / 82
2. Gas data [2)]					
Combustion air consumption	kg/h	19070	22248	25427	28605
Exhaust gas flow	kg/h	19640	22913	26187	29460
Exhaust gas temperature	℃	333	340	340	340
Allowable exhaust gas back pressure, max.	mbar	30	30	30	30

Engine MCR	Cyl.	6	7	8	9
	KW	3000	3500	4000	4500
3. Heat radiation					
Engine radiation [1)]	kW	123	144	164	185
Alternator radiation	kW	(See separate data from alternator maker)			
Starting air					
Air consumption per start [7)]	N㎥	4.8	5.0	5.45	5.55
Starting air source, pressure (20 ℃) max. / min.	bar	30 / 15	30 / 15	30 / 15	30 / 15
4. Pump capacities					
Engine driven pumps [4)]					
Lubricating oil pump (6 bar)	㎥/h	95	95	120	140
High temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
Low temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
External pumps [5)]					
Marin diesel oil pump (head) - (8 bar)	㎥/h	2.13	2.48	2.84	3.19
Heavy fuel oil supply pump (head) - (4 bar)	㎥/h	1.06	1.24	1.42	1.60
Heavy fuel oil booster pump (8 bar at Engine inlet, F1) [6)]	㎥/h	2.13	2.48	2.84	3.19
Pilot supply pump (6 bar at Engine inlet, F9)	㎥/h	0.3	0.3	0.3	0.3

Remark

1) Under tropical condition (turbocharger air inlet pressure 1 bar, intake air temperature 45℃, L.T cooling water temperature 36℃) flow tolerance ± 5 % at 100 % load. Heat dissipation tolerance for cooling water ± 10 %, heat dissipation tolerance for radiation ± 30 %. A margin and fouling factors to be taken into account when design heat exchangers.
2) Exhaust gas mass flow tolerance ± 5 %, Exhaust gas temperature tolerance ± 25℃.
3) Additional heat for lube oil purification should be included. (30 kJ/kWh).
4) Flow capacity to be within a tolerance of 0 % to + 10 %.
5) Flushing oil quantity of automatic filter is included.
6) Heavy fuel booster pump head to be designed by external system designer considering pressure loss of external system.
7) This value includes slow turn consumption.

Table 3.5 Engine capacity data (Gas mode – rated power : 500kW / cylinder at 720 rpm)

Engine MCR	Cyl. / KW	6 / 3000	7 / 3500	8 / 4000	9 / 4500
1. Cooling capacities					
Charge air					
High temperature cooling water - heat dissipation [1]	kW	600	700	800	900
Low temperature cooling water - heat dissipation [1]	kW	205	240	274	308
Cooling water flow (High temperature and low temperature)	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	36 / 39	36 / 39	36 / 39	36 / 39
Lubricating oil					
Heat dissipation [1] [3]	kW	450	525	600	675
Low temperature cooling water flow	㎥/h	70	70	85	85
Low cooling water temperature, cooler in / out	℃	39 / 46	39 / 46	39 / 46	39 / 47
Cylinder jacket					
Heat dissipation [1]	kW	425	496	567	638
High temperature cooling water flow	㎥/h	70	70	85	85
High cooling water temperature, engine in / out	℃	76 / 82	75 / 82	76 / 82	75 / 82
2. Gas data [2]					
Combustion air consumption	kg/h	15030	17535	20040	22545
Exhaust gas flow	kg/h	15540	18130	20720	23310
Exhaust gas temperature	℃	390	390	390	390
Allowable exhaust gas back pressure, max. [6]	mbar	(24)	(24)	(24)	(24)

Engine MCR	Cyl.	6	7	8	9
	KW	3000	3500	4000	4500
3. Heat radiation					
Engine radiation [1]	kW	110	128	147	165
Alternator radiation	kW	(See separate data from alternator maker)			
4. Pump capacities					
Engine driven pumps [4]					
Lubricating oil pump (6 bar)	㎥/h	95	95	120	140
High temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
Low temperature cooling water pump (1 ~ 2.5 bar)	㎥/h	70	70	85	85
External pumps [5]					
Pilot supply pump (6 bar at engine inlet, F9)	㎥/h	0.3	0.3	0.3	0.3

Remark

1) Under tropical condition (turbocharger air inlet pressure 1 bar, intake air temperature 45℃, L.T cooling water temperature 36℃) flow tolerance ± 5 % at 100 % load. Heat dissipation tolerance for cooling water ± 10 %, heat dissipation tolerance for radiation ± 30 %. A margin and fouling factors to be taken into account when design heat exchangers.
2) Exhaust gas mass flow tolerance ± 5 %, Exhaust gas temperature tolerance ± 25℃.
3) Additional heat for lube oil purification should be included. (30 kJ/kWh).
4) Flow capacity to be within a tolerance of 0 % to + 10 %.
5) Flushing oil quantity of automatic filter is included.
6) The maximum exhaust gas back pressure of gas mode is defined depending on allowable exhaust gas back pressure of diesel mode.

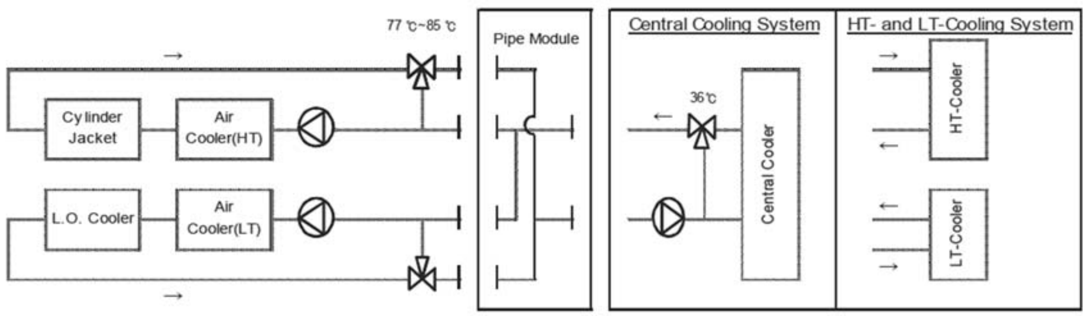


Figure 3.2 Cooling system arrangement

3.3 Engine performance - 720 rpm

Table 3.6 Engine performance data (Diesel mode - rated power : 480 kW / cylinder at 720 rpm)

Performance data		Engine load (%)				
		110	100	90	75	50
1. Cylinder data						
Cylinder output	kW	528	480	432	360	240
Mean effective pressure	bar	22.9	20.8	18.7	15.6	10.4
2. Combustion air data 1), 4)						
Mass flow	kg/kWh	6.6	6.8	6.9	7.2	7.5
Air pressure (Absolute)	bar	5.7	5.3	4.9	4.2	2.9
Air temperature after cooler	℃	45	45	45	45	45
3. Exhaust gas data 1), 4)						
Mass flow	kg/kWh	6.8	7.0	7.1	7.4	7.7
Gas temperature after turbine	℃	325	315	320	325	350
4. Heat balance data 2)						
Charge air, stage 1 (High temperature)	kJ/kWh	955	910	855	805	500
Charge air, stage 2 (Low temperature)	kJ/kWh	265	270	280	305	310
Lubricating oil	kJ/kWh	615	605	605	680	870
Jacket cooling water	kJ/kWh	555	560	560	570	715
Exhaust gas	kJ/kWh	1975	1985	2025	2000	2440
Radiation	kJ/kWh	150	145	150	165	200
5. Specific fuel oil consumption 3), 4)						
Specific fuel oil consumption	g/kWh	188	187	187	187	195

Remark

Reference condition is based on ISO 3046-1 (turbocharger air inlet pressure 1 bar, intake air temperature 25℃, L.T cooling water temperature 25℃). The above values are based on IMO Tier II emission level on diesel mode without selective catalyst reduction operation.

1) Mass flow tolerance ± 5 %, temperature tolerance ± 25℃ (50 % < load ≤ 110 %).
   Mass flow tolerance ± 10 %, temperature tolerance ± 35℃ (Load ≤ 50%).
2) Heat dissipation tolerance ± 10 % for cooler, ± 15 % for heat recovery.
   Additional heat for lube oil purification should be included. (30 kJ/kWh).
3) Specific fuel oil consumption tolerance + 5 % at 100 % load.
   Engine driven pumps attached : lubricating oil pump, high temperature cooling water pump, low temperature cooling water pump.
   Specific fuel oil consumption includes the pilot oil consumption and excludes clean leakage fuel oil.
   Main fuel oil based on marine diesel oil, lower calorific value 42700 kJ/kg.
   Specific fuel oil consumption is warranted at 100 % engine load without selective catalyst reduction operation.
4) When an engine is operated with exhaust gas after-treatment system (for example: SCR), the values may change to ensure the proper operation of after-treatment system.

Table 3.7 Engine performance data (Gas mode - rated power : 480 kW / cylinder at 720 rpm)

Performance data		Engine load (%)				
		110	100	90	75	50
1. Cylinder data						
Cylinder output	kW	-	480	432	360	240
Mean effective pressure	bar	-	20.8	18.7	15.6	10.4
2. Combustion air data 1), 4)						
Mass flow	kg/kWh	-	5.2	5.3	5.6	5.9
Pressure after compressor (Absolute)	bar	-	4.3	4.0	3.5	2.5
Temperature after compressor	℃	-	195	185	160	125
Air temperature after cooler	℃	-	45	45	45	45
3. Exhaust gas data 1), 4)						
Mass flow	kg/kWh	-	5.3	5.5	5.7	6.1
Gas temperature after turbine	℃	-	385	395	415	445
4. Heat balance data 2)						
Charge air, stage 1 (High and low temperature)	kJ/kWh	-	675	615	495	235
Charge air, stage 2 (Low temperature)	kJ/kWh	-	230	235	245	270
Lubricating oil	kJ/kWh	-	535	540	630	830
Jacket cooling water	kJ/kWh	-	505	515	535	690
Exhaust gas	kJ/kWh	-	1785	1965	2215	2870
Radiation	kJ/kWh	-	135	140	150	170
5. Fuel consumption 3), 4)						
Specific fuel gas consumption	kJ/kWh	-	7343	7443	7672	8396
Specific pilot oil consumption	g/kWh	-	2.3	2.4	2.9	4.8
Total heat rate	kJ/kWh	-	7441	7545	7796	8601

<u>Remark</u>

Reference condition is based on ISO 3046-1 (turbocharger air inlet pressure 1 bar, intake air temperature 25℃, L.T cooling water temperature 25℃). The above values are based on IMO Tier III emission level on gas mode without selective catalyst reduction operation.

1) Mass flow tolerance ± 5 %, temperature tolerance ± 25℃ (50 % < load ≤ 110 %).
   Mass flow tolerance ± 10 %, temperature tolerance ± 35℃ (Load ≤ 50%).

2) Heat dissipation tolerance ± 10 % for cooler, ± 15 % for heat recovery.
   Additional heat for lube oil purification should be included. (30 kJ/kWh).

3) Specific fuel oil consumption tolerance + 5 % at 100 % load.
   Engine driven pumps attached : lubricating oil pump, high temperature cooling water pump, low temperature cooling water pump.
   Fuel gas based on natural gas, lower heating value 36 MJ/N㎥ (≒ 50 MJ/kg), min. methane number (MN) 80.
   The methane number of the fuel gas is to be calculated by using " AVL Methane version 3.20 " of AVL's software
   Pilot fuel oil based on marine diesel oil, lower calorific value 42700 kJ/kg.
   Warranted total heat rate at 100% load only.

4) When an engine is operated with exhaust gas after-treatment system (for example: SCR), the values may change to ensure the proper operation of after-treatment system.

Table 3.8 Engine performance data (Diesel mode - rated power : 500 kW / cylinder at 720 rpm)

Performance data		Engine load (%)				
		110	100	90	75	50
1. Cylinder data						
Cylinder output	kW	550	500	450	375	250
Mean effective pressure	bar	23.8	21.7	19.5	16.2	10.8
2. Combustion air data [1), 4)]						
Mass flow	kg/kWh	6.6	6.8	6.9	7.0	7.6
Air pressure (Absolute)	bar	5.8	5.3	5.0	4.3	3.0
Air temperature after cooler	℃	45	45	45	45	45
3. Exhaust gas data [1), 4)]						
Mass flow	kg/kWh	6.8	7.0	7.1	7.2	7.8
Gas temperature after turbine	℃	335	325	325	335	350
4. Heat balance data [2)]						
Charge air, stage 1 (High temperature)	kJ/kWh	945	900	850	795	495
Charge air, stage 2 (Low temperature)	kJ/kWh	260	265	280	300	310
Lubricating oil	kJ/kWh	615	605	605	680	850
Jacket cooling water	kJ/kWh	560	560	560	565	700
Exhaust gas	kJ/kWh	1995	2020	2025	1965	2255
Radiation	kJ/kWh	150	145	150	160	195
5. Specific fuel oil consumption [3), 4)]						
Specific fuel oil consumption	g/kWh	189	188	187	186	195

Remark

Reference condition is based on ISO 3046-1 (turbocharger air inlet pressure 1 bar, intake air temperature 25℃, L.T cooling water temperature 25℃). The above values are based on IMO Tier II emission level on diesel mode without selective catalyst reduction operation.

1) Mass flow tolerance ± 5 %, temperature tolerance ± 25℃ (50 % < load ≤ 110 %).
Mass flow tolerance ± 10 %, temperature tolerance ± 35℃ (Load ≤ 50%).
2) Heat dissipation tolerance ± 10 % for cooler, ± 15 % for heat recovery.
Additional heat for lube oil purification should be included. (30 kJ/kWh).
3) Specific fuel oil consumption tolerance + 5 % at 100 % load.
Engine driven pumps attached : lubricating oil pump, high temperature cooling water pump, low temperature cooling water pump.
Specific fuel oil consumption includes the pilot oil consumption and excludes clean leakage fuel oil.
Main fuel oil based on marine diesel oil, lower calorific value 42700 kJ/kg.
Specific fuel oil consumption is warranted at 75 % engine load without selective catalyst reduction operation.
4) When an engine is operated with exhaust gas after-treatment system (for example: SCR), the values may change to ensure the proper operation of after-treatment system.

Table 3.9 Engine performance data (Gas mode - rated power : 500 kW / cylinder at 720 rpm)

Performance data		Engine load (%)				
		110	100	90	75	50
1. Cylinder data						
Cylinder output	kW	-	500	450	375	250
Mean effective pressure	bar	-	21.7	19.5	16.2	10.8
2. Combustion air data [1), 4)]						
Mass flow	kg/kWh	-	5.2	5.3	5.6	5.9
Pressure after compressor (Absolute)	bar	-	4.3	4.0	3.5	2.5
Temperature after compressor	℃	-	195	185	160	125
Air temperature after cooler	℃	-	43	45	45	45
3. Exhaust gas data [1), 4)]						
Mass flow	kg/kWh	-	5.4	5.5	5.8	6.1
Gas temperature after turbine	℃	-	385	395	415	445
4. Heat balance data [2)]						
Charge air, stage 1 (High and low temperature)	kJ/kWh	-	650	590	475	225
Charge air, stage 2 (Low temperature)	kJ/kWh	-	220	225	235	260
Lubricating oil	kJ/kWh	-	535	540	630	830
Jacket cooling water	kJ/kWh	-	505	515	535	690
Exhaust gas	kJ/kWh	-	1850	2000	2240	2890
Radiation	kJ/kWh	-	135	140	150	170
5. Fuel consumption [3), 4)]						
Specific fuel gas consumption	kJ/kWh	-	7343	7463	7626	8329
Specific pilot oil consumption	g/kWh	-	2.3	2.4	2.9	4.8
Total heat rate	kJ/kWh	-	7441	7565	7750	8534

Remark

Reference condition is based on ISO 3046-1 (turbocharger air inlet pressure 1 bar, intake air temperature 25℃, L.T cooling water temperature 25℃). The above values are based on IMO Tier III emission level on gas mode without selective catalyst reduction operation.

1) Mass flow tolerance ± 5 %, temperature tolerance ± 25℃ (50 % < load ≤ 110 %).

Mass flow tolerance ± 10 %, temperature tolerance ± 35℃ (Load ≤ 50%).

2) Heat dissipation tolerance ± 10 % for cooler, ± 15 % for heat recovery.
Additional heat for lube oil purification should be included. (30 kJ/kWh).

3) Specific fuel oil consumption tolerance + 5 % at 100 % load.
Engine driven pumps attached : lubricating oil pump, high temperature cooling water pump, low temperature cooling water pump.

Fuel gas based on natural gas, lower heating value 36 MJ/N㎥ (≒ 50 MJ/kg), min. methane number (MN) 80.

The methane number of the fuel gas is to be calculated by using " AVL Methane version 3.20 " of AVL's software
Pilot fuel oil based on marine diesel oil, lower calorific value 42700 kJ/kg.
Warranted total heat rate at 75% load only.

4) When an engine is operated with exhaust gas after-treatment system (for example: SCR), the values may change to ensure the proper operation of after-treatment system.

3.4 Exhaust gas emission

3.4.1 General

HiMSEN H35DF is designed for environment-friendly engine and complies with the IMO NO_X emission limits with low fuel consumption and less smoke.
Typical composition of exhaust gas emission in volume ratio at full load are as follows:

Table 3.8 Typical compositions of exhaust gas emission

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

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

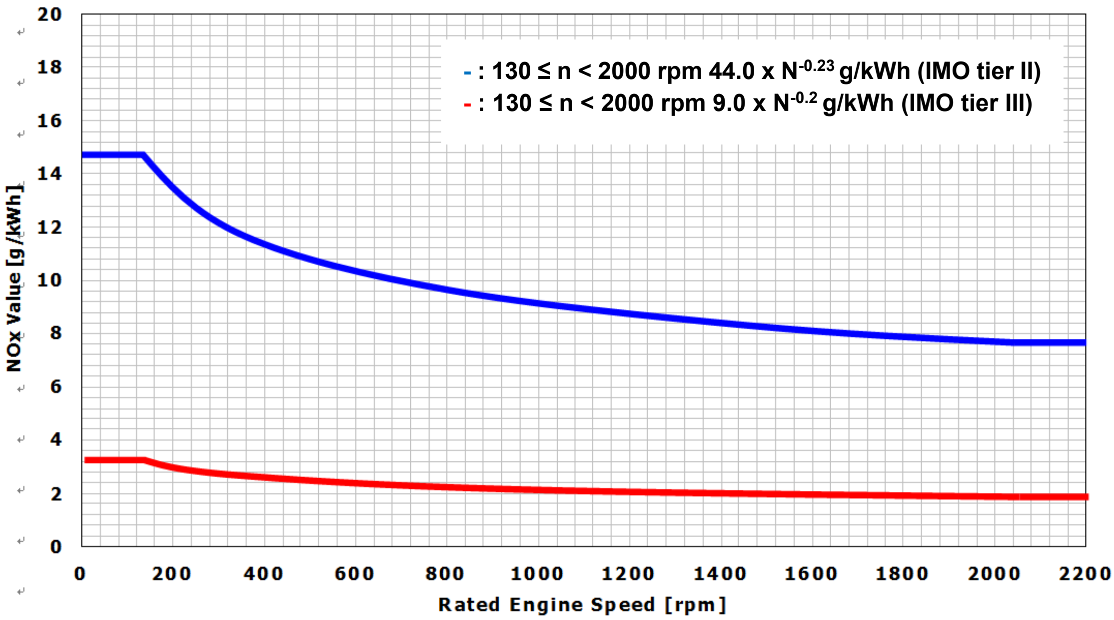
If there is no special requirements from customer regarding the exhaust gas emission, HiMSEN Generating-set shall be delivered with optimized performance conditions fulfilling the MARPOL 73/78 ANNEX VI, Regulation 13 of value of NO_X emissions.

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

3.4.2 Engine international air pollution prevention (EIAPP) certificates

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

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



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

Figure 3.3 IMO tier II and tier III limits

3.5 Power de-rating diagram

3.5.1 Gas operation

De-rating due to suction air temperature and altitude

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

NOx : IMO Tier III

Charge air coolant temperature : 36[℃]

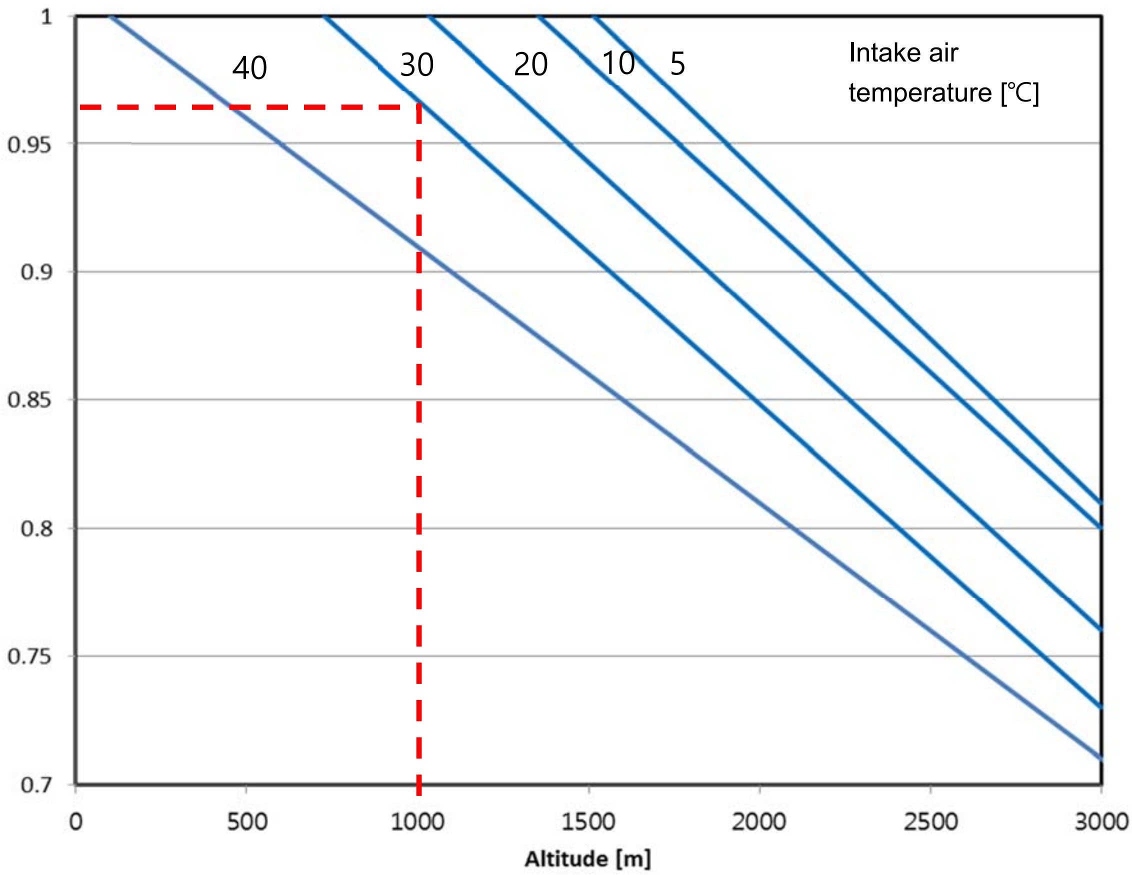


Figure 3.4 De-rating due to suction air temperature and altitude

1. Minimum suction air temperature is 5 ℃
2. Temperatures given above are maximum (continuous) operating temperature at site.
3. For intake air temperatures above 40 ℃ or charge air coolant temperatures above 36 ℃, please contact HHI-EMD.
4. All design modifications related to the combustion may change characteristics of power de-rating. For example; turbocharger specification, compression ratio of cylinder, external exhaust gas system and etc. Beside the power de-rating factors (ambient condition, charge air coolant, the fuel gas properties, the fuel gas supply condition and the supply gas pressure), can reduce the engine maximum power.

Example

Cooling water temperature before charge air cooler : 35 ℃

Suction air temperature : 30 ℃
Site altitude : 1000 m

From the power de-rating diagram, the power de-rating factor at actual operating condition is 0.96 therefore the engine output power at actual operating condition should be de-rated to the 96 % of the standard engine rated power.

The power de-rating diagram of dual fuel engine is usually determined by gas mode de-rating. Therefore, it has been evaluated for gas mode de-rating and the de-rating factors of diesel mode is not provided.

Minimum de-rating due to charge air temperature and methane number (MN)

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

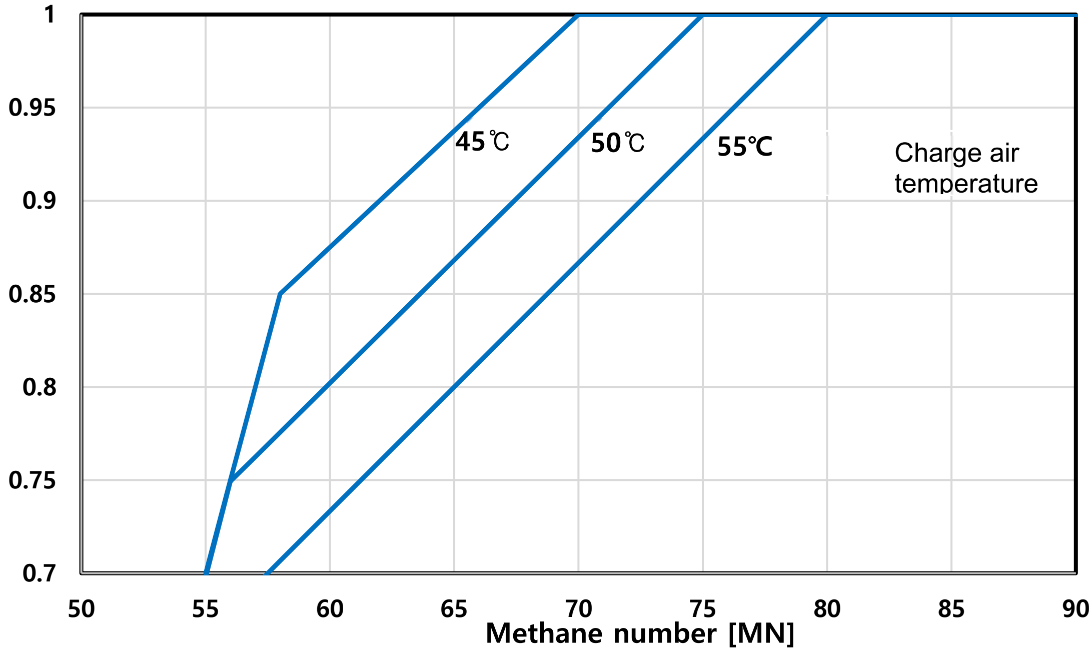


Figure 3.5 Minimum de-rating due to charge air temperature and methane number

100 % load operation of gas mode is possible when operating with min MN 70 gas fuel and below 45 ℃ of charge air temperature. In the case, the pilot oil consumption and total heat rate are permanently changed in gas mode operation.

De-rating due to gas lower calorific value (LCV) and gas feed pressure

Engine output power at maximum continuous rating shall be reduced depending on the gas lower heating value and gas feed pressure.

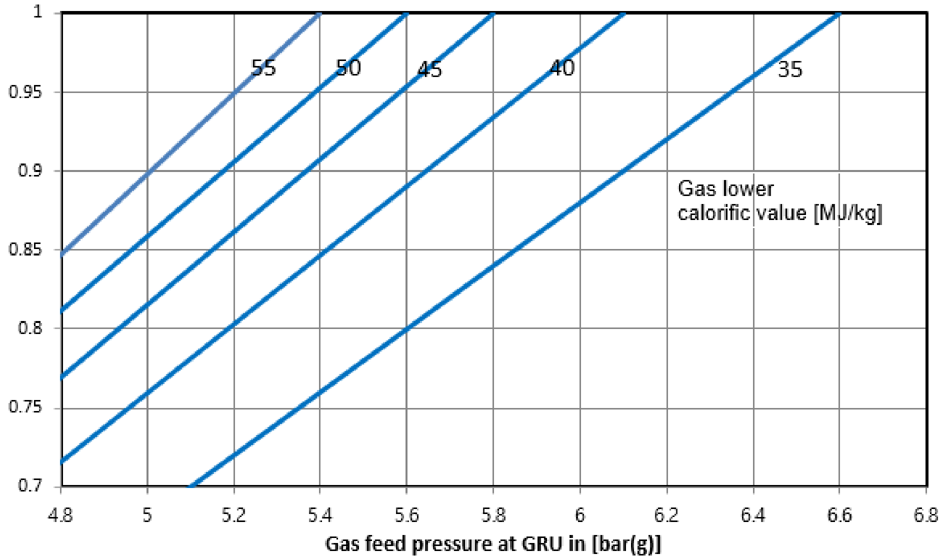


Figure 3.6 De-rating due to gas lower calorific value and gas feed pressure

Engine output power at maximum continuous rating shall be reduced depending on the charge air coolant temperature.

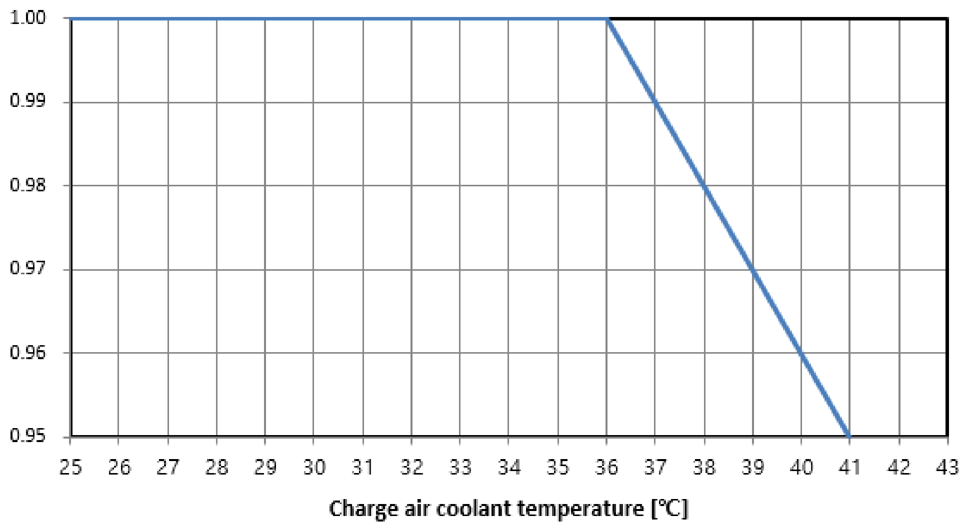


Figure 3.7 De-rating due to charge air coolant temperature

Engine output power at maximum continuous rating shall be reduced depending on the anti-freezing coolant volume.

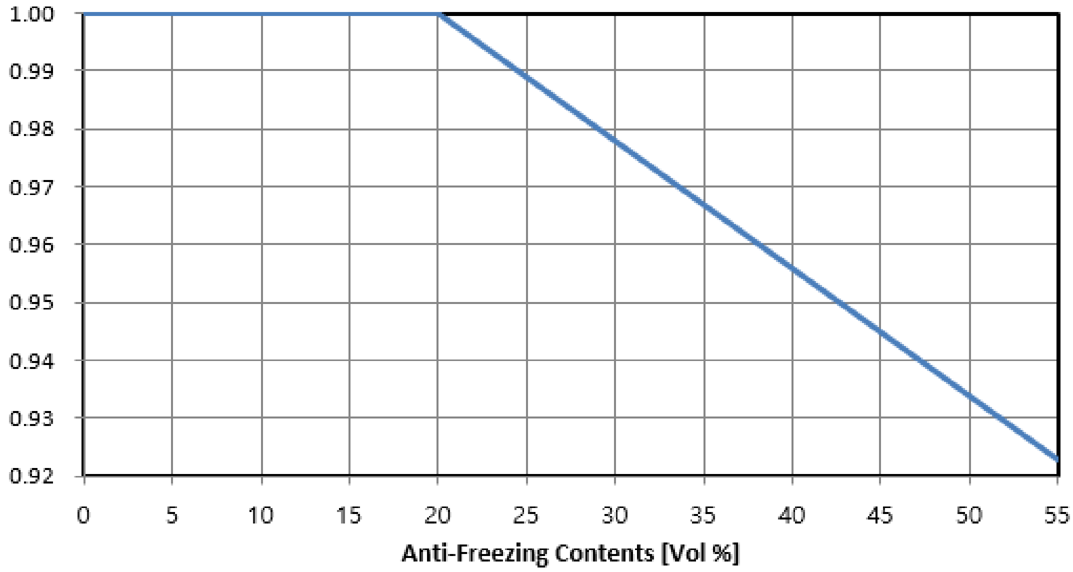


Figure 3.8 De-rating due to contents of anti-freezing coolant

When using anti-freezing coolant inevitably, it is recommended to use up to 55% maximum, because using anti-freezing coolant more than 55% of the total mixture does not affect further decrease of freezing point.

