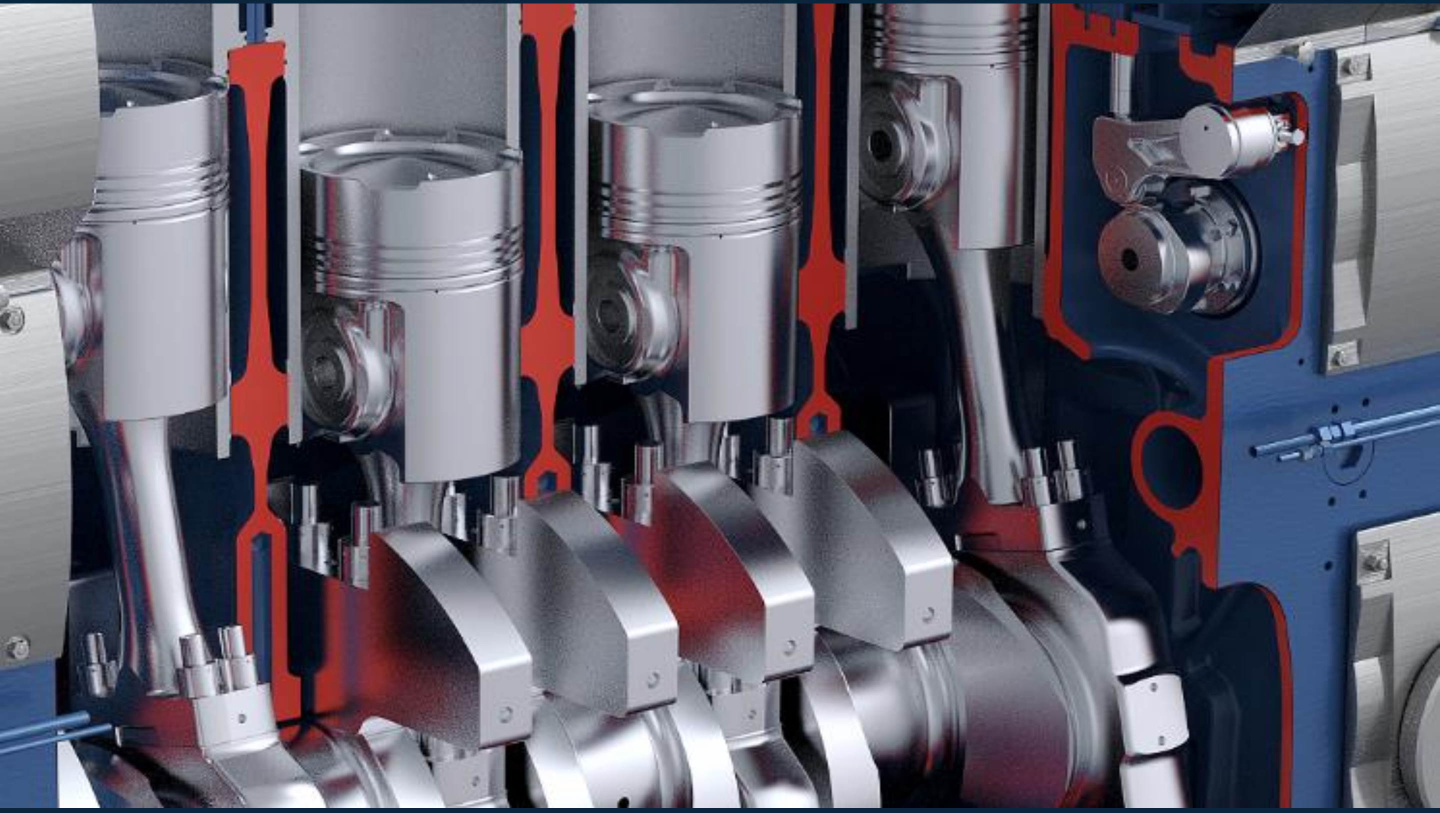
PROJECT GUIDE

HiMSEN H35DF(V)P

FOR PROPULSION

2023 1st EDITION



HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY

HiMSEN

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

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General

This project guide provides necessary information and recommendations for the application of HYUNDAI's HiMSEN H35DF(V)P marine propulsion engine.

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

The HiMSEN H35DF(V)P marine propulsion engines are delivered as propulsion packages, which consists of the reduction gear, propulsion shaft & propeller, control system and auxiliary equipment depending on project inquiries.

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

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

Engine model designation

12 H 35 DF V P

- 12 — No. of Cylinders (6,7,8,9,12,14,16,18,20)
- H — HYUNDAI's HiMSEN
- 35 — Cylinder Bore in cm
- DF — Dual Fuel
- V — Type configuration(L or V)
- P — Propulsion application

Sheet number

P . XX . XXX

- P — Project guide book
- XX — Section number
- XXX — Sub - section with serial number

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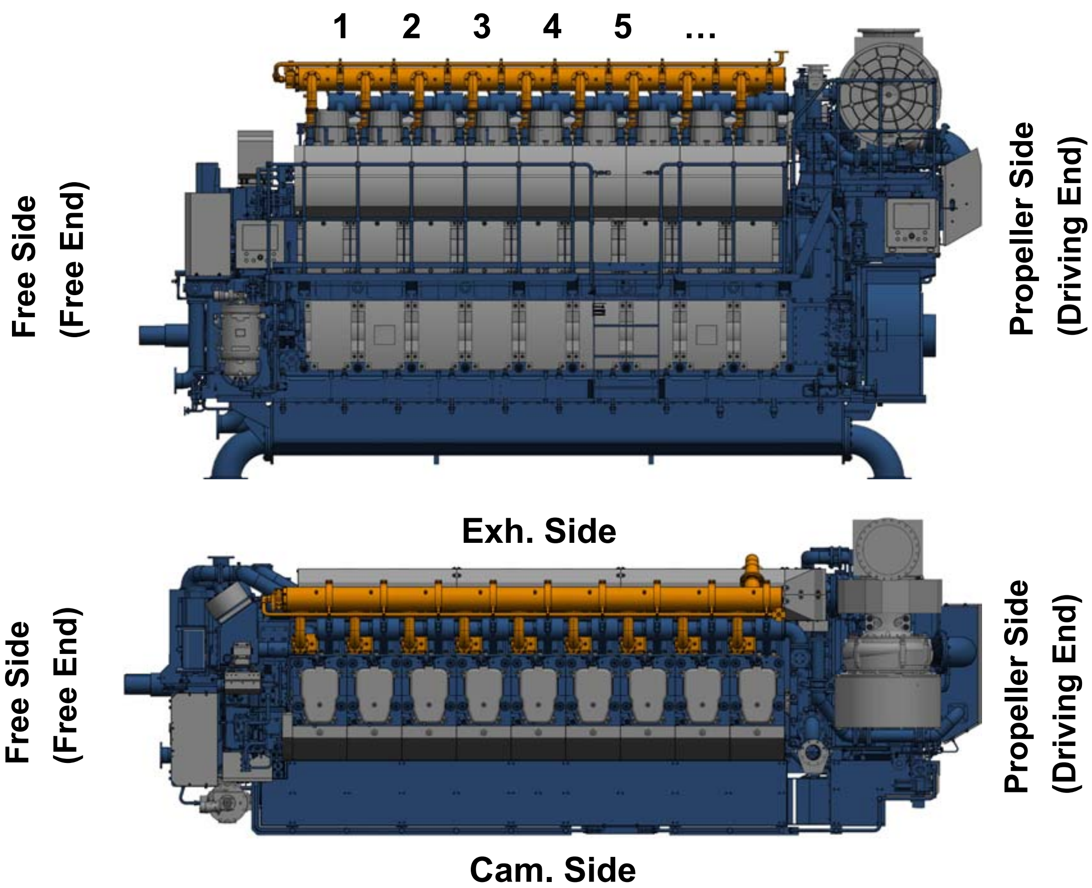
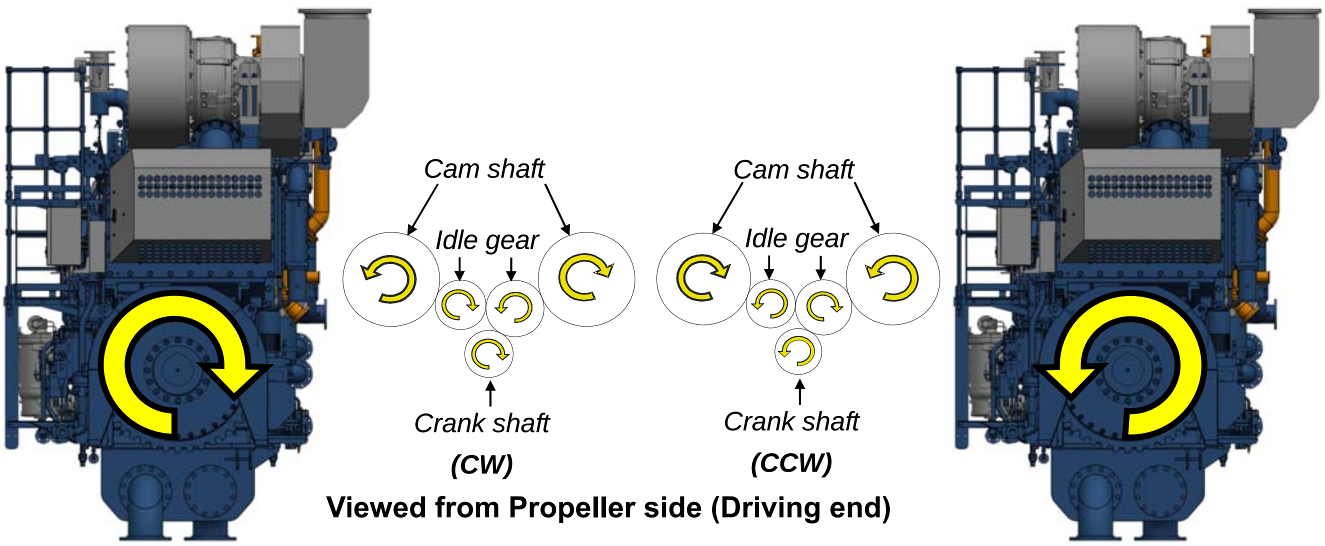
Cylinder Numbering(L-type)

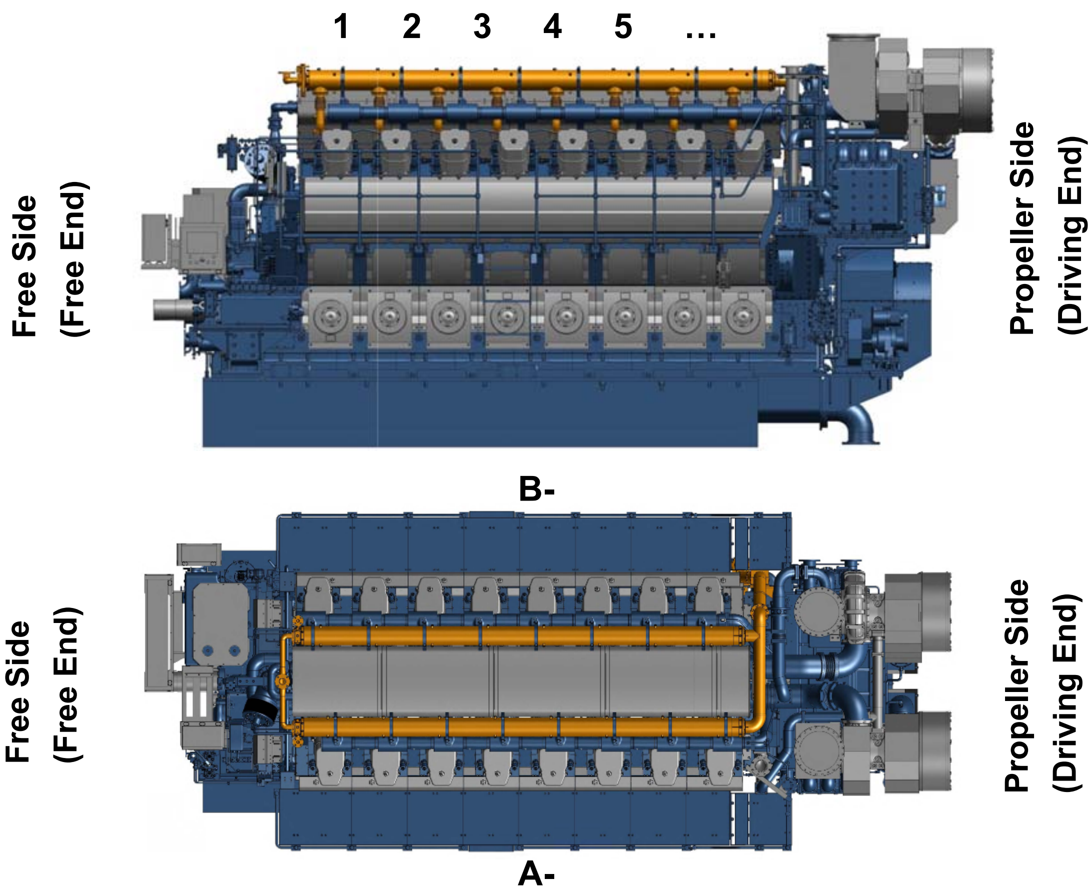


Direction of Engine Rotation

Clockwise Rotation **Counterclockwise Rotation**

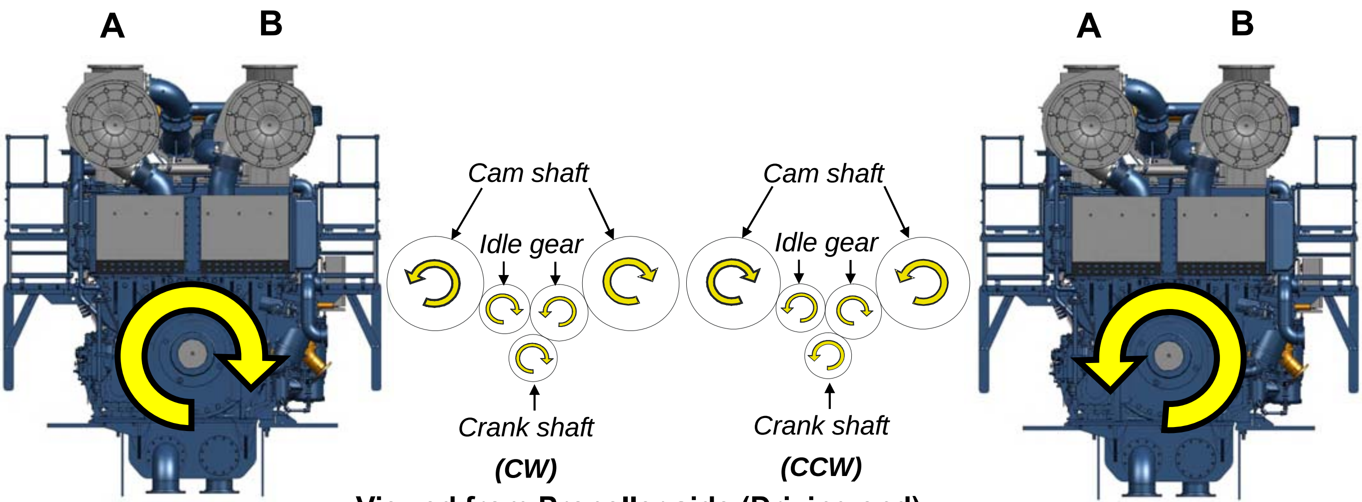


Cylinder Numbering(V-type)



Direction of Engine Rotation

Clockwise Rotation **Counterclockwise Rotation**



Viewed from Propeller side (Driving end)

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Appendix

Type of engine		4-stroke, vertical, direct injection, Single acting and trunk piston type with turbocharger and inter-cooler
Cylinder configuration		L- type, V-type
Number of cylinder		6, 7, 8, 9, 12, 14, 16, 18, 20
Rated speed	rpm	750
Power per cylinder	kW	500
Cylinder bore	mm	350
Piston stroke	mm	400
Swept volume per cylinder	dm^3	38.5
Mean piston speed	m/s	10.0
Mean effective pressure	bar	20.8
Compression ratio		13.5 : 1
Direction of engine rotation Viewed from propeller side (driving end)		Clockwise (standard) Counterclockwise (option) Non-reversible

Cylinder firing order (CW)		Cylinder firing order (CCW)	
6H	1 - 4 - 2 - 6 - 3 - 5	6H	1 - 5 - 3 - 6 - 2 - 4
7H	1 - 2 - 4 - 6 - 7 - 5 - 3	7H	1 - 3 - 5 - 7 - 6 - 4 - 2
8H	1 - 3 - 5 - 7 - 8 - 6 - 4 - 2	8H	1 - 2 - 4 - 6 - 8 - 7 - 5 - 3
9H	1 - 3 - 5 - 7 - 9 - 8 - 6 - 4 - 2	9H	1 - 2 - 4 - 6 - 8 - 9 - 7 - 5 - 3
12H	1 - 4 - 2 - 6 - 3 - 5	12H	1 - 5 - 3 - 6 - 2 - 4
14H	1 - 2 - 4 - 6 - 7 - 5 - 3	14H	1 - 3 - 5 - 7 - 6 - 4 - 2
16H	1 - 3 - 5 - 7 - 8 - 6 - 4 - 2	16H	1 - 2 - 4 - 6 - 8 - 7 - 5 - 3
18H	1 - 3 - 5 - 7 - 9 - 8 - 6 - 4 - 2	18H	1 - 2 - 4 - 6 - 8 - 9 - 7 - 5 - 3
20H	1 - 5 - 9 - 4 - 3 - 10 - 6 - 2 – 7 - 8	20H	1 - 8 - 7 - 2 - 6 - 10 - 3 - 4 - 9 - 5

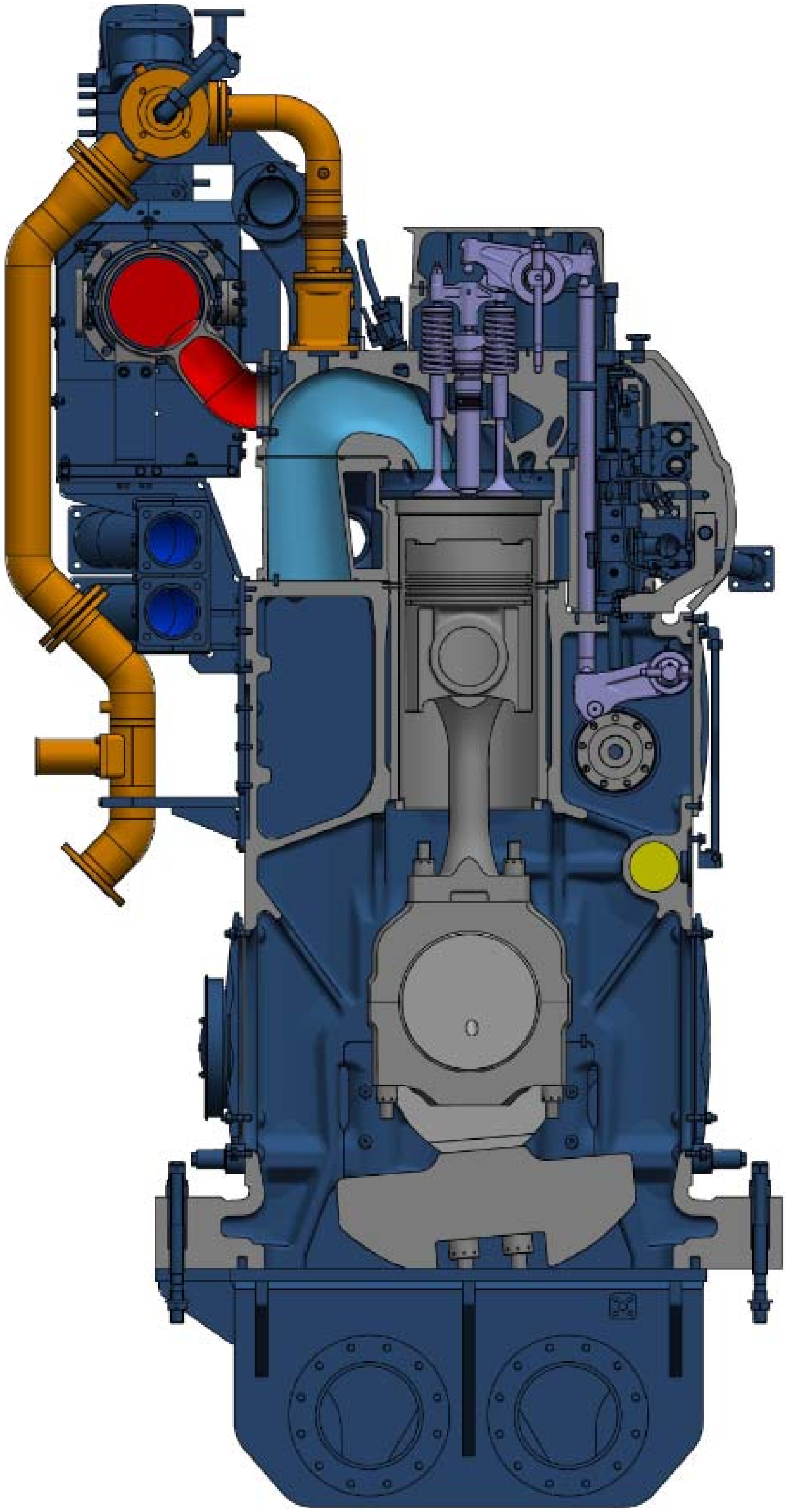


Figure 1-2-1: In-line engine cross section

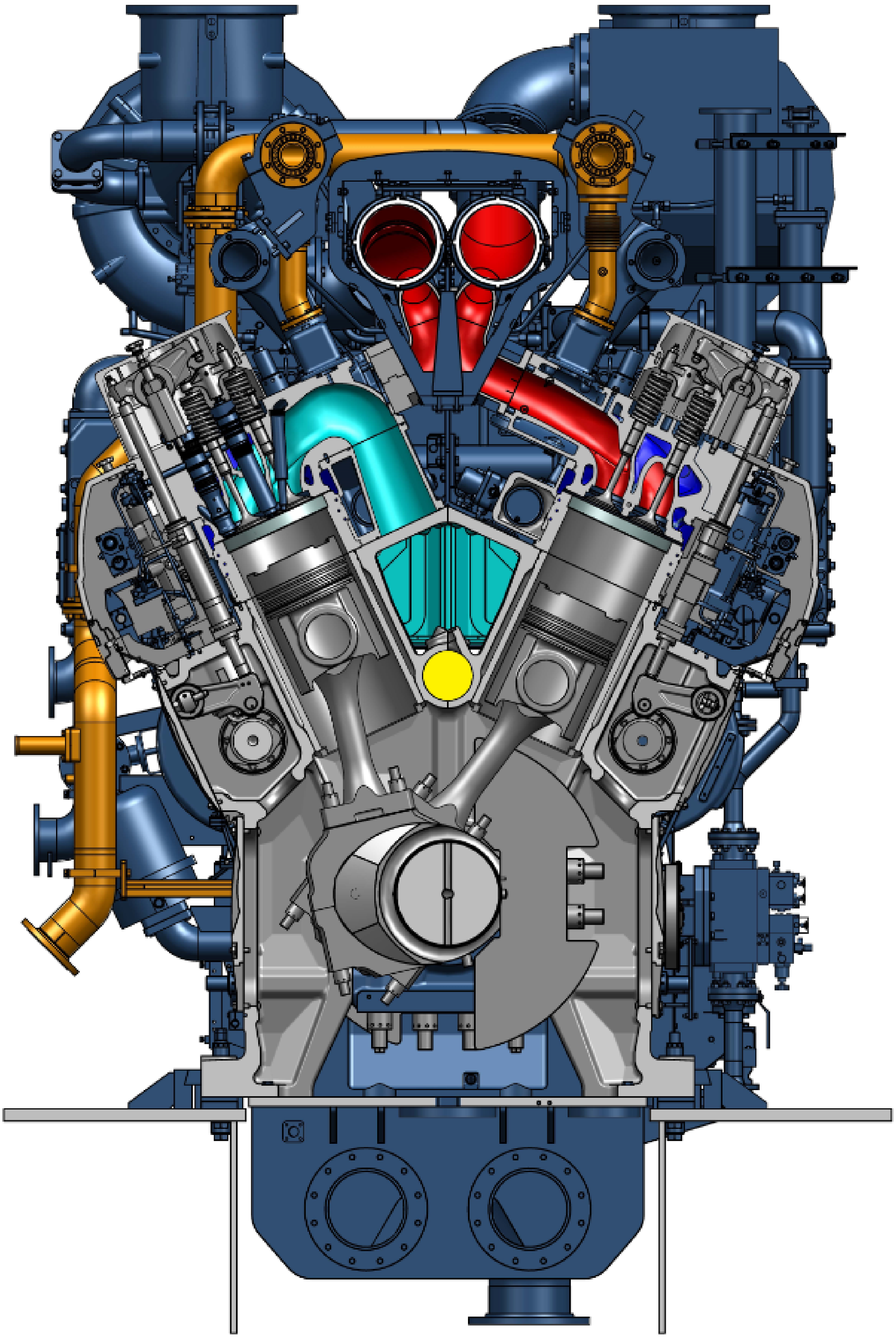


Figure 1-2-2: V-type engine cross section

General

Hyundai's “HiMSEN H35DF(V)P” family have simple and smart design suitable for marine propulsion with high reliability and performance, which are available for CPP (controllable pitch propeller). The key features are summarized as follows:

A dual fuel engine can be run with liquid or gaseous fuel alternatively

Custom Design for Propulsion Engine with Practical Functions

- Excellent transient response and low smoke with high efficiency turbocharging system
- Optimized load control with governor

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

- High stroke to bore ratio,
- High compression ratio,
- Optimized supercharging with miller cycle,
- High fuel injection pressure,
- Optimized air fuel ratio control and combustion parameters.