Table 3.9 Anti-freezing coolant, fresh water, freezing points

Anti-freezing coolant (Volume %)	20	25	30	35	40	45	50	55
Fresh water (Volume %)	80	75	70	65	60	55	50	45
Freezing Points (℃)	-10.5	-13.5	-16.5	-20.5	-26.5	-31.5	-37.5	-43.5

3.6 Correction of fuel oil consumption

3.6.1 Correction of ambient condition (Diesel operation)

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

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

Where :

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

Example,
Intake air temperature (T_{intake}) : 30 ℃, P_{amb} : 1000 (mbar)
Cooling water temperature (T_{cw}) : 30 ℃
Lower calorific value (LCV) : 42700 kJ / kg
$SFOC_{ISO}$: 183 g/kWh at 720 rpm, maximum continuous rating
then, dSFOC = 1.006 and the SFOC at site condition will be increased to 184.1 g / kWh.

3.6.2 Clean leak fuel oil

Clean leak fuel oil (recycling fuel oil) during engine operation is subtracted from measured fuel oil consumption.
(Refer to 6.2 Internal fuel oil system)

FOCamb = FOC - clean leak fuel oil *)

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

3.6.3 Correction of additional fuel oil consumption

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

Table 3.10 Correction of additional fuel consumption

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

When low and high temperature cooling water pump is attached on engine
Additional specific fuel oil consumption by water pump

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

When lubricating oil pump is attached on engine
Additional specific fuel oil consumption by lubricating pump

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

Table 3.11 Additional specific fuel oil consumption of each load

Load	100 ~ 25 %	Under 25 %
x	1.15	1.28

3.7 Correction of fuel gas consumption

3.7.1 General

Correction for ambient condition (Gas operation)

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 maximum continuous rating can be estimated according to the below mentioned 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

Effamb = EffISO x dEff
dEff = [100 - (Tintake- 25)*0.021 - (1000- Pamb)*0.0025 - (Tcharge- 45)*0.008] / 100

where :

Effamb : Engine efficiency at actual operating condition [%]
EffISO : Engine efficiency at ISO 3046-1 standard condition [%]
dEff : Deviation of the efficiency
Tintake : Intake air temperature at actual operating condition [℃]
Pamb : Ambient air pressure at actual operating condition [mbar]
Tcharge : Charged air temperature after charge air cooler(CAC) at actual operating condition [℃]

Notice)
1) Maximum value of dEff 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 ℃
Pamb : 990 [mbar]
Charge air temperature(Tcharge) : 47 ℃
EffISO : 48.38 [%] at 720[rpm], MCR (Total Heat rate : 7,441 [kJ/kWh])
then, dEff = 0.9985 and the efficiency (Effamb) 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.

3.7.2 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 [Nm3/h] = Heat rate [kJ/kWh] x Engine output [kW] / LCV [kJ/Nm3]
Mass flow of fuel gas [kg/h] = Volume flow of fuel gas [Nm3/h] x Density [kg/Nm3]

3.7.3 Correction of additional fuel gas consumption

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

Table 3.12 Correction of additional fuel gas consumption

Item	Additional heat [kJ/kWh]
Lubricating oil pump	+ 86
Low temperature cooling water pump.	+ 43
High temperature cooling water pump	+ 43
Fuel oil feed pump	Contact to HHI-EMD
Charge air pressure control device	Contact to HHI-EMD
400 mmWC > Exhaust gas back pressure after turbine > 240 mmWC (Gas mode*)	+ 120 Per 80 mmWC of Gas mode
Fuel gas with lower methane number (MN70)	+ 187

Remark)
*) The exhaust back pressure of the gas mode is defined as a value changed over from the diesel mode.
The maximum back pressure of gas mode is approximately the back pressure of diesel mode x 0.8.

LT & HT Pump attached engine(Genset & Propulsion)
Additional heat rate by water pump =
Additional heat rate at 100% load * (100/Load)^x * (actual rpm/nominal rpm)^3 [g/kWh]

LO Pump attached engine(Genset & Propulsion)
Additional heat rate by LO pump =
Additional heat rate at 100% load * (100/Load)^x * (actual rpm/nominal rpm) [g/kWh]

Table 3.13 Additional specific fuel gas consumption of each load

Load	100 ~ 25 %	Under 25 %
x	1.15	1.28

3.8 Correction of exhaust gas temperature

3.8.1 General

Correction for ambient condition

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

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

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

where :

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

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

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

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

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

Example,

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

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

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

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

4 Dynamic characteristics and noise

4.1 External forces and couples

Table 4.1 External forces and couples (Diesel mode)

Engine type	Speed	External forces and moments				Guide force moments		
		Order		Moment		Order		Moment
				Horizontal	Vertical			
	rpm	No.	Hz	kNm	kNm	No.	Hz	kNm
6H35DF	720	1	12.0	0.0	0.0	3	36.0	24.8
		2	24.0	0.0	0.0	6	72.0	18.7
	750	1	12.5	0.0	0.0	3	37.5	21.3
		2	25.0	0.0	0.0	6	75.0	18.7
7H35DF	720	1	12.0	2.0	30.8	3.5	42.0	68.1
		2	24.0	0.0	25.4	7	84.0	13.8
	750	1	12.5	2.2	33.4	3.5	43.8	68.1
		2	25.0	0.0	27.5	7	87.5	13.8
8H35DF	720	1	12.0	0.0	0.0	4	48.0	55.7
		2	24.0	0.0	0.0	8	96.0	10.2
	750	1	12.5	0.0	0.0	4	50.0	55.3
		2	25.0	0.0	0.0	8	100.0	10.2
9H35DF	720	1	12.0	1.5	22.5	4.5	54.0	54.8
		2	24.0	0.0	13.8	9	108.0	7.6
	750	1	12.5	1.6	24.4	4.5	56.3	54.8
		2	25.0	0.0	15.0	9	112.5	7.6

Table 4.2 External forces and couples (Gas mode)

Engine type	Speed	External forces and moments				Guide force moments		
		Order		Moment		Order		Moment
				Horizontal	Vertical			
	rpm	No.	Hz	kNm	kNm	No.	Hz	kNm
6H35DF	720	1	12.0	0.0	0.0	3	36.0	21.0
		2	24.0	0.0	0.0	6	72.0	17.7
	750	1	12.5	0.0	0.0	3	37.5	17.6
		2	25.0	0.0	0.0	6	75.0	17.7
7H35DF	720	1	12.0	2.0	30.8	3.5	42.0	64.0
		2	24.0	0.0	25.4	7	84.0	13.1
	750	1	12.5	2.2	33.4	3.5	43.8	64.0
		2	25.0	0.0	27.5	7	87.5	13.1
8H35DF	720	1	12.0	0.0	0.0	4	48.0	52.3
		2	24.0	0.0	0.0	8	96.0	9.8
	750	1	12.5	0.0	0.0	4	50.0	52.0
		2	25.0	0.0	0.0	8	100.0	9.8
9H35DF	720	1	12.0	1.5	22.5	4.5	54.0	51.8
		2	24.0	0.0	13.8	9	108.0	7.5
	750	1	12.5	1.6	24.4	4.5	56.3	51.8
		2	25.0	0.0	15.0	9	112.5	7.5

4.2 Moment of inertia

Table 4.3 Moment of inertia

Engine type	Speed	Rating	Moments of inertia ; J 1)				
			Engine MOI	Flywheel		Alternator MOI 2)	Total MOI
				MOI	Mass		
	rpm	kW	kgm^2	kgm^2	kg	kgm^2	kgm^2
6H35DF	720	2880	400.4	60.0	276.0	508.9	969.3
	750	2880	400.4	60.0	276.0	508.9	969.3
7H35DF	720	3360	458.8	400.0	1633.0	563.0	1421.8
	750	3360	458.8	400.0	1633.0	563.0	1421.8
8H35DF	720	3840	517.1	190.0	809.0	704.0	1411.1
	750	3840	517.1	190.0	809.0	704.0	1411.1
9H35DF	720	4320	575.5	60.0	276.0	704.0	1339.5
	750	4320	575.5	60.0	276.0	704.0	1339.5

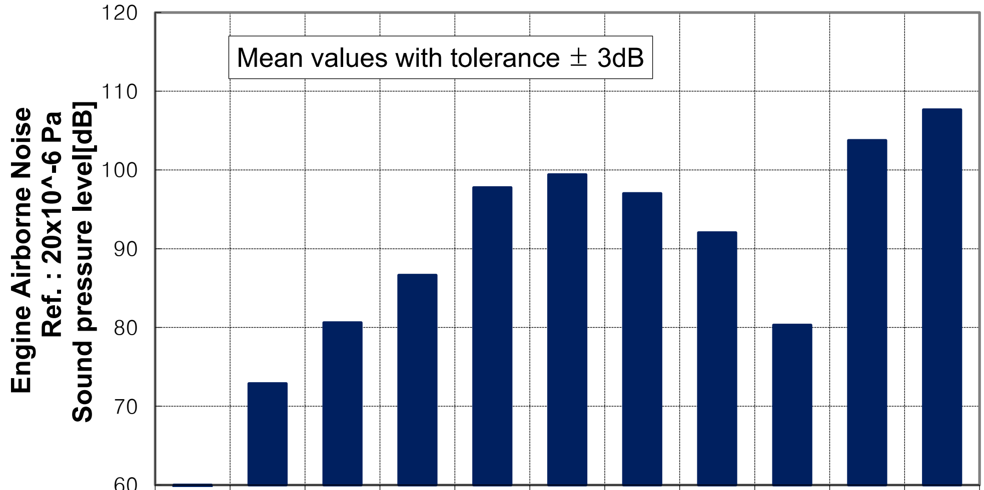
1) Moment of Inertia : $GD^2 = 4 \times J$ (kgm^2)
2) Recommended values, the case of different MOI should be confirmed by a torsional vibration analysis.

4.3 Noise measurement

4.3.1 General description

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

720 rpm (Diesel mode)

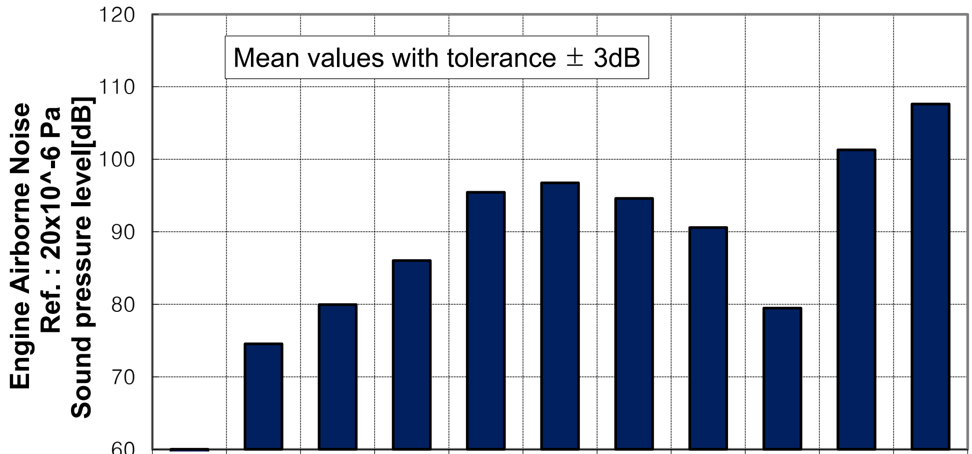


	31.5	63	125	250	500	1k	2k	4k	8k	A	L
Engine Airborne	0	73	81	87	98	99	97	92	80	104	108

Octave band center frequency[Hz]

Figure 4.1 Engine air airborne noise level (Diesel mode)

720 rpm (Gas mode)



	31.5	63	125	250	500	1k	2k	4k	8k	A	L
Engine Airborne	0	75	80	86	95	97	95	91	79	101	108

Octave band center frequency[Hz]

Figure 4.2 Engine air airborne noise level (Gas mode)

5 Operation and control system

5.1 Engine operation

5.1.1 General

HiMSEN dual fuel engine is able to run in both diesel oil fuel and gas fuel.

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

5.1.2 Engine fuel mode

Diesel mode

- ✓ Diesel fuel and pilot fuel system active.
- ✓ Diesel fuel is injected by conventional injection system and the actuator adjusts the amount of fuel injection.
- ✓ Pilot fuel system is electrically controlled by common rail system.
- ✓ When manually selected or gas mode operation is not available (gas trip condition).

Gas mode

- ✓ Gas fuel and pilot fuel system active.
- ✓ Gas fuel is electronically injected by gas admission valve and the amount of gas injection is adjusted by its opening duration.
- ✓ When manually selected.
- ✓ MSS (Methane slip solution) operation[1)] for reducing CH4 slip.
  MSS operation is available for low load condition if predefined conditions are satisfied in gas mode.

Backup mode operation

- ✓ Only diesel fuel system active. (Heavy fuel oil / marine diesel oil / marine gas oil)
- ✓ In heavy fuel oil application, maximum backup mode operation time : 30 minutes
- ✓ In marine diesel oil, marine gas oil application, maximum backup mode operation time : 10 hours
- ✓ In case, backup mode operation exceeds the above specified time, abnormal conditions (blocking of injection hole or wear) of the micro pilot injector may occur by backup mode which not activate pilot injection system. After backup mode operation, Engine & Auxiliary facility check is required if necessary.

1) Description for MSS operation is excluded in this document.
Contact HHI-EMD for detailed information of MSS operation.

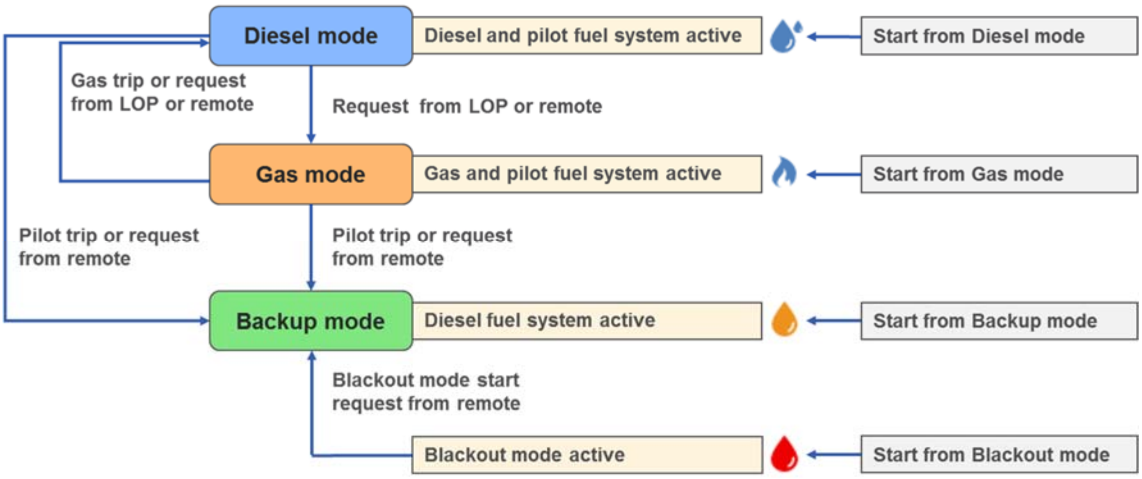


Figure 5.1 Engine fuel mode

Fuel mode can be selected from

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

The Gas and pilot trip condition is specified in safety list.

5.1.3 Starting condition

Normal starting condition

Lubricating oil

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

Cylinder cooling water

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

Combustion Air

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

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

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

Fuel gas

- ✓ Temperature : 0 ~ 50 ℃
- ✓ Refer to Figure 5.2 for required gas pressure.

Emergency cold starting condition

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

Cooling water : minimum 15 ℃

Lubricating oil : minimum 10 ℃, pre-lubricated
(Approx.1,000 cSt based on SAE 40)

Intake air temperature : minimum 0 ℃

Required gas supply pressure

Gas supply pressure can be interpolated in case of 36 MJ / Nm^3 and 28 MJ / Nm^3 of gas lower heating value as Figure 5.2. The gas supply pressure at gas regulating unit inlet, G11 (See the diagram Figure 6.7) should be considered as followings;

1) Pressure loss at the GRU (Generally, 0.6 bar can be used.)
2) Pressure loss in the pipe between GRU and engine.

The fuel gas specification should be satisfied the requirements in the Table 6.17. Admissible gas supply pressure fluctuation : Less than 0.1 bar / sec of pressure variation (peak ±0.5 bar) can be absorbed in gas regulating unit and no effect on engine operation. The supplied gas pressure with deviation should be set higher than the required gas pressure at corresponding engine operating condition.

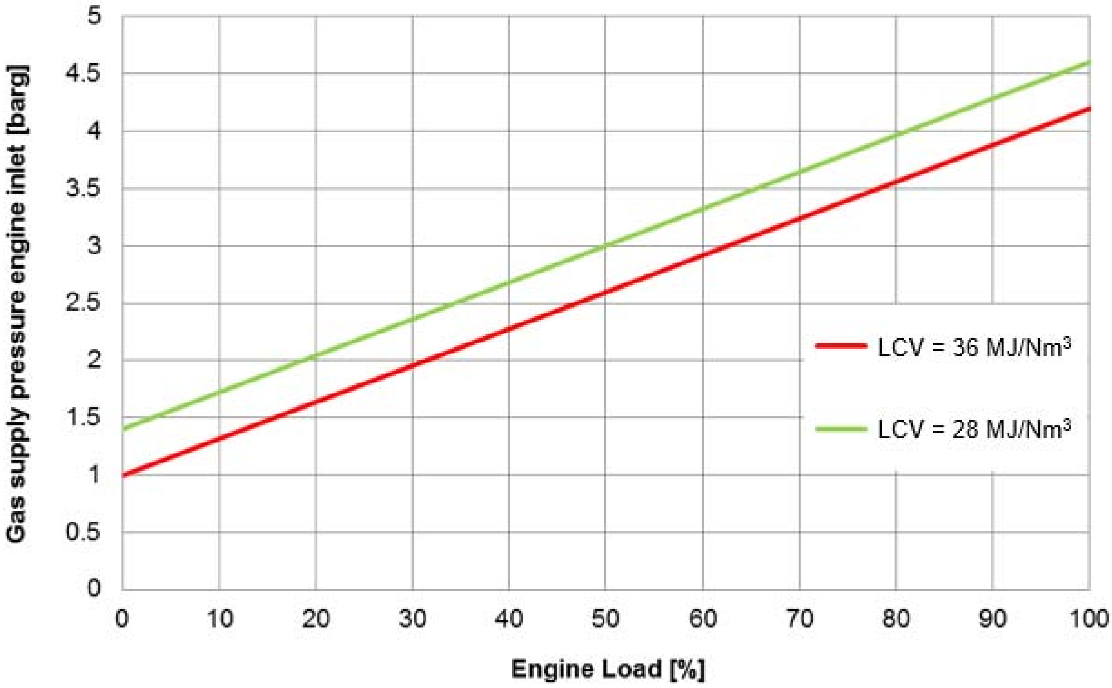


Figure 5.2 Gas supply pressure at engine inlet

5.1.4 Engine start

Engine start ready

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

Start block signals

- ✓ Lubricating oil pressure at engine inlet low
- ✓ Starting air pressure engine inlet low (Option)
- ✓ High temperature cooling water at engine inlet low (Option)
- ✓ Turning gear engaged
- ✓ Slow turning failure
- ✓ Engine speed high before start
- ✓ Exhaust gas vent sequence in active
- ✓ Low inert gas pressure during engine shutdown sequence (Gas natural ventilation in progress)
- ✓ Start block in test mode
- ✓ Start block from remote system

Engine start at different fuel mode

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

Start from each fuel mode is available when predefined condition for selected fuel mode is satisfied

Engine start at diesel mode

- ✓ For diesel mode start, there should not be any pilot trip condition before start.
- ✓ Compressed air is directly injected to the combustion chamber and initial firing is made by main diesel fuel injection.
- ✓ As soon as combustion chamber is fired and speed is quickly increased, the starting air injection is deactivated.
- ✓ At idle speed, pilot injection test is performed. Idle speed is normally 500 rpm.
- ✓ During pilot injection test, engine run only by pilot fuel injection and check each cylinder's exhaust gas temperature or indicated mean effective pressure.
- ✓ If all conditions are satisfied, the speed is ramp up to rated speed automatically.
- ✓ Circuit breaker can be closed after about 1.0 min. from diesel mode start.

Engine start at gas mode

- ✓ For gas mode start, there should not be any gas trip condition before start.
- ✓ Compressed air is directly injected to the combustion chamber and initial firing is made by main diesel fuel injection. Even at gas mode start, the fuel is initiated by diesel fuel until reaching idle speed.
- ✓ As soon as combustion chamber is fired and speed is quickly increased, the starting air injection is deactivated.
- ✓ At idle speed, pilot injection test is performed idle speed is normally 500 rpm
- ✓ During pilot injection test, engine run only with pilot fuel injection and check each cylinder's exhaust gas temperature or indicated mean effective pressure.
- ✓ If pilot fuel injection test is successfully completed, the gas valves are open and after predefined CH4 purging delay, gas is injected and gas fuel takes over diesel fuel.
- ✓ The engine speed is ramp up to rated speed automatically.
- ✓ Circuit breaker can be closed after about 2.5 min. from gas mode start

Engine start at backup mode

- ✓ Backup mode start will be initiated in any case of start under pilot trip condition or emergency situation e.g. blackout start.
- ✓ Compressed air is directly injected to the combustion chamber and initial firing is made by main diesel fuel injection.
- ✓ As soon as combustion chamber is fired and speed is quickly increased, the starting air injection is deactivated.
- ✓ Pilot injection test is skipped at backup mode
- ✓ The engine speed is ramp up to rated speed automatically.
- ✓ Circuit breaker can be closed after about 20 sec. from backup mode start.
- ✓ If blackout start mode is activated, start block conditions as below are overridden and engine is operated on backup mode.

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

- ✓ The speed is increased without staying in idle speed and reach to rated speed as fast as possible.

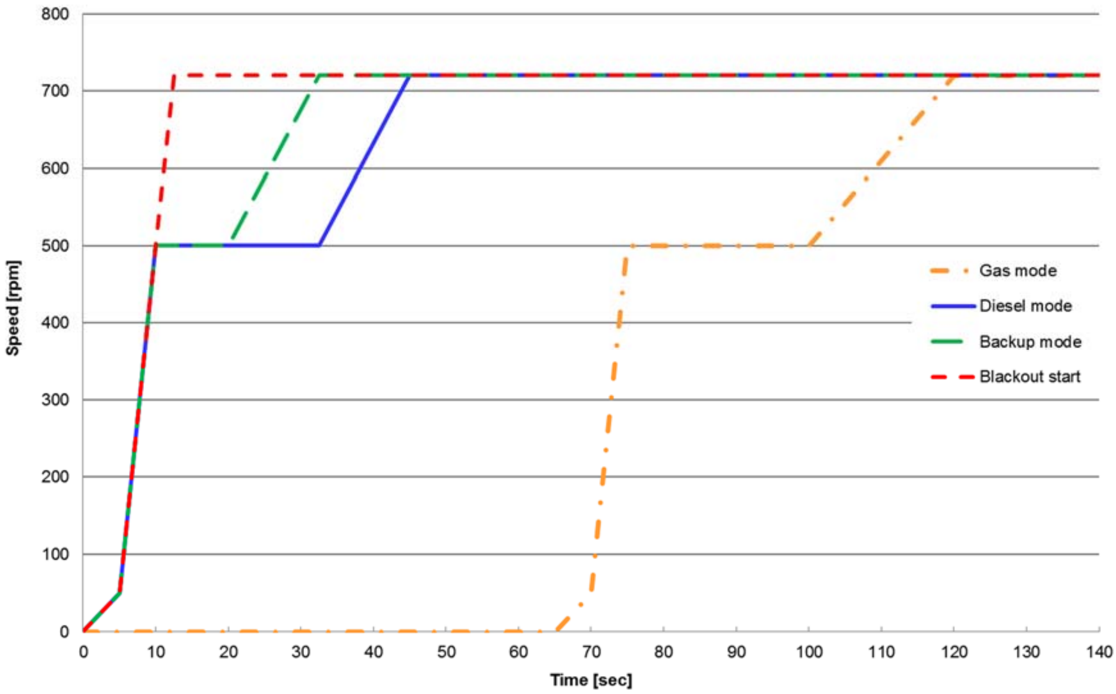


Figure 5.3 Engine start at different fuel mode

5.1.5 Restriction for low load operation

Idle running

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

Long term low load operation

Gas and marine diesel oil and marine gas oil operation

- ✓ Over 15 % load operation : no restriction
- ✓ Below 15 % load operation : load up over 70 % load at every limited time at corresponding load in Figure 5.4.

Heavy fuel oil operation

- ✓ Over 20 % load operation : no restriction
- ✓ Below 20 % load operation : load up over 70 % load at every limited time at corresponding load in Figure 5.4.

Duration of flushing operation (See Figure 5.4)

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

Example

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

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

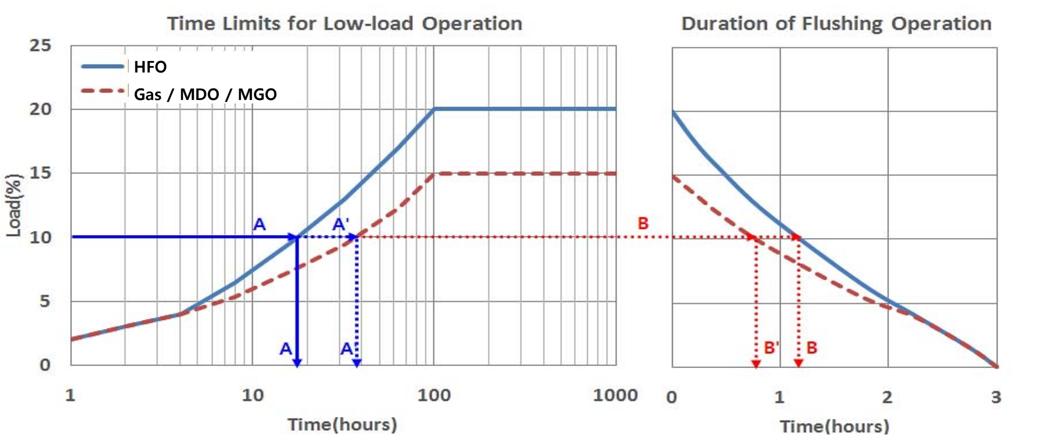


Figure 5.4 Time limits for low load operation

5.1.6 Engine load-up

HiMSEN engines fulfill all requirements regarding the load application of all major classification societies and IACS at diesel mode.
At gas mode, both continuous and step by step load up should be taken carefully for stable and safe operation of engine.

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

Continuous load-up

The continuous load up capacity at each fuel mode is referred in Figure 5.5

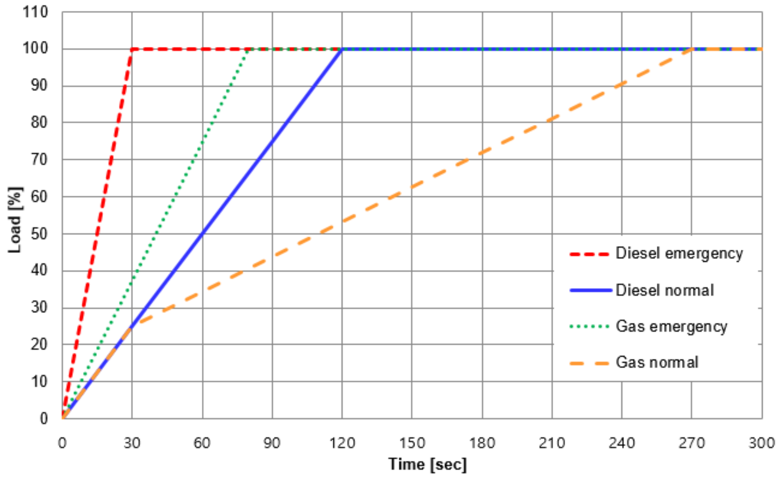


Figure 5.5 Engine load up capacity in ramp

Diesel mode

At warm condition, the 100 % load can be achieved in 2 min. by continuous ramping up at normal condition. At emergency condition, the load can be more quickly increased to 100 % in 30 sec.

Gas mode

At warm condition, the 100 % load can be achieved in 270 sec. by continuous ramping up at normal condition. For fast loading, the load can be more quickly increased to 100 % in 80 sec.
It should be taken into account that load increase at gas mode need to be more careful. 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.

Step by step load-up

Considering the time and safety required for stabilizing the frequency due to sudden load up, it is recommended to load up from idle to full load by more than three steps in diesel mode and five steps in gas mode. Frequency deviation and recovery time when loading up by step is referred in Figure 5.6 and Figure 5.7. At gas mode, the amount of load step is decreased at high load due to the higher knock tendency at high load.

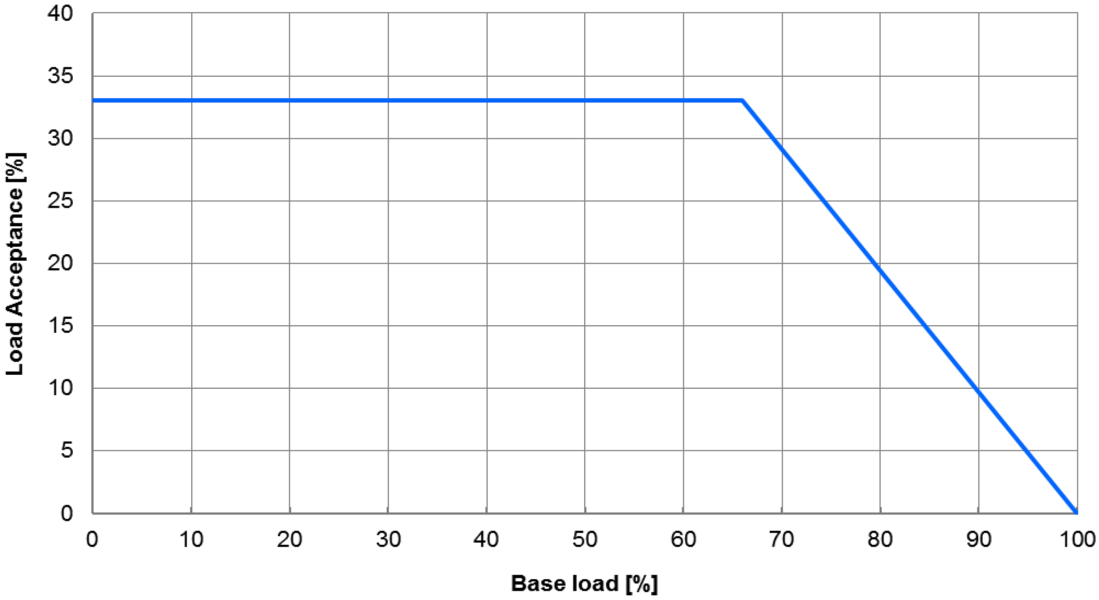


Figure 5.6 Step load acceptance at diesel mode

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

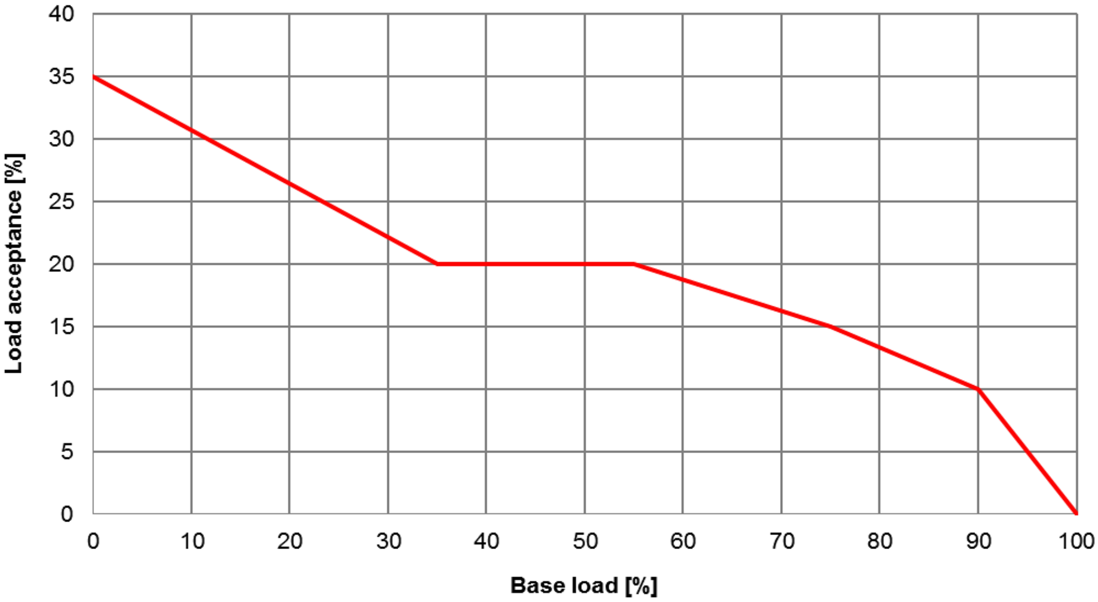


Figure 5.7 Step load acceptance at gas mode

1. Max instant load step: 0 – 35 – 55 – 75 – 90 - 100
2. Max speed variation ≤ 10 %
3. Steady-state speed band ≤ 1.5 %
4. Recovery time ≤ 5 sec
5. Time between next load step ≥ 15 sec

5.1.7 Fuel mode changeover

HiMSEN dual fuel engine operation at diesel or gas mode is possible when predefined condition for each mode is satisfied.
Fuel mode changeover is available from

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

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

From gas to diesel mode

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

From diesel to gas mode

- ✓ Changeover is available at load range of 0 % ~ 80 %
- ✓ Gas leakage test is performed before changeover.
- ✓ Changeover takes approx. 2 min. including gas leakage test (Refer to Figure 5.9).
- ✓ In order to change over heavy fuel oil to gas operation, marine diesel oil / marine gas oil flushing operation is required.

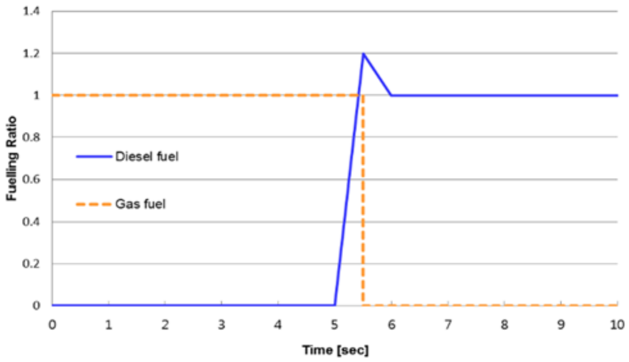


Figure 5.8 Fuel mode changeover from gas to diesel

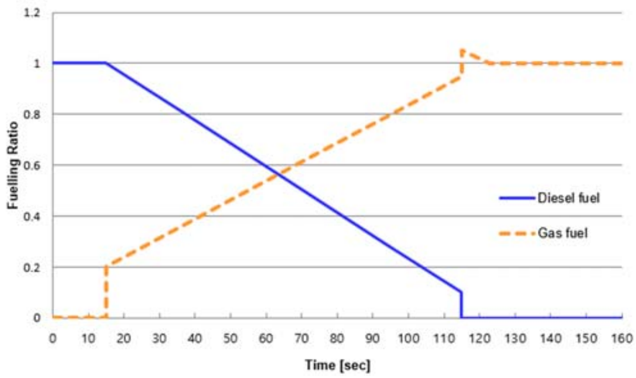


Figure 5.9 Fuel mode changeover from diesel to gas

5.1.8 Engine stop

Normal stop

When stop command is activated at gas mode, the fuel mode is automatically changeover to diesel mode. Before engine stop, the engine will run at cool-down speed to dissipate the heat of engine. After cool-down phase, the fuel rack goes back to zero position and the pilot injection system is activated until predefined speed in order to prevent clogging on nozzle holes by carbon deposits.

Engine shutdown

When the engine enters predefined shutdown condition due to certain abnormality, the engine is stopped immediately and the circuit breaker is opened automatically without de-load.
If the engine is shutdown at gas mode operation, the shut-off valves and venting valves in gas regulating unit are activated and gas supply pipe on engine is purged with inert gas.
The pilot injection system is active until predefined speed to burn the rest of gas in chamber. After the engine stop from gas mode, the external exhaust gas system should be ventilated and blow-out by exhaust gas ventilation unit during certain time to prevent unexpected explosion of unburned gas. And before completion of this sequence, the engine start is blocked.
If the engine is shutdown at diesel mode operation, solenoid valve or stop air cylinder is activated so that it pushes fuel rack to move zero position.
At both shutdown phases from gas and diesel mode, the pilot injection system is activated except the cases that overspeed and/or malfunction of both speed pick up sensors. In this case, the pilot injection system is deactivated at once.

Emergency stop

When emergency stop signal is entered from local operating panel and/or remote system by activating the switch signal, the engine will be stopped immediately.
The stop sequence is similar with shutdown except that pilot injection system is deactivated at once in emergency stop case.

5.1.9 Engine safety

The HiMSEN dual fuel engine control system monitors the signals from all sensors on engine and takes an appropriate action against abnormality of engine for safe operation. All engine reaction including limit value and delay defined in HiMSEN dual fuel engine control system.
HiMSEN dual fuel engine control system fulfills and satisfies redundant and independent safety function against critical shutdown conditions. HiMSEN dual fual engine control system implements safety functions written in next Figure 5.10 describes layout of HiMSEN dual fuel engine safety system.

Alarm

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

Start block

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

Load reduction

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

Gas trip

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

Pilot trip

Engine control system release alarm message and the fuel mode is transferred from gas (diesel) to backup mode. The pilot trip condition has to be cleared before go back to gas fuel mode
If pilot trip is released, gas fuel mode is blocked due to former backup mode operation.
And, pilot fuel injection test has to be performed by restart in order to clear gas mode block.

Shutdown

Engine control system release shutdown message and the engine is shutdown after predefined delay. Pilot injection system is alive until injection-off speed to burn the rest of gas in combustion chamber.

Emergency stop

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

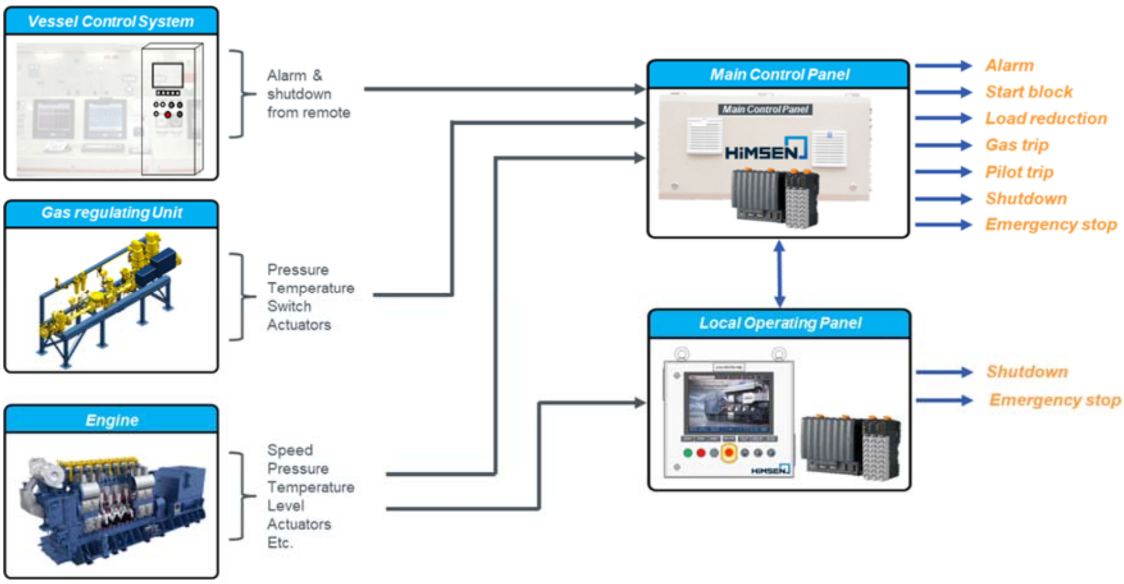


Figure 5.10 H35DF engine safety function layout

5.2 Engine control system

5.2.1 General

The HiMSEN DF ECS (Engine Control System), performs the complete engine management with all marine application of HiMSEN 4-stroke dual fuel engines.

For the V-type engine application, only fuel injection driving and sensing part for extended cylinder will be added and main controller will stay in identical with in-line engine. The applications of HiMSEN DF ECS (Engine Control System) shall be marine auxiliary generator engine and multiple propulsion engines.

Since all HiMSEN DF(Dual Fuel) engines shall be equipped with double wall gas piping system, machinery space is regarded as 'gas safe area' and thus HiMSEN DF(Dual Fuel) ECS (Engine Control System) is not required to be explosion proof design.
However based on explosion zone definition of the engine and auxiliary components, some signals can be interfaced with IS barrier.

The HiMSEN DF ECS mainly consists of MCP (Main control panel), ICM (Injection Control Module integrated with Cylinder Monitoring Module), KMM (Knock Monitoring Module / Optional applied), IOP (Input & Output Panel), LOP (Local Operating Panel), and ACP (Auxiliary Control Panel)

HiMSEN DF ECS is responsible for operation, full monitoring of engine and safety function.
All sensors and actuators are connected and dedicated actions are taken for more optimized and safe operation condition.

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

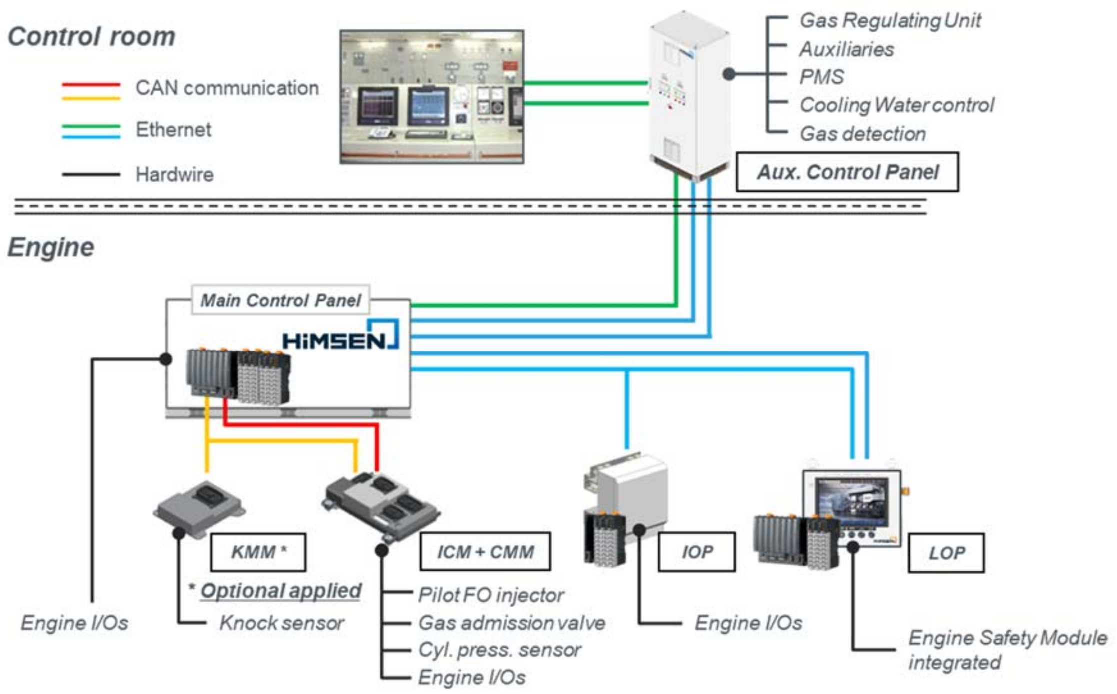


Figure 5.11 HiMSEN DF ECS overview

5.2.2 Hardware description

Main Control Panel (MCP)

MCP is the central control unit of HiMSEN DF ECS which consists of the main processor module for engine control and I/O modules for communication and I/O interfaces.
MCP is mounted directly on the engine and interfaced with all other panels and modules of HiMSEN DF ECS and all instruments on engine for control and monitoring.

- ✓ 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 DF engine
  - Engine safety control
  - Engine control and safety parameter tuning

Injection Control Module (ICM + CMM)

ICM is integrated with Cylinder Monitoring Module (CMM).
ICM is mounted on the engine and connected to gas admission valves, pilot fuel injectors, exhaust gas temperature sensor and cylinde pressure sensor on each cylinder.
CMM is integrated as stack on ICM 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
  - Driving gas admission valve
  - Driving pilot fuel injector
  - Actuating high pressure pump for pilot fuel oil
  - Measurement and process of engine I/O and

- ✓ Transmit data to MCP for control
  - Measurement and process of cylinder pressure signal and transmit data to MCP for control
  - Calculation of combustion characteristics and knock intensity

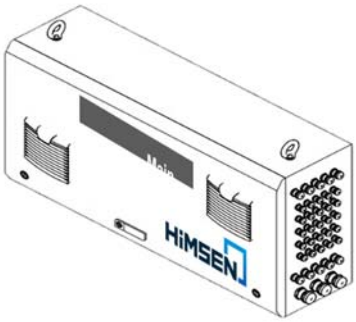


Figure 5.12 Main control panel

Figure 5.13 Injection control module

Knock Monitoring Module (KMM)

When knock sensor is installed, they are connected to KMM (Knock Monitoring Module) and it calculates the knock intensity and send the information to MCP (Main Control Panel) for knock control.

✓ Location : Mounted on engine(1 set per engine : Optionally applied)

✓ Responsible for
- Measurement and process of knock signal
- Calculation of knock intensity
- Transmission of data to MCP for control

Local Operating Panel (LOP)

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

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

✓ Consist of
- Touch screen HMI PC
- Switches and buttons for engine operation
- Engine Safety Module (ESM)

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

Figure 5.14 Knock monitoring module

Figure 5.15 Local operating panel

Input Output Panel (IOP)

IOP (Input Output Panel) is the control unit of HiMSEN DF ECS which consists of Input, Output processor module for engine control and modules for communication and I/O interfaces.
IOP is mounted directly on the engine and interfaced with all other panel and module of HiMSEN DF ECS and instruments on engine for control and monitoring.

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

- ✓ Responsible for
  - Measurement and process of engine I/O
  - Transmit data to MCP for control

Auxiliary Control Panel (ACP)

ACP (Auxiliary Control Panel) is normally installed in ECR (Engine control room) as self-standing cabinet.
ACP is in charge of not only GRU and cooling water control but also interface with VCS, MSB and PMS via communication and hard-wire.

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

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

- ✓ Responsible for
  - Control of GRU and cooling water valve
  - Engine status indication via lamp
  - Emergency stop button
  - Interface with MSB, PMS and VCS

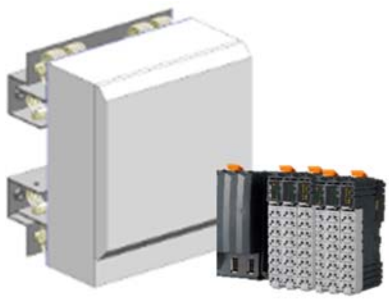


Figure 5.16 Input output panel

Figure 5.17 Auxiliary control panel

5.2.3 Local and remote operation of engine

Engine operation at local (Engine)

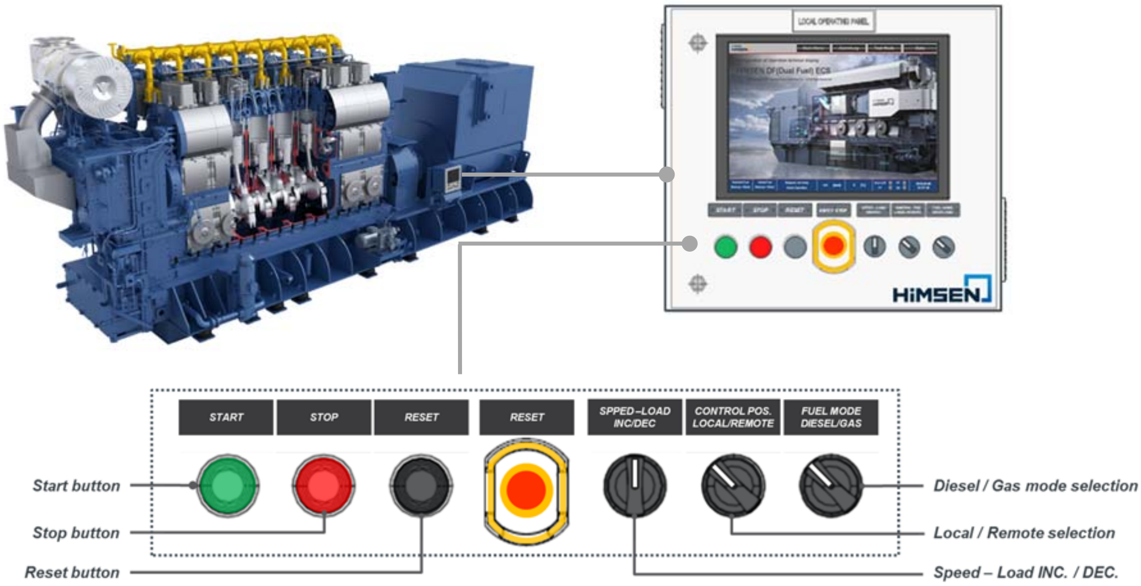


Figure 5.18 Engine operation at local

Engine operation at Remote (VCS or PMS / MSB)

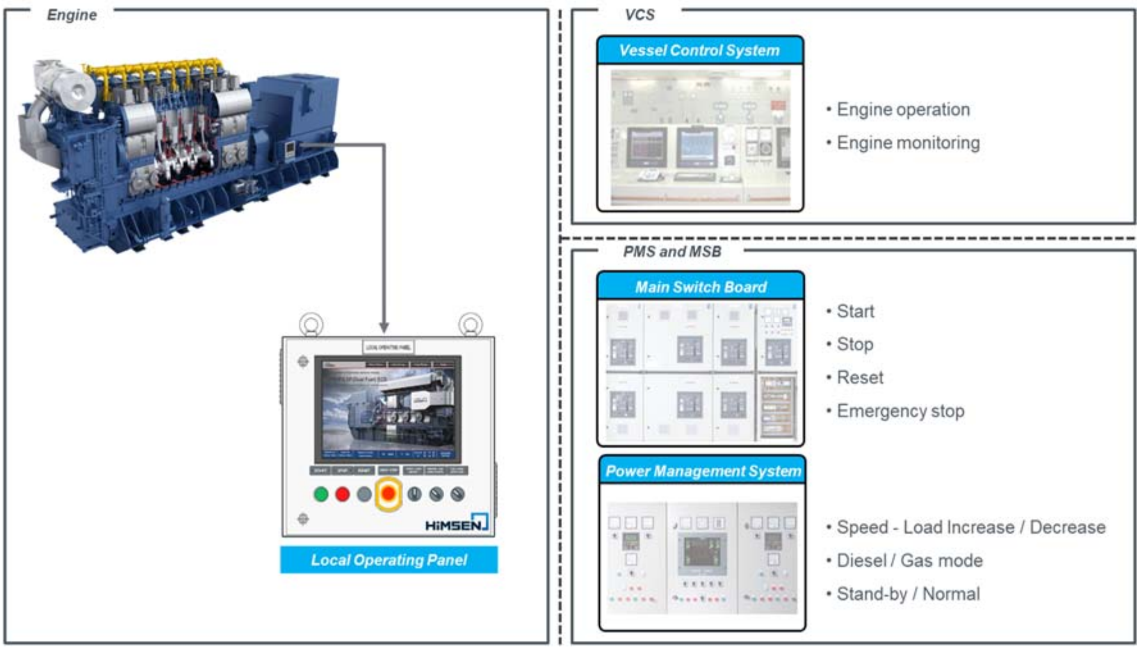


Figure 5.19 Engine operation at remote (VCS or PMS / MSB)

5.2.4 Functional description

Speed control

At gas fuel mode, ECS regulate the duration of gas admission valve for speed & power control.
At diesel fuel mode, ECS regulate the diesel actuator to adjust the amount of fuel to main fuel injector.

Air Fuel ratio control

AFR is controlled by adjusting the opening ratio of wastegate. The wastegate control the amount of bypassed gas of exhaust gas to turbocharger.

The operating point shall be defined by charged air pressure at each load point.

Pilot fuel injection control

In HiMSEN DF engine, pilot injection is ignition source of combustion. Pilot fuel injection system is common rail electronic fuel injection system.
ECS should control pilot fuel injection timing and duration of electronic pilot fuel injector and pilot fuel injection pressure of HP pump.

Fuel gas pressure and valve control

HiMSEN DF 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 DF ECS.
This control function guarantees sophisticated anti-knocking control and cylinder combustion balancing control.

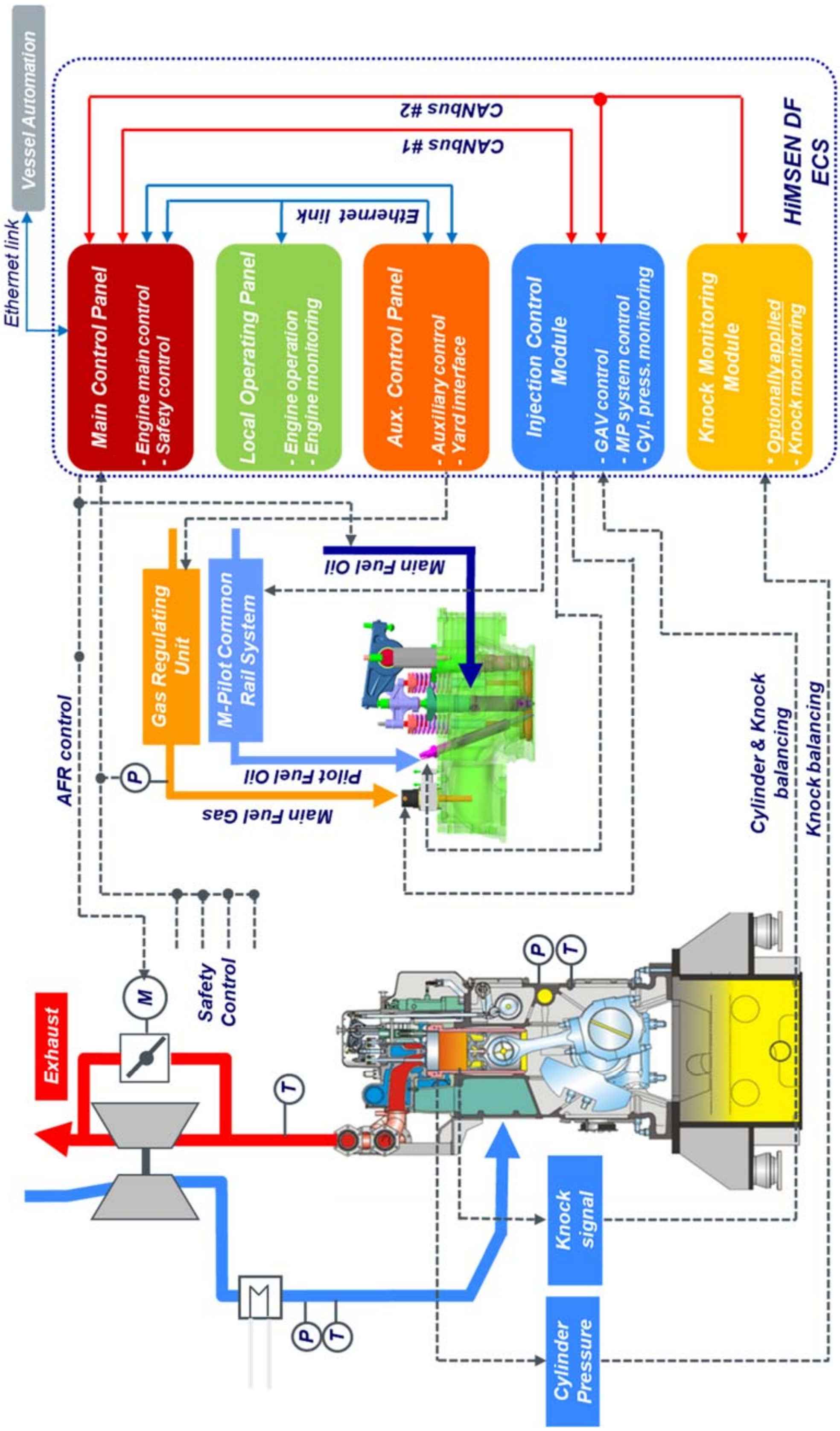


Figure 5.20 Overview of HiMSEN DF engine control function

5.3 Outline of engine automation

5.3.1 General

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

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

Refer to Fig. 5.21 for system schematic of the external interface.

This information is only for reference with single engine diagram.

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

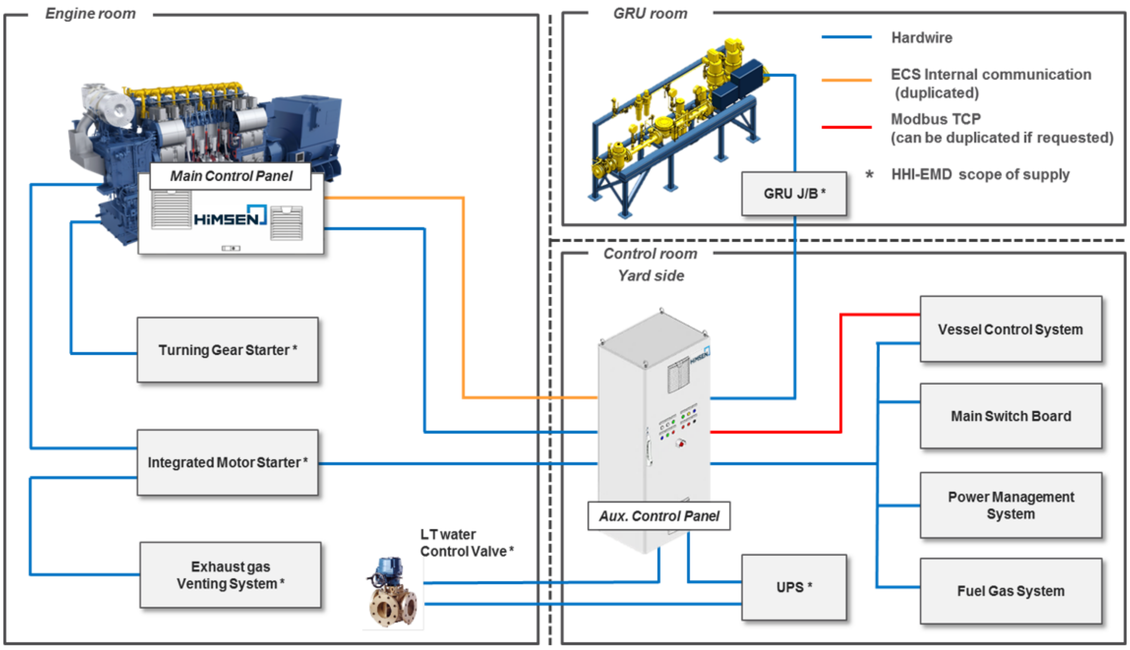


Figure 5.21 HiMSEN DF ECS external interface (system schematic)

5.3.2 Communication interface

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

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

Refer to Fig. 5.22 for concept of system bus.

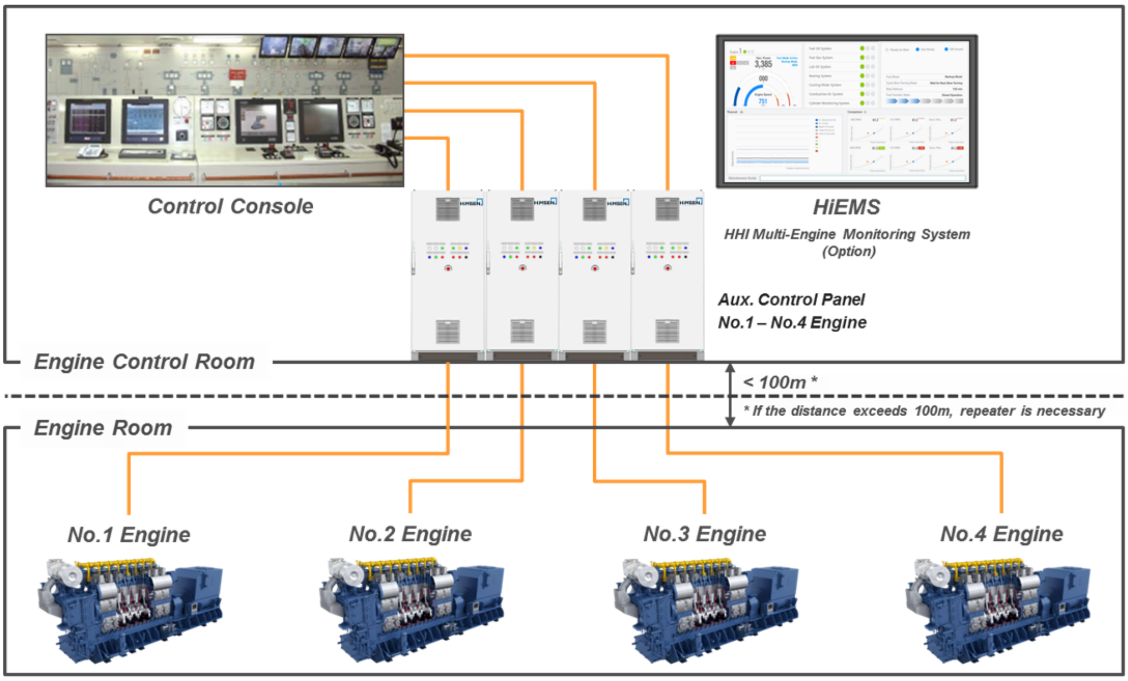


Figure 5.22 HiMSEN DF ECS communication interface

5.3.3 Power distribution

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

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

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

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

Refer to Fig. 5.23 for the concept of power distribution to ECS and specification of UPS.