Reliable and Practical Engine with simple, smart and robust structure

- Number of engine components is minimized with pipe-free design,
- Most of the components are directly accessible for easier maintenance.
- Feed system is fully modularized with direct accessibility.
- Highly integrated control system.

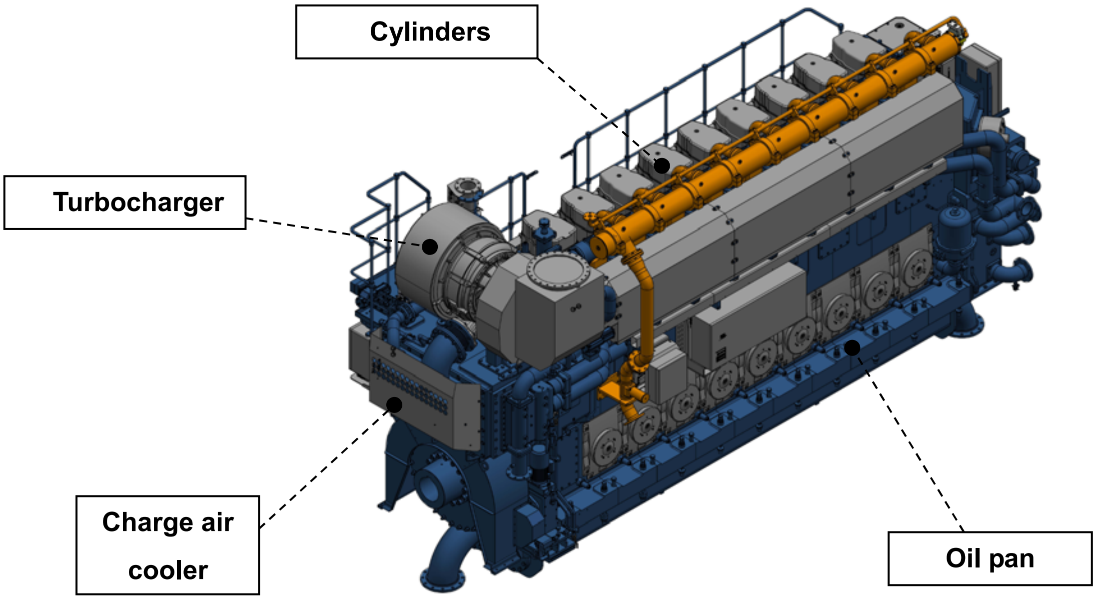


Figure 1-3-1: In-line engine outline

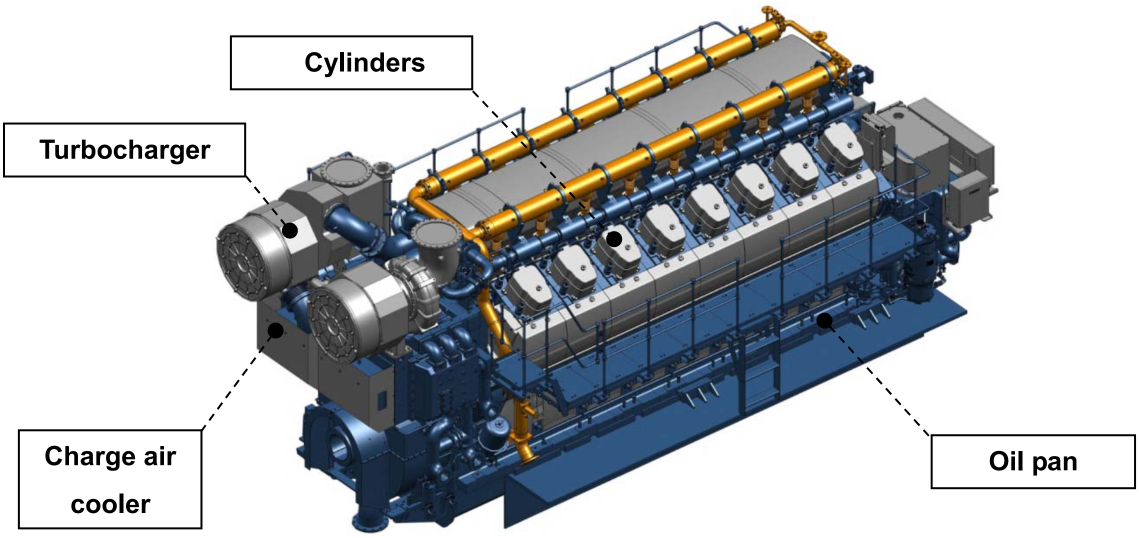


Figure 1-3-2: V-type engine outline

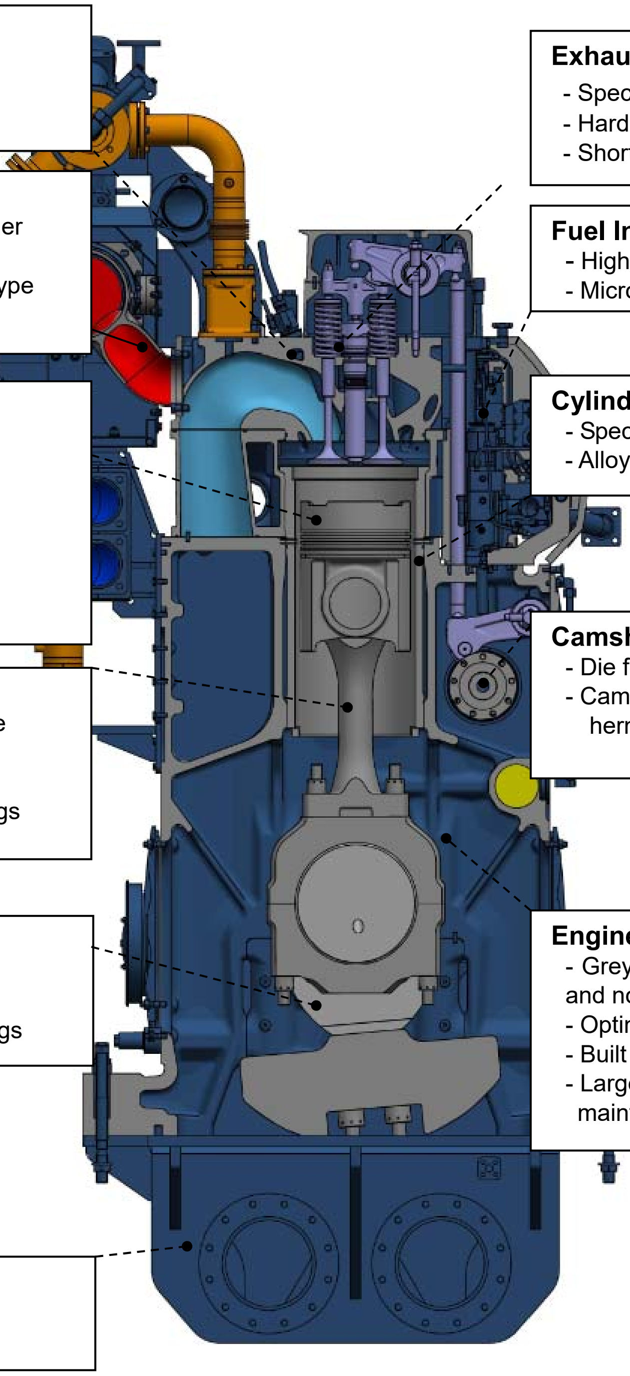


Figure 1-3-3: In-line main components of the engine

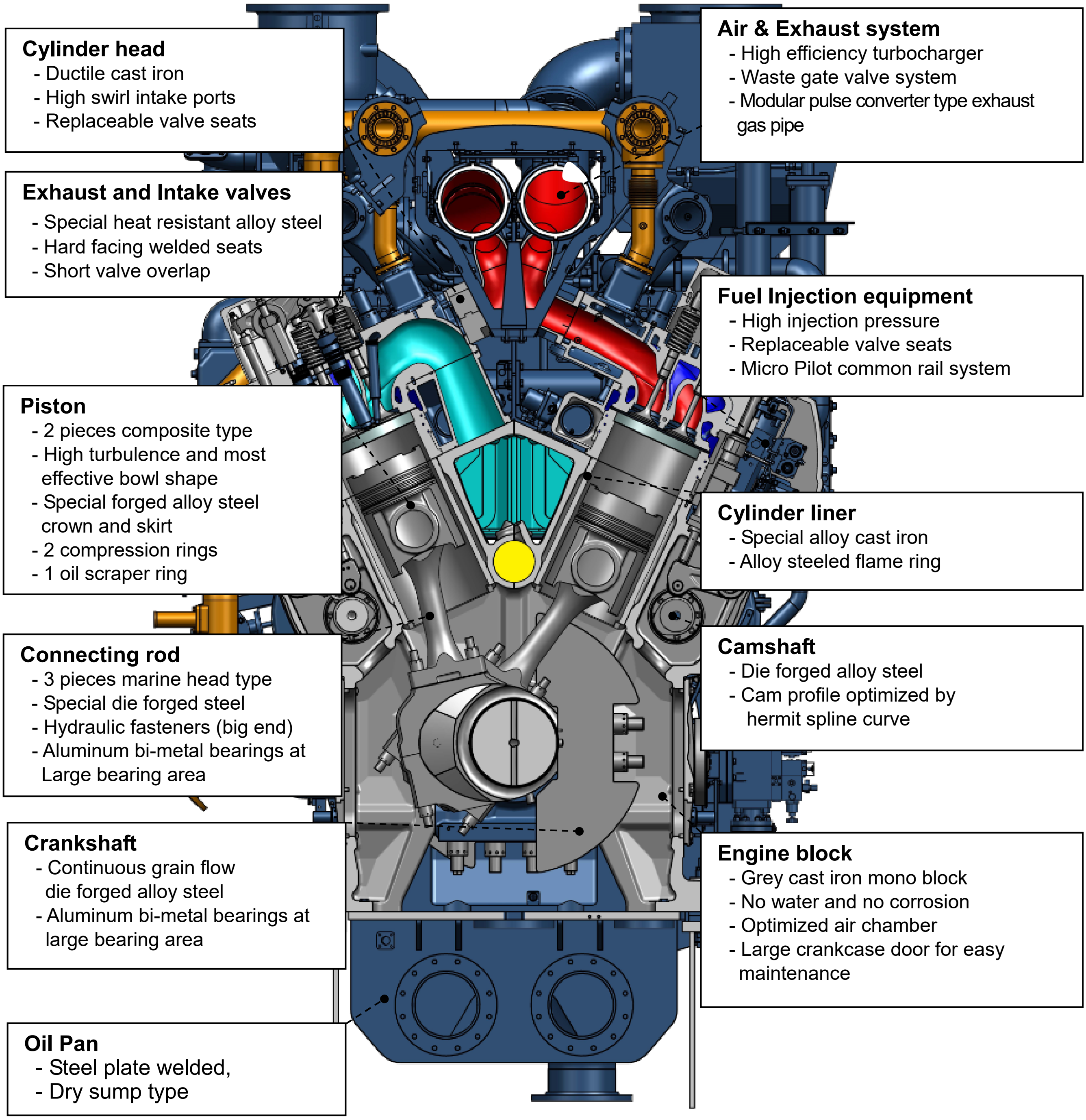


Figure 1-3-4: V-type main components of the engine

Engine Dimension and Weight

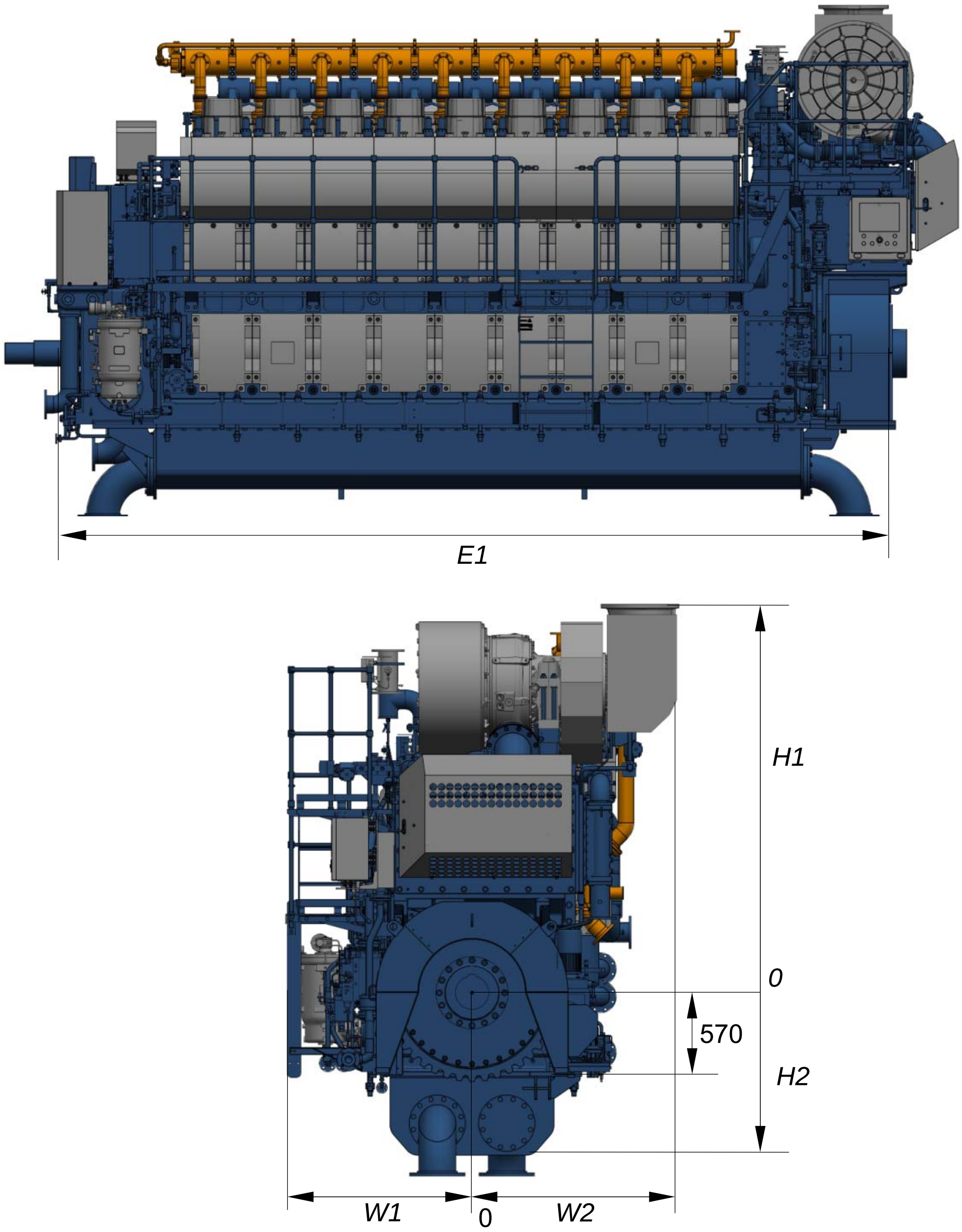
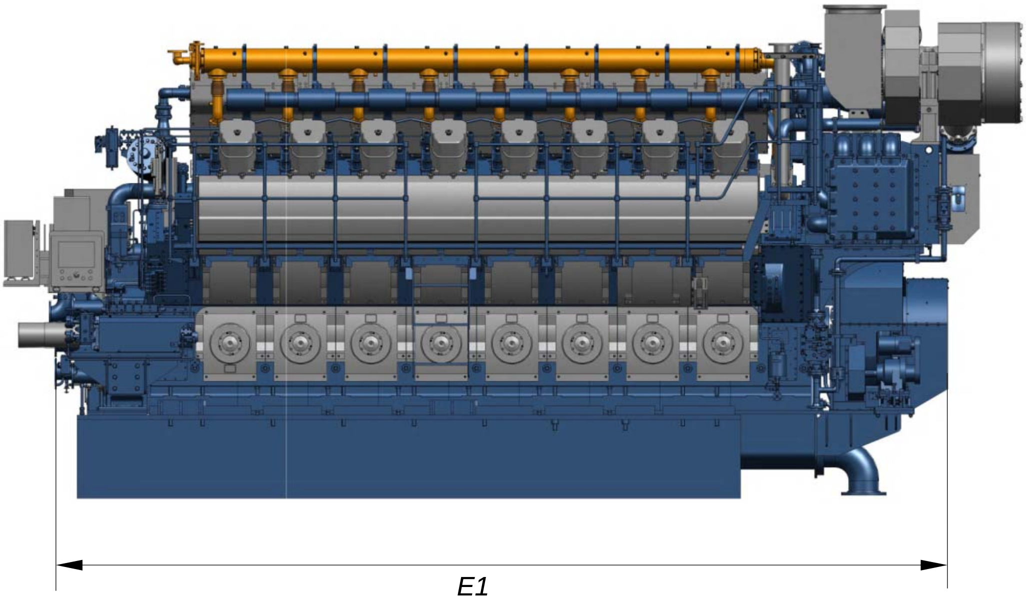


Figure 1-4-1: Engine outline dimension and weight

Engine type	Dimensions [mm]					Dry weight [ton]
	E1	H1*)	H2	W1	W2*)	
6H35DFP	5,007	2,381	1,170	1,304	1,373	39.2
7H35DFP	5,497	2,473	1,170	1,304	1,430	44.9
8H35DFP	6,009	2,799	1,170	1,304	1,490	48.0
9H35DFP	6,477	2,799	1,170	1,304	1,490	51.5

E1 : Dimension between engine flywheel and engine free end

*) depending on maker's model of turbocharger



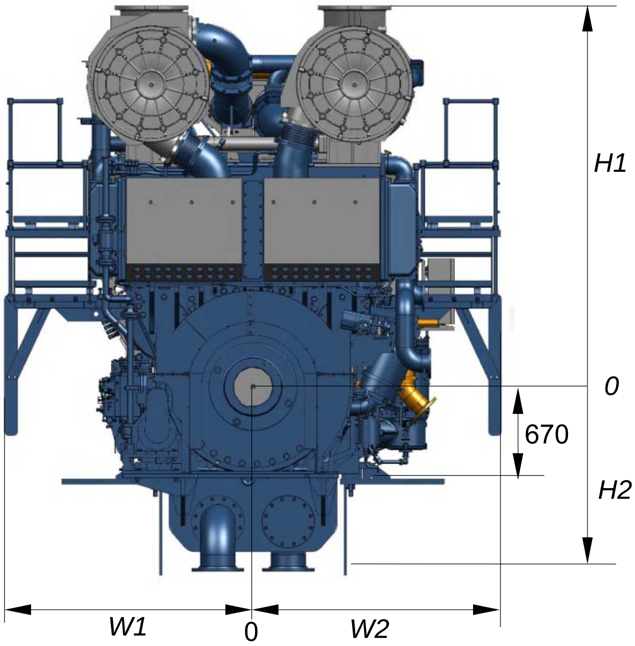


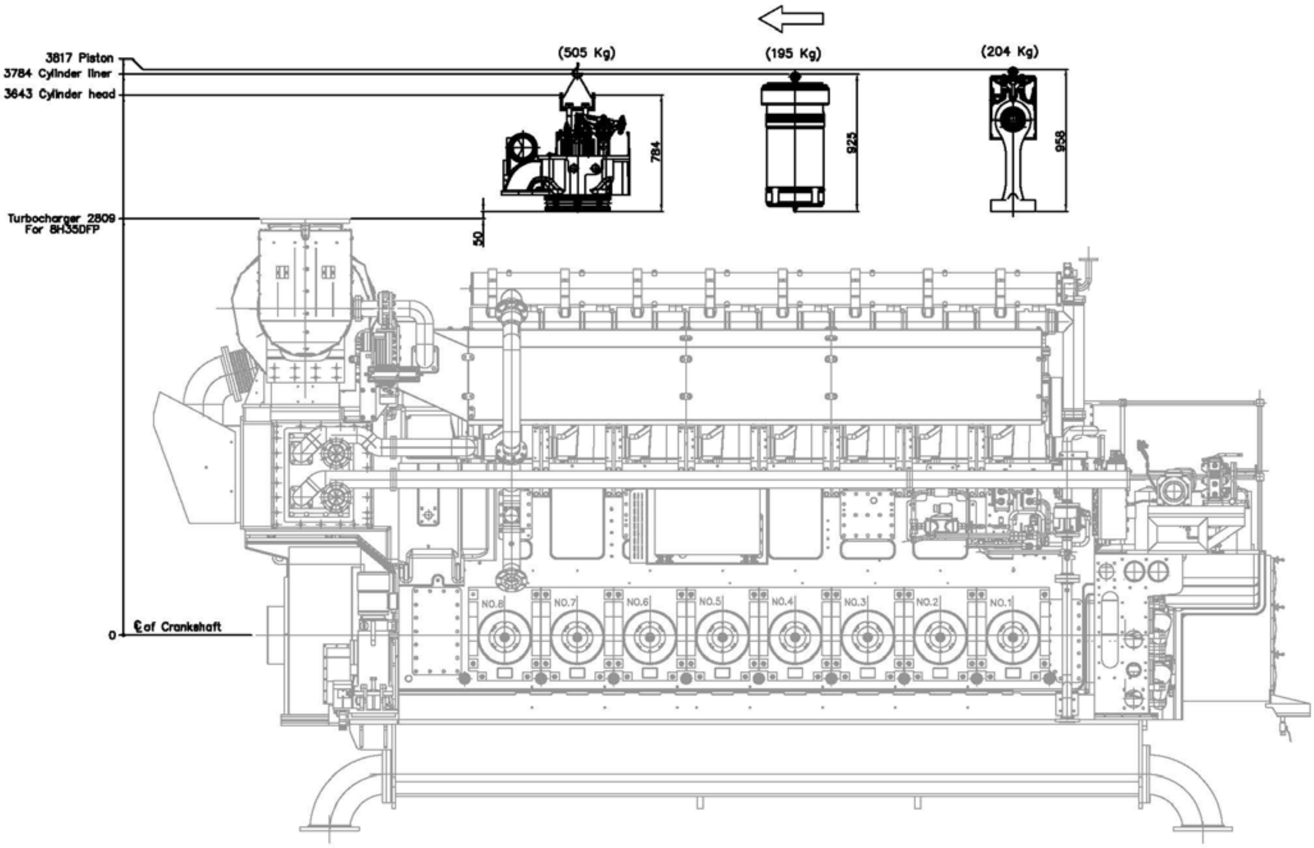
Figure 1-4-2: Engine outline dimension and weight