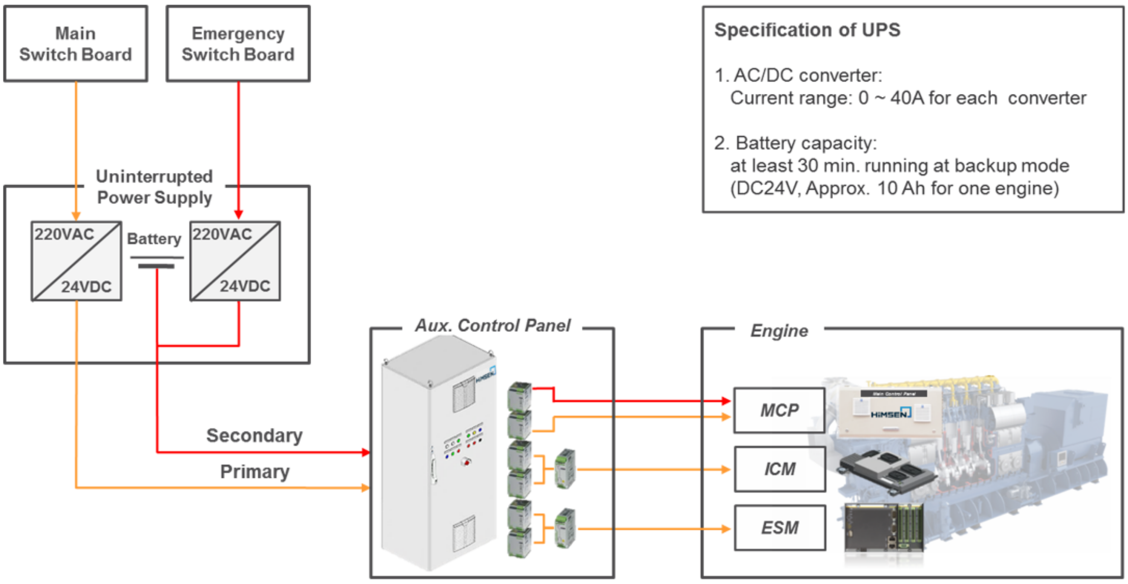


Figure 5.23 HiMSEN DF ECS power distribution

5.4 Operation data and alarm points

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

Table 5.1 Operation data of the engine

	Descriptions		Normal operation range at rated power	Alarm and sensor		Auto stop of engine	
Speed control	Engine speed	SE11	720 rpm	AL High	110%	SD High	115%
			750 rpm				113%
	Engine speed and position	SE12	720 rpm				
			750 rpm				
	TC speed	SE14		AL High	(A)		
Fuel oil system	Fuel oil filter differential pressure	PT51-52		AL High	1.5 bar		
	Fuel oil pressure engine inlet	PT52					
	For continuous HFO operation	(MDO / MGO)	4.0 ~ 6.0 bar	AL Low	4 bar		
		(HFO)	7.0 ~ 10.0 bar	AL Low	6 bar		
	For continuous MDO operation	(MDO / MGO)	7.0 ~ 8.0 bar	AL Low	6 bar		
	Fuel oil temperature engine inlet	TE52					
		(MDO / MGO)	30 ~ 45 °C	AL High	50 °C		
		(HFO)	110 ~ 140°C	AL High	155 °C		
	Nozzle cooling oil temperature engine outlet	TE58*)	70 °C	AL High	85 °C		
	Pilot fuel oil filter differential pressure	PT30-31		AL High	1.5 bar		
	Pilot fuel oil pressure HP pump inlet	PT31	5 ± 1 bar	PT Low	3 bar		
				PT High	7 bar		
	Pilot fuel oil pressure engine inlet	PT32	800 ~ 1000 bar	PT Low	750 bar		
				PT High	1300 bar		
				PT Low	200 bar from ref.		
	Pilot fuel oil temperature HP pump inlet	TE31	30 ~ 45 °C	AL High	50 °C		
	Clean fuel oil leakage tank level	LS54		AL High	High level		

	Descriptions	Normal operation range at rated power		Alarm and sensor		Auto stop of engine	
Fuel gas system	Main gas pressure engine inlet	PT87	depends on load	AL High	0.5 bar from ref		
Fuel gas system	Main gas pressure engine inlet		depends on load	GT High	1.0 bar from ref.		
Fuel gas system	Gas supply pressure filter outlet	PT81	1.0 ~ 6.0 bar	GT High	9.0 bar		
Fuel gas system	Gas supply pressure filter outlet	PT81	1.0 ~ 6.0 bar	AL Low	1.8 bar from C.A		
Fuel gas system	Gas supply pressure filter outlet		1.0 ~ 6.0 bar	GT Low	1.5 bar from C.A		
Fuel gas system	Gas filter differential pressure	PT80-81		AL High	0.5 bar		
Fuel gas system	Gas supply temperature filter outlet	TE80	10 ~ 35 °C	AL Low	5 °C		
Fuel gas system	Gas supply temperature filter outlet	TE80	10 ~ 35 °C	GT Low	0 °C		
Fuel gas system	Gas supply temperature filter outlet	TE80	10 ~ 35 °C	AL High	65 °C		
Fuel gas system	Gas supply temperature filter outlet	TE80	10 ~ 35 °C	GT High	70 °C		
Fuel gas system	Control air pressure gas regulating unit	PT83	5 ~ 10 bar	GT Low	4 bar		
Fuel gas system	Inert gas pressure	PT89	4 ~ 8 bar	AL Low	3.5 bar		
Lubricating oil system	Lubricating oil filter differential pressure	PT61-62		AL High	1.5 bar		
Lubricating oil system	Lubricating oil pressure engine inlet	PT62	4.0 ~ 5.0 bar	AL Low	3.3 bar	SD Low	3 bar
Lubricating oil system	Lubricating oil pressure engine inlet	PT62	4.0 ~ 5.0 bar	LR Low	(Option)		
Lubricating oil system	Lubricating oil temperature engine inlet	TE62	60 ~ 70 °C	AL High	80 °C		
Lubricating oil system	Lubricating oil pressure TC inlet	PT63	(A)	AL Low	(A)		
Lubricating oil system	Lubricating oil temperature TC outlet	TE64	65 ~ 75 °C	AL High	(A)		
Lubricating oil system	Lubricating oil pressure HP pump inlet	PT66*)	4.0 ~ 5.0 bar	AL Low	3.0 bar		
Lubricating oil system	Lubricating oil pressure HP pump inlet	PT66*)	4.0 ~ 5.0 bar	PT Low	2.7 bar		
Lubricating oil system	Lubricating oil sump tank level	LS68		AL High	High level		
Lubricating oil system	Lubricating oil sump tank level	LS68		AL Low	Low level		
Cooling Water System	High temperature water pressure engine inlet	PT75	2.0 ~ 5.0 bar	AL Low	Mapped (B)		
Cooling Water System	High temperature water pressure engine inlet	PT75	2.0 ~ 5.0 bar	LR Low	(Option)		
Cooling Water System	High temperature water temperature engine inlet	TE75	70 ~ 80 °C	AL Low	50 °C		
Cooling Water System	High temperature water temperature engine outlet	TE76	75 ~ 85 °C	AL High	92 °C	SD High	95 °C
Cooling Water System	Low temperature water pressure air cooler inlet	PT71	2.0 ~ 5.0 bar	AL Low	Mapped (B)		
Cooling Water System	Low temperature water temperature air cooler inlet	TE71	30 ~ 40 °C	AL High	55 °C		

	Descriptions	Normal operation range at rated power		Alarm and sensor		Auto stop of engine
Combustion gas / air system	Exhaust gas temperature cylinder outlet	TE25	350 ~ 580°C	AL High	610 °C	
				GT High	615 °C	
				LR High	620 °C	
				GT High	mapped ± (C)	
				LR High	100 ℃ ± (C)	
	Exhaust gas temperature T/C inlet	TE26	480 ~ 590°C	AL High	600 °C	
				LR High	620 °C	
	Exhaust gas temperature TC outlet	TE27	300 ~ 500°C	AL High	500 °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	5.0 barA	
	(At diesel mode)			AL High	6.0 barA	
	(At gas mode)			GT High	0.5 bar ± (G)	
	(At diesel mode)			AL High	Dev. ± (G)	
	Charge air temperature air cooler outlet	TE21	43 ~ 50 °C			
	(At gas mode)			AL High	53 °C	
	(At gas mode)			GT High	55 °C	
	(At diesel mode)			AL High	60 °C	
	(At diesel mode)			LR High	(Option)	
Compressed air system	Starting air pressure engine inlet	PT40	30 bar	AL Low	18 bar	
	Control air pressure engine inlet	PT41	6.0 ~ 8.0 bar	AL Low	5 bar	
				GT Low	3.5 bar	
	Control air pressure DVT inlet	PT43		AL Low	3 bar (D)	
				LL High	3 bar (D)	

	Descriptions	Normal operation range at rated power		Alarm and sensor		Auto stop of engine	
Cylinder monitoring system	Knock sensor	LT94		AL High	(E) > 6 °CA		
				GT High	(E) > 10 °CA		
	Cylinder combustion pressure	PT24★)					
	(At gas mode)			AL High	190 bar		
	(At gas mode)			GT High	200 bar		
	(At diesel mode)			AL High	180 bar		
	(At diesel mode)			LR High	190 bar		
Liner and bearing	Main bearing temperature	TE05★)		AL High	95 °C	SD High	100 °C
	Cylinder liner temperature	TE07★)		AL High	155 °C	SD High	162 °C
Miscellaneous system	Oil mist detector	LS92		AL High	High level	SD High	High level
	Crankcase pressure	LS92	1 ~ 4 mbar				
	(At gas mode)			AL High	6 mbar		
	(At gas mode)			GT High	10 mbar		
	(At diesel mode)			AL High	12 mbar		

Table 5.2 Definition of code

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 stop

(A). Depending on cylinder No. and T/C maker
(B). Depend on the height of expansion tank
(C). Average exhaust temperature
(D). Depends on DVT on/off condition
(E). Total retardation of ignition timing generated by knocking
(F). When predefined times of last 10 cycle exceed this value
(G). Predefined Charge air pressure at Diesel / Gas mode

★) Can be applied as an option.

Table 5.3 Operation data for each T/C maker

T/C maker	T/C type	T/C lubricating inlet pressure		T/C lubricating outlet temperature	
		Pressure range	Alarm	Pressure temperature	Alarm
		Bar	Bar	°C	°C
KBB	ST - series	2.0 ~ 4.0	1.5	70 ~ 100	120
ABB	TPS - series	2.0 ~ 3.0	1.5	70 ~ 140	160
	A130 ~ A145	2.0 ~ 4.5	1.5	70 ~ 140	160
	A150 ~ A155	2.0 ~ 3.5	1.3	70 ~ 125	145
	TPL - series	1.5 ~ 2.5	1.3	70 ~ 120	140
MHI	MET30SRC	0.6 ~ 1.5	0.6	60 ~ 95	105
	MET37SRC	0.6 ~ 1.5	0.6	60 ~ 95	105
Napier	Na - series	1.5 ~2.5	1.3	60 ~ 95	115

1. Note. This value was selected after review by the engine builder based on the turbocharger maker manual.

5.5 Local instrumentations

Table 5.4 The symbol number and measuring range for local instrument

	Description	Symbol No.	Measuring range
Pressure	Fuel oil pressure at engine inlet	PI 52	0 ~ 16 bar
	Gas supply pressure at filter outlet	PI 81	0 ~ 10 bar
	Gas supply pressure at regulator outlet	PI 82	0 ~ 10 bar
	Lubricating oil pressure at engine inlet	PI 62	0 ~ 10 bar
Temperature	Fuel oil temperature at engine inlet	TI 52	0 ~ 200 ℃
	Low temperature water temperature air cooler inlet	TI 71	0 ~ 120 ℃
	Low temperature water temperature air cooler outlet	TI 72	0 ~ 120 ℃
	Gas supply temperature	TI 80	0 ~ 50 ℃

1. All measurement can be monitored on local operating panel.

5.6 Hyundai intelligent Equipment Management Solution (HiEMS)

Introduction

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.

Benefits

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.

On Shore

Ship managers can manage the fleet of HiMSEN engines with HiEMS, accessible 24*7 through the Digital Innovation (DI) center of HD Hyundai Marine Solution (HMS).
Ship managers can get real-time remote diagnostics, qualified advices and services from our engineers and service experts. (On reporting service version)

Main features

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.

On Shore

Status monitoring of the fleet of HiMSEN engines

- ✓ Overall status of alarm and running hour.
- ✓ Long term data management and reporting service

License policy

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.

Reporting service version

Including “Standard version” features, regular reporting service is available through HD Hyundai Marine Solution (HMS).
Contact HD Hyundai Marine Solution (HMS) for reporting service

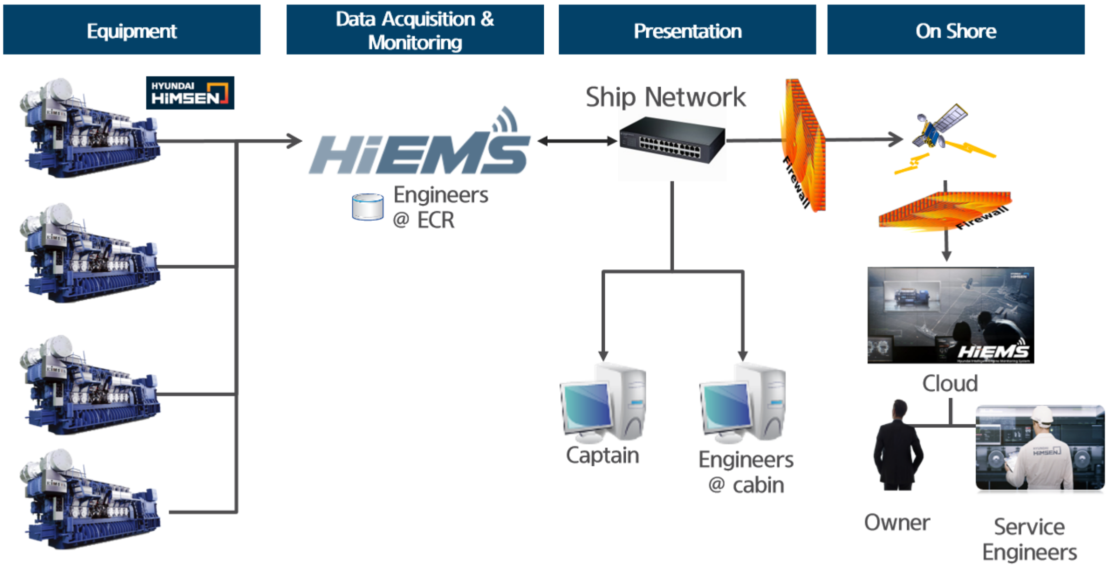


Figure 5.24 HiEMS configuration and network

Key functions

Real-time status monitoring of the HiMSEN engine

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

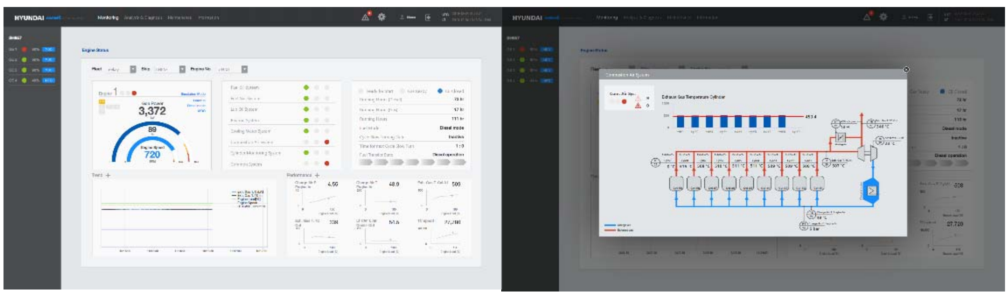


Figure 5.25 display of real-time status monitoring

Maintenance

Maintenance and guidance based on the instruction guide

- ✓ Alarm/Event, maintenance, wearing parts manager.

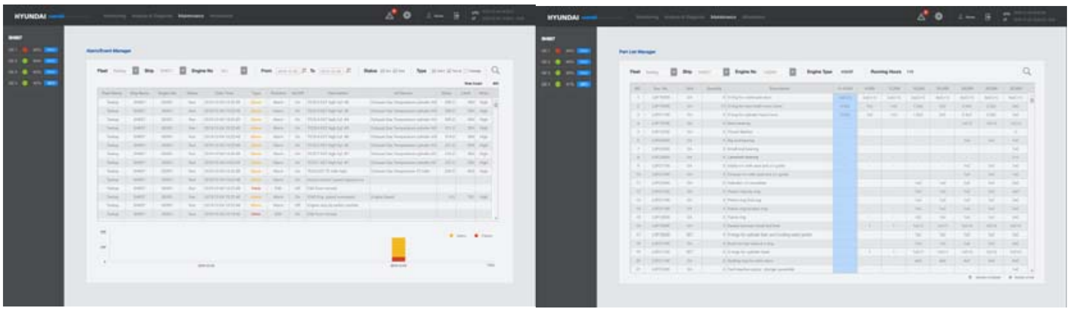


Figure 5.26 Display for the maintenance and guide

Analysis and diagnosis

Analysis tools for engine data

- ✓ Performance, deviation, correlation analysis and statistics.
- ✓ Compare FAT data with current state.

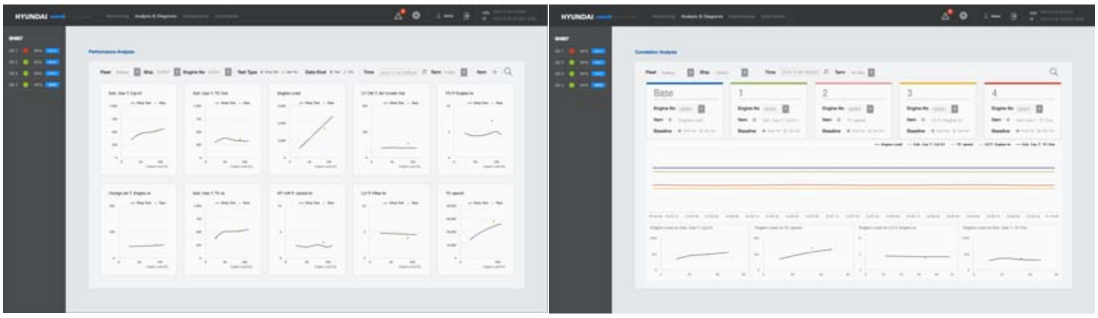


Figure 5.27 Display for the engine analysis

Fleet management (Option)

On shore, status monitoring of the fleet of HiMSEN engines

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

Figure 5.28 Digital innovation center

6 Fuel system

6.1 Modes of engine operation

Engine operation mode

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

- ✓ Gas mode : Natural gas + pilot oil
- ✓ Diesel mode : Main fuel oil + pilot oil
- ✓ Backup mode : Main fuel oil

Gas mode

In gas mode, the natural gas as main fuel is injected to the intake ports of each cylinder through the gas admission valve. The fuel gas is ignited by the micro pilot oil which is injected by pilot injector to the main combustion chamber.

The gas admission valve and pilot injector are operated by solenoid and electric controlled. The injection timing, the amounts of the fuel gas and / or pilot oil shall be adjusted at each cylinder by the engine control system.

Diesel mode

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

The micro pilot oil system is activated same as gas operating mode to keep the injector nozzles clean and ready for gas operating mode.

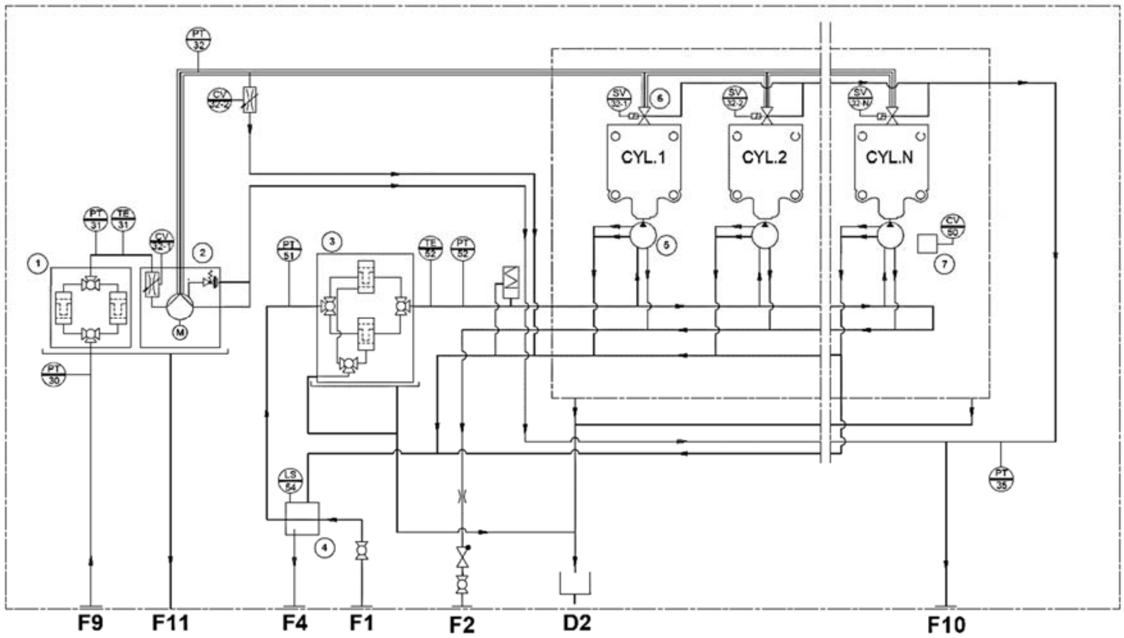
Backup mode

Backup mode is for the safety operation. When the engine control system, safety system or blackout detection system are activated, the engine is transferred to backup mode.

In backup mode, the engine is operated by just the main fuel (marine diesel oil) while the micro pilot oil system is not operated. Please refer to the 5.1.2 regarding the operating time of the backup mode.

6.2 Internal fuel oil system

Diagram for Internal fuel oil system



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

Figure 6.1 Diagram for Internal fuel oil system [BP0061790-0.4]

Table 6.1 Size of external pipe connections

Code	Description	Size	Remark
F1	Fuel oil inlet	25 A	JIS B 2220
F2	Fuel oil outlet	25 A	JIS B 2220
F4	Leaked fuel oil drain (clean)	15 A	JIS B 2220
F9	Pilot fuel oil inlet	15 A	JIS B 2220
F10	Pilot fuel oil outlet	15 A	JIS B 2220
F11	Leaked pilot fuel oil drain (dirty)	Ø15	JIS B 2220
D2	Waste Oil Drain (dirty)	Ø25	JIS B 2220

Table 6.2 System components

No	Description	Remark
1	Pilot oil filter	6㎛

No	Description	Remark
2	Pilot fuel pump	
3	Fuel oil filter	50㎛
4	Clean fuel oil leakage alarm tank	
5	Fuel injection pump	
6	Micro pilot injector	
7	Governor	

6.2.1 General description

Fuel system for the dual fuel engine is designed for a reliable combustion of heavy fuel oil or marine diesel oil as well as the natural gas. Therefore, it is possible to change over the fuel mode between HFO, MDO and natural gas without loss of the rated output.

The micro pilot oil system is designed as ignition source in gas operation. But it is also active in diesel to prevent the clogging of the pilot injector.

Fuel oil system

The fuel injection equipment comprises an injection pump, connection block, injection pipe and injection valve, which are installed on each cylinder. The system is designed for operating the high pressure of the fuel injection with better combustion.
The amount of fuel injection is controlled by the engine control system via the common regulating shaft and spring loaded linkage.
The control system can maintain the engine speed at the preset-value by continuous positioning of the fuel injection pump rack.

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

- Estimated fuel oil drain amount [liter/hr per a cylinder]
  - For heavy fuel oil : 0.3 (50% tolerance) at 12 cSt
  - For distillate fuel oil : 1.2 (50% tolerance) at 2 cSt

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

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

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

6.2.2 Micro pilot oil system

The micro pilot oil system comprises the pilot fuel pump, duplex filter and micro pilot injector on each cylinder. It is applied with the common rail system which is able to control the injection of the small amount of pilot oil with suitable timing and duration.

At the pilot fuel pump, the pilot oil is pressurized up to 1,000 bar and conveyed to each injector via the high pressure pipes which are made of the double walled structure for safety.
The return pilot oil from injectors and the pilot fuel pump is collected to common return pipes and can be recycled. The return flow rate of pilot oil is approx. 0.07 liter / Cyl. min (Tolerance ± 50 %).

The leak rate of the micro pilot oil system is normally zero. Any leak from high pressure pipes, it is drained via the intermediate space of double walled pipes or the safety valve of the distribute block and collected to the recycling fuel oil alarm tank for clean oil. The clean leak oil is led to recycling fuel oil drain and can be reused.
For the micro pilot oil system, only marine diesel oil (DMA, DMB, DMZ) can be used.

6.3 External fuel oil system

Diagram for heavy fuel oil system – Normal operation

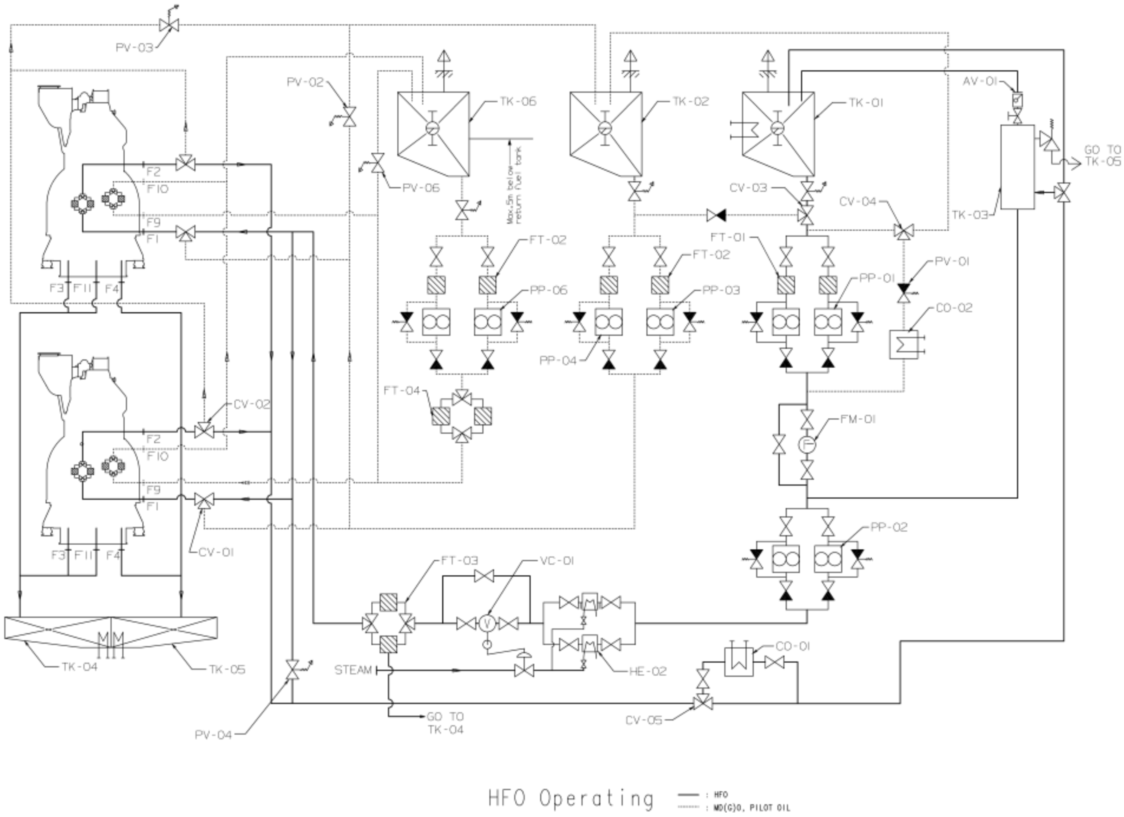


Figure 6.2 Diagram for heavy fuel oil system (B91-328884-8.0)

Table 6.3 System components

Code	Description	Code	Description
TK-01	Day tank, heavy fuel oil	FT-01	Suction strainer, heavy fuel oil
TK-02	Day tank, marine diesel oil	FT-02	Suction strainer, marine diesel oil, pilot oil
TK-03	Mixing tank	FT-03	Automatic filter
TK-04	Drain tank for dirty oil	FT-04	Duplex filer
TK-05	Drain tank for clean oil	CO-01	Marine diesel oil cooler
TK-06	Day tank, pilot oil	CO-02	Cooler
AV-01	Auto deaerating valve	HE-02	Heater
FM-01	Flow meter	VC-01	Viscosity controller
PP-01	Heavy fuel oil supply pump (4 bar)	PV-01	Pressure control valve (Main fuel)

Code	Description	Code	Description
PP-02	Heavy fuel oil booster pump (8 bar at fuel oil inlet, F1)	PV-02	Marine diesel oil inlet pressure control valve (6 bar)
PP-03/04	Emergency marine diesel oil pump (6 bar)	PV-03	Marine diesel oil outlet pressure control valve (2 bar)
PP-06	Pilot fuel oil pump (6 bar)	PV-04	Heavy fuel oil inlet pressure control valve (9 bar)
CV-01~02	Heavy fuel oil, marine diesel oil change over valve	PV-06	Pressure control valve (Pilot fuel)

1. In case of continuous marine diesel oil operation, contact to HHI-EMD.
2. Additional day tanks for low sulfur heavy fuel oil and / or marine diesel oil could be required due to IMO MARPOL Annex VI, a special notation of classification societies, a local regulation, or other reasons.
3. This external fuel oil system is only for guidance for generator engines. All external piping design and system arrangement should be designed by shipbuilder in accordance to the classification rules and building specifications.

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

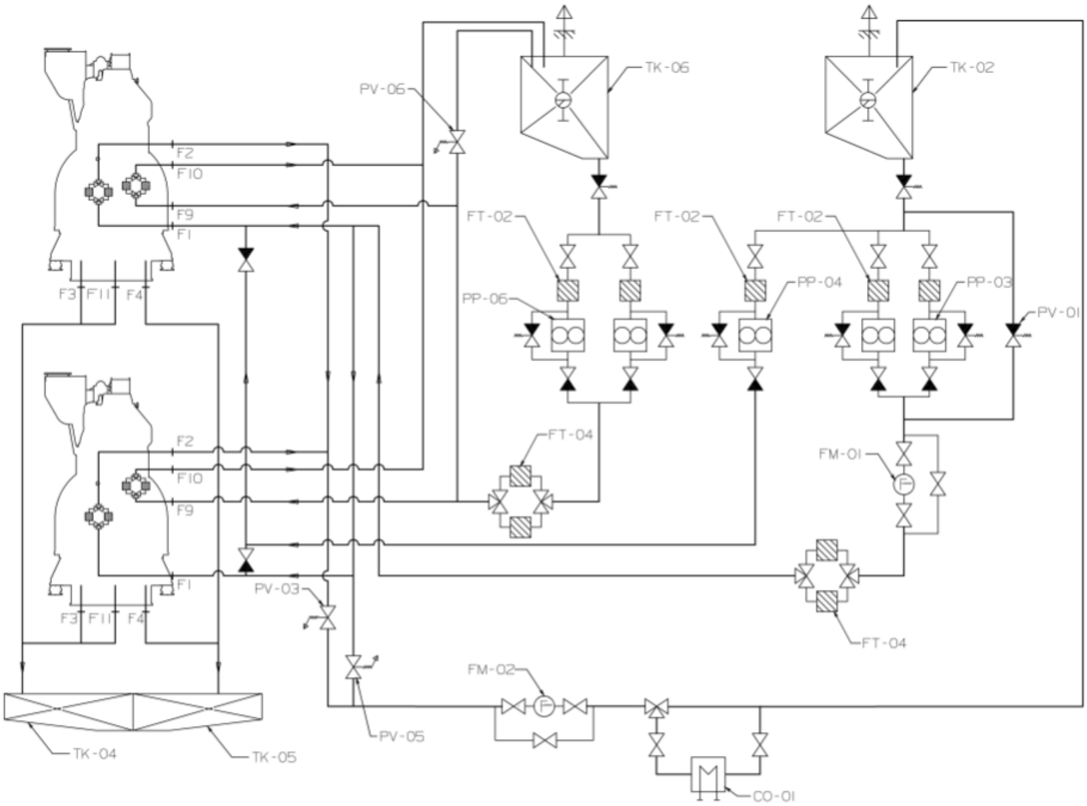


Figure 6.3 Diagram for marine diesel oil (marine gas oil) system (B91-328884-8.1)

Table 6.4 System components

Code	Description	Code	Description
TK-02	Day tank, marine diesel oil	CO-01	Marine diesel oil cooler
TK-04	Drain tank for dirty oil	PV-01	Pressure control valve (Main fuel)
TK-05	Drain tank for clean oil	PP-03	Marine diesel oil supply pump (8 bar)
TK-06	Day tank, pilot oil	PP-04	Emergency marine diesel oil pump (6 bar)
FM-01	Flow meter	PP-06	Pilot fuel oil pump (6 bar)
FT-02	Suction strainer, marine diesel oil, pilot oil	PV-03	Marine diesel oil outlet pressure control valve (2 bar)
FM-02	Flow meter	PV-05	Pressure control valve (8 bar)
FT-04	Duplex filer	PV-06	Pressure control valve (Pilot fuel)

1. In case of continuous marine diesel oil operation, contact to HHI-EMD.
2. Additional day tanks for low sulfur heavy fuel oil and / or marine diesel oil could be required due to IMO MARPOL Annex VI, a special notation of classification societies, a local regulation, or other reasons.
3. This external fuel oil system is only for guidance for generator engines. All external piping design and system arrangement should be designed by shipbuilder in accordance to the classification rules and building specification

6.3.1 General requirements

The external fuel system for the auxiliary engines can be a common system with main engine or an independent system depending on the shipbuilder's choice.
In any cases, the condition of fuel oil, especially heavy fuel oil, is critical for the reliable operation of the engine. The most important conditions and requirements of the external fuel oil system are described as follows :

Well cleaned fuel

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

Proper viscosity, temperature, pressure

The appropriate viscosity, temperature and pressure are necessary. Therefore, preheating, insulation with heat tracing, and pressurizing equipment should be included in the external fuel oil system. Especially if the fuel is at low viscosity, fuel temperature should be controlled to meet the required viscosity by fuel cooling device such as cooler unit.

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

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

Marine diesel fuel oil

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

External fuel oil system

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

Fuel oil treatment system

The fuel treatment system should be designed for proper cleaning of heavy fuel oil considering total fuel consumption of the vessel. Centrifugal separators should be an automatic type with the same additional stand-by unit. The separator should be capable of purifying the worst grade of the fuel oil. Normally, the fuel oil grade of H380 to H700 requires the capability of up to 1010 kg/㎥.
For distillate fuel, an independent purifier system is required.

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

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

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

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

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

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

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

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

6.3.2 Fuel feed system

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

Day tank for heavy fuel oil and marine diesel oil

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

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

Heavy fuel oil / marine diesel oil changeover valve

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

Suction strainer

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

Supply pump

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

Flow meter

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

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

Mixing tank

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

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

Pressure control valve

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

Booster pump

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

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

Heater and viscosity controller

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

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

Auto back flushing filter

In the circulating lines, absolute 10 μm automatic back-flushing filter must be installed before the branch pipe for each engine to ensure the cleanness of the fuel oil. If the cleaning cycles of the automatic back-flushing filter are increased, the fuel oil treatment system must be optimized in order to protect the engine. If a stand-by filter is equipped, the absolute 25 μm is required.
The location of installing filter is acceptable in the supply lines.

Drain tank for dirty oil

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

Drain tank for clean oil

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

Marine diesel oil cooling system

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

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

Emergency start

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

6.3.3 Pilot fuel oil supply system

Pilot fuel oil is supplied from marine diesel oil / marine gas oil day tank via the feed pump and filter, which system can be common with other engines. The pilot fuel oil supply pressure should be constant and heavy fuel oil is not allowed to enter the pilot oil system.

The pilot oil return from the engine can be led to marine diesel oil / marine gas oil day tank directly.

The back pressure in the return line is allowed maximum 2.0 bar to ensure function and reliability of the pilot oil system on the engine.

Suction strainer

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

Pilot fuel oil supply pump

- ✓ Capacity : min. 0.009 m^3 / cylinder hour
- ✓ Pump head : 5 ± 1 bar at pilot oil inlet, F9
- ✓ Operating temperature : 40 ℃
- ✓ Viscosity (For electric motor) : 1.8 ~ 11 cSt

Fine filter

We recommend the installation of the fine filter before the engine on the pilot oil supply system, which is a duplex type with filtration of 34 ㎛ absolute and equipped with differential pressure indicator. The filter should be placed as close to the engine as possible.

Pressure control valve

The pressure control valve is required for the constant supply pressure at the pilot fuel oil supply line with bypassing to the marine diesel oil / marine gas oil day tank.
The pressure control valve should be controlled to set the target pressure 5 bar of pilot oil to engine.
The bypassing pilot oil after pressure control valve (PV-06) should not be connected to the returned pilot line.

6.3.4 Pilot fuel oil cooling system

If the viscosity of marine diesel oil / marine gas oil in day tanks drops under the minimum value of recommended viscosity ranges for pilot fuel oil system, it is required to install a pilot fuel oil cooler on the engine supply line for reliable viscosity of fuel oil.

The pilot fuel oil cooling system should maintain the temperature of marine diesel oil low than 50 °C at engine inlet. For very light sulfur fuel oil, the temperature should be adjusted in accordance to the fuel oil specification.

The cooler should be installed at the return line after the engine(s) and composed with the by-pass pipe and manual valve to ensure fuel oil circulation while the cooler is overhauled.
The minimum required capacity of pilot fuel oil cooler can be estimated as following formula:

$$P = Q \times \rho \times c \times dT$$

P (kcal / h) = required capacity of the cooler
Q (m^3 / h) = maximum delivery quantity of fuel oil
(Equal to the flow capacity of pilot fuel oil supply pump)
ρ (kg / m^3) = fuel oil density at 15 ℃ (Typical value: 900 kg / m^3)
c (kcal / kg℃) = specific heat of fuel oil (Typical value: 0.478 kcal / kg℃)
dT (℃) = temperature difference between the fuel oil of marine diesel oil /marine gas oil day tank and the cooler outlet

1. The cooler outlet temperature should be obtained in order to meet the minimum value of the recommended viscosity range for pilot fuel oil system.

2. These parameters suggested typically are only for reference. When dimensioning pilot fuel oil cooler capacity, the parameters must be taken into account based on actual fuel oil properties.

6.4 Fuel oil specification

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

The terminologies of marine fuel oil to be called after 1st January 2020 have been determined as below Table 6.5. In accordance with the most relevant characteristics.

HiMSEN is able to operate with all fuels specified in the below table. The simplified terminologies listed in Table 6.5 allows easy determination if the fuel can be applicable for HiMSEN.

Table 6.5 Designation of fuel grades

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

Table 6.6 Specifications of distillate fuel

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

a) 1 mm^2 / s = 1 cSt
b) Notwithstanding the limits given, a purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See introduction of ISO 8217 : 2017.
c) If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required. See 6.8 and 6.12 of ISO 8217 : 2017.
d) If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.
e) See 5.1 and Annex A ISO 8217 : 2017
f) Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, cold filter plugging point) are suitable for the ship's design and intended voyage. See 6.11 of ISO 8217 : 2017.
g) If the sample is dyed and not transparent, then the water limit and test method as given in 6.12 of ISO 8217 : 2017 shall apply.
h) Water content at engine inlet should be controlled under max. 0.02 mass % specified in the chapter 6.6.1.
i) This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0.050 mass %).

Table 6.7 Specifications of residual fuel

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

a) 1 mm^2 / s = 1 cSt
b) The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations.
c) See Annnex H of ISO 8217 : 2017.
d) The purchaser should confirm that this pour point is suitable of the ship's intended area of operation.
e) Water content at engine inlet should be controlled under max. 0.2 mass % specified in the chapter 6.6.1.
*) International statutory requirements
This document specifies allowable minimum flash point limits following the provisions given in the SOLAS convention. MARPOL Annex VI, which controls air pollution from ships, includes a requirement that either the fuel shall not exceed a specified maximum sulfur or an approved equivalent alternative means be used. During the lifetime of this document, regional and/or national bodies may introduce their own local emission requirements, which can impact the allowable sulfur content, for example, the EU sulfur directive. It is the purchaser's and the user's responsibility to establish which statutory requirements are to be met and specify on that basis the corresponding maximum fuel sulfur content to the supplier.

Characteristics		Unit	Limit	Category ISO-F-							Test method reference
				RMG				RMK			
				180	380	500	700	380	500	700	
Kinematic viscosity at 50 ℃		mm²/s a)	max.	180.0	380.0	500.0	700.0	380.0	500.0	700.0	ISO 3104
Density at 15 ℃		kg/m³	max.	991.0				1,010.0			ISO 3675 or ISO 12185
CCAI		-	max.	870				870			
Sulfur b)		wt %	max.	Statutory requirements *)							ISO 8754 ISO 14596 ASTM D4294
Flash point		℃	min.	60.0				60.0			ISO 2719
Hydrogen sulfide		mg/kg	max.	2.0				2.0			IP 570
Acid number c)		mg KOH/g	max.	2.5				2.5			ASTM D664
Total sediment aged		wt %	max.	0.1				0.1			ISO 10307-2
Carbon residue : micro method		wt %	max.	18.0				20.0			ISO 10370
Pour point(upper) d)	Winter	℃	max.	30				30			ISO 3016
	Summer	℃	max.	30				30			
Water e)		vol %	max.	0.50				0.50			ISO 3733
Ash		wt %	max.	0.10				0.15			ISO 6245
Vanadium		mg/kg	max.	350				450			IP 501, IP 470 or ISO 14597
Sodium		mg/kg	max.	100				100			IP 501, IP 470
Aluminum plus silicon		mg/kg	max.	60				60			IP 501, IP 470 or ISO 10478
Used lubricating oils (ULO) Calcium and Zinc ; or calcium and phosphorus		mg/kg	-	Do not use if : calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15							IP 501 or IP 470, IP 500

a) 1 mm²/ s = 1 cSt
b) The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations.
c) See Annnex H of ISO 8217 : 2017.
d) The purchaser should confirm that this pour point is suitable of the ship's intended area of operation.
e) Water content at engine inlet should be controlled under max. 0.2 mass % specified in the chapter 6.6.1.
*) International statutory requirements
This document specifies allowable minimum flash point limits following the provisions given in the SOLAS convention. MARPOL Annex VI, which controls air pollution from ships, includes a requirement that either the fuel shall not exceed a specified maximum sulfur or an approved equivalent alternative means be used. During the lifetime of this document, regional and/or national bodies may introduce their own local emission requirements, which can impact the allowable sulfur content, for example, the EU sulfur directive. It is the purchaser's and the user's responsibility to establish which statutory requirements are to be met and specify on that basis the corresponding maximum fuel sulfur content to the supplier.

Biofuels

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

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

HiMSEN is able to operate continuously with biofuels specified in the below Table 6.8 and Table 6.9

- ✓ When using biofuels included in quality standards Table 6.8 and Table 6.9, you need to get confirmation from HiMSEN.

Biodiesel / Fatty Acid Methyl Ester (FAME)

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

International standards EN 14214 or ASTM D 6751-19 are commonly used to specify the quality of biodiesel. (See the Table 6.8)

Table 6.8 Specifications of biodiesel(FAME)

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

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

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

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

Hydrotreated Vegetable Oil (HVO)

The EN 15940:2016 + A1:2018 + AC:2019 standard covers hydrotreated paraffinic renewable diesel fuel and synthetic Fischer-Tropsch products GTL, BTL and Coal-to-Liquid (CTL).
Since HVO consists of paraffinic hydrocarbons, it cannot meet the requirements set by EN 14214:2013+ A2:2019, which is a standard developed and valid only for methyl ester chemistry type biodiesel, namely FAME. As a matter of fact, HVO meets EN 590, except the requirement for minimum density. International standards EN 15940 are commonly used to specify the quality of HVO. (See the Table 6.9)

Table 6.9 Specifications of HVO(EN15940)

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

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

Bio-blends

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

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

The quality standards of biodiesel-blends(BD##) are referred to the Table 6.8 and the bio-blends(B##) except for biodiesel-blends(BD##) are referred to the Table 6.10.

General biofuels

The quality standards of general liquid biofuels except biodiesel(FAME) are as shown below Table 6.10.(General biofuels include a wide range of specifications. In order to reduce confusion when applying biofuel standards, HiMSEN set the integrated standard with the Table 6.10.)
Only biofuels that meet EN14214 or EN15940 can be applied to Micro-Pilot (MP) injector. The information of storage and deterioration of biofuels should be discussed/checked by fuel oil supplier before the biofuel is applied to engine.

Table 6.10 Specifications of general biofuel, bio-blends.

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

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

Characteristics	Unit	Min. limit	Max. limit	Test method reference
Iodine number	g I/100g	-	120	ISO 3961
Oxidation stability	h	5	-	EN 14112
Synthetic polymers	%m	-	0	LP 2501
Lower calorific value	MJ/kg	35	-	DIN 51900-3

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

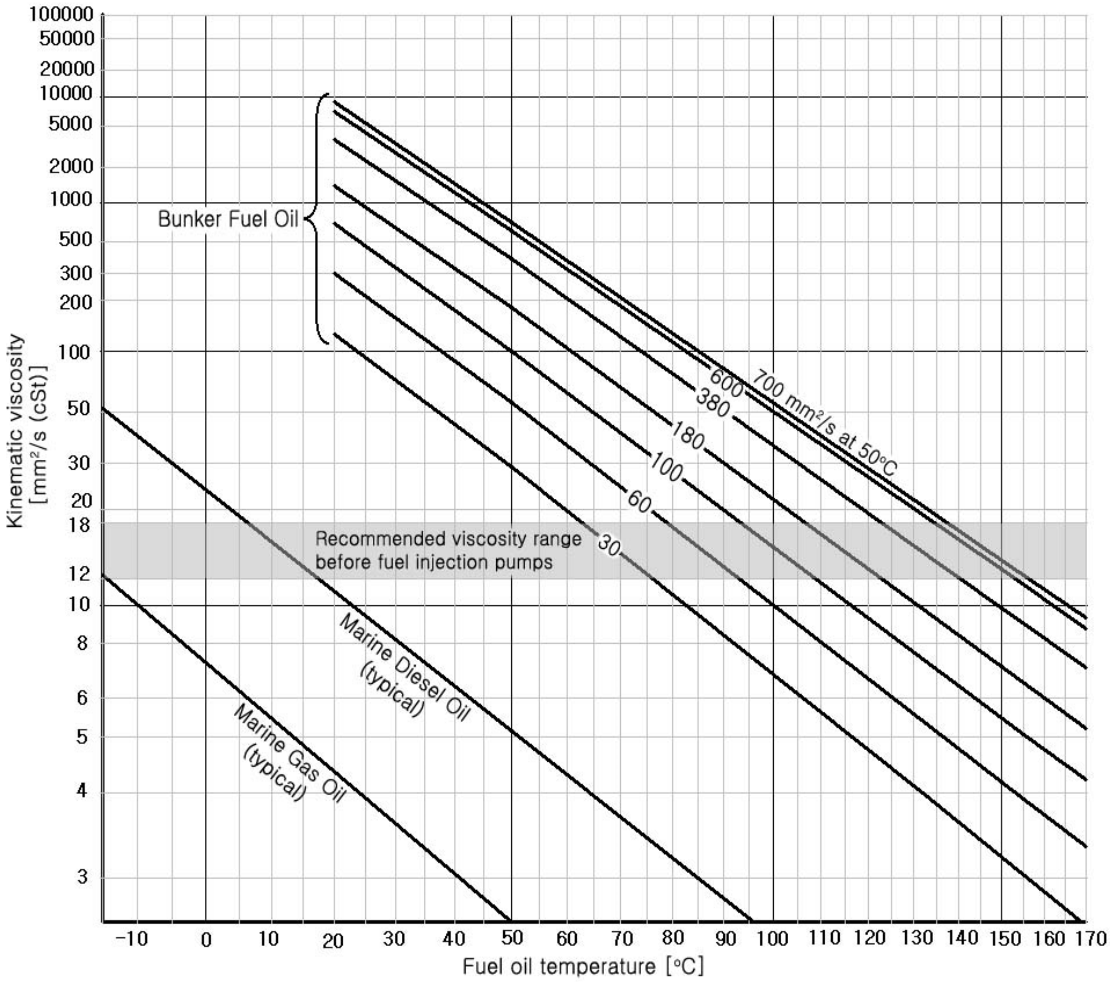
b) It is required the agreement of FIP maker and HHI if the total acid number is more than 2.5 mg KOH/g.

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

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

6.5 Fuel oil viscosity diagram

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



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

Figure 6.4 Diagram for fuel oil viscosity

6.6 Fuel oil quality

6.6.1 Fuel characteristics

Viscosity

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

Density

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

Sulfur

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

Ash

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

Vanadium and sodium

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

Conradson carbon

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

Asphaltenes

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

Water

The water content can be measured by a standardized distillation test. The water causes corrosion and cavitation of the fuel system and fouling of the exhaust system and turbochargers. Therefore, water content at engine inlet should be controlled under the following limit according to fuel type.

- ✓ Residual fuel : Max. 0.2 mass %
- ✓ Distillate fuel : Max. 0.02 mass%

Abrasive particles

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

6.6.2 Ignition quality

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

Calculated carbon aromaticity index

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

Where :

D (kg / ㎥ at 15 ℃) = Density

Vk (cSt at 50 ℃) = Viscosity

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

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

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

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

For residual fuels,

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

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

For marine distillate fuels,

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

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

Where :

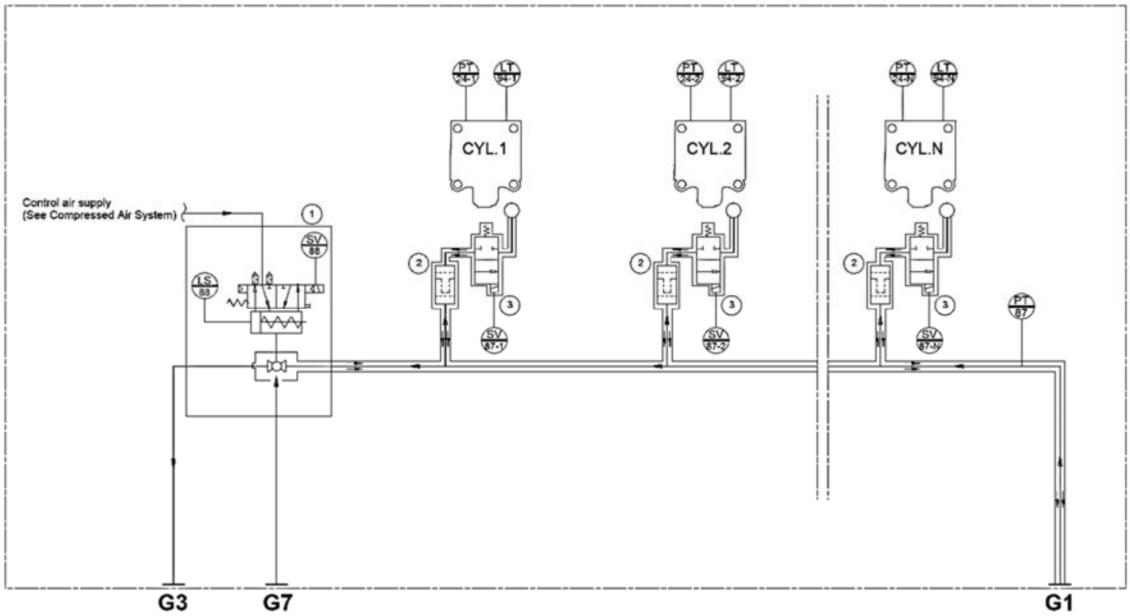
N (MJ/kg) = Net specific energy
G (MJ/kg) = Gross specific energy
ρ (kg/m^3) = Density at 15℃
w (mass %) = Water content
a (mass %) = Ash content
s (mass %) = Sulfur content

Ref. ISO 8217:2017(E)

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

6.7 Internal fuel gas system

Diagram for Internal fuel gas system



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

Figure 6.5 Diagram for internal fuel gas system [BP0061847-0.4]

Table 6.11 External pipe connection size

Code.	Description	Size
G1	Fuel gas inlet (double wall)	80A SCH.40 125A SCH.10
G3	Fuel gas ventilation	10K-25A
G7	Air inlet to double wall pipe	5K-40A

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

Table 6.12 System components

No.	Description	Remark
1	Fuel gas venting valve	
2	Fuel gas safety filter	80μm
3	Gas admission valve	

6.7.1 General description

In gas mode, the regulated fuel gas from the external fuel gas system is to be injected to the intake port of each cylinder by gas admission valve. The gas and air mixture is led into the main combustion chamber through an intake valve and ignited by pilot fuel oil.

At the time of the change over from gas to diesel (including gas trip condition), emergency stop in gas mode or maintenance work of gas supply line, fuel gas should be purged out with inert gas (Nitrogen) with dry & clean, which is supplied from the gas regulating unit.

The fuel gas pipes on the engine are made of double walled structure up to the gas admission valves for the safety from the gas leakage. The annular intermediate space of double walled pipes shall be continuously ventilated under the negative pressure by the ventilation fan.

Gas admission valve

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

The gas admission valves are enclosed by the molded-cases which are connected to the annular intermediate space of double walled pipes. Therefore, it is possible to detect the gas leakage from the valves by the gas detectors equipped with the external double walled pipes at yard system.

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

The valve has special design for not only gas vent but also ventilation air inlet to annular intermediate space of double walled pipe.

In case of emergency stop in gas mode or gas trip, the gas ventilation valve is to be operated according to the specific sequence in order to vent out the fuel gas in double walled gas pipe on DF engine.

Fuel gas vent line should not be 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 no any ignition sources is existed.

Please refer to relevant rules and class regulation for further requirements regarding gas vent line. The pressure drop in fuel gas vent line is to be designed as minimum as possible.

6.7.2 Annular intermediate space of double walled pipe

The annular intermediate space of double walled pipe should be continuously ventilated under the negative pressure suctioned with ventilation fan unit and the ventilation air is supplied through ventilation air inlet (G7) or ambient air in engine room (see the Figure 6.5).

The ventilation air inlet is located at gas ventilation valve of engine and the ventilation air should be came from gas safe area. Please refer to relevant rules and class regulation for further requirements regarding air ventilation.

Table 6.13 Double walled gas pipe external volume

Engine type	Double walled gas pipe external volume (Annular space) (liter)
6H35DF	66.3
7H35DF	74.4
8H35DF	82.4
9H35DF	90.5

6.7.3 Purging with inert gas

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

Inert gas to double walled gas piping

Connection code : G16 or G17 (See the Figure 6.5 external fuel gas system)

Supply pressure : minimum 3 barg / maximum 6 barg

Alarm set point : 3.5 barg

Recommended : 4.0 barg

Table 6.14 Double walled gas pipe internal volume

Engine type	Double walled gas pipe internal volume (liter)
6H35DF	73.0
7H35DF	83.3
8H35DF	93.6
9H35DF	103.9

Inert gas to crankcase

Connection code : L6 (see the lubricating oil system Figure 7.1)

Supply pressure : minimum 3 barg / maximum 6 barg

Required inert gas volume : 20.5 N㎥ (1atm, 0℃)

Table 6.15 Crankcase volume

Engine type	Crankcase volume (liter)
6H35DF	7,890
7H35DF	8,995
8H35DF	10,099
9H35DF	11,204

1. It is prohibited to supply inert gas to crankcase during engine operation.
2. The required inert gas volume could be changed according to yard system

6.8 External fuel gas system

Diagram for external fuel gas system

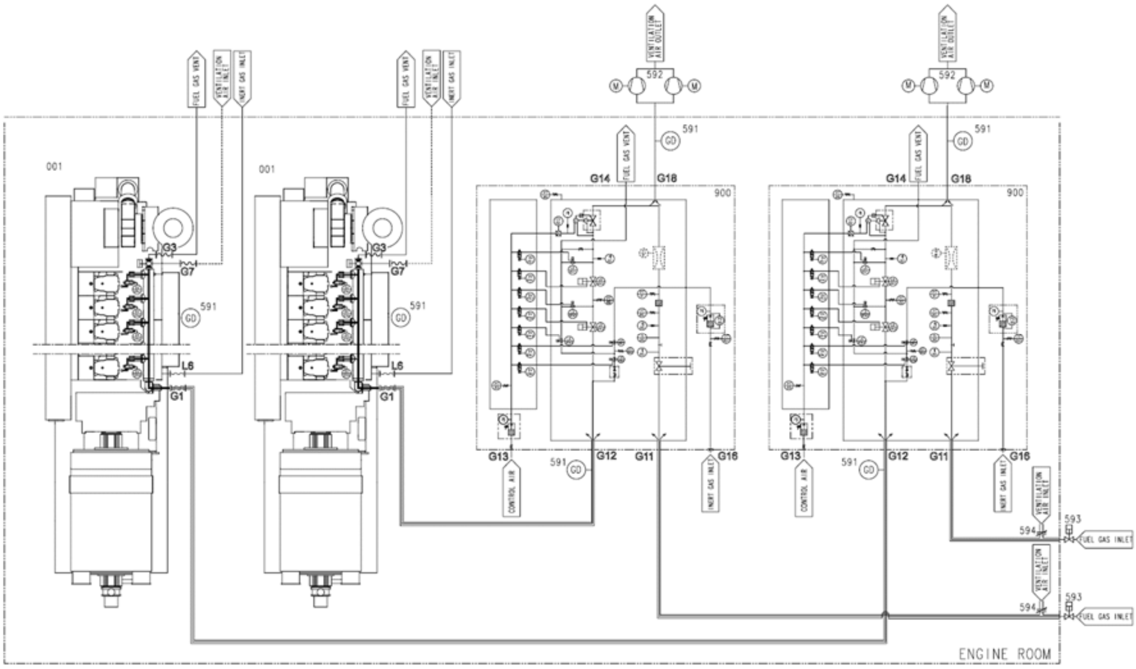


Figure 6.6 Diagram for external fuel gas system (BH1-104579-4.3)

Table 6.16 System components

No.	Description
001	HiMSEN DF engine
591	Gas detector
592	Ventilation fan
593	Master fuel gas valve
594	Adjustable orifice for air inlet
900	Enclosed type gas regulating valve unit

6.8.1 General description

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.

6.8.2 Double walled gas piping

The fuel gas supply pipes in the engine room should be double walled and connected to the gas regulating valve unit space. The design of the gas pipe should satisfy the requirements of classification societies.

The annular intermediate space of double walled pipes should be continuously ventilated by negative pressure suctioned by ventilation fan. The gas leakage from the inner pipes is to be monitored by the gas detectors at all times.

The ventilation system for the double walled gas pipes should be equipped with the minimum capacity of 30 air changes per hour, and the differential pressure of annular space should be monitored to check possible loss of the negative pressure.

6.8.3 Gas detector

The annular intermediate space of double walled gas pipe should be continuously ventilated under the negative pressure at the gas regulating unit room / gas regulating unit enclosure and the gas leakage from annular intermediate space of double walled gas pipe is monitored by gas detector.
In the Figure 6.6 : Diagram for the external fuel gas system, the location and number of gas detectors are described which are generally accepted.
Please refer to relevant rules and class regulation for further requirements regarding the location, number and alarm limit of gas detectors

6.8.4 Ventilation fan

To keep the annular intermediate space of double walled pipe under negative pressure, the ventilation fan should be applied.
The preliminary design value for the negative pressure is – 20mbar, but the actual pressure might be various depending on the design of annular space. It could be accepted by appropriate analysis or measurement.
The minimum capacity for the ventilation fan is 30 air changes per hour according to the class regulation.
It is necessary to design the ventilation fan to consider the volume and pressure drop value of the annular intermediate space in order to achieve the minimum capacity as 30 air changes per hour.
Please refer to the Figure 6.5 (Internal fuel gas system) for further information for HiMSEN DF engine double walled fuel gas piping.
Please refer to relevant rules and class regulation for further requirements regarding air ventilation.

6.8.5 Master fuel gas valve

The master fuel gas valve is required to install at the upstream of the gas regulating unit according to relevant rules. It should be located outside the engine room.

6.8.6 Adjustable orifice for air inlet

In case of external fuel gas system with enclosed type gas regulating unit, there are two ventilation air inlet in the system. One is located in gas venting valve (G7) HiMSEN DF engine. The other should be located at annular space of fuel gas supply line. This adjustable orifice should be applied at the air inlet of annular space of fuel gas supply line in order to adjust the ventilation air balancing with G7 connection.
Please refer to relevant rules and class regulation for further requirements regarding air ventilation.

6.8.7 Gas supply pressure

The gas supply pressure to HiMSEN DF 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 gas mode operation.

Please refer to the ‘Figure 5.2 Gas supply pressure at engine inlet' for detail information.

6.8.8 Gas regulating valve unit

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

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

Installation

The gas regulating valve unit shall be located as close to engine as possible for stable gas mode operation. Therefore, the distance between the fuel gas inlet of HiMSEN DF engine and gas regulating valve unit is recommended within 10 m (Maximum 20 m).

Type of gas regulating valve unit

- ✓ Open type gas regulating valve unit (GRU)

It should be installed in seperated room so-called GRU room with appropriate ventilation system and gas detection system.

- ✓ Enclosed type gas regulating valve unit (ED Type GRU)

The ED TYPE GRU that has enclosure such as separated room so-called GRU room. It should be equipped with appropriate ventilation system and gas detection system.

The major function of gas regulating valve unit

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

The comprisal of gas regulating valve unit

- ✓ Manual shut-off valve
- ✓ Gas filter
- ✓ Flow meter (Option)
- ✓ Gas pressure regulator
- ✓ I/P converter
- ✓ Double block and bleed valve for fuel gas line
- ✓ Double block and bleed valve for inert gas line
- ✓ Gas ventilation valve
- ✓ Closable non return valves
- ✓ Instruments (Pressure indicator, sensor, temperature indicator, transmitter)
- ✓ Inert gas filter with differential pressure switch

Open type gas regulating valve unit

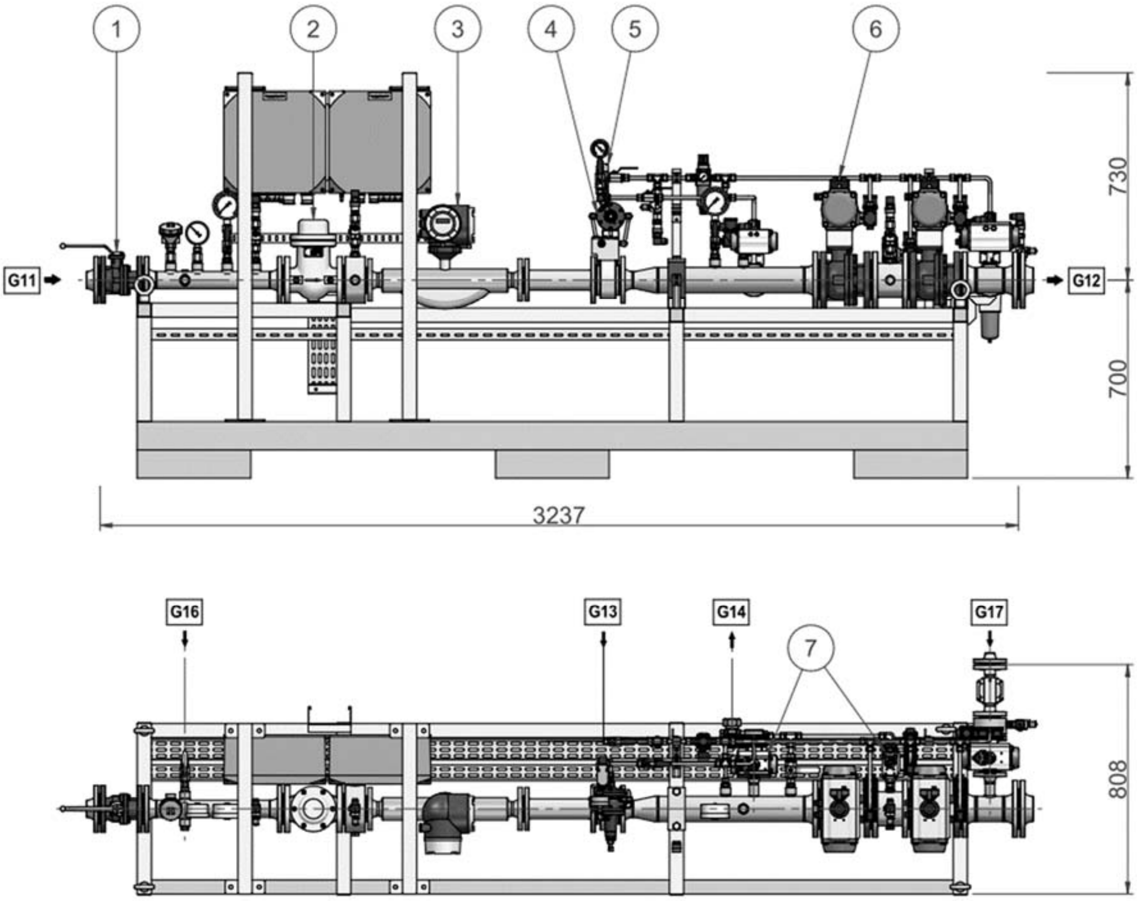


Figure 6.7 Typical drawing of gas regulating valve unit

Table 6.17 System components

No.	Description	Size
1	Manual shut off valve	
2	Fuel gas filter	2 ㎛
3	Flow meter	
4	Gas pressure regulator	
5	I/P convertor	
6	Double block valve	
7	Gas ventilation valves	

1. This drawing is only for reference in order to show the gas regulating valve unit figure. The exact dimension
2. Scope of supply will be followed according to extent of delivery for each project and engine builder’s standard.

Enclosed type gas regulating valve unit

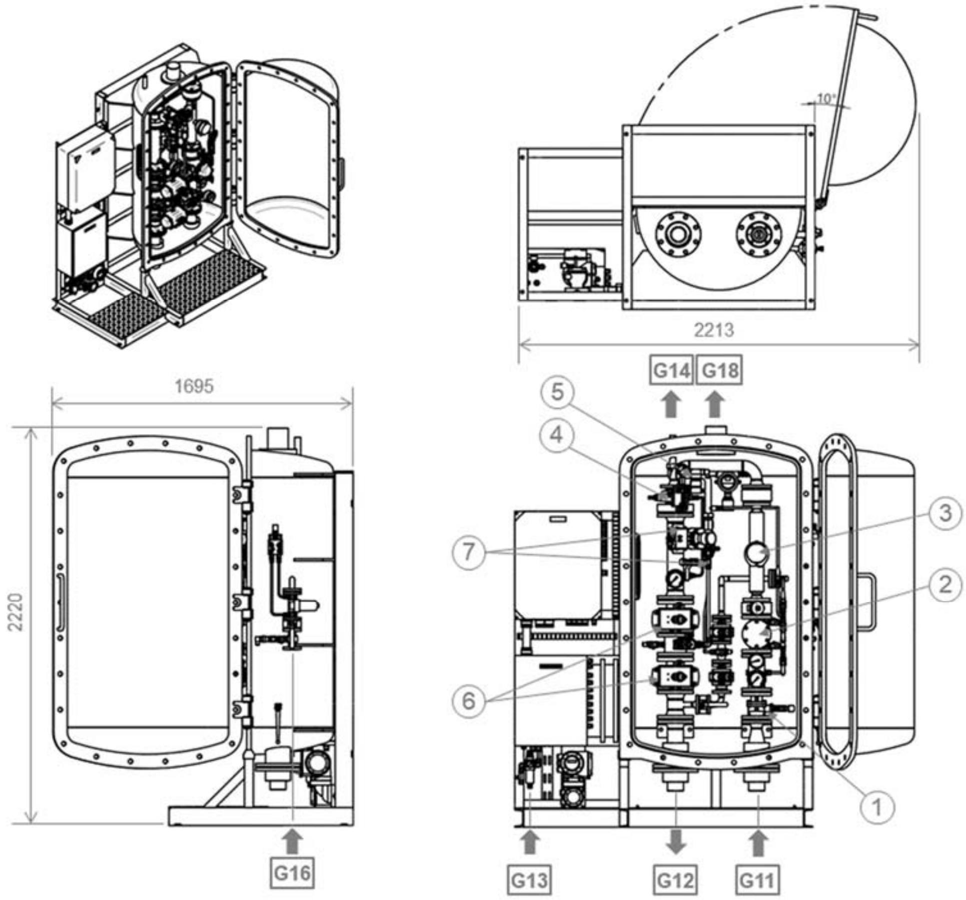


Figure 6.8 Typical drawing of enclosed type gas regulating valve unit

Table 6.18 System components

No.	Description	Size
1	Manual shut off valve	
2	Fuel gas filter	2 ㎛
3	Flow meter	
4	Gas pressure regulator	
5	I/P convertor	
6	Double block valve	
7	Gas ventilation valves	

1. This drawing is only for reference in order to show the gas regulating valve unit figure. The exact dimension
2. Scope of supply will be followed according to extent of delivery for each project and engine builder’s standard.