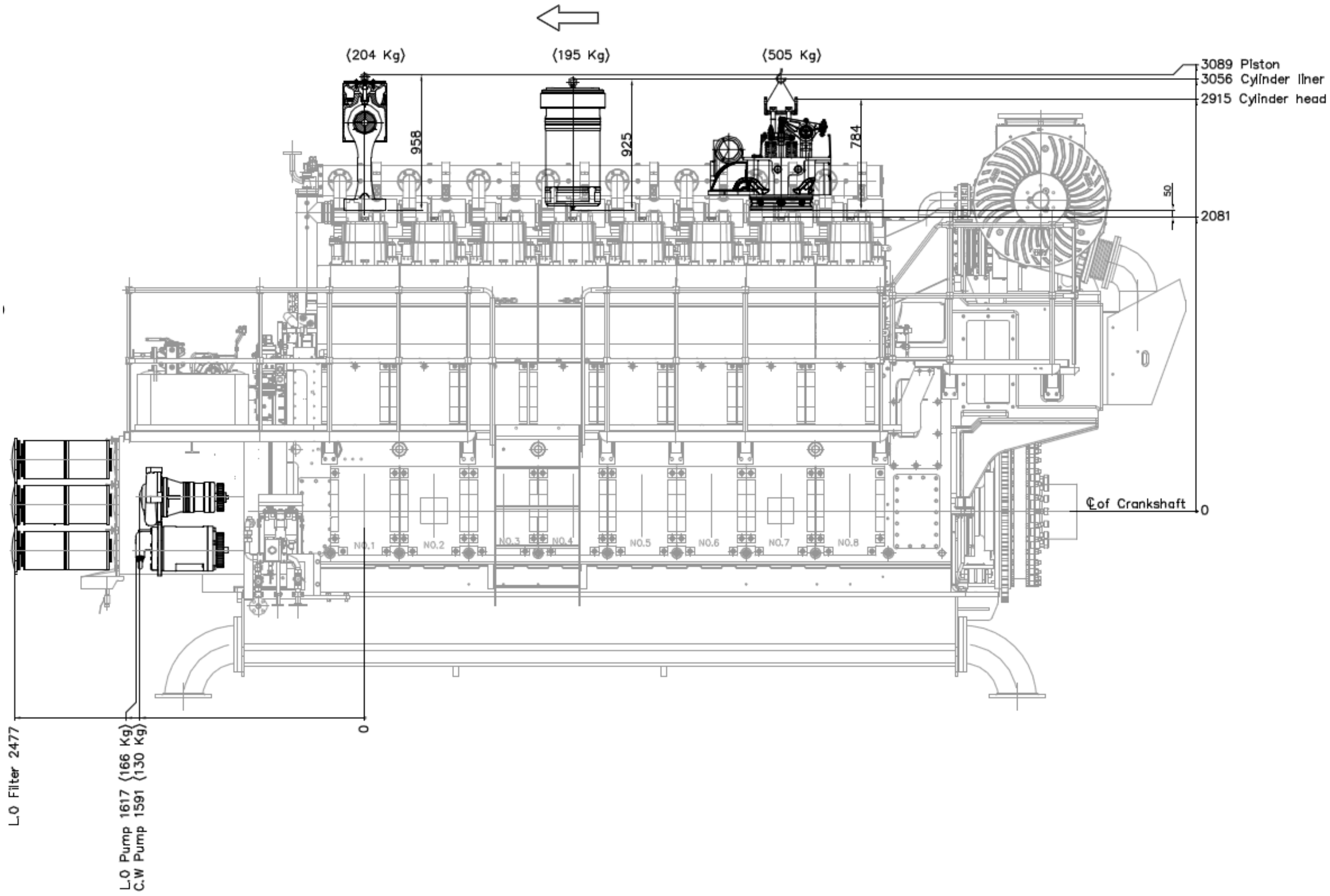
Engine type	Dimensions [mm]					Dry weight [ton]
	E1	H1*)	H2	W1	W2*)	
12H35DFVP	6,092	2,725	1,192	1,277	1,412	79.7
14H35DFVP	6,717	2,933	1,192	1,277	1,412	84.7
16H35DFVP	7,342	2,933	1,192	1,277	1,412	92.9
18H35DFVP	7,967	2,933	1,192	1,277	1,412	98.4
20H35DFVP	8,592	2,933	1,192	1,277	1,412	107.3

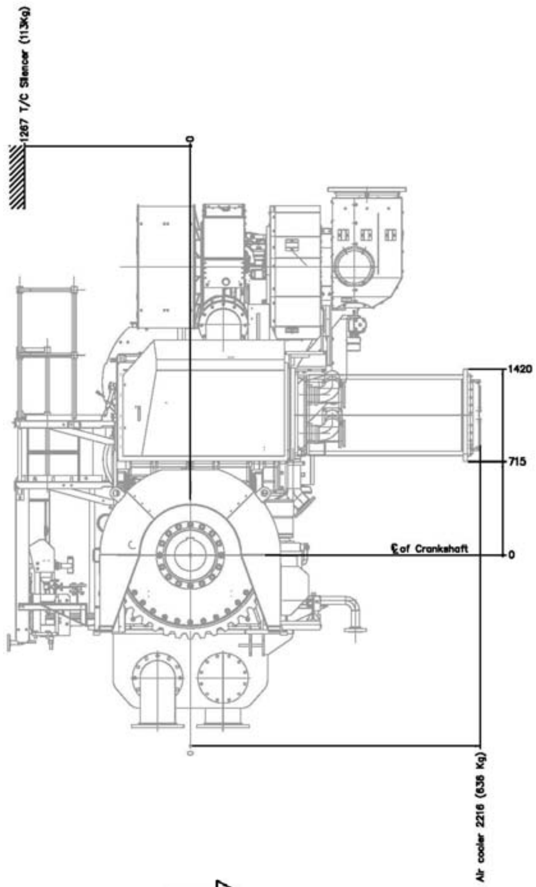
E1 : Dimension between engine flywheel and engine free end

*) depending on maker's model of turbocharger

Overhaul Dimension







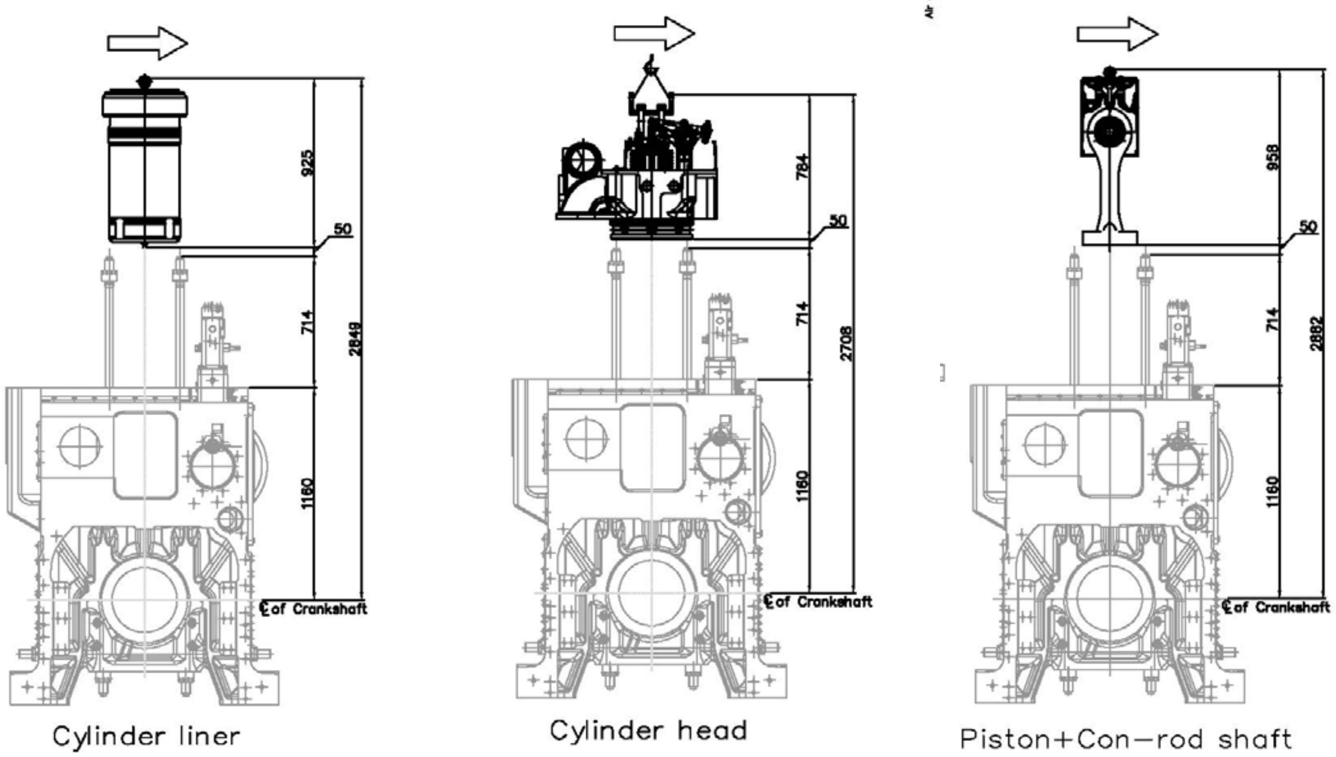
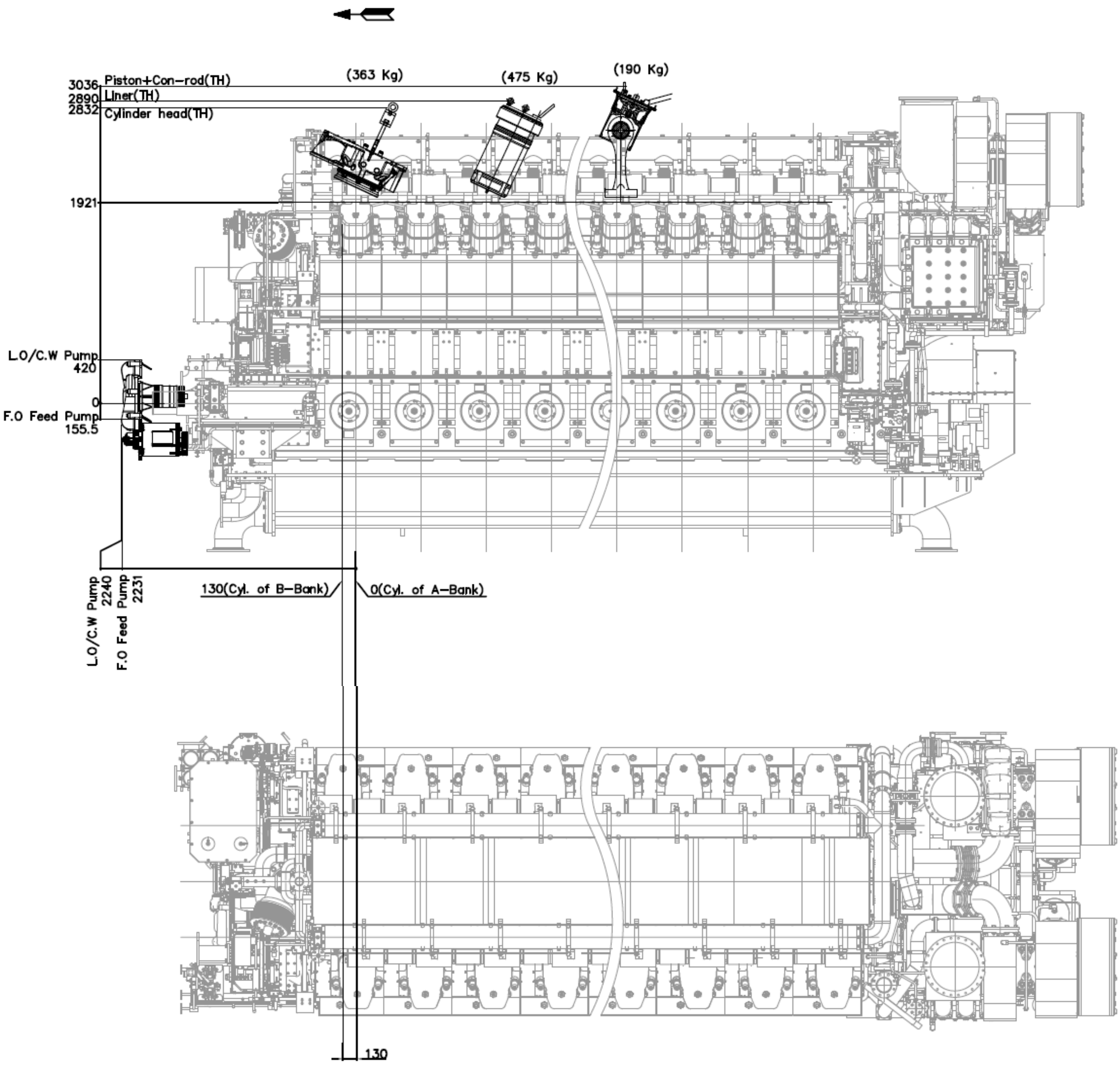


Figure 1-4-3 : In-line engine overhaul dimensions for major components


3036 Piston+Con-rod(TH)
2890 Liner(TH)
2832 Cylinder head(TH)
(363 Kg)
(475 Kg)
(190 Kg)
1921
L.O/C.W Pump 420
0
F.O Feed Pump 155.5
L.O/C.W Pump 2240
F.O Feed Pump 2231
130(Cyl. of B-Bank)
0(Cyl. of A-Bank)
130

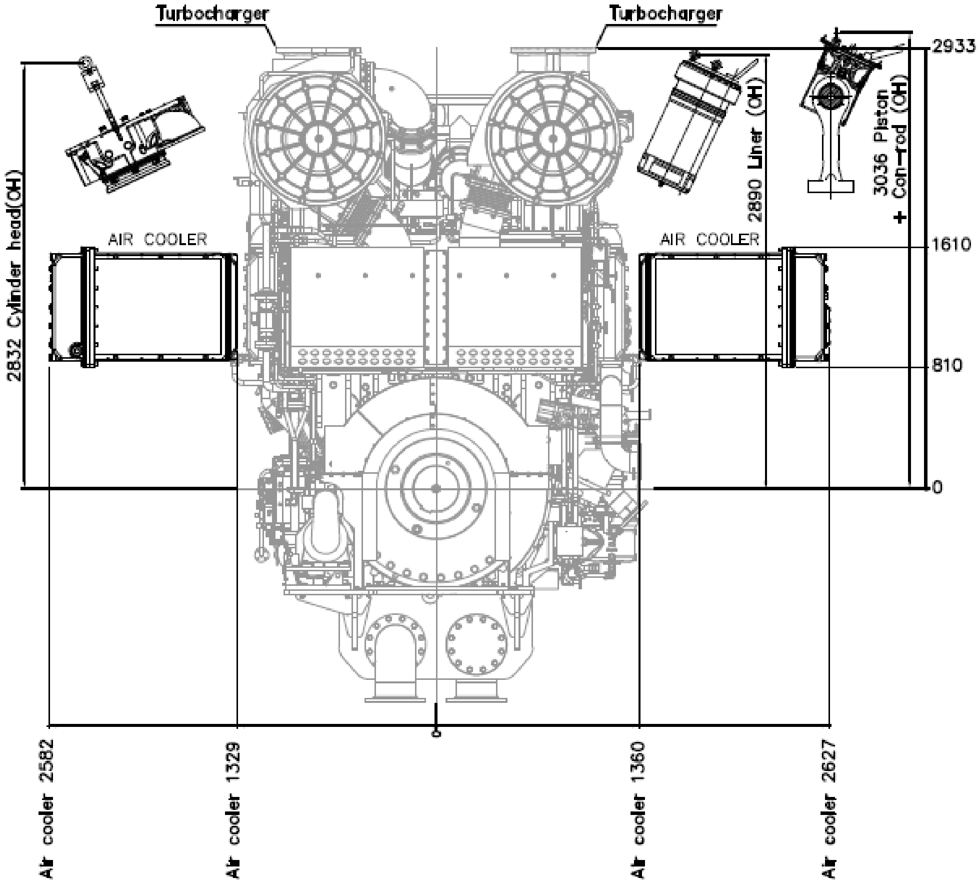


Figure 1-4-4 : V-type engine overhaul dimensions for major components

General

The engine can be rigidly mounted to a foundation either on steel chocks or synthetic resin chocks.

Foundation

The foundation should be as stiff as possible in all direction to absorb the dynamic forces caused by the engine and others.

Bolts must be pre-tightened to arrange the position of the engine. After that, bolts must be tightened from the propeller side to the free side of the engine by keeping the order. The number and location of stoppers are to be in accordance with an actual project drawing.

After drilling the foundation bolt holes, the contact face of the fitting accessory has to be machined to get a perfect nuts seating.

Top plate

The top plate of which thickness is thinner than those recommended in this guide is not allowed.

Before or after having been welded in place, the contact surface should be machined and freed from scale. Grease oil, milling scale, rust or paint should be removed before fitting the steel or resins chocks.

The finished surface of foundation as well as the chocks should be a roughness of maximum Ra 3.2.

Fitting on steel chock

The chock plate should be designed so that the wedge type chocks could be easily fitted on the position. The number and size of wedge type chocks can be referred to the actual project drawing.

Contact surface of the chock plate should be grinded until contact area of min 80% is obtained. Clearance between chock hole and bolt should not exceed 3mm in diameter except fitted bolt.

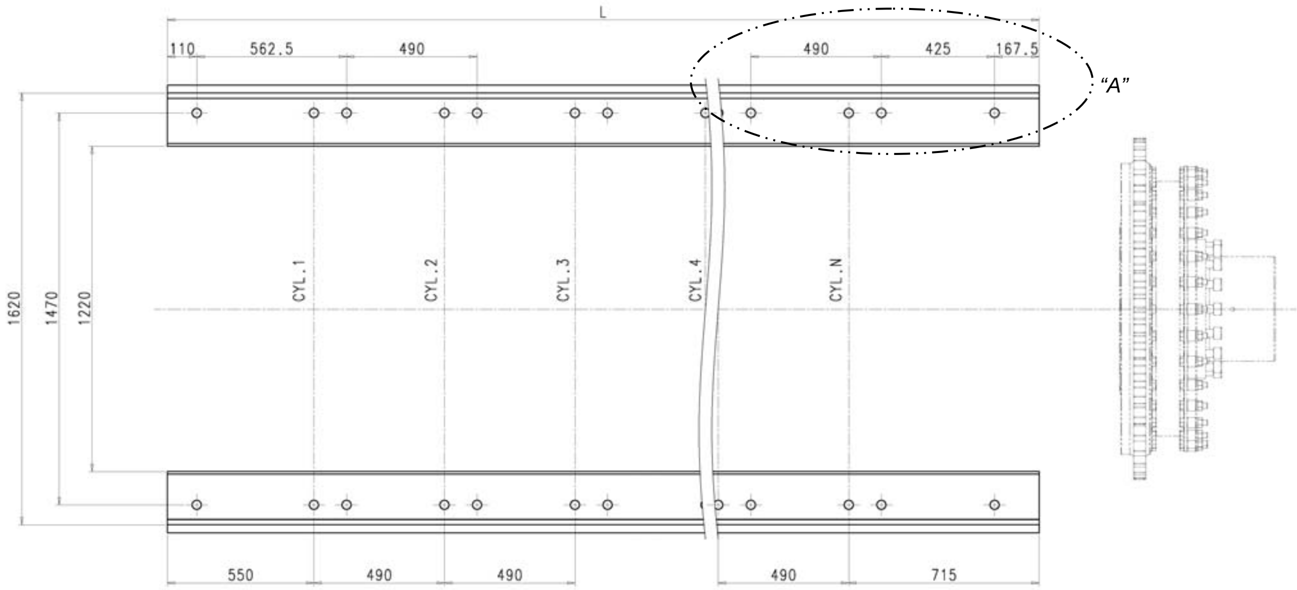
Fitting on synthetic resin chock

The synthetic resins chock is used for mounting engine and other machinery. The classification society responsible has approved the synthetic resin chock to be used for a specific pressure (engine deadweight + foundation bolt tension).

The chock surface is wide enough so that the surface area load due to the engine weight should not exceed 7kgf/cm^2. The static stress on the chocks due to the deadweight plus the bolt tension is typically designed to 35kgf/cm^2 and the appropriate classification approval for maximum stress is 45kgf/cm^2. Continuous chock temperature should not exceed 80°C.

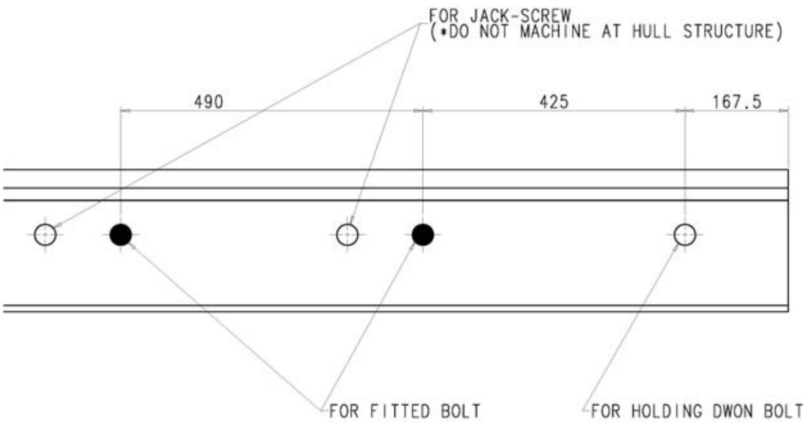
Recommended synthetic resin chock makers are Epocast (springer) and chockfast (Philadelphia Resins Corp).