System diagram for enclosed type gas regulating valve unit

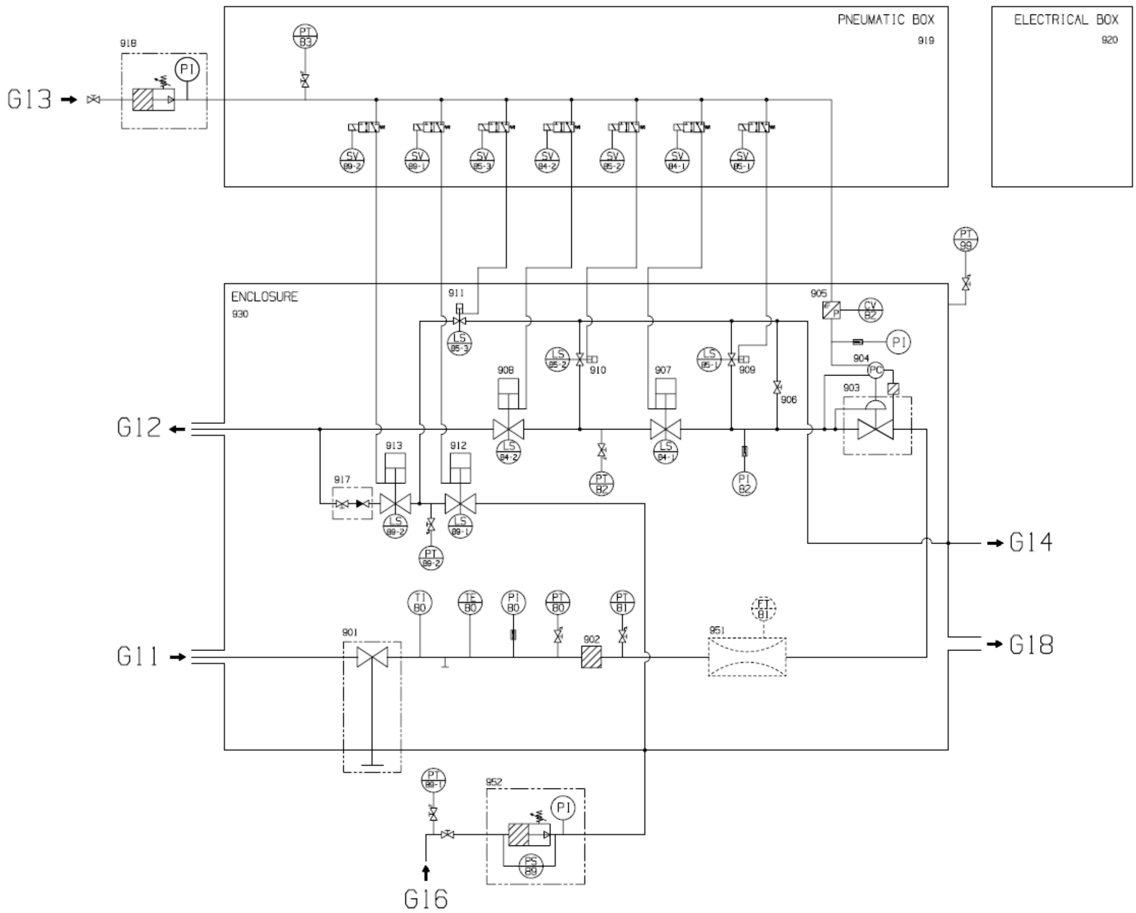


Figure 6.9 Enclosed type gas regulating unit valve system (BH2-062069-3)

Table 6.19 Size of the external pipe connections

No.	Description	Size	Remark
G11	Fuel gas inlet to gas regulating unit	80A 125A	Welded Type (pipe end)
G12	Fuel gas outlet to engine	80A 125A	Welded Type (pipe end)
G13	Control air to gas regulating unit	OD 12	Bite Type (connector end)
G14	Fuel gas ventilation from gas regulating unit	25A	Welded Type (pipe end)
G16	Inert gas inlet to gas regulating unit	20A	JIS B 2220 (flange end)
G18	Ventilation on enclosure	100A	Welded Type (pipe end)

Table 6.20 System components

No.	Description	Size
901	Manual shut off valve	
902	Fuel gas filter	2 μm
903	Gas pressure regulator	
904	Pilot regulator	
905	I/P convertor (CV82)	
906	Manual vent valve	
907	First block valve (SV84-1)	Normal close
908	Second block valve (SV84-2)	Normal close
909	Vent valve (SV85-1)	Normal open
910	Vent valve (SV85-2)	Normal open
911	Vent valve (SV85-3)	Normal close
912	First block valve (SV89-1)	Normal close
913	Second block valve (SV89-2)	Normal close
917	Closable non return valve	
918	Air filter	5 μm
919	Pneumatic box	
920	Electrical box	
930	Enclosure for GRU	
951	Coriolis type mass flow meter	Option
952	Inert gas filter with DPS (PS89)	

Gas filter

The gas filter protects the downstream equipment like the pressure regulators from impurities such as dust, rust, and other solid particles. The filtration of the gas filter is abs. 2 micron, 99 % efficiency.

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

Flow meter (Option)

The Flow meter can measure flow rates directly and integrate the measured values. As a result, the gas volume which flowed through the flow meter is registered by an electronic totalizing unit. The pressure loss at this filter is monitored by the front and the rear of pressure transmitter.

Double block valve

The Double Block and Bleed valve (DBB valve) is composed with two shut off valves (block valves) and one vent valve (bleed valve) between the shut off valves. The two shut off valves cut off the fuel gas supply to the DF engine according to specific sequence controlled by Engine Control System (ECS). And the vent 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 safety.
The double block and bleed valve is arranged in fuel gas line and inert gas line.

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 leaked from these valves.

Gas pressure regulating valve

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

Purging with inert gas

When emergency stop in gas mode or gas trip, fuel gas in double walled gas pipe should be purged out with inert gas (nitrogen). 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).

Gas vent line

Fuel gas vent line Should not be common with any other pipes to prevent unintended gas flowing to the other engines 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. Please refer to relevant rules and class regulation for further requirements regarding gas vent line.

Annular intermediate space volume for Enclosure : 1,300 liter

6.9 Fuel gas specification

Fuel gas characteristics

For continuous operation without reduction at the rated output, the fuel gas has to fulfill the below fuel gas quality requirements. In order to avoid operational problems such as de-rating, corrosion, wear, lube oil contamination etc., the fuel gas composition must be submitted to the engine manufacturer.

Table 6.21 Fuel gas characteristics

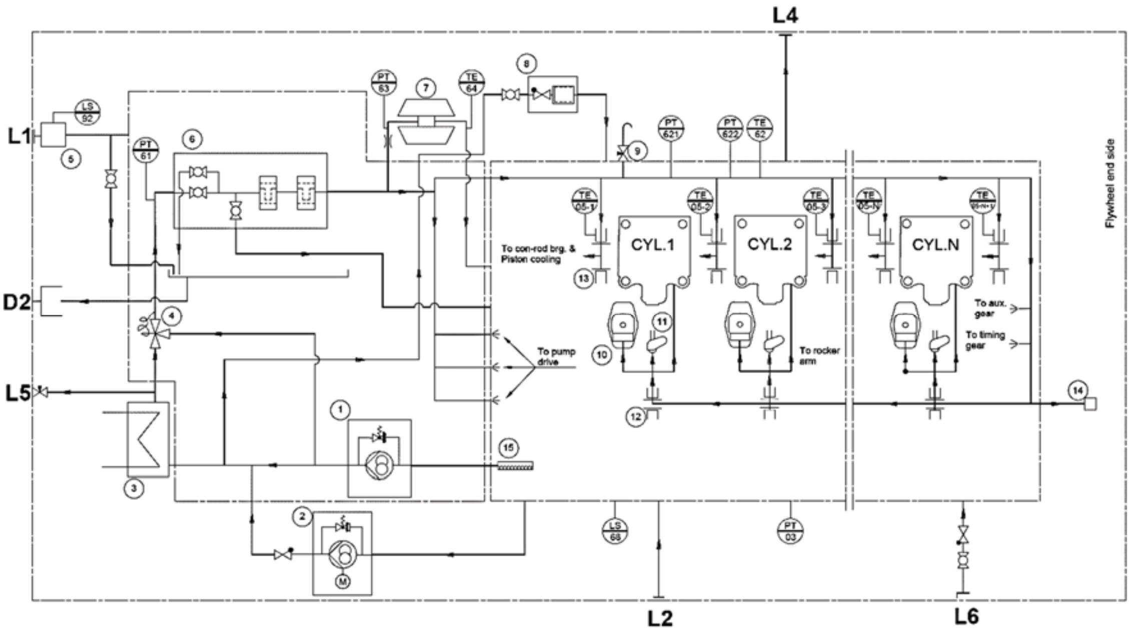
Property	Unit	Value
Lower calorific value (LCV), min. 3)	MJ/Nm3 1)	28
Methane number (MN), min. 2)	-	70
Methane (CH_4) content, min	Vol %	75
Total content of C3, C4, C5, C6, Heavier, max (Propane, Butane, Pentane, Hexane, Heptane, Octane, Cetane …)	Vol %	3
Particles or solids at engine inlet, max	㎛	5
Particles or solids at engine inlet	mg/Nm^3	50
Hydrogen sulphide content (H_2S), max	mg/Nm^3	30
Gas inlet temperature	˚C	0 ~ 50
Oil content, max	mg/Nm^3	0.01
Water or liquids	Condensate not allowed at engine inlet	

1) Reference condition for the volume designation Nm^3 (Temperature 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 heating value is in the range of 28 ~ 36 MJ/Nm3 or the MN is in the range of 70 ~ 80.

7 Lubricating oil system

7.1 Internal lubricating oil system

Diagram for Internal lubricating oil system



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

Figure 7.1 Diagram for internal lubricating oil system [BP0061792-0.4]

Table 7.1 Sizes of external pipe connections

Code	Description	Size
L1	Lubricating oil vapor discharger	125A
L2	Lubricating oil from separator	50A
L4	Lubricating oil to separator	50A
L5	C.W. auto shut off valve	PF1/4
L6	Inert gas supply to crankcase (for maintenance)	50A
D2	Oil drain	Ø25

1. Connection size is according to JIS B 2220.

Table 7.2 System components

No	Description	Remark
1	Eng. Driven lub oil pump	
2	Ele. Motor driven pre-lub oil pump	
3	Lub oil cooler	
4	Lub oil thermostatic valve	60/69℃
5	Oil mist detector	
6	Lub oil fine filter	1st : 15㎛, 2nd : 60㎛ Chamber : 3EA
7	Turbocharger	
8	Centrifugal by-pass filter	
9	Lub oil sampling valve	
10	Fuel pump drive	
11	Valve drive	
12	Cam shaft bearing	
13	Main bearing	
14	Governor drive	
15	Suction mesh	

7.1.1 General description

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

The internal lubricating oil system comprises following equipment :

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

Quantity of lubricating oil (wet sump)

Table 7.3 Total quantity of lubricating oil inside the engine

Engine type	Oil quantities in liter 720/750rpm	
	Min.	Max.
6H35DF	1900	2450
7H35DF	2080	2710
8H35DF	2460	3160
9H35DF	2730	3520

Lubricating oil consumption

Gas mode : 0.25 g / kWh
Diesel mode : 0.4 g / kWh

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

Engine driven lubricating oil pump

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

Pre-lubricating oil pump

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

Lubricating oil cooler

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

Thermostatic valve

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

Lubricating oil filter

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

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

Pressure regulating valve

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

Centrifugal oil filter

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

Lubricating oil sump drain

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

7.2 External lubricating oil system

Diagram for external lubricating oil system

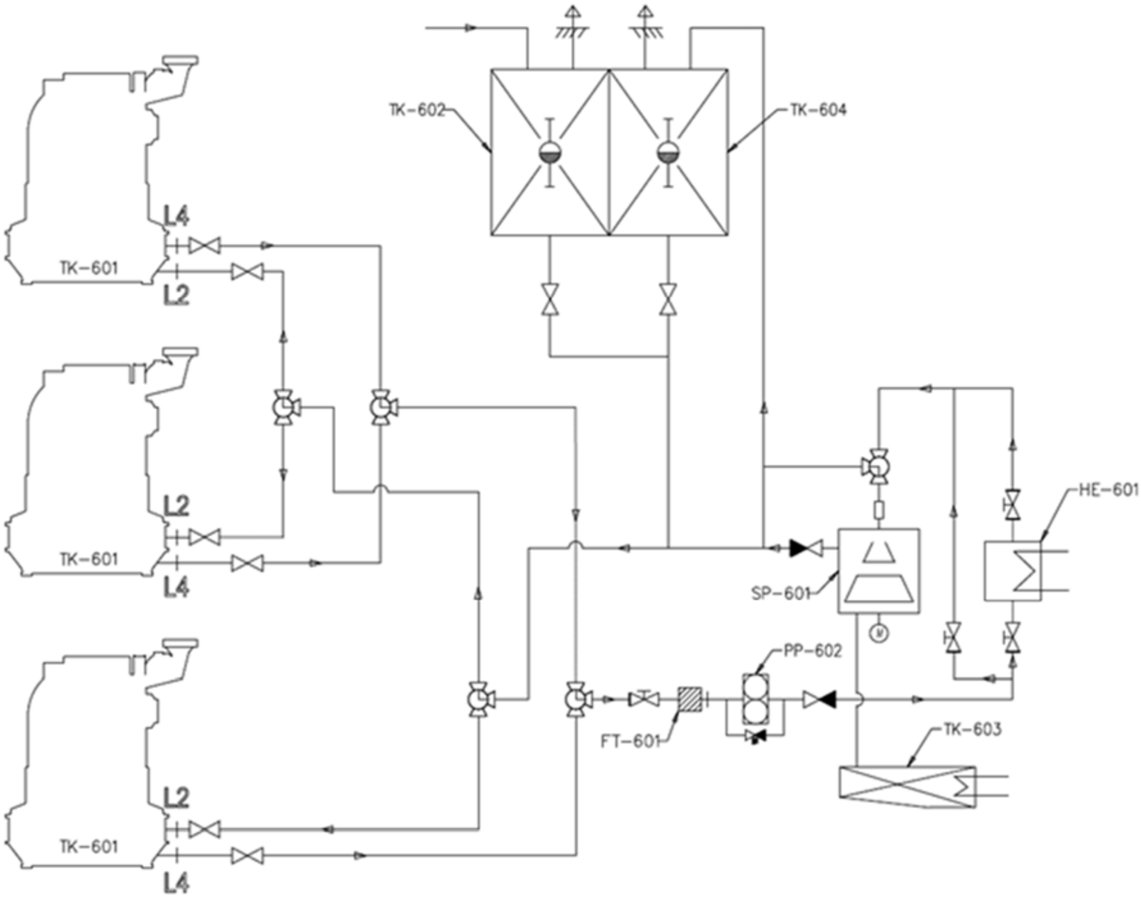


Figure 7.2 *Diagram for external lubricating oil system (B91-314112-7.1)*

Table 7.4 System components

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

7.2.1 General description

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

7.2.2 Lubricating oil separator

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

Separator capacity

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

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

Where :

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

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

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

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

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

Where :

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

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

Separator installation

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

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

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

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

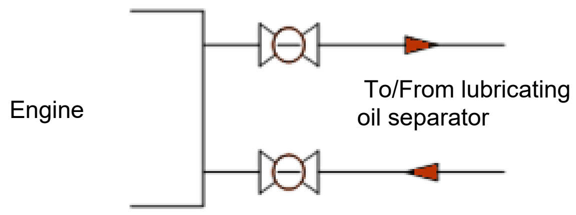


Figure 7.3 Principle layout for direct separating on single engine.

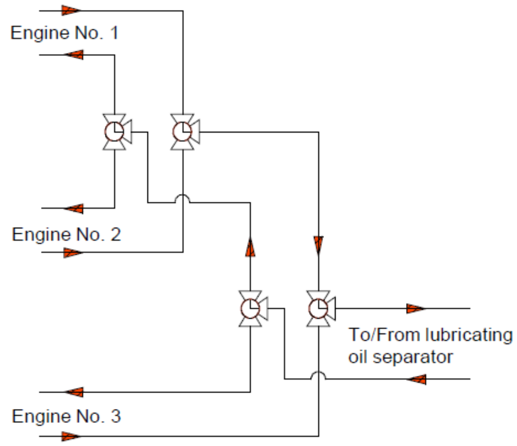


Figure 7.4 Principle layout for direct separating on multi engines

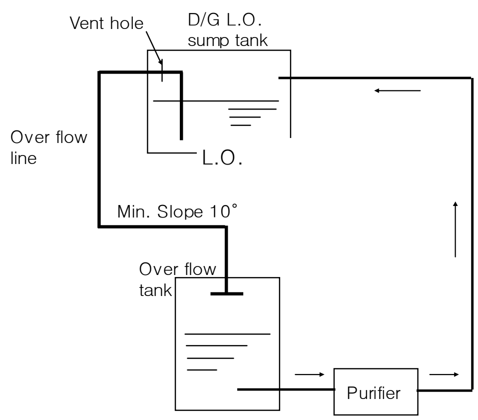


Figure 7.5 Principle layout for overflow system

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

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

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

Overflow system

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

Suction strainer

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

Pump for separator

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

Heater for separator

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

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

7.2.3 Velocities and pressure losses

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

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

7.2.4 Crank case ventilation

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

- ✓ The crankcase vent pipes from each engine shall be led independently to a safe location outside of engine room distant from any source of ignition. The pipes should not be connected to any other branch such as a tank vent, etc.
- ✓ The outlet of vent pipe is to be fitted with corrosion resistant flame screen separately for each engine.
- ✓ The vent pipe should have a continuous upward gradient of minimum 10 degrees without high point or low point.
- ✓ The vent pipe should be equipped with condensate trap and drain within 1~2m from the engine.
- ✓ The connection between the engine and yard vent pipe is to be flexible, if resilient mounting is applied.
- ✓ The dimension of the flexible connection is 125 A, and the vent pipe size after the flexible connection must be min. 125 .A.
- ✓ The oil mist should not be gone into suction side of intake duct located outside (for outdoor type) or engine room (for indoor type)
- ✓ Inert gas purging in the crank case is required manually before crankcase door open through L6 connection. The volume of the inert gas is referred to [6.7.3 purging with inert gas]
- ✓ The oil mist with air and gas mixture would be vent out from crankcase lube oil vent during gas mode operation.

7.2.5 Crankcase gas detection

The crankcase of trunk-piston type and Otto cycle gas fueled engine may contain very small amount of fuel gas due to blow-by gases. In case that the gas detection in the crankcase is required by classification societies, a shipyard should install a gas detection system in the crankcase vent pipe after the engine.

- ✓ The gas detector should be located away from the crankcase vent connection of the engine and recommended to be installed on the sampling line fitted on the crankcase vent in parallel.
- ✓ The appropriate arrangement should be considered to prevent the gas detector from being contaminated by oil vapor and/or particles.
- ✓ The gas detector should be selected and calibrated according to the detector maker’s recommendation based on components and characteristics of mixed gas in the crankcase.

  For example, Consilium’s Band B type gas detector(*) has to be calibrated in accordance with the below table provided by Consilium’s guidance.

  (*) The Band B type gas detector may be physically marked as Searchpoint Optima Plus gas detector. The Honeywell’s Searchpoint Optima Plus gas detector is supplied to Consilium, and Consilium renames the gas detector as Band B type.

Gas	Calibration gas concentration	Detector response at calibration
Methane (CH_4)	70% LEL	42% LEL
	50% LEL	30% LEL

Remark: LEL - Lower explosive limit

The values are only for reference and it is not guaranteed by an engine manufacturer. Therefore, please contact to the gas detector maker which is installed on the external system for appropriate values for each gas detector.

- ✓ The gas detector's alarm level should be arranged by the yard according to the classification socieities' requirement for the gas fueled internal combustion engines.

7.3 Lubricating oil specification and list of lubricants

7.3.1 Oil grade

The medium-alkaline, heavy duty (HD) oils in API-CD class have to be used for HiMSEN engine including turbocharger lubrication. Please refer to the Table 7.7

7.3.2 Oil viscosity

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

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

7.3.3 Governor oil grade

In case of the hydraulic governor, an independent oil system is required. For further information, please refer to the Table 7.7

BN value

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

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

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

7.3.4 Lubricating oil selection

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

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

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

Refer to the 6.4 and 6.9 for specification of fuel oil and fuel gas.

Table 7.5 Recommended BN for DF engine operation cases

Aux. fuel \ Main fuel			Natural gas
			No sulfur
Natural gas		No sulfur	BN 3 ~ 7
Distillated fuel (MGO / MDO)		- 0.1% S	BN 3 ~ 7 with limit 1)
		0.1 - 0.5% S	BN 3 ~ 7 with limit 1)
Residual fuel	ULSFO	- 0.1% S	BN 15 ~ 20 with limit 2)
	VLSFO	0.1 - 0.5% S	BN 15 ~ 20 with limit 3)
	HSHFO	0.5 - 3.5% S	BN 20 ~ 30 with limit 4)
		3.5 - % S	BN 30 ~ 40 with limit 5)

Table 7.6 Limitation (Allowed Max. operating hours)

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

7.4 List of lubricants

Table 7.7 List of lubricants

Oil brand	Engines system lubricating oil			Governor oil
Oil company	Brand name	SAE	BN *)	
Shell	Mysella S3 N40	40	5	1) Same as engine system lubricating oil 2) Refer to the governor manual for detailed lubricating oil specification, volume of governor. 3) Initial filling : oil filled 4) Electrical (Digital) governor: not applied
	Mysella S5 N40		4.5	
	Shell Gadinia S3 40		12	
	Shell Argina S2 40		20	
	Shell Argina S3 40		30	
	Shell Argina S4 40		40	
	Shell Argina S5 40		50	
TOTAL (Lubmarine)	Aurelia LNG	40	5	
	Nateria X 405		5.2	
	DISOLA M 4012		12	
	DISOLA M 4015		14	
	AURELIA TI 4020		20	
	AURELIA TI 4030		30	
	AURELIA TI 4040		40	
	AURELIA TI 4055		55	
Chevron (Texaco, Caltex)	HDAX 9700	40	5.8	
	DELO SHP 40		12	
	DELO 1000 Marine 40		12	
	TARO 20 DP 40(X)		20	
	TARO 30 DP 40(X)		30	
	TARO 40 XL 40(X)		40	
	TARO 50 XL 40(X)		50	
ExxonMobil	Pegasus 805 Ultra	40	5.4	
	Pegasus 805		6.2	
	Pegasus 1005		5.4	
	Pegasus 1105		6.2	
	Pegasus 1107		7.3	
	Pegasus 1		6.5	
	Mobilgard ADL 40, Mobil Delvac 1640		12	
	Mobilgard 412		15	
	Mobilgard M420		20	
	Mobilgard M430		30	
	Mobilgard M440		40	
	Mobilgard M50		50	
BP (Castrol)	CASTROL Duratex L	40	4.5	
	CASTROL MHP 154		15	
	CASTROL TLX 2-40		20	
	CASTROL TLX 3-40		30	
	CASTROL TLX 4-40		40	
	CASTROL TLX 5-40		53	
SK Lubricants	SUPERMAR 13TP 40	40	13	
	SUPERMAR 24TP 40		24	
	SUPERMAR 30TP 40		30	
	SUPERMAR 40TP 40		40	
LUKOIL	Navigo TPEO 12/40	40	12	
	Navigo TPEO 15/40		15	
	Navigo TPEO 20/40		20	
	Navigo TPEO 30/40		30	
	Navigo TPEO 40/40		40	
	Navigo TPEO 50/40		50	
	Navigo TPEO 55/40		55	

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

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

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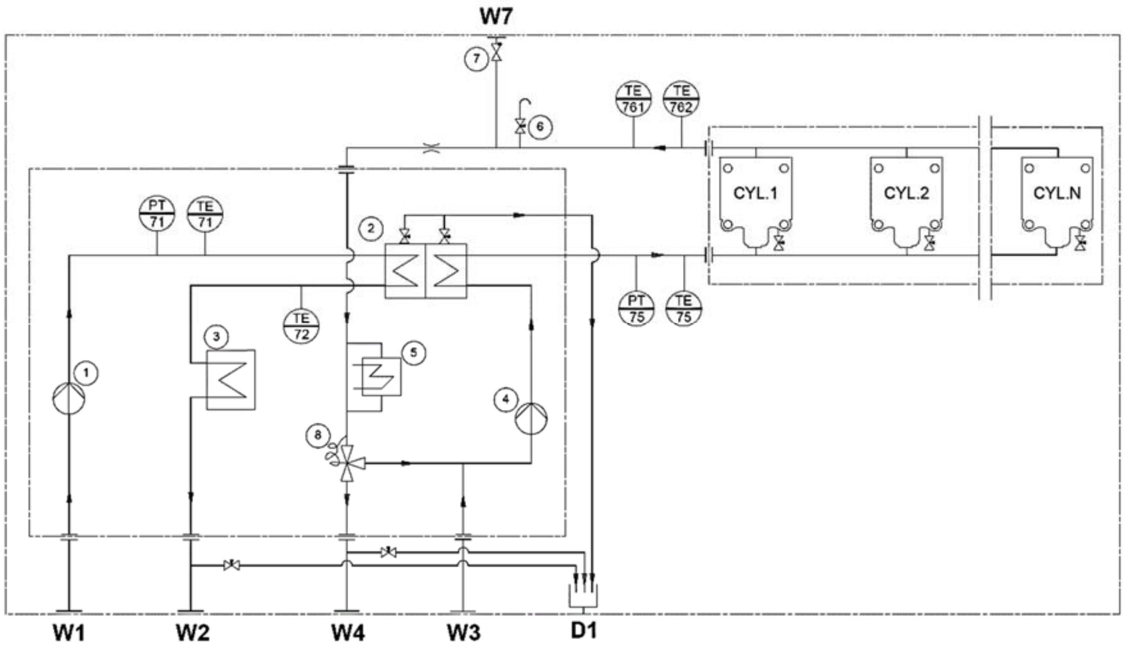
8 Cooling water system

8.1 Internal cooling water system

Diagram for internal cooling water system



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

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

Table 8.1 Sizes of external pipe connections

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

1. Connection size is according to JIS B 2220.

Table 8.2 System components

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

8.1.1 General description

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

Low temperature water circuit comprises :

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

High temperature water circuit comprises :

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

Scope of supply

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

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

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

8.2 External cooling water system

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

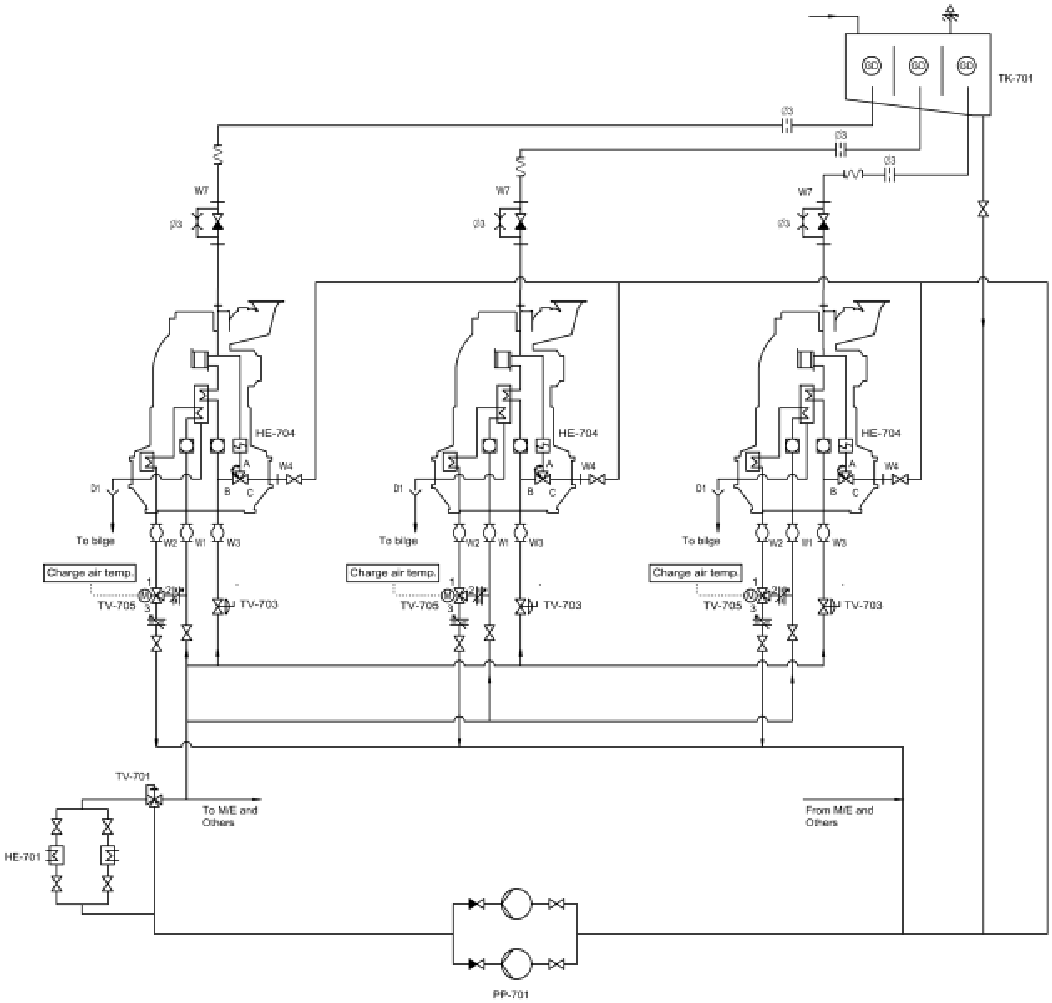


Figure 8.3 Diagram for external cooling water system with electric pre-heating element (B92-329026-6.1)

Table 8.3 System components

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

Diagram for external cooling water system with pre-heating unit

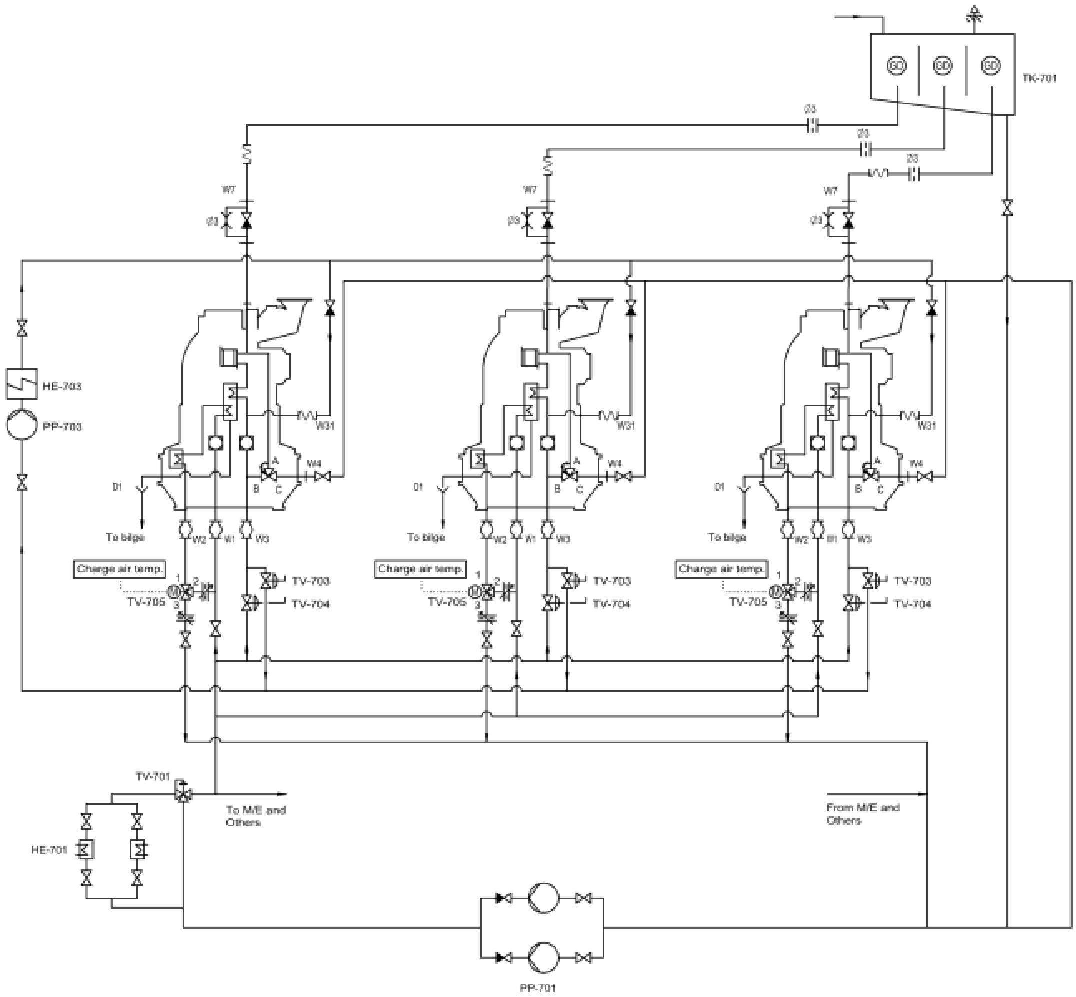


Figure 8.4 Diagram for external cooling water system with pre-heating unit (B92-329027-8.1)

Table 8.4 System components

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

8.2.1 General description

Pressure drop

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

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

Fresh water velocity

- ✓ Max. 2.5 m / s

Sea water velocity

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

Expansion tank

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

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

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

Table 8.5 Cooling water volume of the engines

Engine type	High temperature cooling water and low temperature cooling water volume
6H35DF	582 liter
7H35DF	617 liter
8H35DF	651 liter
9H35DF	686 liter

In unusual situation, the fuel gas could be enter into expansion tank. This unburned gas should be vent out through ventilation pipes to the safe zone on the open deck.

Central cooling

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

1) Fresh water side

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

2) Sea water side

- ✓ Flow quantity : 1.1 ~ 1.5 times of fresh water flow
- ✓ Pressure drop : 1.0 ~ 1.5 bar

8.2.2 Cooling water pressure of engine inlet

Pressure of engine inlet should be kept under 2.5 bar.

8.2.3 Cooling water

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

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

Pre-heating

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

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

Electric pre-heating element (Option)

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

Table 8.6 Recommended capacity of pre-heater

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

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

Operation

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

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

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

Preheating unit (Option)

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

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

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

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

Preheating of stand-by engine

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

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

8.3 Cooling water quality and treatment

8.3.1 Quality of cooling water

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

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

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

Table 8.7 Quality of cooling water

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

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

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

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

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

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

8.3.2 Treatment of cooling water

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

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

The recommended products are listed in following table.

Table 8.8 Recommended products list

Manufacturer	Brand name	Constituent	Delivery form	Recommended Dosage
Chevron (FAMM)	DELO XLI(Havoline XLI)	Carboxylates	Liquid	75 liter / 1000 liter
VECOM	Cooltreat NCLT	Nitrite	Liquid	48 liter / 1000 liter
Wilhelmsen Chemicals	Rocor NB	Nitrite, Borate	Liquid	63 liter / 1000 liter
NALCO	NALCOOL2000, TRAC102	Nitrite, Borate	Liquid	128 liter / 1000 liter
	TRAC100	Molybdate, silicate	Liquid	17.5 liter / 1000 liter
	TRAC115,TRAC108	Nitrite, Borate	Liquid	28 liter / 1000 liter
GE Water and Process Technologies	CorrShield NT4200	Nitrite	Liquid	30 liter / 1000 liter
Shell	Shipcare Cooling Water Treat	Nitrite, Borate	Liquid	128 liter / 1000 liter
Drew marine	LIQUIDEWT	Nitrite	Liquid	24 liter / 1000 liter
	MAXIGARD	Nitrite	Liquid	64 liter / 1000 liter
Houghton	Tectyl CW-70N-TEA	Nitrite	Liquid	66 liter / 1000 liter

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

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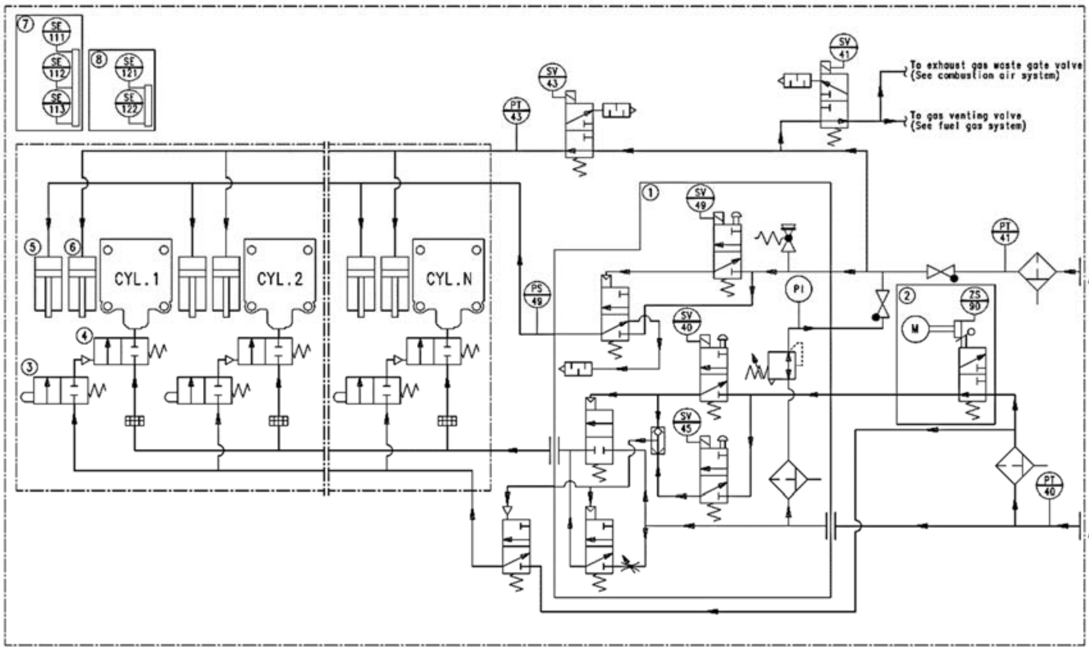
9 Air and exhaust gas system

9.1 Internal compressed air system

Diagram for internal compressed air system



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

Figure 9.1 Diagram for internal compressed air system [B92-128948-4.1]

Table 9.1 Size of external pipe connection

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

1. Connection size is according to JIS B 2220.

Table 9.2 System components

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

No	Description	Remark
5	Fuel pump rack	
6	DVT pusher	
7	Crankshaft	
8	Camshaft	

9.1.1 General description

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

Starting system

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

Engine stopper

Engine stopper consists of stop pilot valve and emergency stop cylinder. It is for immediate engine stop. In the emergency stop in diesel mode operation, emergency stop cylinder pushes the governor linkage not to move the fuel pump racks.

Slow turn

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

Scope of supply

The internal compressed air system consists of the following equipment :

- ✓ Main starting valve
- ✓ Stop solenoid valve and stop cylinders
- ✓ Manual stop valve
- ✓ Turning gear
- ✓ Slow turn valve assembly

9.2 External compressed air system

Diagram for external compressed air system

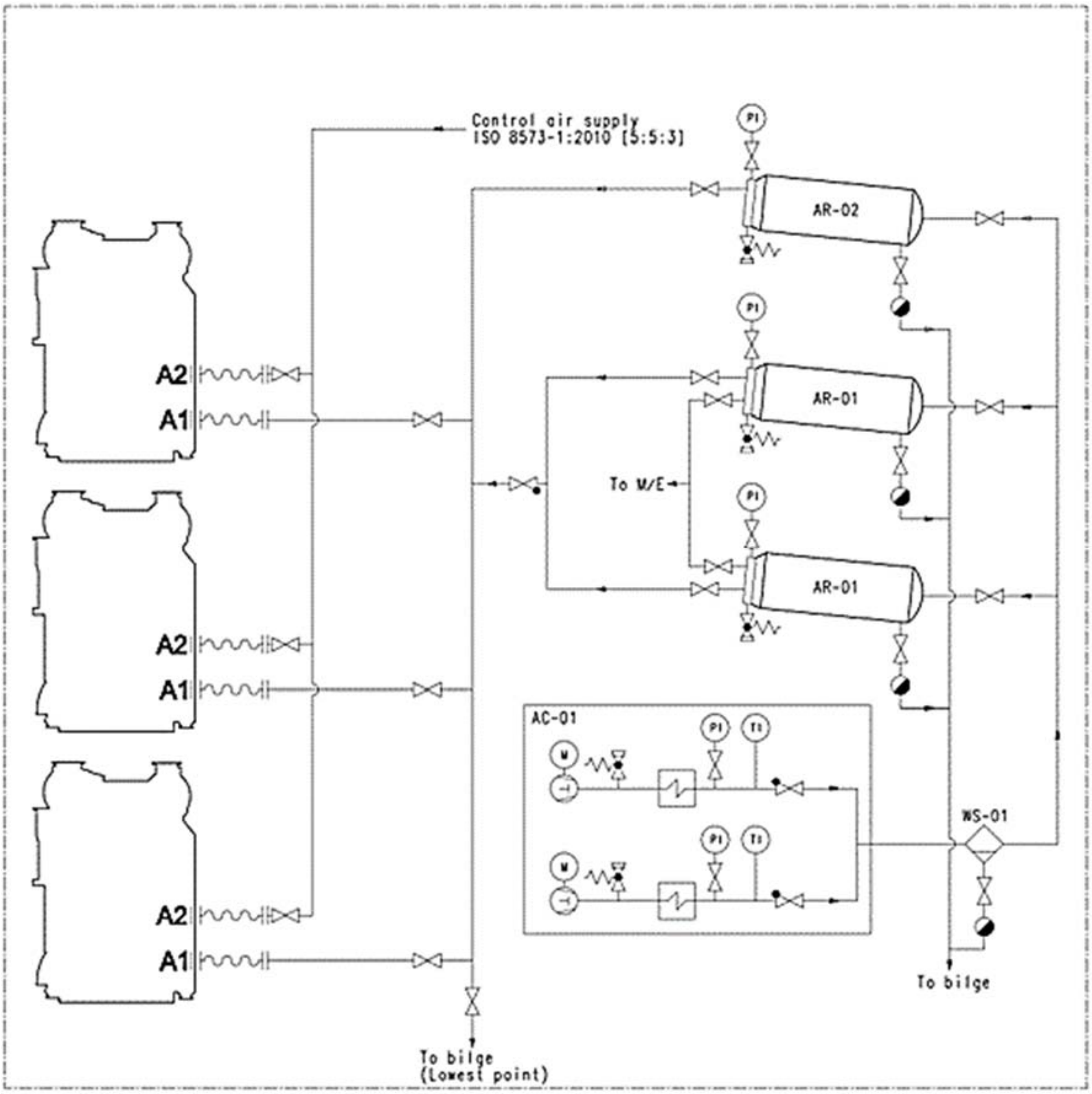


Figure 9.2 Diagram for external compressed air system

Table 9.3 System components

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

9.2.1 General requirements

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

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

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

9.2.2 Starting air volume of the engine

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

Table 9.4 Starting air volume of the engines

Engine type	Volume (liter)
6H35DF	960
7H35DF	1000
8H35DF	1090
9H35DF	1110

9.2.3 Compressed air specification

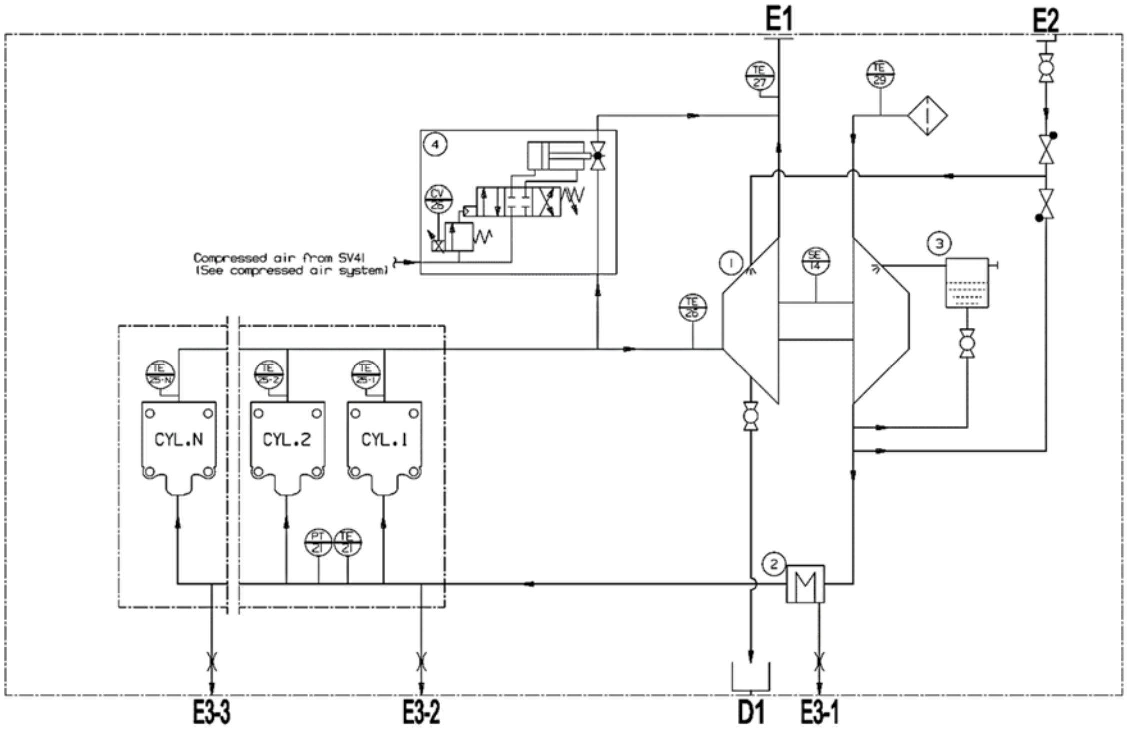
To ensure reliable engine operation and prevent damage to the components in the compressed air system, the compressed air must be free from contaminants such as particles, water, and oil. The required compressed air specification is as follows;

Table 9.5 compressed air specification

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

9.3 Internal combustion air system

Diagram for internal combustion air system



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

Figure 9.3 Diagram for combustion and exhaust gas system [B92-128959-1.1]

Table 9.6 Size of external pipe connection

Code.	Description	Size	Remark
E1	Exhaust gas outlet	1)	Acc. to project
E2	Turbine cleaning water inlet	-	Quick coupler
E3 - 1	Condensate water drain (Water mist catcher)	OD Ø10	Bite type Conn.
E3 - 2	Condensate water drain (1st cylinder)	OD Ø10	Bite type Conn.
E3 - 3	Condensate water drain (Last cylinder)	OD Ø10	Bite type Conn.
D1	Water drain	-	Acc. to project

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

Table 9.7 System components

No	Description	Remark
1	Turbocharger	
2	Charge air cooler	
3	Compressor washing device (Water vessel)	
4	EWG (Exh. gas waste gate valve)	

9.3.1 General description

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

Turbocharger

Turbocharger is a radial type with high efficiency and mounted on the feed module of the engine. The water washing systems for the compressor and turbine are supplied as standard.

Charge air cooler

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

Water mist catcher

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

Waste gate

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

Air chamber

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

Exhaust pipe system

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

Water drain pipes

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

Charge air by-pass valve

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

9.4 External combustion air system

9.4.1 General description

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

9.4.2 Combustion air

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

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

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

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

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

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

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

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

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

Ventilation of engine room

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

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

Where :

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

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

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

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

9.5 External exhaust gas system

9.5.1 General description

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

Independent exhuast gas system

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

Exhaust gas back pressure

Back pressure of the exhaust system in total is recommended to be less than 300 mmWC at maximum countious rating. The maximum back pressure should not exceed 500 mm WC at maximum countious rating. Please see the 3.6 correction of fuel consumption for the fuel consumption correction in case of exceeding 300 mmWC at maximum countious rating. The measuring position is approx. 1 ~ 2 m after the turbocharger gas outlet casing.

9.5.2 Velocity

Velocity of exhaust gas through pipe is more or less 40 m/sec.

Insulation

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

9.5.3 Piping design for exhaust gas system

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

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

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

9.5.4 Expansion bellows

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

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

Installation procedure for expansion bellow

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

9.5.5 Exhaust gas boiler

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

9.5.6 Exhaust gas silencer

Exhaust gas silencer can be supplied as option on request. The noise attenuation of silencer shall be either 25 dB(A) or 35 dB(A). For more information, please refer to the sheets for '9.7 exhaust gas silencer with spark arrestor'

9.5.7 Exhaust gas ventilaton unit

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 should not to head to the engine direction. The ventilation unit is controlled by engine control system automatically.

9.5.8 Relief valve (or rupture disc)

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.

9.6 External exhaust gas pipe connection

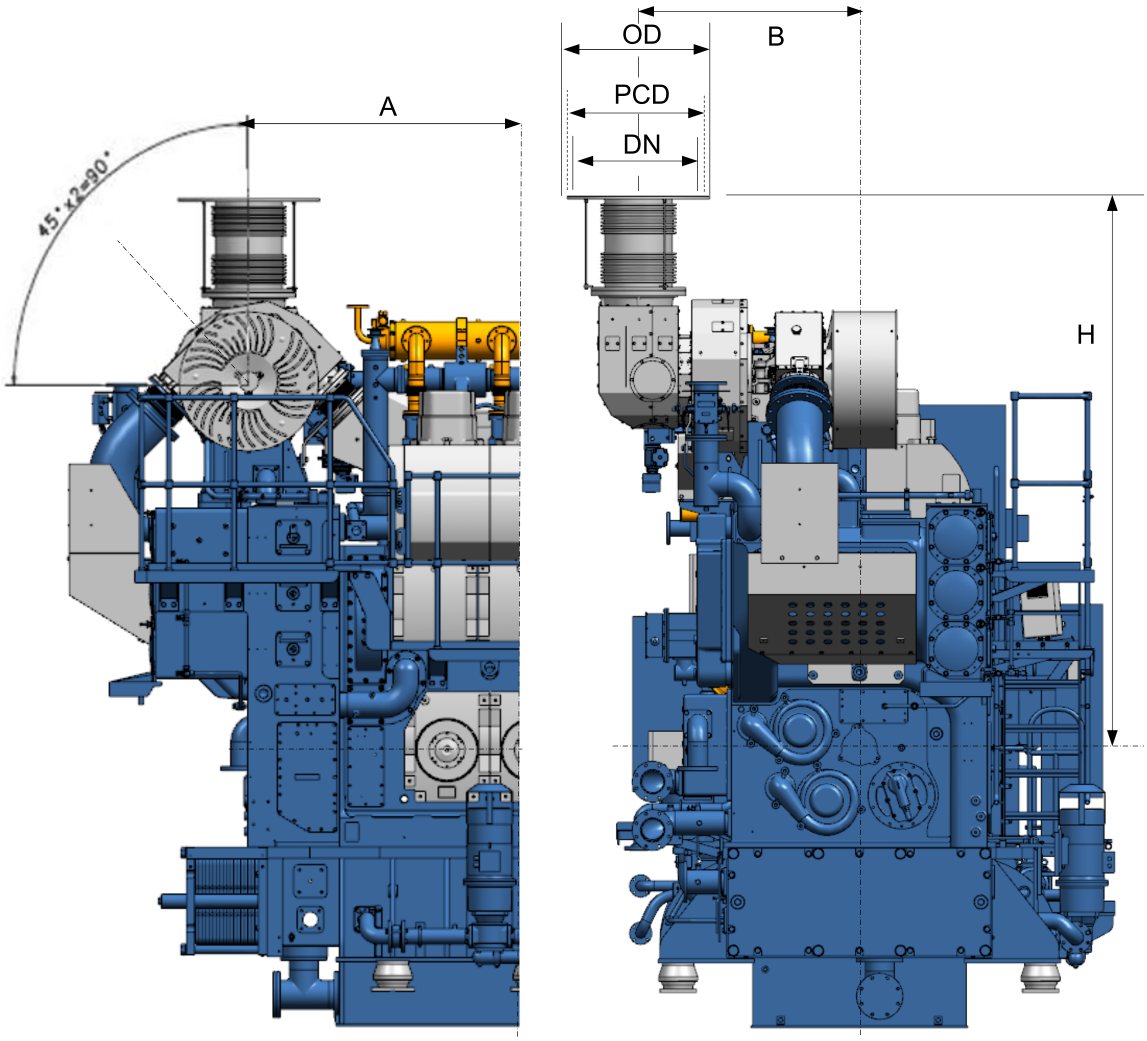


Figure 9.4 External exhaust gas pipe connection.

Table 9.8 Exhaust gas connection size

Engine type	Exhaust gas outlet position (mm)			Exhaust gas connection flange (mm)				
	A	B	H	DN	OD	T	PCD	N-d
6H35DF	1,790	1,143	2,276	600	710	16	670	16-22
7H35DF	1,790	1,260	2,530	650	760	16	720	16-22
8H35DF	1,790	1,260	2,530	700	856	20	800	24-22
9H35DF	1,790	1,348	2,530	750	907	20	860	24-22

9.7 Approach of SCR (Selective Catalytic Reduction) system installation

9.7.1 General description

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

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

Note !
The GAS mode operation of HiMSEN DF engines is met the IMO Tier III regulation without any aftertreatment equipment. However, if the diesel mode operation is required in emission controlled area (ECA), it should be installed an aftertreatment equipment such as the SCR in order to reduce the NOx emission on the vessel.

9.7.2 Boundary conditions for SCR operation

General boundary conditions for SCR operation :

Mode

- ✓ SCR operation is allowed in diesel mode, not gas mode

Main diesel fuel oil

- ✓ The diesel fuel for SCR should be selected according to the sulfur content in consideration of the sailing region and SCR specifications.

Exhaust gas temperature

- ✓ The minimum required temperature for SCR peration is determined by the sulfur content in fuel and SCR specifications.
- ✓ Exhaust gas temperature is controlled to increase by adjustable waste gate valve automatically for SCR active or ready condition.
- ✓ Exhaust gas SCR chamber bypass system need to be considered according to the gas mode exhaust gas temperature and SCR specifications.

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

Maximum exhaust gas back pressure

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

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

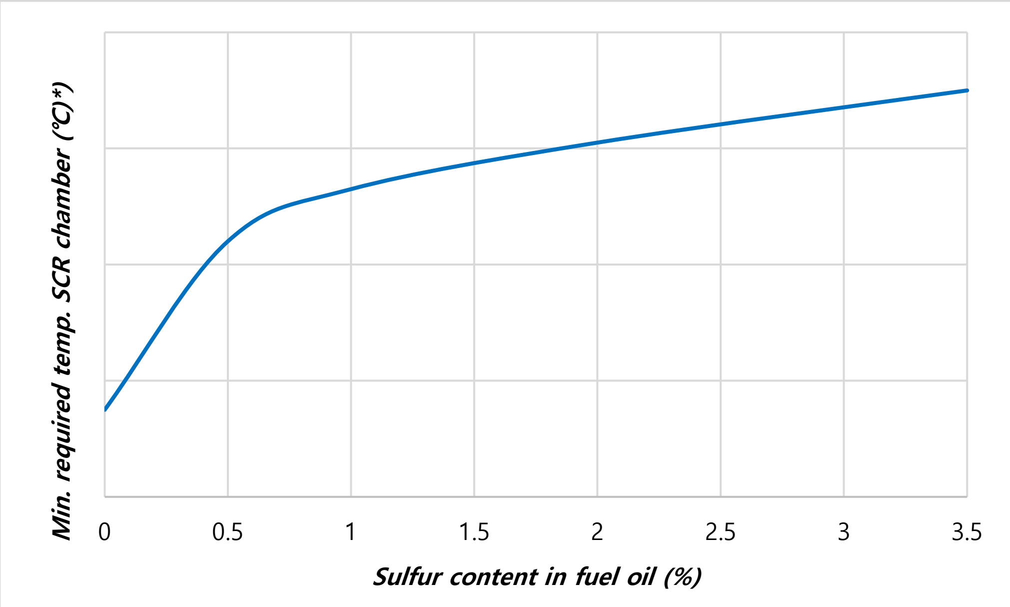


Figure 9.5 Minimum required exhaust gas temperature for SCR operation

\) The minimum required exhaust gas temperature for SCR operation is confirmed through the document from SCR supplier.

9.7.3 Operation and performance change

The HiMSEN DF engine is equipped with a waste gate valve as standard design in order to control air /fuel ratio in gas mode operation. As the SCR system is installed, the waste gate valve can be used in diesel mode to increase the exhaust gas temperature in the SCR operation at certain loads which is lower exhaust gas temperature.

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

The performance of gas mode is no difference because SCR operation is not necessary.

9.7.4 Exceptionals

In exceptional cases of SCR installation, please contact to HHI-EMD.

9.8 Exhaust gas silencer with spark arrestor

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

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

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

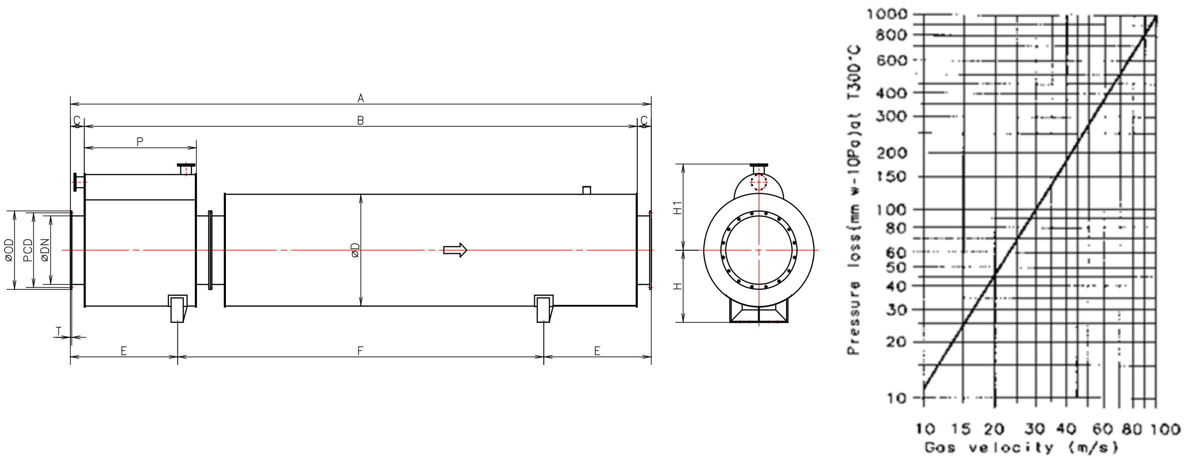


Figure 9.6 Exhaust gas silencer (25 dB type).

Table 9.9 Exhaust gas silencer size (25 dB type)

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

Cylinder type	H	H1	P	PCD	OD	T	N-d	Weight (kg)
6 (720 rpm)	700	792	1000	670	710	16	16- Ø23	1873
7 (720 rpm)	730	819	1100	720	760	16	16- Ø23	2080
8 (720 rpm)	750	885	1200	775	815	16	16- Ø23	2385
9 (720 rpm)	780	910	1200	825	865	20	20- Ø23	2660

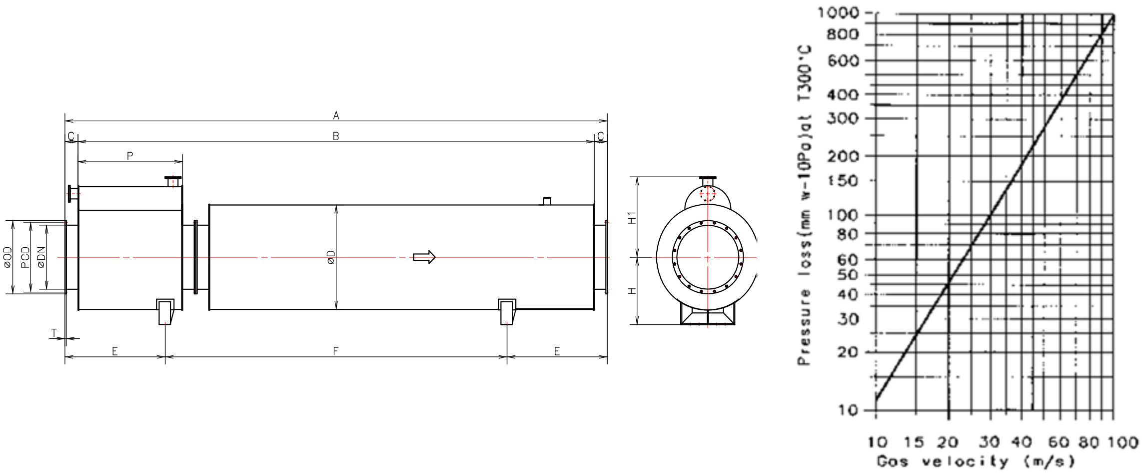


Figure 9.7 Exhaust gas silencer (35 dB type).

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

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

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

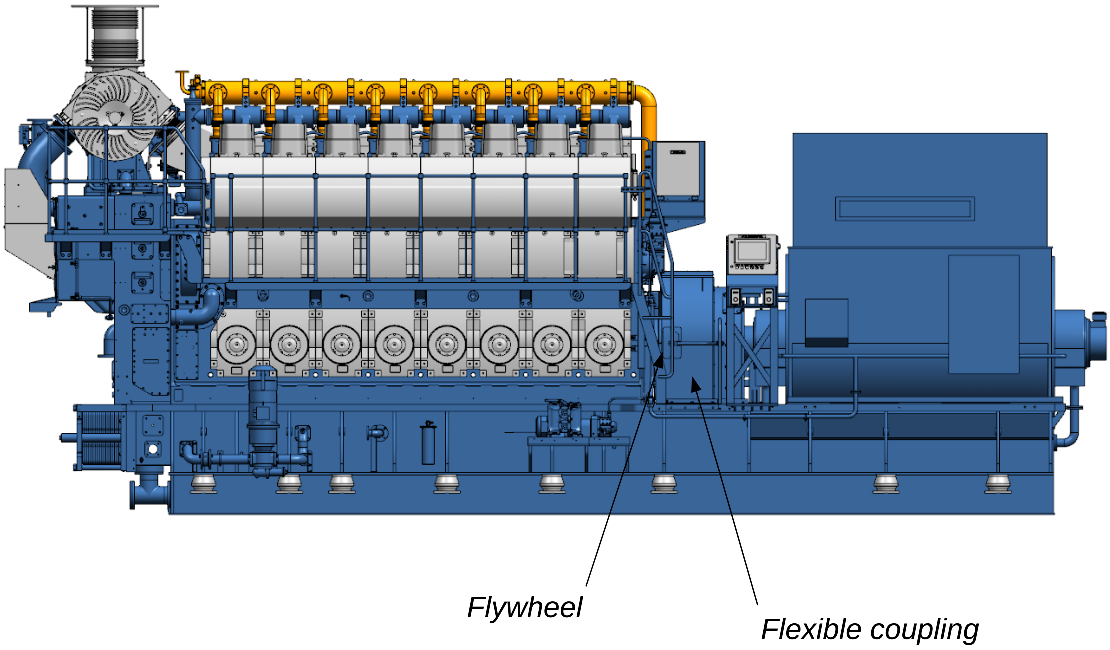
9.9 Generator information

Mounting of generator

As a standard design of H35DF engine, the engine and generator are coupled with flexible coupling and rigidly mounted on common base frame.