Foundation seat arrangement



*   *LIMITED LENGTH TO SEAT OIL PAN*

**   *CUT-OUT REQUIRED FOR STANDARD FLYWHEEL*

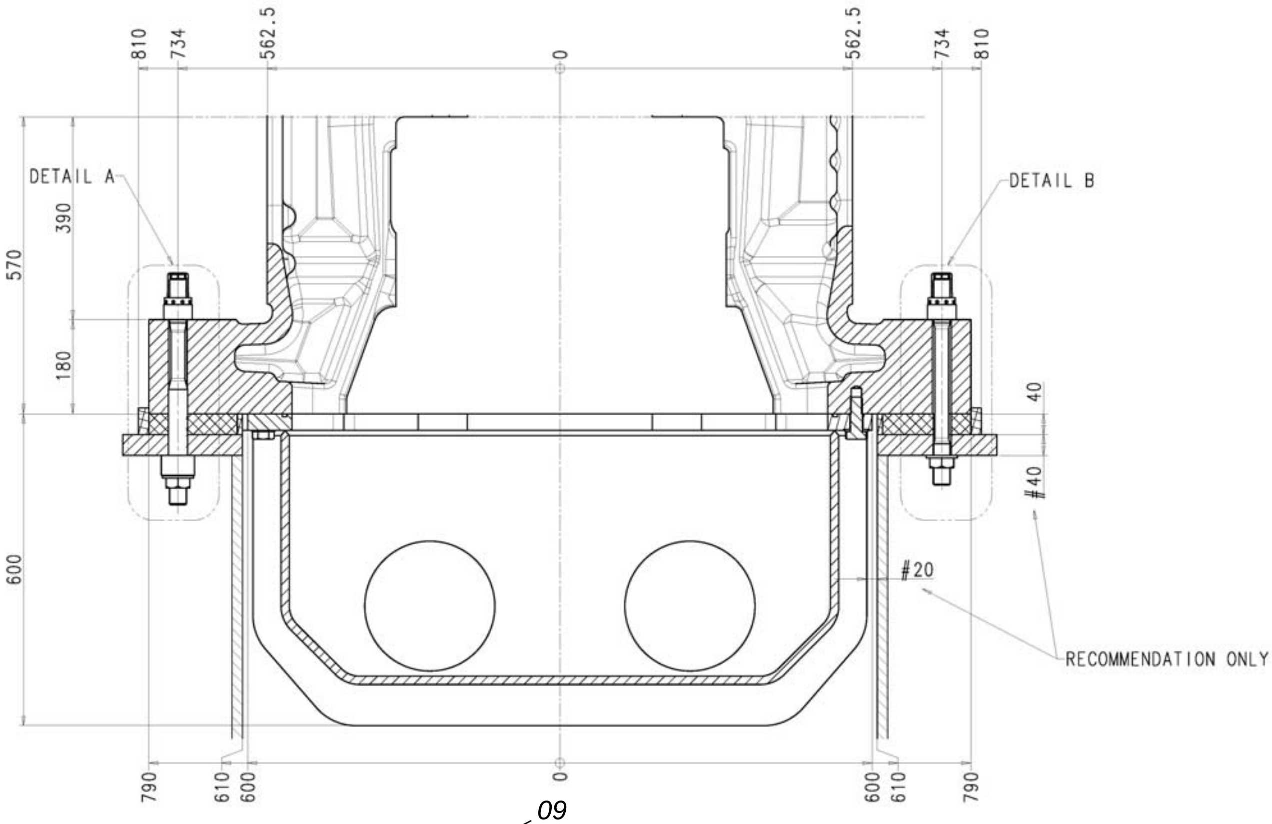


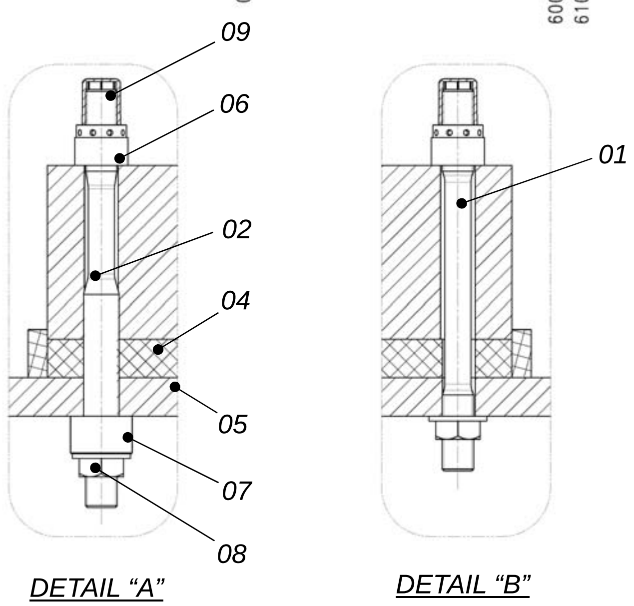
DETAIL "A"

Engine type	Quantities [EA]			Length [mm]
	Fitted bolt	Holding down bolt	Jack screw	L
6H35DFP	4	12	12	3,715
7H35DFP	4	14	14	4,205
8H35DFP	4	16	16	4,695
9H35DFP	4	18	18	5,185

Figure 1-5-1: In-line foundation seat arrangement

Cross section for the foundation

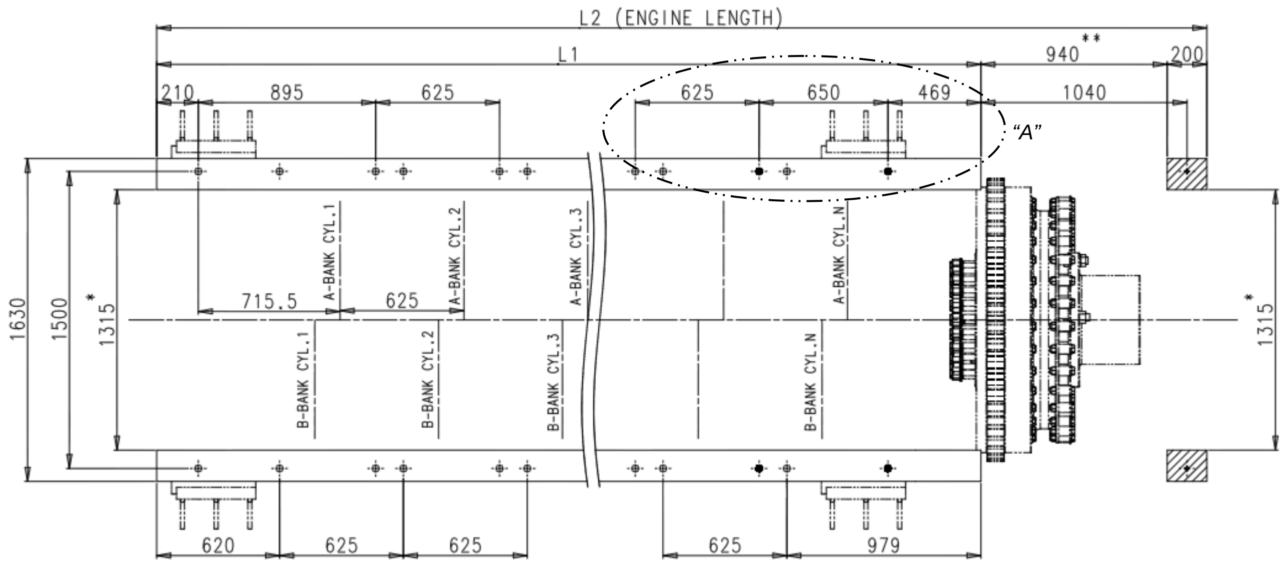




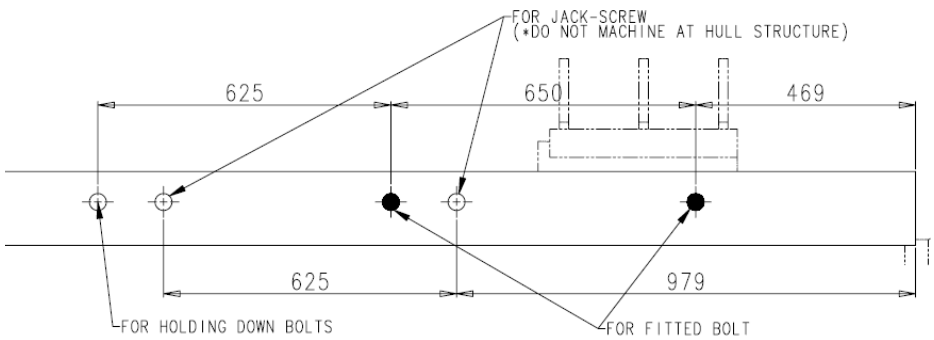
Code	Description	Code	Description
01	Holding down bolt	06	Hydraulic nut
02	Fitted bolt	07	Distance piece
04	Chock fast	08	Special nut
05	Foundation seat	09	Protection cap

Figure 1-5-2: In-line cross-section for foundation

Foundation seat arrangement



* LIMITED LENGTH TO SEAT OIL PAN
** CUT-OUT REQUIRED FOR STANDARD FLYWHEEL

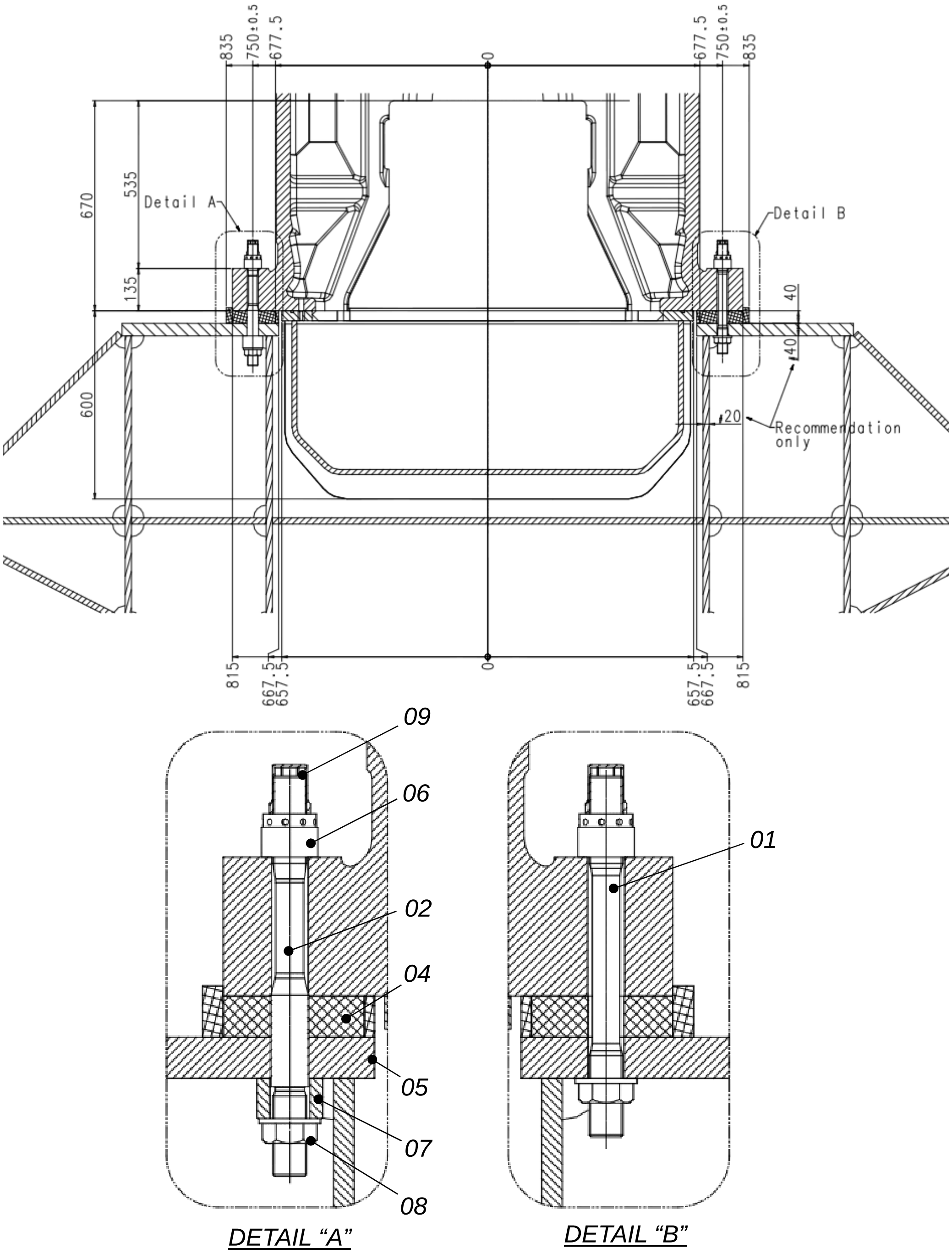


DETAIL "A"

Engine type	Quantities [EA]			Length [mm]	
	Fitted bolt	Holding down bolt	Jack screw	L1	L2
12H35DFVP	4	10	12	4,724	5,864
14H35DFVP	4	12	14	5,349	6,489
16H35DFVP	4	14	16	5,974	7,114
18H35DFVP	4	16	18	6,599	7,739
20H35DFVP	4	18	20	7,224	8,364

Figure 1-5-1 : V-type foundation seat arrangement

Cross section for the foundation



Code	Description	Code	Description
01	Holding down bolt	06	Hydraulic nut
02	Fitted bolt	07	Distance piece
04	Chock fast	08	Special nut
05	Foundation seat	09	Protection cap

Figure 1-5-2: V-type cross-section for foundation

General

A resilient mounting can be provided for a propulsion engine on the request. The resilient mounting of the engine is made with a number of conical mounts to isolate vibration between the engine and hull structure and to reduce the dynamic forces transmitted into foundation. These conical mounts are bolted to the engine brackets.

Design of resilient mount

The number and position of the resilient mounts depend on the dynamic characteristics of a vessel. Therefore, the final specifications of the mounts shall be decided based on the information from a shipyard for the case by case.

Connections to the engine

The engine mounted on the resilient mounts usually has some relative motions to the hull structure. Any rigid fixing between the engine and hull structure causes damages of the engine or hull structure.

Therefore, all connections, for example, pipes, gratings, ladders, electric wires and etc. should be flexible enough to absorb the relative movements.

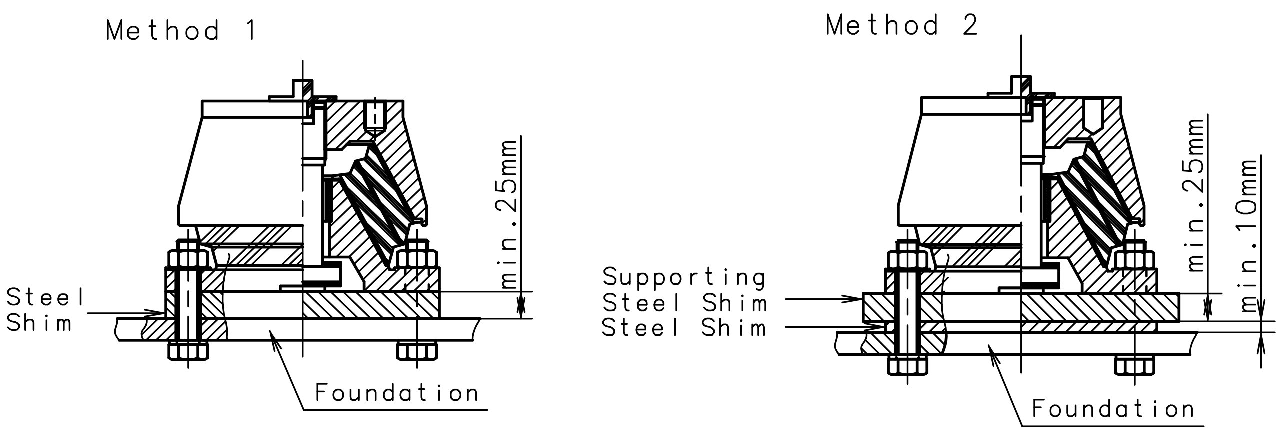


Figure 1-6-1: Resilient mounting adjustments

Recommendations for seating design and adjustment

The foundation for main engine should be rigid enough to support the load from main engine.

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(min. thickness 10mm) can be used for adjustments(Method 2) as shown below. It is also recommended to check the crankshaft deflection before starting up the plant to secure the correct adjustments of the shim plate and leveling of the main engine.

H35DFP foundation for reference

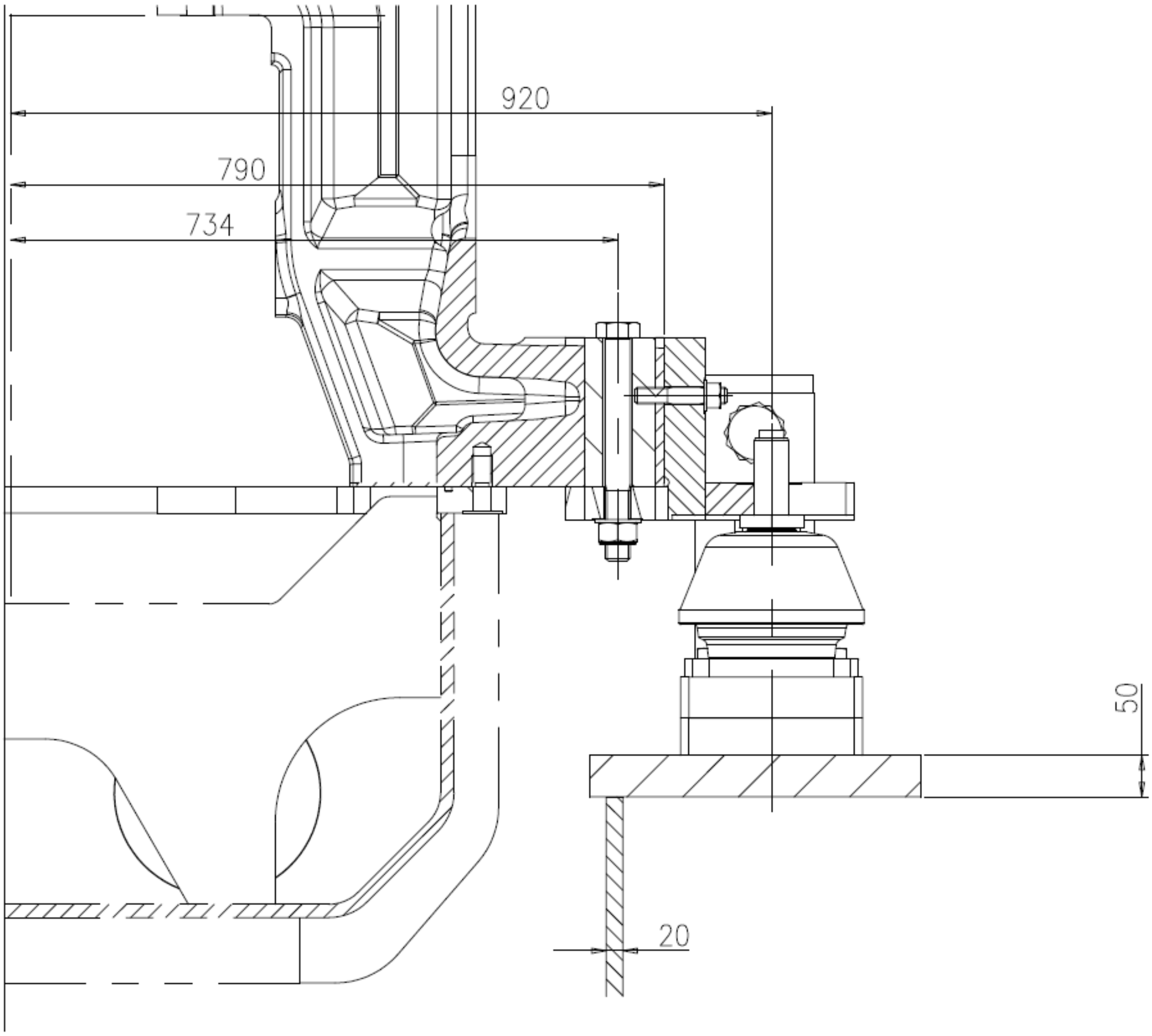


Figure 1-6-2: H35DFP Engine foundation (only for reference)[1)]

H35DFVP foundation for reference

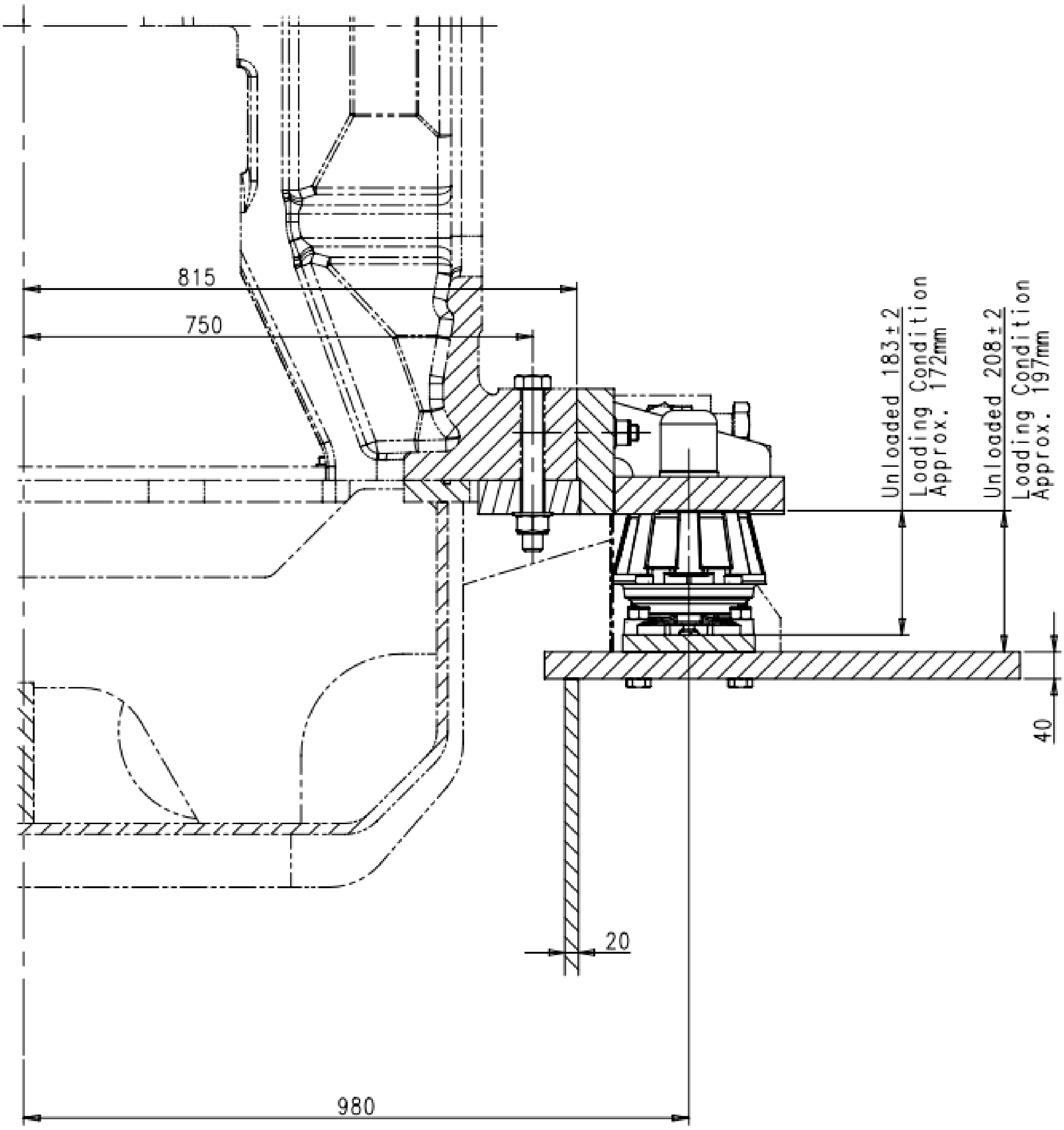


Figure 1-6-3 : H35DFVP Engine foundation (only for reference)[1)]

1) *Detailed foundation information for project should be obtained from engine maker.*

General Information **P.00.000**

Structural Design and Installation **P.01.000**

Performance Data **P.02.000**

Dynamic Characteristics and Noise **P.03.000**

Operation and Control System **P.04.000**

Fuel System **P.05.000**

Lubricating Oil System **P.06.000**

Cooling Water System **P.07.000**

Air and Exhaust Gas System **P.08.000**

Engine Maintenance **P.09.000**

Theoretical Performance **P.10.000**

Electric Control System **P.11.000**

Appendix

Rated power

Engine type	Rated output at 750rpm			
	kW		PS [3]	
	FPP [1]	CPP [2]	FPP [1]	CPP [2]
6H35DFP	-	3,000	-	4,080
7H35DFP	-	3,500	-	4,760
8H35DFP	-	4,000	-	5,440
9H35DFP	-	4,500	-	6,120
12H35DFVP	-	6,000	-	8,160
14H35DFVP	-	7,000	-	9,520
16H35DFVP	-	8,000	-	10,880
18H35DFVP	-	9,000	-	12,240
20H35DFVP	-	10,000	-	13,600

[1] *FPP: Fixed pitch propeller*

[2] *CPP: Controllable pitch propeller (constant engine speed)*

[3] *PS: Metric horse power, 1 kW = 1.36 PS*

Remark:

1. No overload operation is permissible except 10% overload of diesel mode during official factory test only.
2. Power adjusting (de-rating or uprating) must be consulted with HHI-EMD.
3. The position of brake (horse) power is the engine flywheel side.

Reference condition

The general definition of an engine rating is specified in accordance with ISO 3046-1:2002. However, the engine outputs are available in tropical conditions without de-rating.

ISO conditions

Turbocharger air inlet pressure : 1 bar

Intake air temperature : 298 K (25°C)

Relative humidity : 30%

LT cooling water temperature : 298 K (25°C)

Tropical conditions

Turbocharger air inlet pressure	: 1 bar
Intake air temperature	: 318 K (45°C)
LT cooling water temperature	: 309 K (36°C)

Rated Power : 500 kW/cyl. at 750 rpm (T/C driving end)

Engine MCR [Diesel Mode]	Cyl kW	6 3,000	7 3,500	8 4,000	9 4,500
Cooling Capacity					
Cylinder Jacket					
Heat dissipation 1)	kW	425	495	565	635
HT-cooling water flow	m^3/h	70	70	85	85
HT-cooling water temperature, engine in/out	℃	76 / 82	76 / 82	76 / 82	76 / 82
Charge Air					
HT - Heat dissipation 1)	Kw	895	1040	1,190	1,340
LT - Heat dissipation 1)	kW	400	465	530	600
LT-cooling water flow	m^3/h	70	70	85	85
HT-cooling water temperature, engine in/out	℃	82 / 93	82 / 95	82 / 94	82 / 96
LT-cooling water temperature, engine in/out	℃	36 / 42	36 / 42	36 / 42	36 / 42
Lubricating Oil					
Heat dissipation 1),3)	kW	410	480	545	615
LT-cooling water flow	m^3/h	70	70	85	85
LT-cooling water temperature, cooler in/out	℃	42 / 48	42 / 48	42 / 48	42 / 48
External L.T / H.T System 1)					
Capacity of L.T central cooler	kW	810	945	1,075	1,215
L.T-water temperature, after central cooler	℃	36	36	36	36
Capacity of H.T central cooler	kW	1,320	1,535	1,755	1,975
H.T-water temperature, after central cooler	℃	76	76	76	76
Exhaust Gas Data2)					
Combustion air consumption	kg/h	20,550	23,975	27,400	30,825
Exhaust gas flow	kg/h	21,150	24,675	28,200	31,725
Exhaust gas temperature after turbine, approx.	℃	310	305	305	305
Allowable exhaust gas back pressure, max	mbar	30	30	30	30
HEAT RADIATION					
Engine radiation 1)	kW	85	120	140	155
STARTING AIR4)					
Air consumption per start disengaging propeller shaft	Nm^3	4.7	5.2	5.7	6.2
Air consumption per start with slow turn	Nm^3	6.1	6.8	7.4	8.0
Starting air source, pressure (max.)	bar	30	30	30	30
Starting air source, pressure (min.)	bar	15	15	15	15
Required vessels	liter	Refer to P.08.200			
Air compressor	m^3/h	Refer to P.08.200			

Engine MCR [Diesel Mode]	Cyl kW	6 3,000	7 3,500	8 4,000	9 4,500
PUMP CAPACITIES, ENGINE DRIVEN PUMP					
Lubricating oil pump (6 bar)	m^3/h	140	140	160	160
HT-Cooling water pump (3 + static bar)	m^3/h	70	70	85	85
LT-Cooling water flow at engine inlet (3 + static bar)	m^3/h	70	70	85	85
PUMP CAPACITIES, EXTERNAL PUMP					
HFO supply pump 6) (6 bar)	m^3/h	1.2 + Z	1.4 + Z	1.5 + Z	1.7 + Z
HFO booster pump 6) (6 bar)	m^3/h	2.5 + Z	2.9 + Z	3.4 + Z	3.8 + Z
MDO supply pump 6) (8 bar)	m^3/h	2.7 + Z	3.1 + Z	3.6 + Z	4.0 + Z
Pilot Fuel F.O supply pump (6 bar)	m^3/h	0.3	0.3	0.3	0.3
Stand-by lub. oil pump 6) (6 bar)	m^3/h	140	140	160	160
Stand-by HT-cooling water pump (3 + static bar)	m^3/h	70	70	85	85
Circulation pump for fresh water (3 + static bar)	m^3/h	Please see P.07.200 (PP-701)			

Rated Power : 500 kW/cyl. at 750 rpm

Engine MCR [Diesel Mode]	Cyl kW	12 6,000	14 7,000	16 8,000	18 9,000	20 10,000
Cooling Capacity						
Cylinder Jacket						
Heat dissipation 1)	kW	850	990	1,130	1,275	1,415
HT-cooling water flow	m³/h	140	140	170	170	200
HT-cooling water temperature, engine in/out	℃	76 / 82	76 / 82	76 / 82	76 / 82	76 / 82
Charge Air						
HT - Heat dissipation 1)	Kw	1,785	2,085	2,380	2,680	2,980
LT - Heat dissipation 1)	kW	795	930	1,060	1,195	1,330
LT-cooling water flow	m³/h	140	140	170	170	200
HT-cooling water temperature, engine in/out	℃	82 / 93	82 / 95	82 / 94	82 / 96	82 / 95
LT-cooling water temperature, engine in/out	℃	36 / 39	36 / 39	36 / 39	36 / 39	36 / 39
Lubricating Oil						
Heat dissipation 1),3)	kW	820	955	1,095	1,230	1,365
LT-cooling water flow	m³/h	140	140	170	170	200
LT-cooling water temperature, cooler in/out	℃	39 / 46	39 / 46	39 / 46	39 / 46	39 / 46
External L.T / H.T System 1)						
Capacity of L.T central cooler	kW	1,615	1,885	2,155	2,425	2,695
L.T-water temperature, after central cooler	℃	36	36	36	36	36
Capacity of H.T central cooler	kW	2,635	3,075	3,510	3,955	4,395
H.T-water temperature, after central cooler	℃	76	76	76	76	76
Exhaust Gas Data2)						
Combustion air consumption	kg/h	37,480	43,720	49,970	56,210	62,460
Exhaust gas flow	kg/h	38,630	45,070	51,510	57,950	64,390
Exhaust gas temperature after turbine, approx.	℃	335	335	335	335	335
Allowable exhaust gas back pressure, max	mbar	30	30	30	30	30
HEAT RADIATION						
Engine radiation 1)	kW	170	240	275	310	345
STARTING AIR4)						
Air consumption per start, disengaging propeller shaft	Nm³	7.7	8.6	9.5	10.4	11.3
Air consumption per start with slow turn	Nm³	9.9	10.9	11.9	12.9	13.9
Starting air source, pressure (max.)	bar	30	30	30	30	30
Starting air source, pressure (min.)	bar	15	15	15	15	15
Required vessels	liter	Refer to P.08.200				
Air compressor	m³/h	Refer to P.08.200				

Engine MCR [Diesel Mode]		Cyl kW	12 6,000	14 7,000	16 8,000	18 9,000	20 10,000
PUMP CAPACITIES, ENGINE DRIVEN PUMP							
Lubricating oil pump	(6 bar)	m^3/h	170	170	220	220	220
H.T.C.W pump	(3 + static bar)	m^3/h	140	140	170	170	200
L.T.C.W flow at engine inlet	(3 + static bar)	m^3/h	140	140	170	170	200
PUMP CAPACITIES, EXTERNAL PUMP							
HFO supply pump 6)	(6 bar)	m^3/h	1.9 + Z	2.2 + Z	2.5 + Z	2.9 + Z	3.2 + Z
HFO booster pump 6)	(6 bar)	m^3/h	5.2 + Z	6.1 + Z	6.9 + Z	7.7 + Z	8.6 + Z
MDO supply pump 6)	(8 bar)	m^3/h	5.4 + Z	6.3 + Z	7.2 + Z	8.0 + Z	8.9 + Z
Pilot Fuel F.O supply pump	(6 bar)	m^3/h	0.3	0.3	0.3	0.3	0.3
Stand-by lub. oil pump 6)	(6 bar)	m^3/h	170	170	220	220	220
Stand-by H.T.C.W pump	(3 + static bar)	m^3/h	140	140	170	170	200
Circulation pump for F.W	(3 + static bar)	m^3/h	Please see P.07.200 (PP-701)				

1) *Reference condition based on tropical condition*
(Turbocharger inlet air pressure 1 bar, intake air temperature 45°C, Relative humidity 30%, L.T cooling water temperature 36°C)
Heat dissipation tolerance ±10%, Fuel oil based on MDO, LCV (Low calorific value) 42,700 kJ/kg

A margin and fouling factors for heat exchanger to be taken into account when selecting heat exchangers. The value may be variable depending on the type of heat exchanger, application, operating environment, etc.

2) *Reference condition based on ISO 3046-1:2002 (Turbocharger inlet air pressure 1 bar, intake air temperature 25°C, Relative humidity 30%, L.T cooling water temperature 25°C)*
Mass flow tolerance ±10%, gas temperature tolerance ±25°C

3) *Considering required heat dissipation for Lubricating oil separator which is recommended by a separator maker.*

4) *The consumption and required capacity of compressed air may be variable depending on application and vessel features, etc.*
Before dimensioning the capacity of compressed air system, it shall be considered with more detail information. For more detailed information, please see P.08.200 External compressed air system.

5) *Deleted.*

6) *Z: back-flushing*
To be added flushing oil quantity of automatic back-flushing filter.

7) *In case of CPP without main clutch(Engine connect with reduction gear and shaft directly), air consumption for engine starting will be increased.*
The volume of air vessels should be confirmed by engine maker separately.

6) Z: back-flushing

To be added flushing oil quantity of automatic back-flushing filter.

7) In case of CPP without main clutch(Engine connect with reduction gear and shaft directly), air consumption for engine starting will be increased.

The volume of air vessels should be confirmed by engine maker separately.

Remark

1. In order to choose proper capacity of each machine, the operating hours and the throughput from the machine maker must be considered based on the values on the table.

2. All above capacity is only of calculation base, and to be confirmed by each machine maker.

3. When turbocharger is requested to install on free end side, please contact HHI-EMD.

Rated Power : 500 kW/cyl. at 750 rpm (T/C driving end)

Engine MCR [Gas Mode]	Cyl kW	6 3,000	7 3,500	8 4,000	9 4,500
Cooling Capacity					
Cylinder Jacket					
Heat dissipation 1)	kW	415	485	550	620
HT-cooling water flow	m^3/h	70	70	85	85
HT-cooling water temperature, engine in/out	℃	77 / 82	77 / 82	77 / 82	77 / 82
Charge Air					
HT - Heat dissipation 1)	kW	670	780	890	1,005
LT - Heat dissipation 1)	kW	240	280	320	360
LT-cooling water flow	m^3/h	70	70	85	85
LT-cooling water temperature, engine in	℃	36 / 40	36 / 40	36 / 40	36 / 40
HT-cooling water temperature, engine in	℃	82 / 90	82 / 92	82 / 91	82 / 92
Lubricating Oil					
Heat dissipation 1),3)	kW	400	465	535	600
LT-cooling water flow	m^3/h	70	70	85	85
LT-cooling water temperature, cooler in/out	℃	40 / 45	40 / 45	40 / 45	40 / 45
External L.T / H.T System 1)					
Capacity of L.T central cooler	kW	640	745	855	960
L.T-water temperature, after central cooler	℃	36	36	36	36
Capacity of H.T central cooler	kW	1,085	1,265	1,440	1,625
H.T-water temperature, after central cooler	℃	77	77	77	77
Exhaust Gas Data 2)					
Combustion air consumption	kg/h	15,340	17,890	20,450	23,000
Exhaust gas flow	kg/h	15,830	18,460	21,110	23,740
Exhaust gas temperature after turbine, approx.	℃	380	380	380	380
Allowable exhaust gas back pressure, max 7)	mbar	24	24	24	24
HEAT RADIATION					
Engine radiation 1)	kW	100	115	135	150
STARTING AIR 4)					
Air consumption per start disengaging propeller shaft	Nm^3	4.7	5.2	5.7	6.2
Air consumption per start with slow turn	Nm^3	6.1	6.8	7.4	8.0
Starting air source, pressure (max.)	bar	30	30	30	30
Starting air source, pressure (min.)	bar	15	15	15	15
Required vessels	liter	Refer to P.08.200			
Air compressor	m^3/h	Refer to P.08.200			

Engine MCR [Gas Mode]	Cyl kW	6 3,000	7 3,500	8 4,000	9 4,500
PUMP CAPACITIES, ENGINE DRIVEN PUMP					
Lubricating oil pump (6 bar)	m^3/h	140	140	160	160
HT-Cooling water pump (3 + static bar)	m^3/h	70	70	85	85
LT-Cooling water flow at engine inlet (3 + static bar)	m^3/h	70	70	85	85
PUMP CAPACITIES, EXTERNAL PUMP					
HFO supply pump 6) (6 bar)	m^3/h	1.2 + Z	1.4 + Z	1.5 + Z	1.7 + Z
HFO booster pump 6) (6 bar)	m^3/h	2.5 + Z	2.9 + Z	3.4 + Z	3.8 + Z
MDO supply pump 6) (8 bar)	m^3/h	2.7 + Z	3.1 + Z	3.6 + Z	4.0 + Z
Pilot Fuel F.O supply pump (6 bar)	m^3/h	0.3	0.3	0.3	0.3
Stand-by lub. oil pump 6) (6 bar)	m^3/h	140	140	160	160
Stand-by HT-cooling water pump (3 + static bar)	m^3/h	70	70	85	85
Circulation pump for fresh water (3 + static bar)	m^3/h	Please see P.07.200 (PP-701)			

Rated Power : 500 kW/cyl. at 750 rpm

Engine MCR [Gas Mode]	Cyl kW	12 6,000	14 7,000	16 8,000	18 9,000	20 10,000
Cooling Capacity						
Cylinder Jacket						
Heat dissipation [1]	kW	825	965	1,105	1,240	1,380
HT-cooling water flow	m^3/h	140	140	170	170	200
HT-cooling water temperature, engine in/out	℃	76 / 82	76 / 82	76 / 82	76 / 82	76 / 82
Charge Air						
HT - Heat dissipation [1]	Kw	1,340	1,560	1,785	2,010	2,235
LT - Heat dissipation [1]	kW	480	560	640	720	800
LT-cooling water flow	m^3/h	140	140	170	170	200
HT-cooling water temperature, engine in/out	℃	82 / 90	82 / 92	82 / 91	82 / 92	82 / 92
LT-cooling water temperature, engine in/out	℃	36 / 39	36 / 39	36 / 39	36 / 39	36 / 39
Lubricating Oil						
Heat dissipation [1),3)]	kW	800	930	1,065	1,200	1,335
LT-cooling water flow	m^3/h	140	140	170	170	200
LT-cooling water temperature, cooler in/out	℃	39 / 46	39 / 46	39 / 46	39 / 46	39 / 46
External L.T / H.T System [1]						
Capacity of L.T central cooler	kW	1,280	1,490	1,705	1,920	2,135
L.T-water temperature, after central cooler	℃	36	36	36	36	36
Capacity of H.T central cooler	kW	2,165	2,525	2,890	3,250	3,615
H.T-water temperature, after central cooler	℃	76	76	76	76	76
Exhaust Gas Data[2]						
Combustion air consumption	kg/h	30,670	35,780	40,900	46,010	51,120
Exhaust gas flow	kg/h	31,650	36,930	42,200	47,480	52,760
Exhaust gas temperature after turbine, approx.	℃	390	390	390	390	390
Allowable exhaust gas back pressure, max [7]	mbar	24	24	24	24	24
HEAT RADIATION						
Engine radiation [1]	kW	200	235	265	300	335
STARTING AIR[4]						
Air consumption per start, disengaging propeller shaft	Nm^3	7.7	8.6	9.5	10.4	11.3
Air consumption per start with slow turn	Nm^3	9.9	10.9	11.9	12.9	13.9
Starting air source, pressure (max.)	bar	30	30	30	30	30
Starting air source, pressure (min.)	bar	15	15	15	15	15
Required vessels	liter	Refer to P.08.200				
Air compressor	m^3/h	Refer to P.08.200				

Engine MCR [Gas Mode]	Cyl kW	12 6,000	14 7,000	16 8,000	18 9,000	20 10,000
PUMP CAPACITIES, ENGINE DRIVEN PUMP						
Lubricating oil pump (6 bar)	m^3/h	170	170	220	220	220
H.T.C.W pump (3 + static bar)	m^3/h	140	140	170	170	200
L.T.C.W flow at engine inlet (3 + static bar)	m^3/h	140	140	170	170	200
PUMP CAPACITIES, EXTERNAL PUMP						
HFO supply pump 6) (6 bar)	m^3/h	1.9 + Z	2.2 + Z	2.5 + Z	2.9 + Z	3.2 + Z
HFO booster pump 6) (6 bar)	m^3/h	5.2 + Z	6.1 + Z	6.9 + Z	7.7 + Z	8.6 + Z
MDO supply pump 6) (8 bar)	m^3/h	5.4 + Z	6.3 + Z	7.2 + Z	8.0 + Z	8.9 + Z
Pilot Fuel F.O supply pump (6 bar)	m^3/h	0.3	0.3	0.3	0.3	0.3
Stand-by lub. oil pump 6) (6 bar)	m^3/h	170	170	220	220	220
Stand-by H.T.C.W pump (3 + static bar)	m^3/h	140	140	170	170	200
Circulation pump for F.W (3 + static bar)	m^3/h	Please see P.07.200 (PP-701)				

1) Reference condition based on tropical condition
(Turbocharger inlet air pressure 1 bar, intake air temperature 45°C, Relative humidity 30%, L.T cooling water temperature 36°C)
Heat dissipation tolerance ±10%, Fuel oil based on MDO, LCV (Low calorific value) 42,700 kJ/kg

A margin and fouling factors for heat exchanger to be taken into account when selecting heat exchangers. The value may be variable depending on the type of heat exchanger, application, operating environment, etc.

2) Reference condition based on ISO 3046-1:2002 (Turbocharger inlet air pressure 1 bar, intake air temperature 25°C, Relative humidity 30%, L.T cooling water temperature 25°C)
Mass flow tolerance ±10%, gas temperature tolerance ±25°C

3) Considering required heat dissipation for Lubricating oil separator which is recommended by a separator maker.

4) The consumption and required capacity of compressed air may be variable depending on application and vessel features, etc.
Before dimensioning the capacity of compressed air system, it shall be considered with more detail information. For more detailed information, please see P.08.200 External compressed air system.

5) Deleted.

6) Z: back-flushing
To be added flushing oil quantity of automatic back-flushing filter.

7) The maximum exhaust gas back pressure of gas mode is defined depending on allowable exhaust gas back pressure of diesel mode.

6) Z: back-flushing

To be added flushing oil quantity of automatic back-flushing filter.

7) The maximum exhaust gas back pressure of gas mode is defined depending on allowable exhaust gas back pressure of diesel mode.

8) In case of CPP without main clutch(Engine connect with Reduction gear and shaft directly), air consumption for engine starting will be increased.

The volume of air vessels should be confirmed by engine maker separately.

Remark

1. In order to choose proper capacity of each machine, the operating hours and the throughput from the machine maker must be considered based on the values on the table.

2. All above capacity is only of calculation base, and to be confirmed by each machine maker.

3. When turbocharger is requested to install on free end side, please contact HHI-EMD.

1. Engine Performance Data

Rated Power: 500 kW/Cyl. at 750 rpm

Performance Data – 750 rpm			Engine Load (%) 110	100	85	75	50
Diesel Mode	**CYLINDER DATA**						
	Cylinder Output	kW/Cyl.	550	500	425	375	250
	Mean Effective Pressure	bar	22.9	20.8	17.7	15.6	10.4
	COMBUSTION AIR DAT 1)						
	Mass Flow	kg/kWh	6.7	6.9	7.1	7.2	7.8
	Air temperature after cooler	℃	45	45	45	45	45
	EXHAUST GAS DATA 1)						
	Mass Flow	kg/kWh	6.9	7.1	7.3	7.4	8.0
	Gas Temperature after Turbine	℃	315	315	330	340	365
	FUEL OIL CONSUMPTION 1),3),4)						
	Specific Fuel Oil Consumption	g/kWh	190	189	188	189	202
Gas Mode	**COMBUSTION AIR DATA** 2)						
	Mass Flow	kg/kWh	-	5.2	5.6	5.9	6.1
	Air temperature after Cooler	℃	-	45	45	45	45
	EXHAUST GAS DATA						
	Mass Flow	kg/kWh	-	5.4	5.7	6.0	6.3
	Gas Temperature after Turbine	℃	-	385	415	430	465
	GAS MIXTURE DATA 2),3),4) ,5)						
	Fuel Gas Heat Rate	kJ/kWh	-	7,343	7,643	7,860	8,456
	Pilot Fuel Oil Consumption	g/kWh	-	2.3	2.7	3.1	4.6
	Total Heat Rate	kJ/kWh	-	7,441	7,758	7,933	8,669

1) Reference condition based on ISO 3046-1:2002 (Turbocharger inlet air pressure 1 bar, intake air temperature 25 ℃, Relative humidity 30%, L.T cooling water temperature 25 ℃), under IMO Tier II NOx condition
Mass flow tolerance ±10%, gas temperature tolerance ±25 ℃

2) Reference condition based on ISO 3046-1:2002 (Turbocharger inlet air pressure 1 bar, intake air temperature 25 ℃, Relative humidity 30%, L.T cooling water temperature 25 ℃), under IMO Tier III NOx condition
Mass flow tolerance ±10%, gas temperature tolerance ±25 ℃

3) SFOC, FGHR(Fuel Gas Heat Rate), POC(Pilot Oil Consumption), THR(Total Heat Rate) tolerance for warranty ±5%
Engine driven pumps attached : Lub. oil pumps, HT-pump, LT-pump
Warranted at 100% MCR load only

4) Fuel oil based on MDO, LCV 42,700 kJ/kg

5) Pilot Fuel oil based on MDO, LCV 42,700 kJ/kg

Fuel gas based on LNG, LCV ≥ 36 MJ/Nm³ (≒50 MJ/kg), MN 80

Required fuel gas pressure depends on fuel gas LCV and need to be increased for lower LCV's
Pressure drop in external fuel gas supply system to be considered.

General

HiMSEN engine is designed for environment-friendly engine and complies with IMO NOx emission limits with low fuel consumption and nearly smokeless even in part load operation.

Exhaust gas which HiMSEN Engine discharges mainly consists of Nitrogen (N2), Oxygen (O2), Carbon dioxide (CO2) and water (vapor, H2O). There are some of residue, such as Carbon monoxide (CO), Sulphur oxide (SOx), non-combusted hydrocarbons, ash and Nitrogen Oxides (NOx).

The residue is little in amount but ecologically critical. Therefore, a careful attention is required for the treatment of fuel oil and engine operating conditions.

NOx emissions – Nitrogen Oxides

Nitrogen Oxides (NOx) emissions apply to diesel engines with a power output of more than 130kW which are installed, or designed and intended for installation, on ship built (based on the keel laying date or similar contraction stage on or after 1 January, 2000) subject to IMO MARPOL 73/78 Annex VI regulation 13. And the limitation value (Tier) depends on the ship construction date, engine speed and ship sailing area.

- **EIAPP certificate**

  The EIAPP (Engine International Air Pollution Prevention) certificate is the Engine International Air Pollution Prevention certificate which relates NOx emissions.

  If an engine complies with the NOx emissions limits contained in regulation 13 of Annex VI, the administration or organization on behalf of the administration shall issue an EIAPP certificate with approved NOx technical file. Those are necessary for renewal of IAPP certificate through the on-board NOx verification. Approved NOx technical file and EIAPP certificate shall accompany the engine throughout its life and shall be available on board the ship at all times.

  NOx emission means the total emission of nitrogen oxides, calculated as the total weighted emission of NOx and determined using the relevant test cycles in ISO 8178 test cycles. And when testing the engine for EIAPP certificate, the test shall be performed according to ISO 8178 test cycles. The measured NOx value has to be calculated and corrected according to ISO 8178.