Generator bearing

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



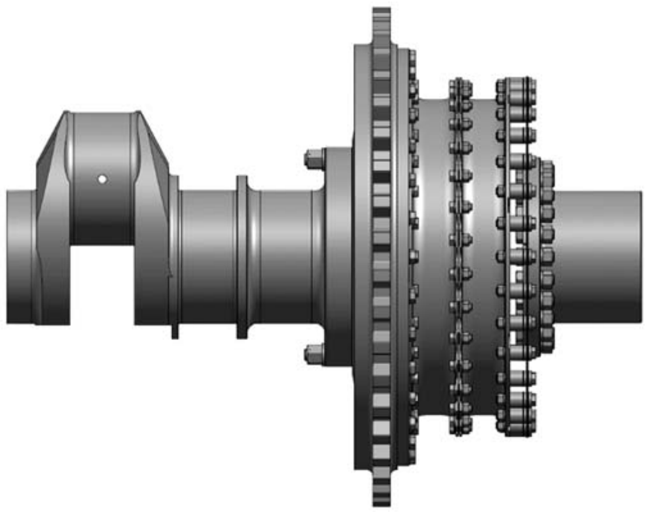


Figure 9.8 Flexible coupling outline

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10 Engine maintenance

10.1 Maintenance schedule

Table 10.1 Maintenance guidance.

Section No.		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Major fasteners - confirmation														
M11100	LDF11100	Bolt for base frame and resilient mount		▲			◆							
G11100	-	Nut for resilient mount and foundation		▲			◆							
-	LDF13000	Hydraulic nut for engine block and base frame		◆			◆							
M13250	LDF13000	Hydraulic nut for main bearing cap		◆			◆							
M21100	LDF13000	Hydraulic nut for cylinder head		◆			◆							
M25000	LDF25000	Bolt and nut for camshaft		▲			◆							
M31000	LDF32000	Hydraulic nut for connecting rod (Shaft)		◆			◆							
M31000	LDF32000	Hydraulic nut for connecting rod (big-end)		◆			◆							
M33200	LDF33000	Hydraulic nut for counter weight		◆			◆							
M35300	LDF35000	Bolt and nut for timing gear		▲			◆							
-	LDF83000	Bolt and nut for turbocharger mounting		▲			◆							

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

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

Section No		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Resilient mount														
M11100	LDF11100	Resilient mount		●			●							**)
Major bearing														
M13250	LDF13250	Main bearing					√		▣					
M13250	LDF13250	Thrust washer : axial clearance					◎						▣	
M25000 M25300	LDF25300	Camshaft bearing : clearance					√		◎				▣	
M31000 M32120	LDF32000	Connecting rod bearing (big-end)					√		▣					
M32130	LDF32000	Connecting rod bearing (small-end)					√		■				▣	
M35300	LDF35000	Bearing bush for Idle gear : clearance							◎				▣	

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

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

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

Section No		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Cylinder unit and connecting rod														
M15100	LDF15000	Cylinder liner					√		■					
M15100	LDF15000	Flame ring					√		▣					
M21100	LDF15000 LDF21100	Cylinder head and water jacket cooling water space					√		■					
M21120 M21130 M21200	LDF21100 LDF21200	Intake/exhaust valve spindle, seat ring and valve guide : overhaul and reconditioning					√		▣					
M21210	LDF21200	Intake/exhaust valve : clearance		●	●									**)
M21210	LDF21200	Rocker arm shaft and bush					√		■					
M21220	LDF21200	Rotocap			○				■					
M21400	LDF21400	Starting valve					√		■					
M24100	LDF24100	Dual valve timing					√		■					
M31100	LDF31100	Piston rings					√		▣					
M31100	LDF31100	Piston and piston pin					√		■					
M31000 M31101	LDF32000	Connecting rod bore (big-end)					√		■					
M31100 M32130	LDF31100 LDF32000	Piston pin and connecting rod (small-end) : clearance					√		■					
M31000	LDF32000	Shim plate for connecting rod					√		▣					
M31000	LDF32000	Stud for connecting rod shaft											▣	

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

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

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

Section No		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Crankshaft and gears														
M33100	LDF33000	Crankshaft : deflection					◎							
-	LDF33300 LDF42300	Gear teeth on flywheel and turning gear					▲							
-	LDF33400	Torsional vibration damper : fluid sampling (only for viscous damper)							◎					***)
-	LDF33500	Flexible coupling	▲											***)
M35300	LDF35000	Timing gear and pump driving gear : clearance and backlash							◎					
Valve operating mechanism														
M23000	LDF23000	Swing arm roller shaft and bush							■				▣	
M25000	LDF23000 LDF25000	Contact faces of cam and swing arm roller camshaft bearing		▲			▲							

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

***) See maker manual recommendation

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

Section No		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Control system														
-	LDF41000	Fuel control linkage : movement check	○											Weekly
G40001	-	Safety device : function check	○											Monthly
-	LDF41000	Governor oil level (only for mechanical hydraulic governor)	▲											***) Daily
-	LDF45000	Engine RPM pick-up sensor : clearance					●							
	LDF45000	Cylinder pressure sensor (if applied)						▣						
-	LDF45000	Knock sensor : tightening torque check						◆						
M45200	LDF45000	Temperature / pressure sensor	○											In case of necessity

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

***) See maker manual recommendation

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

Section No.		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Fuel system														
G05100 G05200	-	Analyze fuel oil properties : sampling	◎											Every bunkering
M51100	LDF51000	Fuel injection pump												
		Deflector : erosion				◎	▣							
		Plunger assembly					■		▣					
		Delivery valve assembly (except case)					■		▣					
		Delivery valve case					■						▣	
		Roller bush for tappet							■				▣	
M52000 M52001 M52002 M52003	LDF52000	Fuel injection valve : opening pressure		●	●	▣								****) ▣ :Atomizer life time
-	LDF52002	Micro pilot injector complete	■											*****)
-	LDF52002	High pressure pump								▣				
-	LDF52003	Micro pilot oil filter	■											If pressure drop reaches limit(See G01400)
-	LDF53000	O-rings for feed block					▣							
M53010	LDF56000	Fuel oil shock absorber				■								
M56000	LDF56000	Fuel oil filter	■											If pressure drop reaches limit(See G01400)

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

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

*****) Every 9000 hours : Injector replacement (9000 / 18000 hours : reconditioning)
(27000 hours : New Injector replacement)

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

Section No.		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Fuel gas supply system														
G05201	-	Analyze fuel gas properties : sampling	◎											Weekly during the first 3 months operation
-	LDF53001	Main gas feed pipe							■					
-	LDF53002	Gas admission valve						▣						
Lubricating oil system														
G06100	-	Analyze lubricating oil properties : sampling	◎											Every 3 month
M61000	LDF61000	Lubricating oil pump							■					
M62000	LDF62000	Lubricating oil cooler							■					***)
M63000	LDF63000	Lubricating oil filter (cartridge type)	■		▣									If pressure drop reaches limit(See G01400)
-	LDF63000	Auto backwashing filter (If applied)	■											***)
-	LDF64000	Thermostatic valve : clean and check the elements							■					***)
M67000	LDF67000	Lubricating oil centrifugal filter	■											***)

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

***) See maker manual recommendation

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

Section No.		Description	Overhaul interval (hours)											Remark
			Others	500 *)	2000	4000	10000	15000	20000	25000	30000	35000	40000	
Cooling water system														
G07100	-	Analyze cooling water properties : sampling	◎											Weekly : test kit every 3 month : Lab. test
M70000	LDF71000	Cooling water pump							■					
-	LDF74000	Thermostatic valve : clean and check the elements							■					***)
Compressed air system														
O02300	-	Air running	○											Monthly
G40000	-	Check starting & stop system	○											Weekly (over a week stand-still condition)
Combustion air system														
G81000	LDF75000	Charge air condensate drain pipe	●											Weekly
M80000		Turbocharger	■											***)
		Clean air filter (only for filter silencer type)	■		▣									Every 500 hours running
		Turbine : water-washing	●											Every 200 hours running
		Compressor : water-washing	●											Every 24 ~ 50 hours running
M83200	-	Exhaust gas waste gate	○											Weekly
M84000	LDF84000	Charge air cooler							■					

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

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

● Check & adjustment ◎ Measuring or sampling without dismantling

○ Function test ▲ Visual inspection

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

***) See maker manual recommendation

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

10.2 Recommended wearing parts

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

Table 10.2 List of consumable parts for one engine

Section No.	Parts description	Quantity for the operating hours								
		Set/ea	0 - 4000	0 - 10000	0 - 15000	0 - 20000	0 -25000	0 - 30000	0 - 35000	0 - 40000
Covers for engine block										
LDF13000	Gaskets for gear case cover	set	-	1	1	2	2	3	3	4
LDF19300	O-ring for crankcase cover	ea	-	2 x C	2 x C	4 x C	4 x C	6 x C	6 x C	8 x C
LDF19300	O-ring for camshaft cover	ea	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
Bearings										
LDF13250	Main bearing (upper & lower)	set	-	-	-	1xC+1	1xC+1	1xC+1	1xC+1	2xC+2
LDF13250	Thrust washer	ea	-	-	-	-	-	-	-	2
LDF25300	Camshaft bearing	ea	-	-	-	1	1	1	1	1xC+1
LDF32000	Big-end bearing (upper & lower)	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF32000	Small-end bearing	ea	-	-	-	-	-	-	-	1 x C
LDF35000	Bearing bush for idle gear	ea	-	-	-	-	-	-	-	1
Cylinder unit and connecting rod										
LDF15000	Flame ring	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF15000	O-rings and gasket for cylinder liner / cooling water jacket	set	-	1	1	1xC+1	1xC+1	1xC+2	1xC+2	2xC+2
LDF21100	O-rings for cylinder head cover	set	0.5 x C	1 x C	1.5 x C	2 x C	2.5 x C	3 x C	3.5 x C	4 x C

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

Section No.	Parts description	Quantity for the operating hours								
		Set/ea	0 - 4000	0 - 10000	0 - 15000	0 - 20000	0 -25000	0 - 30000	0 - 35000	0 - 40000
Cylinder unit and connecting rod										
LDF21100	O-ring for cylinder head	ea	-	1	1	1xC+ 1	1xC+ 1	1xC+ 2	1xC+ 2	2xC+ 2
LDF21100	Bush and O-ring for fuel valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF21100	Bush and O-ring for Micro pilot oil injector	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF21100	O-rings for valve guide and exhaust valve seat ring	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF21100 LDF21200	Intake valve spindle, seat ring and valve guide	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF21100 LDF21200	Exhaust valve spindle, seat ring and valve guide	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF21400	O-rings for starting valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF23000	Roller bush for swing arm	ea	-	-	-	-	-	-	-	1 x C
LDF24100	O-rings for dual valve timing	set	-	1	1	1xC+ 1	1xC+ 1	2xC+ 1	2xC+ 1	3xC+ 1
LDF31100	Piston ring-top ring / 2nd ring / scraper ring	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF32000	Shim plate for connecting rod	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF32000	Stud for connecting rod shaft	ea	-	-	-	-	-	-	-	4 x C
Control system										
LDF45275	Cylinder pressure sensor (if applied)	set	-	-	1 x C	1 x C	1 x C	2 x C	2 x C	2 x C
Fuel system										
LDF51000	Plunger assembly for fuel pump	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF51000	O-rings and seal ring for plunger assembly	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
LDF51000	Gaskets and seal ring for fuel pump	set	-	-	-	-	-	1 x C	1 x C	1 x C

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

Section No.	Parts description	Quantity for the operating hours								
		Set/ea	0 - 4000	0 - 10000	0 - 15000	0 - 20000	0 -25000	0 - 30000	0 - 35000	0 - 40000
Fuel system										
LDF51000	Deflector and gasket for fuel pump	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
LDF51000	Delivery valve assembly (except case)	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF51000	Delivery valve case	ea	-	-	-	-	-	-	-	1 x C
LDF51000	O-ring for fuel pump	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
LDF51000	Roller bush for tappet	ea	-	-	-	-	-	-	-	1 x C
LDF51000	O-ring for fuel pump drive	ea	-	-	-	-	-	-	-	1 x C
LDF52000	Fuel injection nozzle with dowel pin	set	1 x C	2 x C (8,000)	3 x C (12,000)	5 x C	6 x C (24,000)	7 x C (28,000)	8 x C (32,000)	10xC
LDF52000	O-rings and gasket for fuel injection valve	set	2xC	4xC	6xC	8xC	10xC	12xC	14xC	16xC
LDF52002	Replacement of micro pilot injector (9,000 / 18,000 hours : reconditioning) (27,000 hours : New Injector replacement)	set	-	-	-	-	-	1 x C (27,000)	1 x C (27,000)	1 x C (27,000)
LDF52002	O-ring and gasket for micro pilot injector and pipe (Every 9,000 hours)	set	-	1 x C (9,000)	1 x C (9,000)	2 x C (18,000)	2 x C (18,000)	3 x C (27,000)	3 x C (27,000)	4 x C (36,000)
LDF52002	High pressure pump	set	-	-	-	-	1 x C	1 x C	1 x C	1 x C
LDF52003	Spare parts for micro pilot oil filter (See manual for micro pilot oil filter)	set	-	-	-	-	-	-	-	-
LDF52300	O-rings for fuel injection pipe block	set	2xC	4xC	6xC	8xC	10xC	12xC	14xC	16xC
LDF53000	O-rings for fuel feed pipe connection	set	-	1	1	2	2	3	3	4
LDF56000	Spare parts for fuel oil filter (See manual for fuel oil filter filter)	set	-	-	-	-	-	-	-	-
LDF56000	Wearing ring and sealing ring for F.O shock absorber	set	1 x U	2 x U	3 x U	4 x U	5 x U	6 x U	7 x U	8 x U
Fuel gas supply system										
LDF46101	Gas admission valve	set	-	-	1 x C	1 x C	1 x C	2 x C	2 x C	2 x C

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

Section No.	Parts description	Quantity for the operating hours								
		Set/ea	0 - 4000	0 - 10000	0 - 15000	0 - 20000	0 -25000	0 - 30000	0 - 35000	0 - 40000
Fuel gas supply system										
LDF53001	O-rings for gas feed pipe to each cylinder	set	-	1	1	1xC+ 1	1xC+ 1	2xC+ 1	2xC+ 1	3xC+ 1
LDF53001	O-rings and gasket for main gas feed pipe	set	-	-	-	1	1	1	1	2
LDF53002	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										
LDF61000	Bushes for lubricating oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF61000	O-rings for lubricating oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF62000	O-ring for lubricating oil cooler connection (installation on engine side)	ea	-	-	-	4	4	4	4	8
LDF63000	Lubricating oil filter cartridge (paper cartridge type)	ea	2xU	4xU (8,00 0)	6xU (12,0 00)	10xU	12xU (24,0 00)	14xU (28,0 00)	16xU (32,0 00)	20xU
LDF63000	O-rings for lubricating oil filter assembly (paper cartridge type)	set	1 x U	2 x U	3 x U	4 x U	5 x U	6 x U	7 x U	8 x U
LDF63000	Spare parts for auto backwashing filter (see manual for auto backwashing filter)	set	-	-	-	-	-	-	-	-
LDF63000	Packing for auto backwashing filter	ea	-	-	-	1	1	1	1	2
LDF64000	O-ring for lubricating oil thermostat valve	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF64000	Gasket for thermostatic valve cover (No installation of auto backwashing filter)	ea	-	-	-	1	1	1	1	2
LDF67000	Spare parts for centrifugal filter (See manual for centrifugal filter)	set	-	-	-	-	-	-	-	-
Cooling water system										
LDF71000	Oil seal, mechanical seal and O-ring for high and low temperature cooling water pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF74000	O-ring for cooling water thermostat valve (wax type installed on engine)	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U

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

Section No.	Parts description	Quantity for the operating hours								
		Set/ea	0 - 4000	0 - 10000	0 - 15000	0 - 20000	0 -25000	0 - 30000	0 - 35000	0 - 40000
Cooling water system										
LDF74000	Gasket for thermostatic valve cover (wax type installed on engine)	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF77000	O-ring for cooling water connection	ea	-	2	2	4	4	6	6	8
LDF78000	O-ring for cylinder head cooling water connection	ea	-	8	8	(4xC) +6	(4xC) +6	(4xC) +14	(4xC) +14	(8xC) +12
LDF78000	O-ring for cylinder head outlet connection	ea	-	1	1	(1xC) +1	(1xC) +1	(1xC) +2	(1xC) +2	(2xC) +2
Supercharging system										
LDF81000	Gaskets for compressor out	set	-	-	-	1	1	1	1	2
LDF82000	Gasket for connection flange	ea	-	1	1	1xC+ 1	1xC+ 1	2xC+ 1	2xC+ 1	3xC+ 1
LDF83000	O-rings for Turbocharger connection	set	-	-	-	1	1	1	1	2
Charge air cooler										
LDF84000	O-rings and gaskets for air cooler	set	-	-	-	1	1	1	1	2
Turbocharger										
	Spare parts for turbocharger (See manual for turbocharger)	set	-	-	-	-	-	-	-	-
	Air filter mat (Engine room air suction)	ea	2	4 (8,000)	6 (12,000)	10	12 (24,000)	14 (28,000)	16 (32,000)	20

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

10.3 List of standard spare parts

List of minimum spare parts for each plant or each ship (valid for all classification societies)

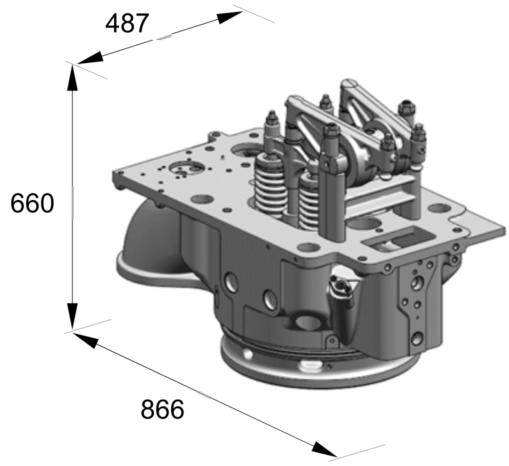
Table 10.3 List of standard spare parts

Parts description	Q'ty	Section No.	Item No.	Remark
Engine block and covers				
Main bearing, upper	1	LDF13250	251	
Main bearing, lower	1	LDF13250	251	
Thrust washer	2	LDF13250	252	
Main bearing stud	2	LDF13000	231	
Nut for main bearing stud	2	LDF13000	232	
Oil sealing ring for crankcase door	1	LDF19300	390	
Cylinder head and cylinder liner				
Valve spindle, intake	2	LDF21200	201	
Valve spindle, exhaust	4	LDF21200	202	
Conical piece	6	LDF21200	206	
Valve spring	6	LDF21200	207	
Valve seat, inlet	2	LDF21100	111	
Valve seat, exhaust	4	LDF21100	112	
Rotocap	6	LDF21200	204	
Air start valve	1	LDF21400	400	
O-ring for starting valve	1	LDF21400	411	
O-ring for starting valve	1	LDF21400	412	
O-ring for starting valve	1	LDF21400	413	
O-ring for starting valve	1	LDF21400	414	

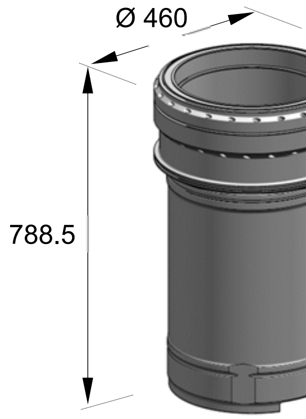
Parts description	Q'ty	Section No.	Item No.	Remark
Cylinder head and cylinder liner				
O-ring for starting valve	1	LDF21400	415	
O-ring for starting valve	1	LDF21400	416	
O-ring for starting valve	1	LDF21400	417	
O-ring for dual valve timing	6	LDF24100	330	
O-ring for dual valve timing	6	LDF24100	420	
O-ring for exhaust valve seat ring	4	LDF21100	118	
O-ring for valve guide	6	LDF21100	291	
O-ring for cylinder head	2	LDF21100	901	
O-ring for cylinder head cover, lower	1	LDF21100	805	
O-ring for cylinder head cover, upper	1	LDF21100	806	
O-ring for cooling water jacket	1	LDF15000	901	
O-ring for cooling water jacket	1	LDF15000	902	
O-ring for cylinder liner	1	LDF15000	192	
O-ring for cylinder liner	1	LDF15000	194	
O-ring for cylinder liner	2	LDF15000	193	
Sealing ring for cylinder liner	1	LDF15000	191	
O-ring for cooling water connection	4	LDF78000	300	
Piston, connecting rod				
Piston pin	1	LDF31100	120	
Piston ring, top	1	LDF31100	151	
Piston ring, 2nd	1	LDF31100	152	
Piston ring, scraper	1	LDF31100	153	

Parts description	Q'ty	Section No.	Item No.	Remark
Piston, connecting rod				
Big end bearing, upper and lower	1	LDF32000	113	
Small end bush	1	LDF32000	114	
Connecting rod big end stud	4	LDF32000	191	
Connecting rod shaft stud	4	LDF32000	194	
Nut for connecting rod	8	LDF32000	192	
Cylindrical pin	4	LDF32000	193	
Ignition system				
Fuel injection pump	1	LDF51000	100	
Fuel injection valve	N/2	LDF52000	100	N : maximum. cylinder No.
Fuel high pressure block	1	LDF52300	100	
Micro pilot injector	N/2	LDF56002	201	N : maximum. cylinder No.
O-ring for micro pilot injector	10	LDF56002	603	
O-ring for SOGAV	1	LDF53002	107	
O-ring for SOGAV	1	LDF53002	106	
Piping system				
Flexible connecting pipe, each type	1 set	LDF98370	-	
Lube oil filter cartridge (primary)	1 set	LDF63000	101	

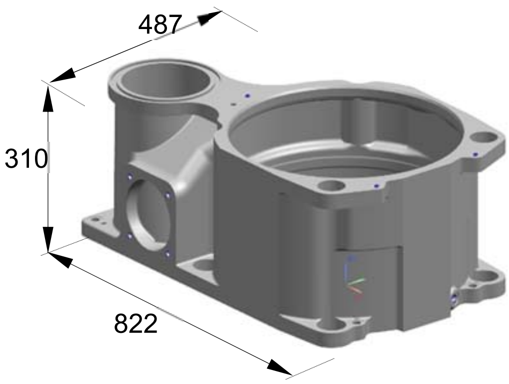
10.4 Heavy parts for maintenance



Cylinder head and rocker arms assembly
(Weight : approx. 492 kg)



Cylinder liner
(Weight : approx. 192.72 kg)



Water jacket
(Weight : approx. 117.75 kg)

Connecting rod shaft
(Weight : approx. 71.36 kg)

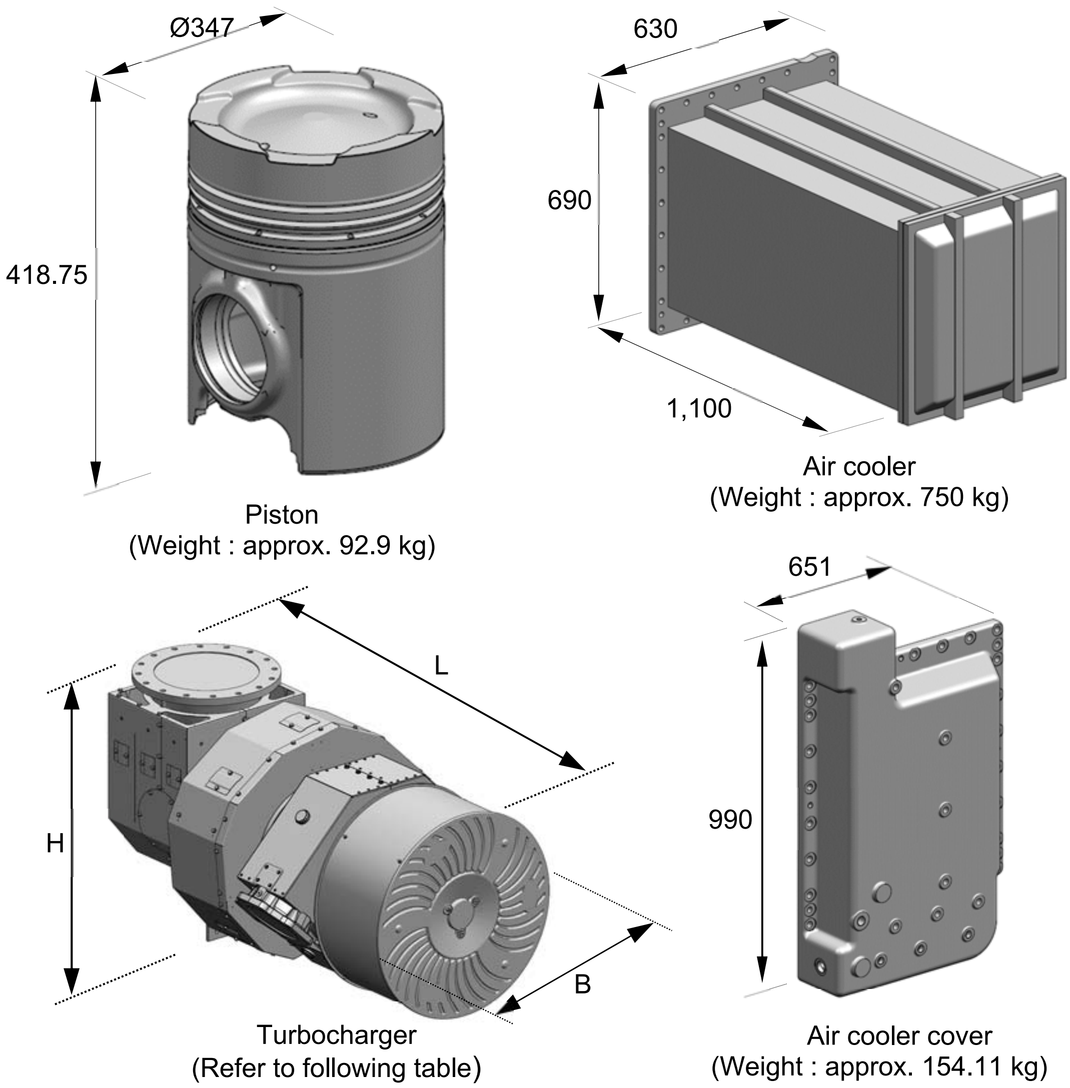


Figure 10.1 Heavy parts dimension and weight.

Table 10.4 List of turbocharger outline dimension and weight

Turbocharger type	B (mm)	H (mm)	L (mm)	Weight (kg)	Remarks
ST6	734	827	1574	582	Without insulation
ST7	870	1530	1960	1270	Without insulation
A145	736	1227	1436	750	Without insulation
A150 - M x 6,7	807	1060	1747	1200	Without insulation
A150 - M x 8	822	1160	1823	1200	Without insulation
A155	840	1262	2052	1800	Without insulation

10.5 List of standard tools

Table 10.5 List of standard tool parts

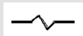
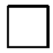
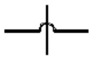
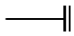
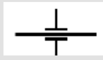
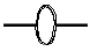
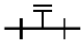
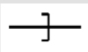
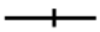
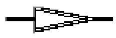
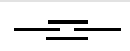
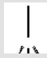
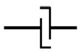
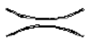
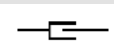
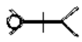
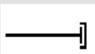
Tool description	Q'ty	Remark
Cylinder head and liner		
Lifting tool for cylinder head	1	
Fitting/removal device for valve conical clamping piece	1	
Grinding tool for cylinder head and liner	1	
Extract/suspension device for cylinder liner	1	
Cylinder bore gauge	1	
Removing device for flame ring	1	
Removal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

Tool description	Q'ty	Remark
Crankshaft and main bearing		
Lifting device for main bearing cap	4	
Fitting device for main bearing	1	
Deflection gauge for crankshaft	1	
Fuel injection pump		
Installing tool set for PTFE seal on barrel	1	
Fuel injection valve		
Fitting device for micro pilot injector bush	1	
Removal device for micro pilot injector bush	1	
Test tool for fuel valve nozzle	1	
Lapping device for fuel injection valve bush	1	
Removal tool for atomizer nut	1	
Cleaning tool for fuel injection valve nozzle	1	
Removal device for fuel injection valve	1	
Long socket for nozzle nut	1	
Removal device for fuel injection valve bush	1	
Spanner for fuel high pressure block	1	
General tools		
Removal device for cooling water connection	1	
Torque wrench 22.5 Nm	1	
Torque wrench spanner head 8	1	
Torque wrench spanner head 16	1	
Turbocharger cleaning hose	1	

Tool description	Q'ty	Remark
Hydraulic tools		
Hydraulic tightening devices M48 (cylinder head, main bearing cap)	4	
Hydraulic tightening devices M39 (side stud, count weight)	2	
Hydraulic tightening devices M36 (coupling stud)	2	
Hydraulic tightening devices M33 (connecting rod shaft, big end)	2	
Set of spare parts for hydraulic tools M48	1	
Set of spare parts for hydraulic tools M39	1	
Set of spare parts for hydraulic tools M36	1	
Set of spare parts for hydraulic tools M33	1	
Insert screw for hydraulic jack M33	2	
Angle piece for hydraulic jack M33	2	
Support for hydraulic tools M48 (main bearing cap)	2	
Support for hydraulic tools M48 (cylinder head)	4	
Support for hydraulic tools M36 (base frame)	2	
Support for hydraulic tools M39 (side stud, count weight)	2	
Support for hydraulic tools M33 (connecting rod shaft, big end)	2	
Extension screw for hydraulic tools M48 (cylinder head)	4	
Distribution pieces 2-POT	1	
Distribution pieces 4-POT	1	
High pressure hose (L=800)	4	
High pressure hose (L=4000)	2	
Adapter for hydraulic handing pump	1	

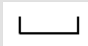
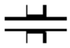
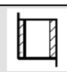
Tool description	Q'ty	Remark
Hydraulic tools		
Turning pin (Φ10)	2	
Turning pin (Φ6)	2	
Cylinder pressure sensor tools		
Installation for cylinder pressure sensor	1	
Dual valve timing tools		
Assembly tool for dual valve timing	1	
Standard tool box		
Spare and tool box	5	
Air starting valve tools		
Lapping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

11 Appendix 1 (Piping symbols)

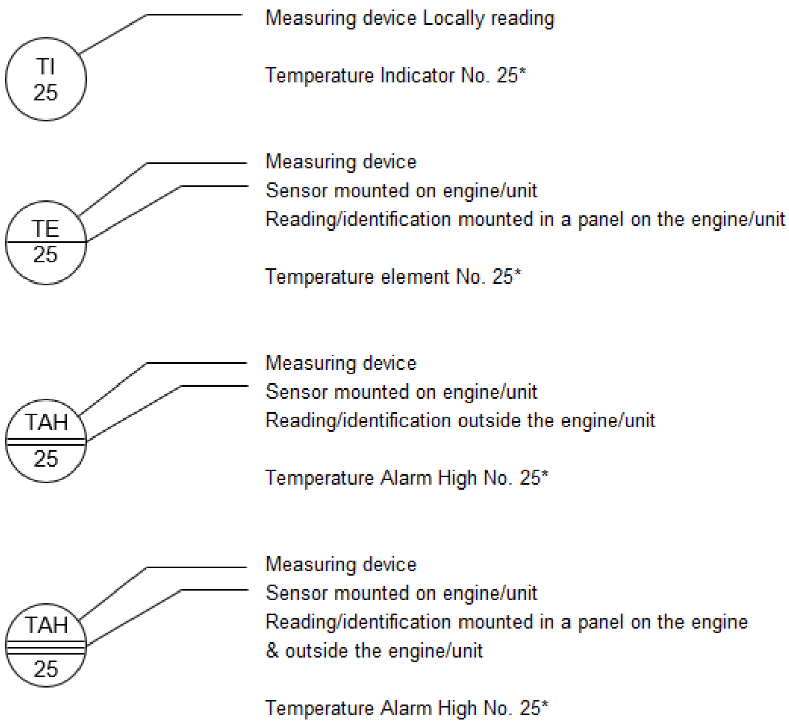
No.	Symbol	Symbol designation	No.	Symbol	Symbol designation
General conventional symbols					
1.1		Pipe	1.5		Indicating and measuring instruments
1.2		Pipe with indication of direction of flow	1.6		High pressure pipe
1.3		Valves, gate valves, cocks and flaps	1.7		Tracing
1.4		Appliances	1.8	— — —	Enclosure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

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

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

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

12 Appendix 2 (Instrumentation code)



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

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

Combustion gas system

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

Compressed air system

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

Fuel oil system

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

Lubricating oil system

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

Cooling water system

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

13 Note

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