Table 2-5-1 Test cycles and weighting factors on ISO 8178

Test cycle	Speed	100%	100%	100%	100%
Type E2	Power	100%	75%	50%	25%
	Weighting Factor	0.2	0.5	0.15	0.15

E2 Cycle : “Constant-speed main propulsion” application : For an engine connected to a diesel electric drive and all controllable pitch propeller irrespective of combinator curve

Test cycle	Speed	100%	91%	80%	63%
Type E3	Power	100%	75%	50%	25%
	Weighting Factor	0.2	0.5	0.15	0.15

E3 Cycle : “Propeller-law operated main and propeller-law operated auxiliary engine” application

Test cycle	Speed	100%	100%	100%	100%	100%
Type D2	Power	100%	75%	50%	25%	10%
	Weighting Factor	0.05	0.25	0.3	0.3	0.1

D2 Cycle : For constant speeed auxiliary engines

- **Engine Family and Engine Group concepts**

To avoid certification testing of every engine for compliance with the NOx emission limits, one of two approved concept may be adopted, namely the Engine Family or the Engine Group concept.

The Engine Family concept may be applied to any series produced engines which, through their design and proven to have similar NOx emission characteristics, are used as produced, and, during installation on board, require no adjustments or modifications which could adversely affect the NOx emissions.

The Engine Group concept may be applied to a smaller series of engine produced for similar engine application and which require minor adjustments and modifications during installation or in service on board.

Initially the engine manufacturer may, at its discretion, determine whether engines should be covered by the Engine Family or Engine Group concept. When the testing of the engine family or engine group, the engine which is expected a worst case NOx emission rate of the engine family, is selected for testing. The engine family is determined by this parent engine and the emission test for certificate is only necessary on the parent engine. From second engine, the certification shall be issued by checking the components, parameters and document which have to compare the parent engine.

- **IMO NOx Tier II Emission limitation**

IMO NOx Tier II emission limitation to be applied to a marine diesel engine that is installed on a ship constructed on or after 1 January 2011. And it applies in global sailing for new marine diesel engine with a power output of more than 130kW.

NOx Tier II emission value : 44.0 x rpm$^{-0.23}$ [g/kWh] : 130< rpm < 2,000

- **IMO NOx Tier III Emission limitation**

IMO NOx Tier III emission limitation to be applied to a marine diesel engine that is installed on a ship constructed on or after 1 January 2016 and which operated in the North American emission control area or the U.S Caribbean Sea emission control area and or after 1 January 2021 and which operated in the Baltic Sea or the North Sea that are designated for the control of NOx emissions. And further NOx Tier III emission control area will be expanded by the plan of administration. And its schedule will be followed to effective date by IMO.

NOx Tier III emission value : 9.0 x rpm$^{-0.2}$ [g/kWh] : 130< rpm < 2,000

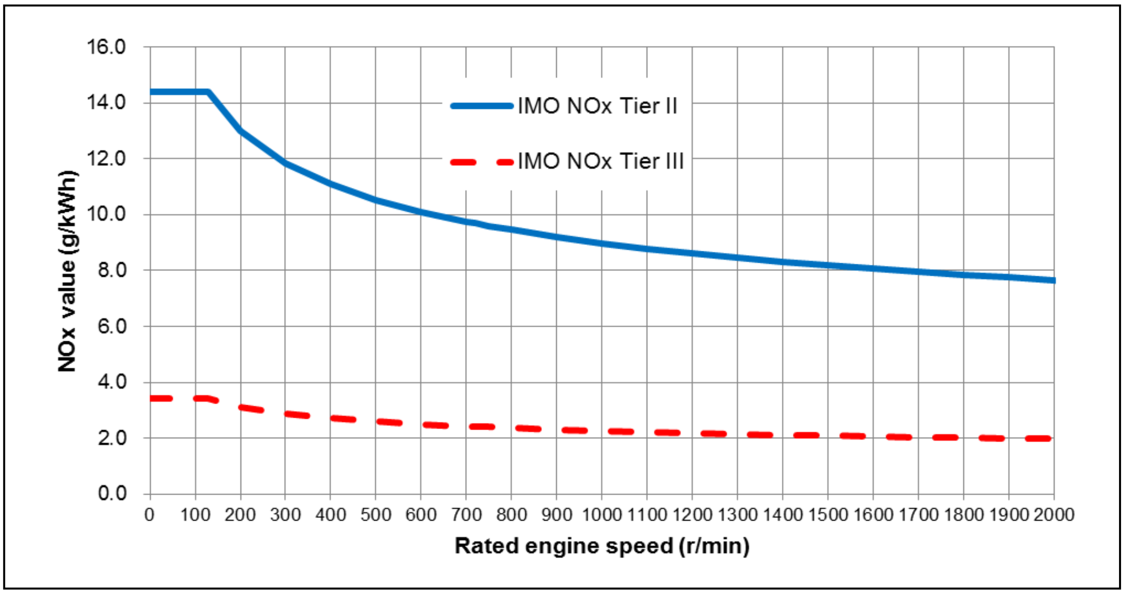


Figure 2-5-1: NOx emission from marine propulsion engine

SOx emissions – Sulphur Oxides

Sulphur Oxides (SOx) is regulated by the sulphur contents of any fuel used on board ships. The limitation of SOx applies to all ships, no matter the date of ship construction. When sailing inside SOx emission control area (SECA), the Sulphur contents must not exceed 0.1% after 1 January 2015. In the outside of SECA, 73/78 Annex VI regulation 14 regulates the Sulphur contents to maximum 3.5% until 1 January 2020 where a new limit of 0.5% Sulphur is introduced.

The after treatment equipment such as scrubber or gas fuels shall be considered in order to avoid the high cost of low Sulphur fuel oil alternatively.

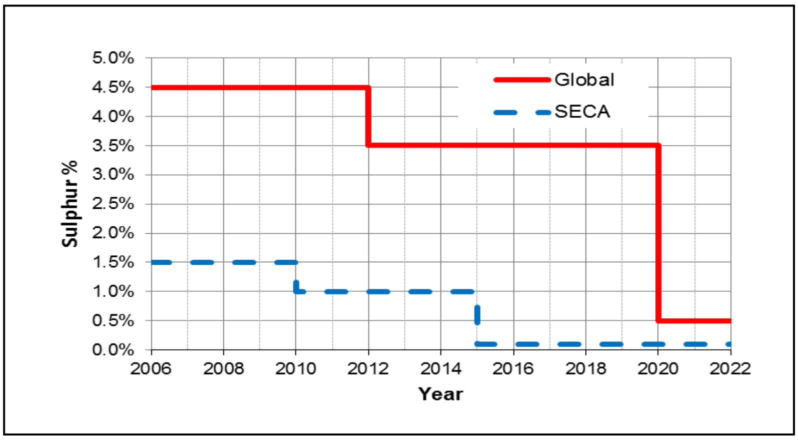


Figure 2-5-2: Sulphur limits in fuels

Additional note

If there is no special requirement from customer regarding the exhaust gas emission, HiMSEN engine shall be delivered with optimized performance conditions fulfilling the IMO limit value of NOx Tier II emission level on diesel mode and Tier III emission level on gas mode. If it has to comply with the Tier III on diesel mode, the SCR(Selective Catalytic Reduction) system is requested as option. For details of SCR, it shall be described separately. Therefore, it is strongly requested to contact the engine maker if there are any further requirements regarding exhaust gas emission or special operating conditions.

Correction for ambient condition

The specific fuel oil consumption (SFOC) is referred to the ISO 3046-1:2002 standard condition normally. However, for the condition other than ISO 3046-1:2002 standard condition, SFOC at MCR can be estimated according to the following formula:

$$SFOC_{amb} = SFOC_{ISO} \times dSFOC$$

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

$SFOC_{amb}$ [g/kWh] = Specific fuel oil consumption at actual operating condition

$SFOC_{ISO}$ [g/kWh] = Specific fuel oil consumption at ISO 3046/1 standard condition

dSFOC [-] = Deviation of the specific fuel oil consumption

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

P_{amb} [mbar] = Turbocharger inlet air pressure at actual operating condition

T_{CW} [°C] = LT 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°C
- Turbocharger inlet air pressure (P_{amb}): 990 mbar
- LT Cooling water temperature (T_{CW}): 30°C
- Lower calorific value (LCV): 42700 kJ/kg
- $SFOC_{ISO}$: 185 g/kWh at 720 rpm, MCR

  Then, dSFOC = 1.0067 and SFOC at site condition will be increased to 186.2 g/kWh.

Clean leak fuel oil

Clean leak fuel oil (recycling fuel oil) during engine operation is subtracted from measured fuel oil consumption.

(Refer to the internal Fuel Oil System, P.05.100)

FOC_{amb} = FOC – clean leak fuel oil *)

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

Correction for engine driven pump

If some of engine driven pumps are detached, the effect value of SFOC and heat rate at MCR is appeared approximately as follows:

Engine driven pump	Effect value
	SFOC (g/kWh)
Lubricating oil pump	2.0
H.T Cooling water pump	1.0
L.T Cooling water pump	1.0

Engine driven L.T & H.T Pump (Genset & Propulsion)
Correction value SFOC by water pump =
Effect value of SFOC at 100% load * (100/Load)^x * (actual rpm/rated rpm)^3 [g/kWh]

Engine driven L.O Pump (Genset & Propulsion)
Correction value SFOC by L.O pump =
Effect value of SFOC at 100% load * (100/Load)^x * (actual rpm/rated rpm)^3 [g/kWh]

Load	100~25%	Under 25%
x	1.15	1.28

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

Item	additional SFOC [g/kWh]
Charge air pressure control device	Please contact to HHI-EMD
Operation on MGO	+ 2
500 mmWC > Exhaust gas back pressure after turbine > 300mmWC	+ 0.5 / 100 mmWC

Correction for ambient condition (Gas operation)

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

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

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

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

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

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

Eff_{amb} [%] = Engine efficiency at actual operating condition

Eff_{ISO} [%] = Engine efficiency at ISO 3046/1 standard condition

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

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

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

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

Notice

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

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

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

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

Example

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

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

***) Remark**

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

Calculation of fuel gas flow

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

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

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

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

Correction of additional fuel gas consumption

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

Item	Additional heat [kJ/kWh]
Lubricating oil pump	+ 86
L.T cooling water pump	+ 43
H.T cooling water pump	+ 43
400mmWC> Exhaust gas back pressure after turbine > 240mmWC (Gas mode*)	+120 per 80mmWC of Gas mode

Remark)

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

LT & HT Pump attached engine

Additional heat rate by water pump =

Additional heat rate at 100% load * (100/Load)^x * (actual rpm/nominal rpm)^3 [kJ/kWh]

LO Pump attached engine

Additional heat rate by LO pump =

Additional heat rate at 100% load * (100/Load)^x * (actual rpm/nominal rpm) [kJ/kWh]

Load	100 ~ 25%	Under 25%
X	1.15	1.28

Correction for exhaust gas temperature after turbine

The exhaust gas temperature after turbine is referred to ISO 3046-1:2002 standard condition normally. However, for the condition other than ISO 3046-1:2002 standard condition, the exhaust gas temperature after turbine could be estimated according to the below mentioned formula:

$$T_{aturb,\ exh} = T_{aturb,\ ISO} + dT_{aturb}$$

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

$T_{aturb,\ exh}$ [°C] = Exhaust gas temperature after turbine on actual operating condition

$T_{aturb,\ ISO}$ [°C] = Exhaust gas temperature after turbine on ISO 3046-1:2002 standard condition

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

T_{intake} [°C] = intake air temperature on actual operating condition

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

Example

- Ambient air temperature (T_{amb}): 35°C
- Cooling water temperature (T_{cw}): 35°C
- $T_{aturb,\ ISO}$: 290°C at 720 rpm, MCR

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

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

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

Gas mode

De-rating due to intake air temperature and altitude

Engine output power at MCR shall decrease depending on the intake air temperature and site altitude.

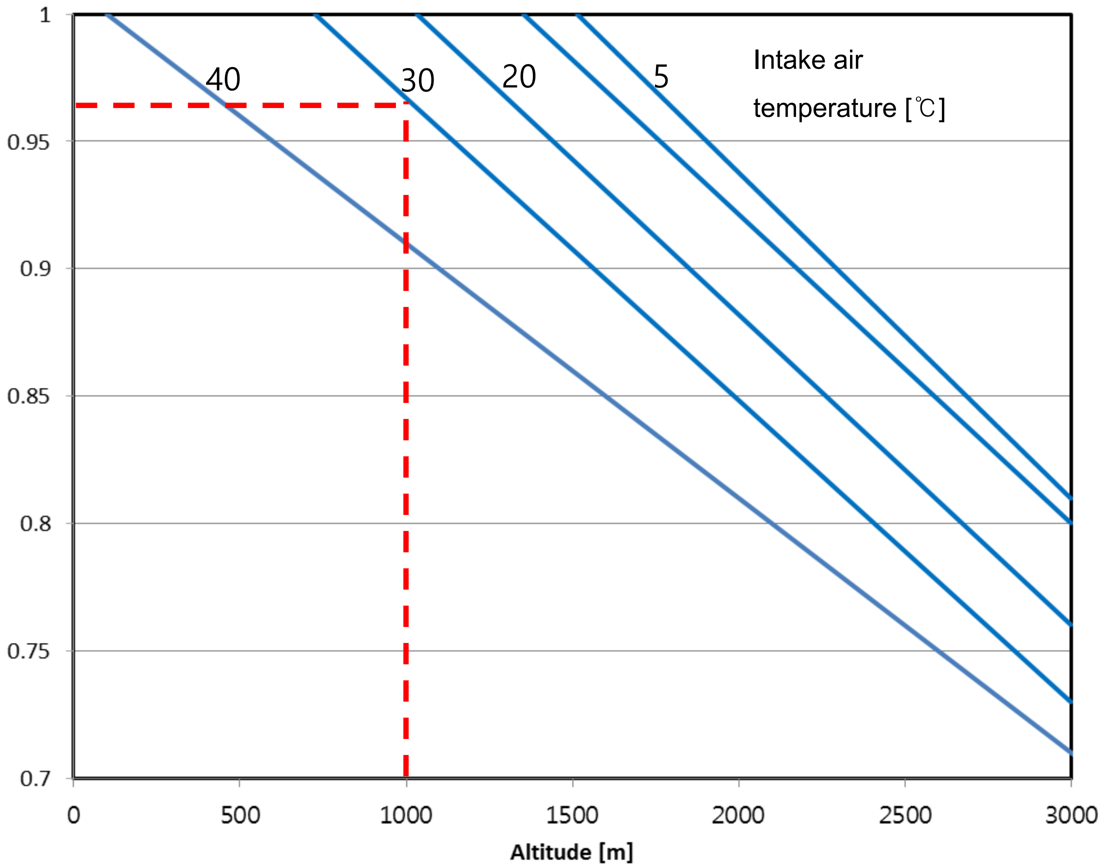


Figure 2-6-1: De-rating due to Intake air temperature and altitude

Remark

1. Minimum intake air temperature: 5°C
2. The temperatures given above are maximum (continuous) operating temperature at a site (or a vessel).
3. For the temperatures above 45°C or L.T cooling water temperatures above 36°C, please contact to HHI-EMD.
4. All design modifications related to the combustion may change the characteristics of de-rating.
   For example, the modifications can be turbocharger specifications, the compression ratio of cylinder, and piston designs, etc.
5. Beside the de-rating factors (ambient condition, the gas properties, the gas supply condition, and charge air temperature), relative humidity and the glycol content for anti-freezing can reduce the engine maximum power.

Example

- L.T cooling water temperature before a charge air cooler: 36°C
- Intake air temperature: 30°C
- Site altitude: 1000m

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

▪ De-rating due to charge air temperature and methane number(MN)

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

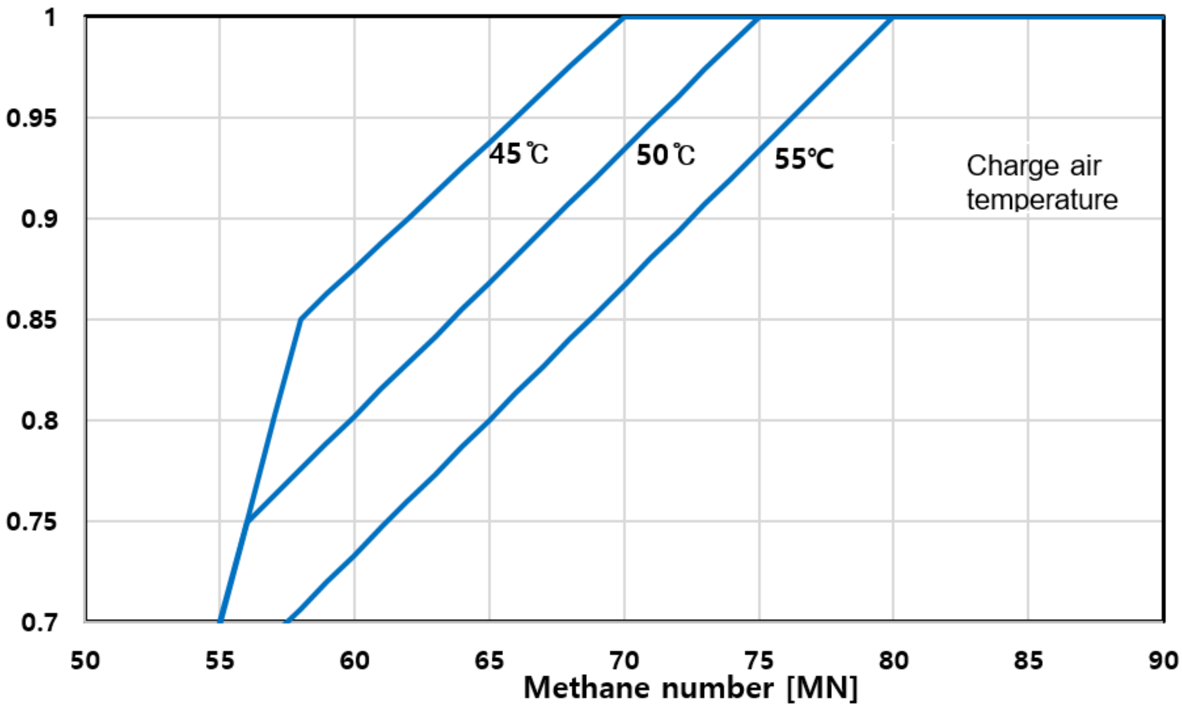


Figure 2-6-2: Minimum de-rating due to Intake air temperature and methane number

100% load operation of gas mode is possible when operating with min. MN70 gas fuel and below 45˚C of intake 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 MCR shall be reduced depending on the LCV and gas feed pressure.

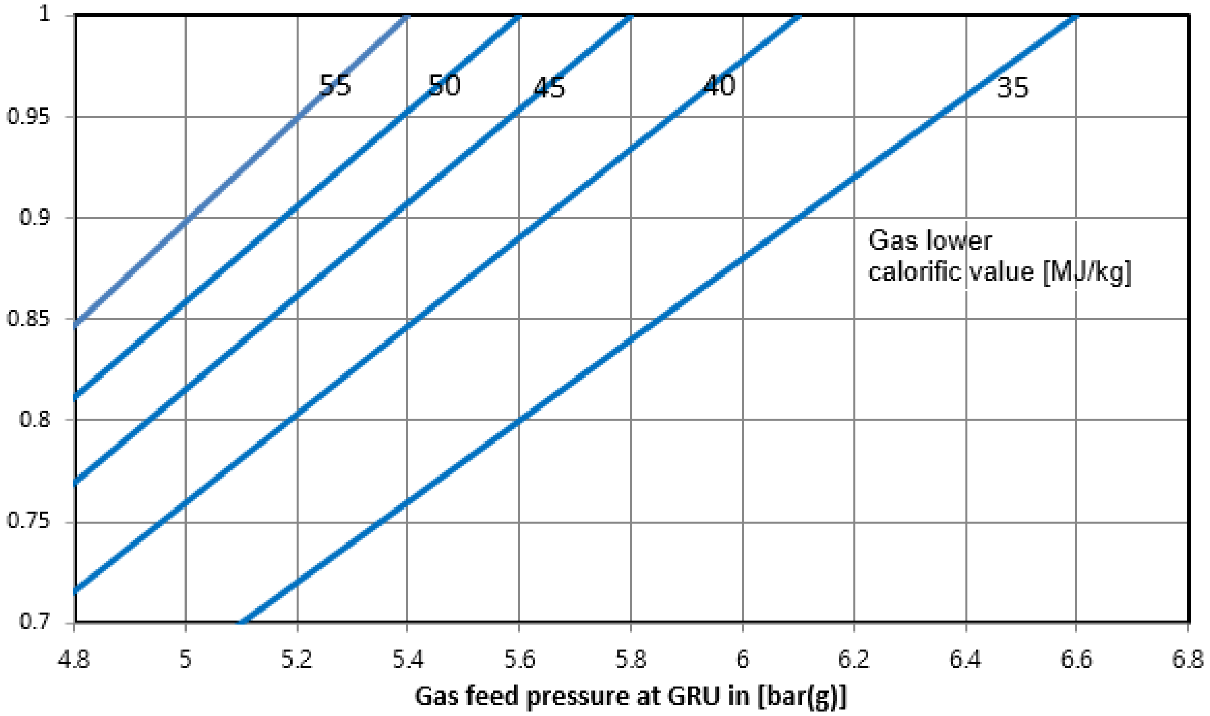


Figure 2-6-3: De-rating due to gas lower calorific value and gas feed pressure

De-rating due to L.T cooling water temperature

Engine output power at MCR shall be reduced depending on the L.T cooling water temperature.

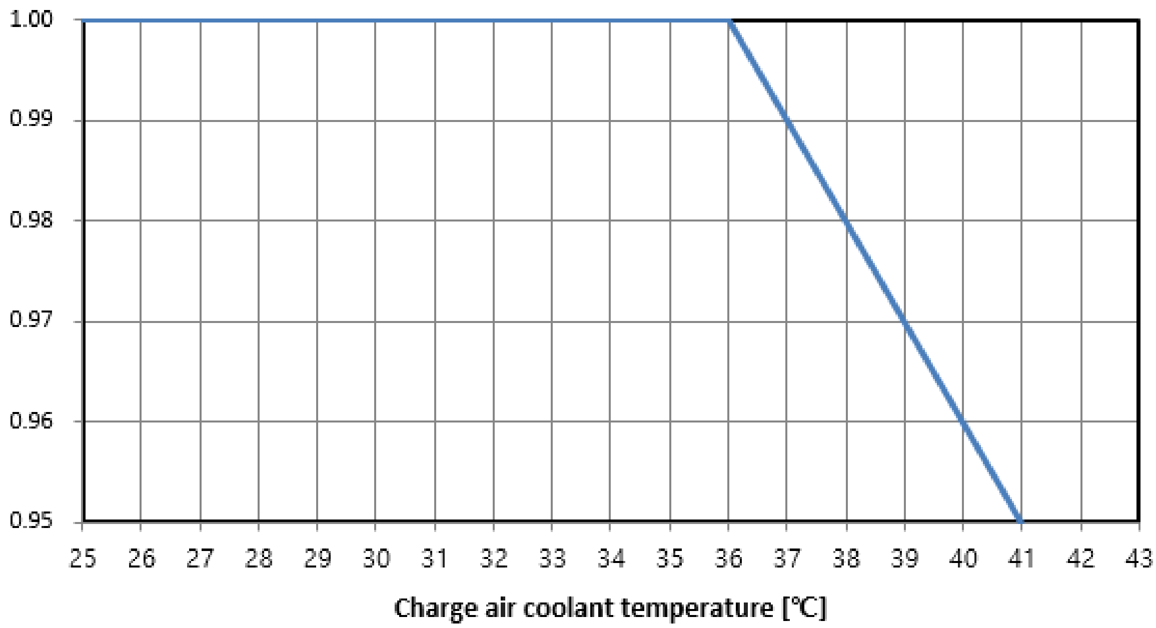


Figure 2-6-4: De-rating due to L.T cooling water temperature

De-rating due to intake air temperature

Engine output power at MCR shall be reduced depending on the intake air temperature.

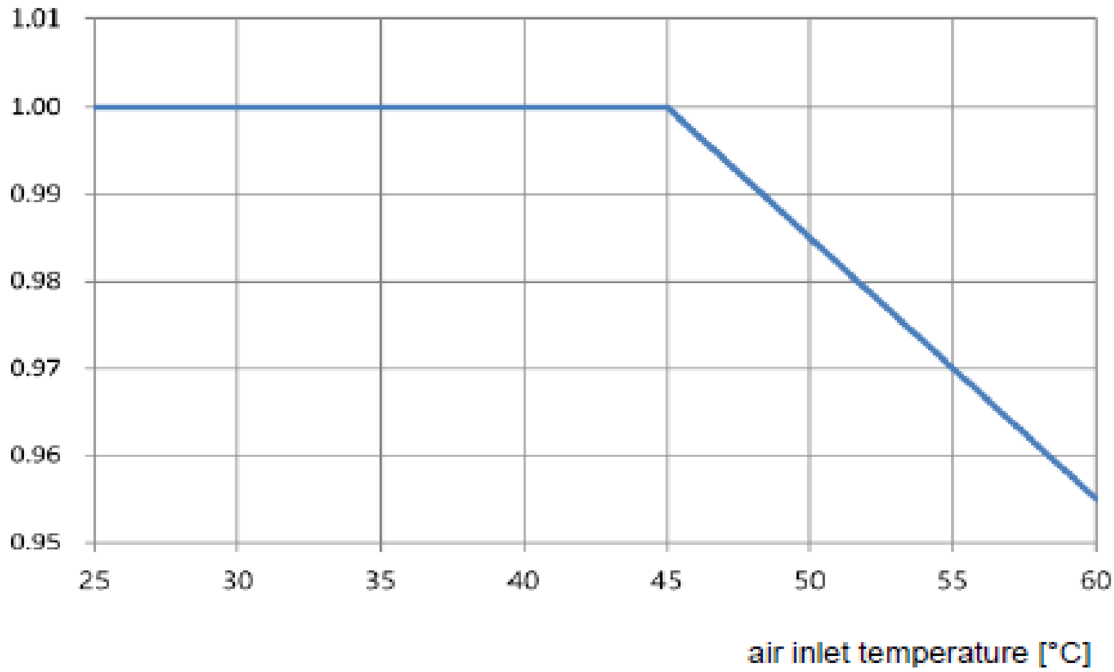


Figure 2-6-5: De-rating due to intake air temperature

De-rating due to intake air pressure

Engine output power at MCR shall be reduced depending on the intake air pressure.

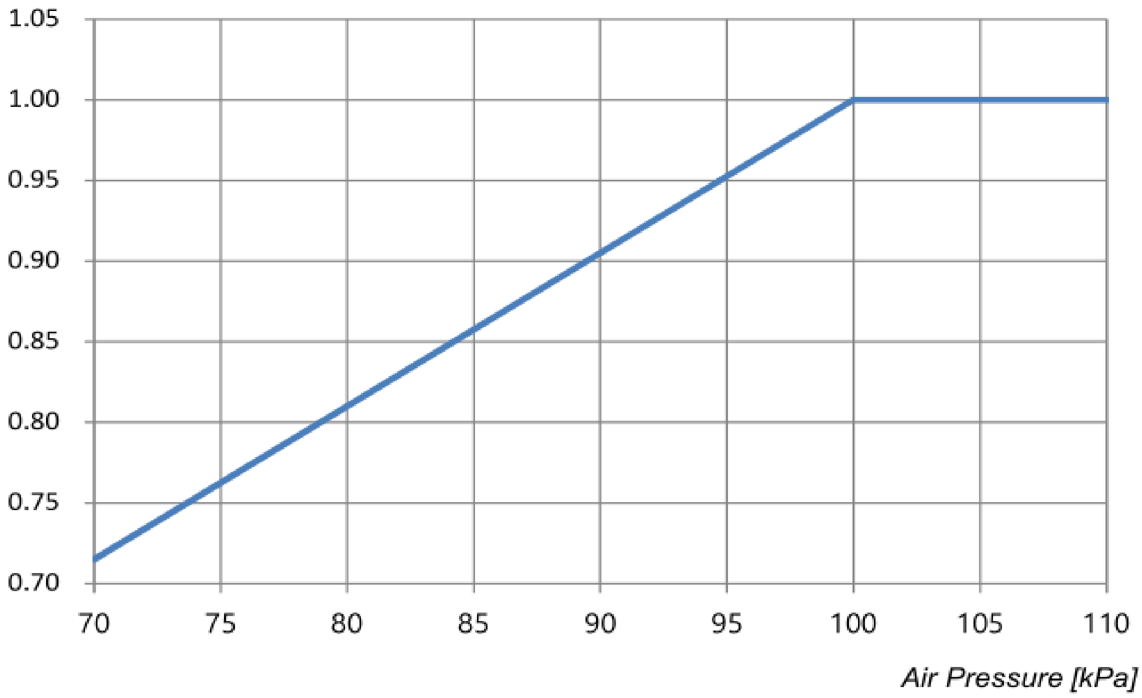


Figure 2-6-6: De-rating due to intake air pressure

De-rating due to contents of anti-freezing coolant

Engine output power at MCR shall be reduced depending on the anti-freezing coolant volume

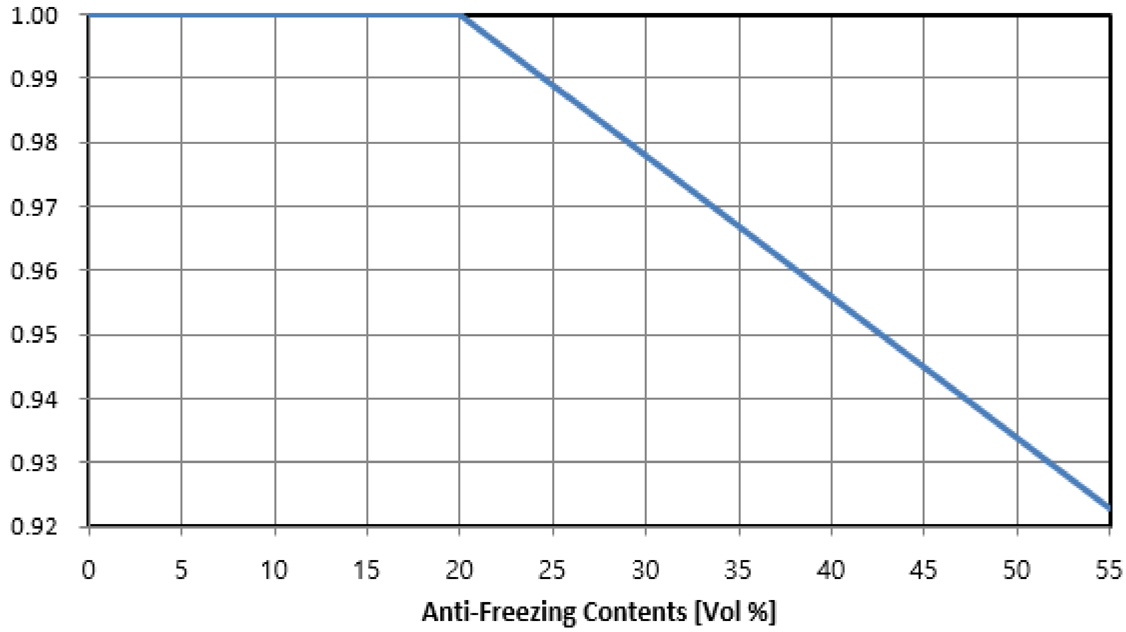


Figure 2-6-7: De-rating due to contents of anti-freezing coolant

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.

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

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Appendix

External forces and couples

Diesel Mode

Engine type	Speed	External forces and moments				Guide force moments		
		Order		Moment Horizontal	Moment Vertical	Order		Moment
	[rpm]	No.	[Hz]	[kNm]	[kNm]	No.	[Hz]	[kNm]
6H35DFP	750	1	12.5	0	0	3	37.5	27.2
		2	25.0	0	0	6	75	19.7
7H35DFP	750	1	12.5	2.2	33.7	3.5	43.8	73.7
		2	25	0	27.6	7	87.5	13.8
8H35DFP	750	1	12.5	0	0	4	50.0	61.8
		2	25	0	0	8	100.0	9.3
9H35DFP	750	1	12.5	1.6	24.4	4.5	56.3	58.9
		2	25.0	0	15.0	9	112.5	6.2

Gas Mode

Engine type	Speed	External forces and moments				Guide force moments		
		Order		Moment Horizontal	Moment Vertical	Order		Moment
	[rpm]	No.	[Hz]	[kNm]	[kNm]	No.	[Hz]	[kNm]
6H35DFP	750	1	12.5	0	0	3	37.5	17.5
		2	25.0	0	0	6	75.0	20.7
7H35DFP	750	1	12.5	2.2	33.7	3.5	43.8	65.2
		2	25.0	0	27.6	7	87.5	16.4
8H35DFP	750	1	12.5	0	0	4	50.0	55.9
		2	25.0	0	0	8	100.0	13.2
9H35DFP	750	1	12.5	1.6	24.4	4.5	56.3	54.8
		2	25.0	0	15.0	9	112.5	10.6

Table 3-1-1: External forces and couples

Remark:

1. The value(s) above is only provided preliminary information purpose. It would be changed without any notice to improve the engine.
   In order to construct a commercial engine project, please contact HHI-EMD.

Moment of inertia

Engine type	Speed	Rating	Moments of inertia (MOI), J			
			Engine	Flywheel [1) MOI	Flywheel [1) Mass	Total
	[rpm]	[kW]	[kg m^2]	[kg m^2]	[kg]	[kg m^2]
6H35DFP	750	3000	380	190	866	570
7H35DFP	750	3500	438	400	1704	838
8H35DFP	750	4000	497	190	866	687
9H35DFP	750	4500	555	100	478	655
12H35DFVP	750	6000	814	700	2391	1514
14H35DFVP	750	7000	885	600	2015	1485
16H35DFVP	750	8000	960	600	2015	1560
18H35DFVP	750	9000	1048	600	2015	1648
20H35DFVP	750	10000	1218	400	1232	1618

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

Table 3-2-1: Moments of inertias

Remark:

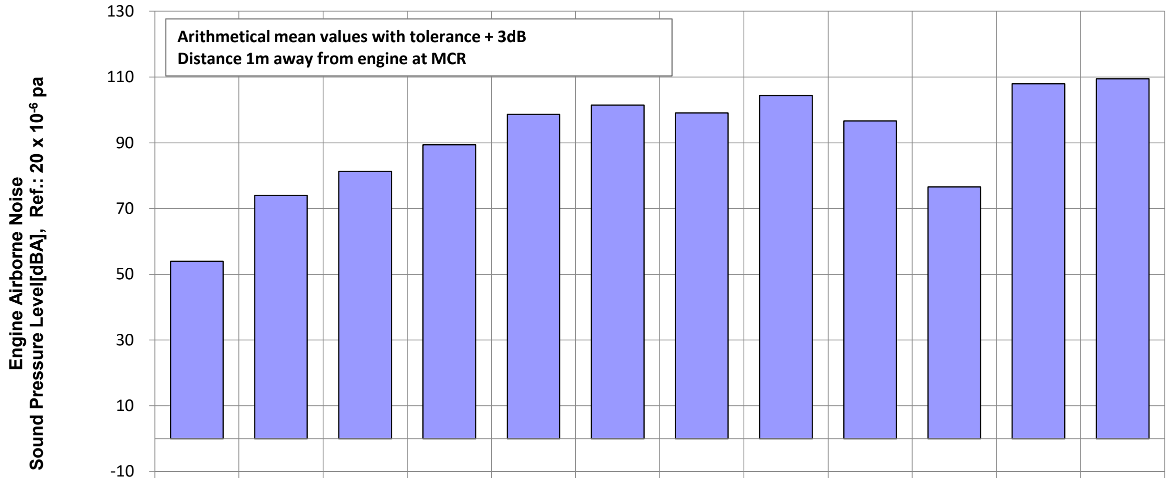
1. The value(s) above is only provided preliminary information purpose. It would be changed without any notice to improve the engine. In order to construct a commercial engine project, please contact HHI-EMD
2. The above data is based on 100% load for 500 kW/cyl. @ 750 rpm
3. The moment of inertia and mass data of the engine flywheel should be dimensioned depending on specific project specifications.

General

The airborne noise of the engines are defined as a sound pressure level according to ISO 6798 and ISO 10816-6. A total 19 measuring points at distance 1m away from the engine surface at full load. The values are average 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 will change, depending on the acoustical properties of the environment and cylinder number.

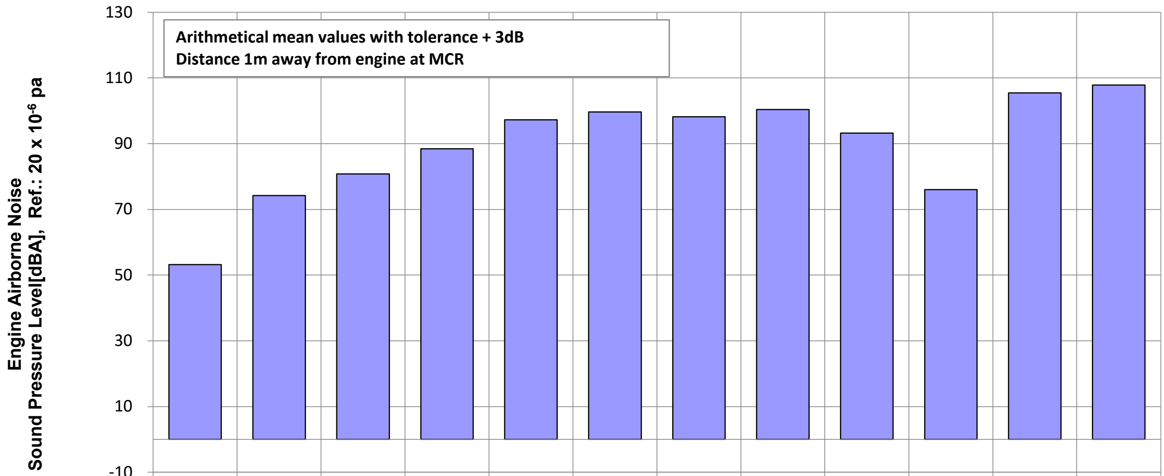
750 rpm (9 cyl.) - Diesel mode



	31.5	63	125	250	500	1k	2k	4k	8k	16k	A-Weighting	Linear
9Cyl. 750rpm	54.0	74.0	81.4	89.4	98.7	101.5	99.1	104.3	96.7	76.6	107.9	109.5

1/1 Octave Band Frequency [Hz]

750 rpm (9 cyl.) - Gas mode



	31.5	63	125	250	500	1k	2k	4k	8k	16k	A-Weighting	Linear
9Cyl. 750rpm	53.2	74.2	80.8	88.5	97.2	99.7	98.1	100.4	93.2	76.0	105.4	107.8

1/1 Octave Band Frequency [Hz]

Figure 3-3-1: Typical noise level of H35DF

Remark:

1. The value(s) above is only provided preliminary information purpose. It would be changed without any notice to improve the engine. In order to construct a commercial engine project, please contact HHI-EMD
2. The above measured results can be changed depending on the specific projects.

General

The shaft system that consists of crankshaft, intermediate shaft, propeller shaft, propeller, flexible coupling and /or PTO(Power Take Off) has its natural frequencies.

Torsional vibration is generated by inertia force of shaft system, gas pressure of cylinder and irregular torque of propeller. If some excitations have resonance with natural frequency of the shaft system, the amplitude will be increased. They cause an important problem such as fatigue in the shaft system and abrasion of gear in the critical speed.

Therefore the shaft diameter, propeller diameter, the number of propeller blade and other details have to be calculated in consideration of additional stresses, amplitudes and frequencies of torsional vibration.

The calculation sheets for the torsional vibration are to be submitted to the relevant Classification Societies and measurements to confirm correctness of the estimated value are to be carried out.

Required data and information for calculation

The required data and information for calculation of torsional vibration are as followings. And the additional consideration beyond the followings can be carried out if the corresponding data is available.

- **General**
  - Type of vessel
  - Classification Society
  - Operation mode
  - Arrangement of whole system including all of propulsion equipment
  - Clutch in speed
  - Operation profile

- **Main engine**
  - Rated power and speed
  - Mounting method (rigid or resilient)
  - Engine operation mode

- **Reduction gear**
  - All clutch possibilities
  - Gear ratio
  - Dimensions for all shafts
  - Moment of inertia for all masses and stiffness data for all shaft
  - Material specification of shafts including tensile strength

- **Propeller and shafting**
  - Type of propeller and the number of propeller blade
  - Dimensions for all shafts
  - Moment of inertia for all masses and stiffness data for all shaft
  - Material specification of shafts including tensile strength

- **Shaft generator and/or pump gear**
  - Operation profile
  - Generator power and speed
  - Moment of inertia for all masses and stiffness data for all shaft (or dimensions for all shafts)
  - Material specification of shafts including tensile strength

- **Flexible coupling**
  - Type and manufacturer
  - Moment of inertia for all masses and stiffness data for all shaft
  - Thermal load and vibratory torque limit

Counter measure

The vibration behavior of the system is adjusted by modification of flywheel size, shaft diameter or flexible coupling type in order to change the natural frequency of the shaft system.

And the high stress on the shaft system due to torsional vibration can be reduced or avoided by installation of a torsional vibration damper at the front of the engine.

For lower energy of torsion vibration can be reduced by using viscous damper. The viscous damper provides torsional vibration damping by the shearing effect of a highly viscous silicone fluid enclosed between the inner ring and out casing. The relative movement between inner ring and the casing shears the film of silicone fluid and absorb vibration energy that is dissipated as heat through the external surfaces of the damper casing.

For higher energy of torsional vibrations can be reduced by using spring damper. The spring damper is a spring coupled torsional vibration damper with an internal hydraulic damping system. Radial arranged leaf springs transmit the elastic torque from the inner member to the damper outer member. The torsional vibrations are damped concurrently by oil displacement from one chamber into the adjoining one. The oil flow resistance retards the relative movements of the two coupling members and dampens the vibration amplitudes.

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Appendix

General

A HiMSEN Dual Fuel Engine is the engine that can run in both fuel gas (natural gas) and fuel oil including HFO, MDO and MGO. The operation characteristics of diesel and gas mode are different. Suitable fuel mode should be selected at each required operating situation and proper action should be taken based on the fuel mode.

Engine Fuel Mode

- **Diesel mode**

  It is activated when manually selected or gas mode is unavailable (gas trip condition). Main fuel oil is injected by conventional main injection system, and pilot fuel oil is injected by common rail system which is electronically controlled.

- **Gas mode**

  It is activated when manually selected. Fuel gas is injected through gas admission valves and the amount of injected fuel gas is adjusted by opening duration. Pilot fuel oil system is operated along the same lines as 'Diesel mode'.

- **Backup mode**

  It is activated when blackout start occurs or both gas and diesel modes are unavailable (gas or pilot trip condition). In case of Backup mode, only main fuel oil system is activated without pilot fuel oil system.

Starting Condition

Normal starting condition

- **Lub. Oil**

  Continuous pre-lubrication is required

  Temperature : over 40 ℃ (Preheated)

- **Cylinder Cooling Water**

  Starting temp. : HFO - over 60℃ (Preheated)

  MDO/MGO - over 40℃ (Preheated)

- **Combustion Air**

  Air temperature : between 0 ℃ and 45 ℃

- **Fuel Oil (MDO/MGO or HFO)**

  Pre-circulation is required

  Engine inlet viscosity : 12 … 18 cSt (HFO)

  2 … 14 cSt (MDO/MGO)

  (See P.05.310 for more information)

- **Fuel Gas**

  Temperature : 0...50℃

  Refer to Figure 4-1-2, 4-1-3 (for constant speed application only) for required fuel gas pressure and allowable variation of pressure.

Emergency cold starting condition

Fuel Oil : only MDO/MGO acceptable

Cooling Water : minimum 15℃

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

Intake air temperature : minimum 0℃

Starting air pressure: Starting condition with warm engine,

Starting air source, pressure, min. is specified in ‘P.02.200/210’+ Min. 5 bar

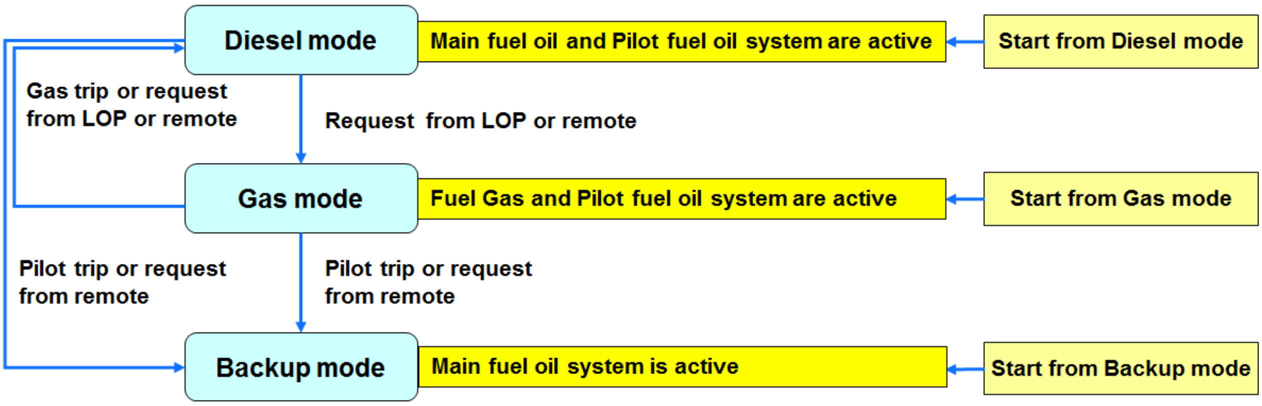

Figure 4-1-1 Engine fuel mode description

Fuel mode can be selected from

- ✓ Switch on LOP (On Engine)
- ✓ From external system (PCS, etc.)

Gas & Pilot trip condition is specified in ’P.04.400 Operation Data & Alarm Points’.

Required fuel gas supply pressure

Fuel gas supply pressure between 36 MJ/Nm^3 and 28 MJ/Nm^3 can be interpolated.

As the graph below, the required fuel gas pressure is different depending on the engine load and LCV (Lower Calorific Value). The fuel gas feed pressure at GRU inlet, G11 (see the diagram P.05.510) should be considered as followings;

1) Pressure loss at a GRU (Typically, 0.6 bar can be used.),

2) Pressure loss in the pipe between a GRU and an engine.

The supply pressure of fuel gas can be increased depending on the GRU design pressure (10 bar or 16 bar).

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

Admissible supply pressure fluctuation of fuel gas: Less than 0.1 bar/sec of pressure fluctuation (peak ± 0.5 bar) can be absorbed in GRU and no effect on engine operation. The fuel gas feed pressure should be higher than the required fuel gas pressure at corresponding engine operating conditions.

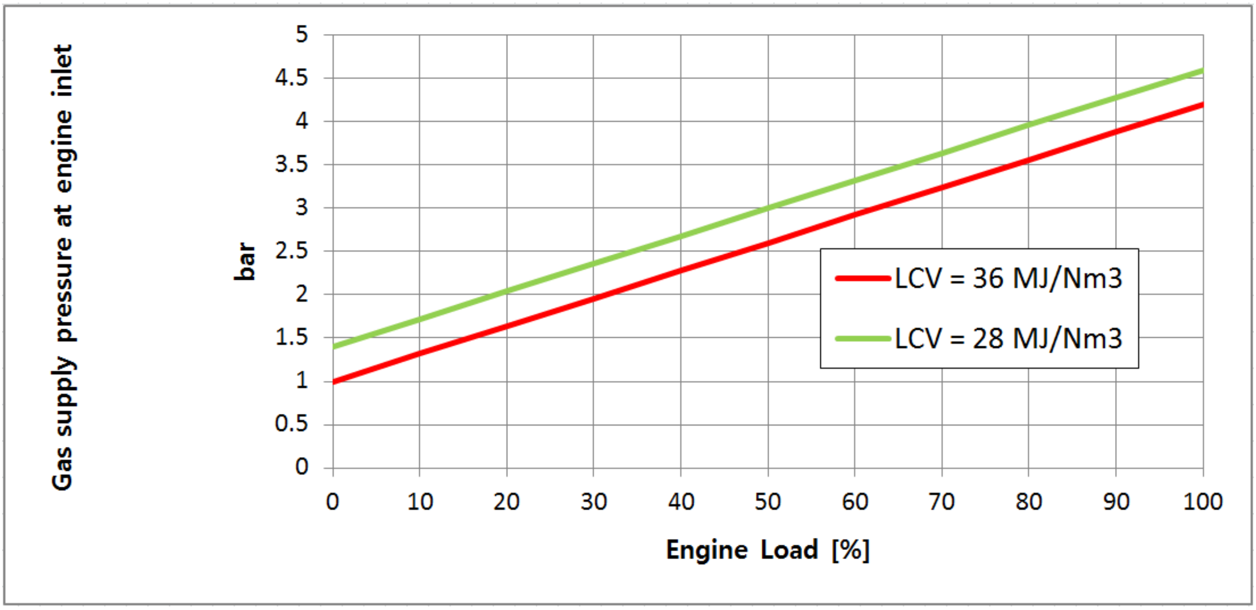

Figure 4-1-2 Fuel gas supply pressure at Engine inlet

Engine Start

Engine Start Ready

Engine start ready conditions are indicated in the local control panel and remote control panel. It is recommended that the engine to be in warm condition before start

- **Start Block Signals**

  Low lubrication oil pressure

  Turning gear engaged

  Signal loss of fuel actuator

  Engine in test mode

  Unexpired run down time

  Under processing exhaust gas ventilation

  Low starting air pressure

  Start blocking from PCS

  Slow turning failure

  Stop command activated

  Start failed

  No reset after engine trip

  Other installation dependent start blocks

Engine Start in Different Fuel Mode

Starting valves are installed in an engine side and operated by compressed air, which is controlled by pneumatic solenoid valve.

(See P.08.100 Internal Compressed Air System)

Start from each fuel mode is available with satisfied pre-defined condition for the selected fuel mode.

- **Engine Start from Diesel Mode**

  For diesel mode start, all conditions for pilot operation have to be satisfied.

  Compressed air is directly injected to the combustion chamber and initial firing is made by main fuel oil injection.

  As soon as combustion chamber is fired, engine speed is quickly increased.

  A pilot injection test is conducted at pre-defined engine speed. The pre-defined engine speed may be variable between approximately 50…70% of rated speed.

During a pilot injection test, the engine is operated only by pilot fuel oil injection and the exhaust gas temperature of each cylinder is monitored for sanity check.

- **Engine Start from Gas Mode**

For gas mode start, all conditions for gas mode operation have to be satisfied.

Compressed air is directly injected to the combustion chamber and initial firing is made by main fuel oil injection. **Even in gas mode start, start is initiated by fuel oil.**

A pilot injection test is conducted at pre-defined engine speed. The pre-defined engine speed may be variable between approximately 50…70% of rated speed.

During pilot injection test, the engine is operated only by pilot fuel oil injection and the exhaust gas temperature of each cylinder is monitored for sanity check.

If pilot fuel oil injection test is successfully completed, gas valves are operated. After predefined CH_4 purging delay, fuel gas is injected and it takes about 2 minutes to change the mode.

- **Engine Start from Backup Mode**

Backup mode start will be initiated in any case of start under gas trip, pilot trip condition, or an emergency situation such as blackout start.

Compressed air is directly injected to the combustion chamber and initial firing is made by main diesel fuel injection. In backup mode, a pilot injection test is skipped. Engine speed reaches idle speed as quickly as possible.

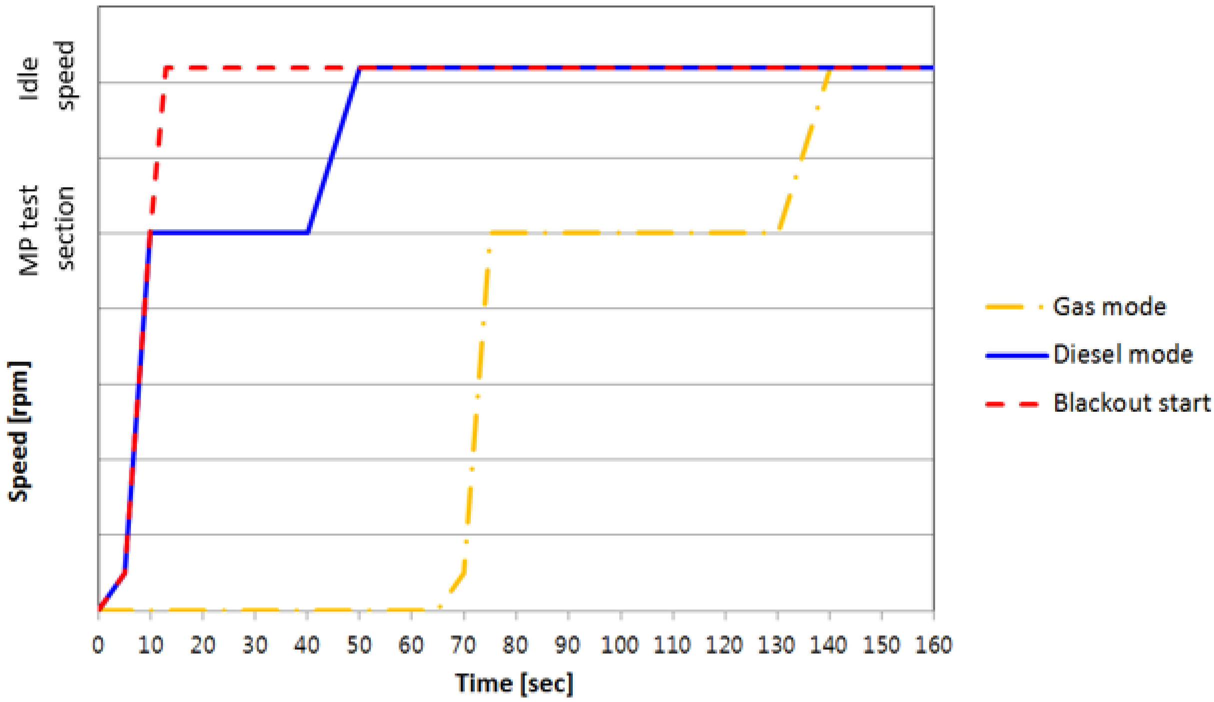

Figure 4-1-3 Start in different fuel mode for constant speed application only

Restriction for Low Load Operation

Idle Running

Less than 5 min. before engine stop

Max. period of 30 min. operation is possible if the engine is loaded after idle running.

Low Load Operation for long term

- **Gas & MDO & MGO 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 4-1-4.

- **HFO 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 4-1-4.

- **Duration of Flushing Operation (See Figure 4-1-4)**

  'Time Limits for Low Load Operation'(Left) shows admissible operation time at certain load, and 'Duration of Flushing Operation'(right) shows the time duration that operates at not less than 70% of full load in order to have deposits burnt away.

<Example>

1. Time Limits for Low Load Operation (Line A, A'). At 10% of full load, HFO operation is permissible for about 17 hours (Line A), whereas MDO operation for 37 hours (Line A').

2. Duration of Flushing Operation (Line B, B') Engine should be operated for roughly 1.15 hours (HFO) and 0.75 hours (MDO) at not less than 70% of full load.

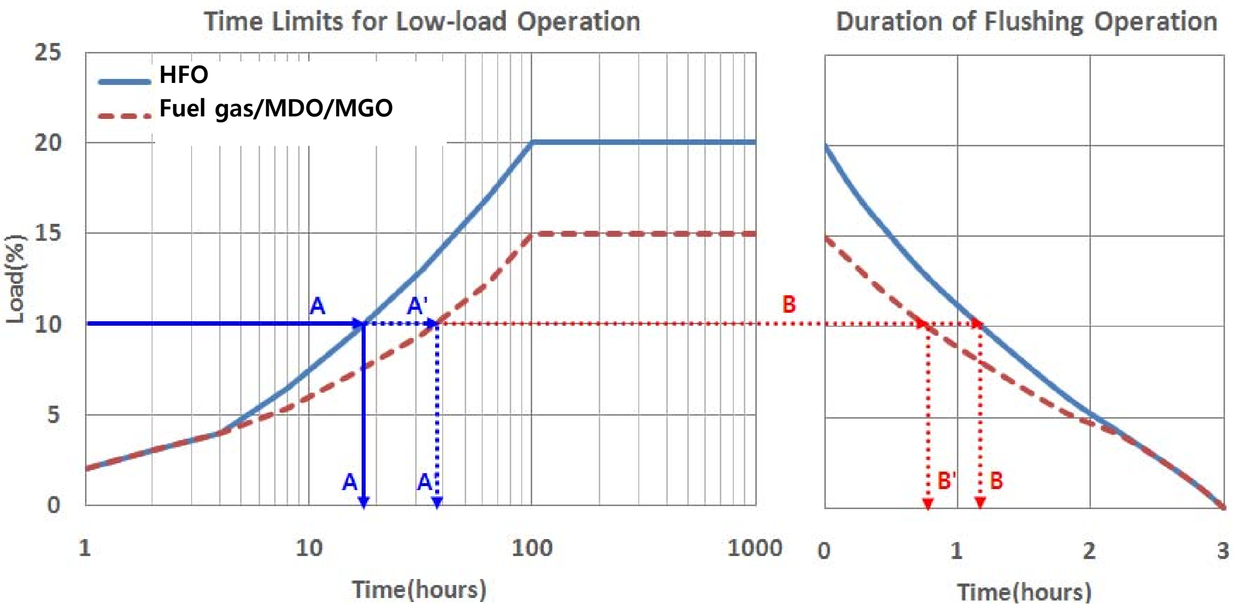

Figure 4-1-4 Time restriction for low load operation

Engine Load-up

HiMSEN DF engine fulfills all requirements regarding the load application of all classification societies and IACS in diesel mode. In gas mode, both continuous and step by step load up should be taken carefully for stable and safe engine operation.

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 warm condition and high step load should be prohibited.

Continuous Load-Up

The continuous load up capacity(Constant speed, controllable pitch propeller(CPP)) in each fuel mode is referred in Figure 4-1-5.

- **Diesel Mode**

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

- **Gas Mode**

  In warm condition, the 100% load can be achieved in 6 min. by continuous ramping up in normal condition. In emergency situation, the load can be more quickly increased to 100% in 150 sec. It should be taken into account that load increase in gas mode need to be operated more carefully.

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

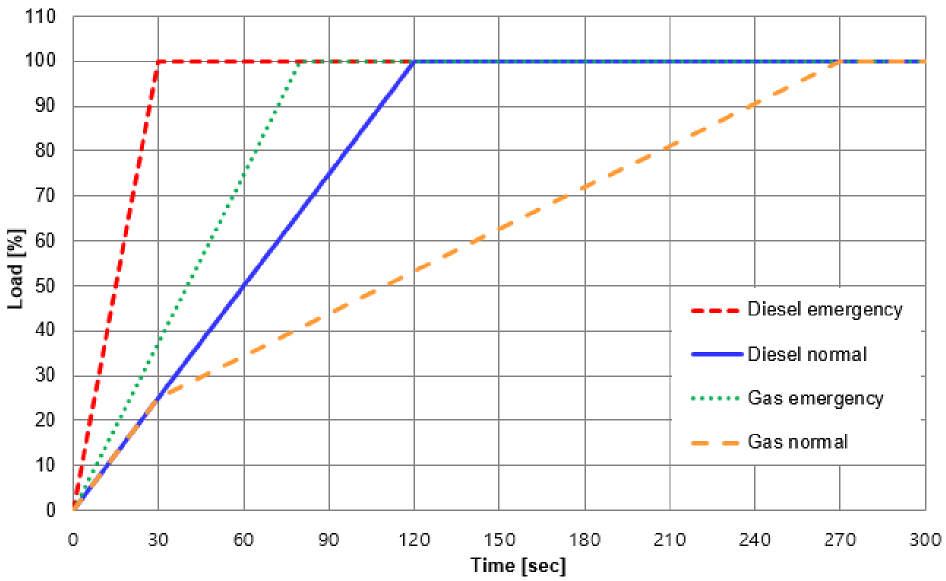

Figure 4-1-5 Engine load up capacity in ramp

Fuel Mode Changeover

Fuel mode changeover is permitted when predefined conditions for each mode are satisfied.

Fuel mode changeover is available from

Switch in local control panel (engine room)

Switch in remote (engine control room)

When any predefined trip condition in each fuel mode is detected, fuel mode is automatically transferred to safer fuel mode (Gas mode to Diesel mode, Diesel mode to Backup mode) for continuous operation without engine shutdown (refer to Figure 4-1-1).

- **From Gas to Diesel mode**

  Changeover is available at the entire load range (0% ... 100%)

  Changeover takes only a second (refer to Figure 4-1-8)

- **From Diesel to Gas mode**

  Changeover is available at the load range of 0% ... 80%

  A fuel gas leakage test is performed before changeover.

  Changeover takes approx. 2 minute. (refer to Figure 4-1-9)

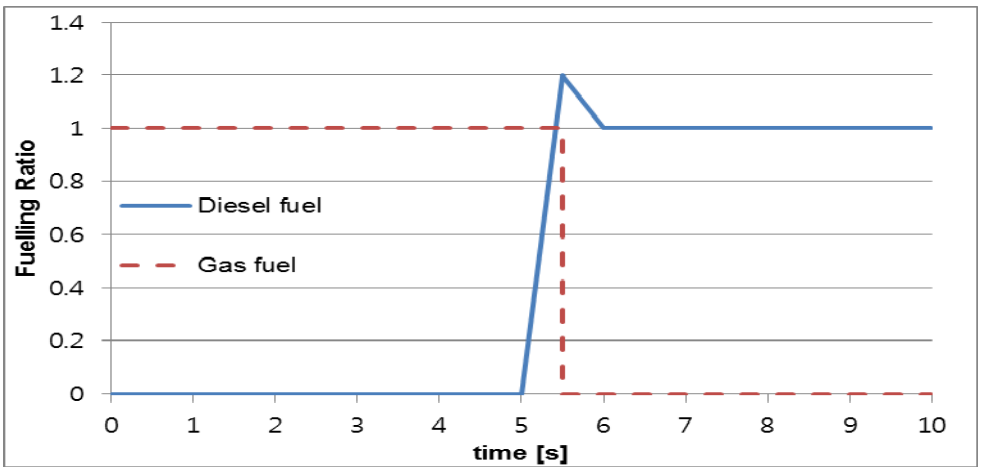

Figure 4-1-8 Fuel mode changeover from gas mode to diesel mode

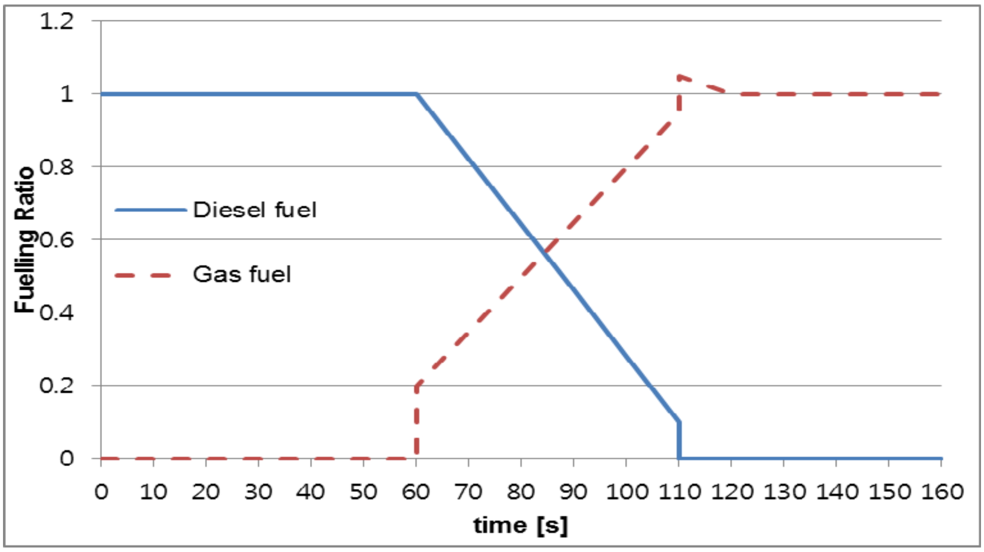

Figure 4-1-9 Fuel mode changeover from diesel mode to gas mode

Engine Stop

- **Normal stop**

  When a stop command is activated in gas mode, the fuel mode automatically changes to diesel mode. Before an engine stops, the engine runs at cool-down speed to dissipate the heat of the engine. After cool-down phase, the fuel racks go back to zero position and the pilot injection system is active until predefined speed to prevent carbon deposit on pilot fuel oil injectors.

- **Engine Shutdown**

  When the engine shutdown occurs due to certain abnormality, the engine is stopped immediately.

  In gas mode, the shut-off valves and venting valves in a GRU are activated and gas circuit on the engine is purged with inert gas. The pilot injection system is active until predefined speed to burn the rest of fuel gas in a chamber. After the engine stops in gas mode, the external exhaust gas system has to be ventilated by an exhaust gas ventilation unit during predefined time and engine start is blocked until the ventilation sequence is finished.

  In diesel mode, an emergency stop air cylinder(s) is activated and it pushes fuel racks to zero position.

  In case of engine shutdown in gas and diesel mode, the pilot injection system is alive until injection-off speed to burn the rest of fuel gas in the engine. . However the pilot injection system is deactivated at once in case of over speed and both speed pick-up failure.

- **Emergency stop**

  When an emergency stop command is activated by pushing the switch on panels, the engine will stop immediately. The stop procedure is similar with engine shutdown except that pilot injection system is deactivated at once.

Engine Safety

The engine control system monitors the signals from all sensors on the engine and takes an appropriate action against abnormality of engine for safe operation. All engine responses and its delays are predefined in the ECS (Engine Control System) according to the safety functional list. HiMSEN DF ECS also fulfills redundant and independent safety functions against critical shutdown conditions.

Fig 4-1-10 is layout of HiMSEN DF engine safety system.

All signals in HiMSEN DF safety functional list are connected to the ECS and it implements the safety functions written in next.

- **Alarm**

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

- **Start block**

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

- **Load reduction**

  The ECS releases an alarm message and load reduction request signal is transmitted to PCS.

- **Gas trip**

  The ECS releases an alarm message and then, the fuel mode is transferred from gas mode to diesel mode. The gas trip condition has to be cleared to go back to gas mode.

- **Pilot trip**

  The ECS releases an alarm message and then, the fuel mode is transferred from gas mode (or diesel mode) to backup mode. The pilot trip conditions have to be cleared to go back to diesel mode.

- **Shutdown**

  The ECS releases a shutdown message and the engine is shut down after predefined delay. The Pilot injection system is alive until injection-off speed to burn the rest of fuel gas in the engine.

- **Emergency stop**

  The ECS releases an emergency stop message and then, the engine is shut down immediately.

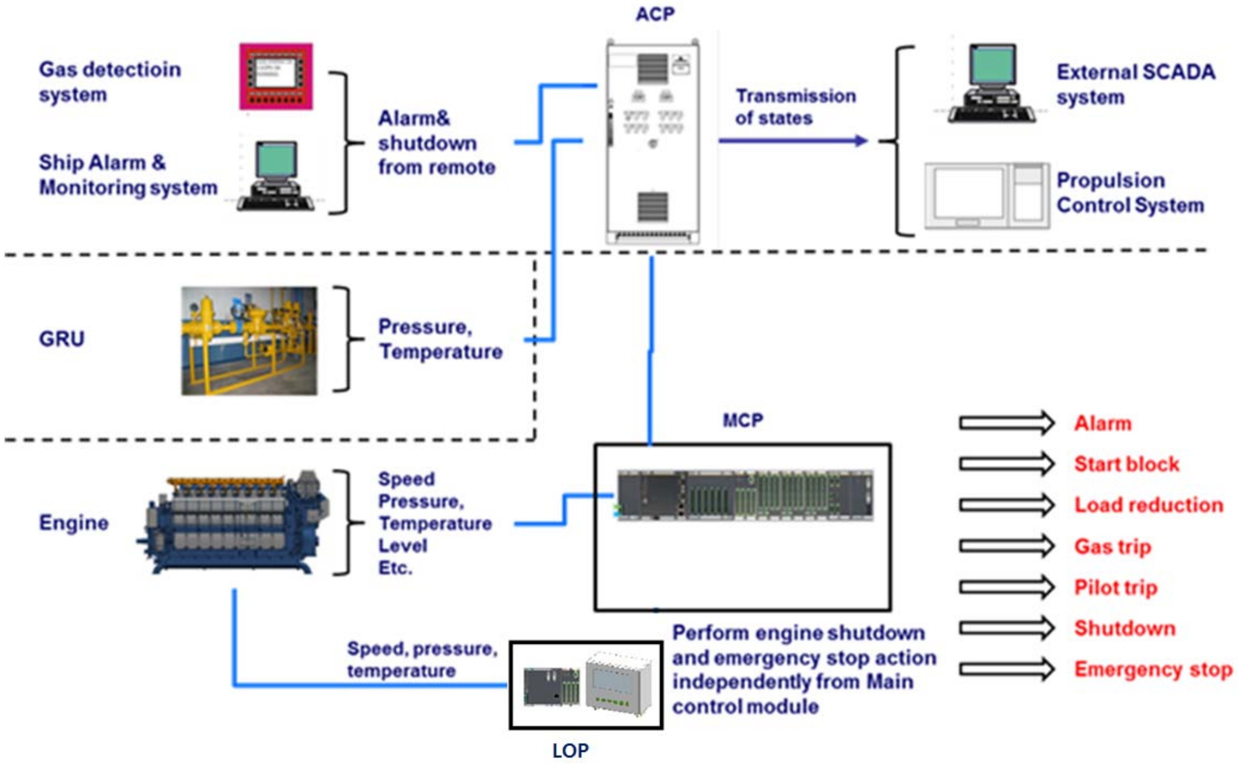

Figure 4-1-10 H35DFP engine safety functions layout

General

The HiMSEN Dual Fuel (DF) Engine Control System (ECS), HiMECS-DF-A is the system for HiMSEN 22CDF, HiMSEN 27DF and HiMSEN 35DF engines. For the V-type engine application, only fuel injection driver and sensing parts for extended cylinder will be added and main controller is identical with in line engine. HiMECS-DF-A can be used for both marine auxiliary generator engine and main propulsion engine(s).

Since all HiMSEN DF Engine is equipped with double wall type of fuel gas piping system, machinery space is regarded as ‘Gas safe area’ and thus HiMSEN DF A is not required to be explosion proof design. However, some signals can be interfaced with IS barrier in accordance with explosion zone definition of engine and auxiliary components.

The HiMECS-DF-A mainly consists of MCP (Main control panel), ICM (Injection Control Module), CMM (Cylinder Monitoring Module, LOP (Local operating panel) and ACP (Auxiliary Control Panel). It is responsible for operation, full monitoring of engine and safety function. Sensors and actuators are connected to HiMECS-DF-A and dedicated actions are taken for optimized and safe operation.

HiMSEN DF A interfaces with the external system through hardwired signal and bus communication. It provides full operation and monitoring capability to the remote control system.

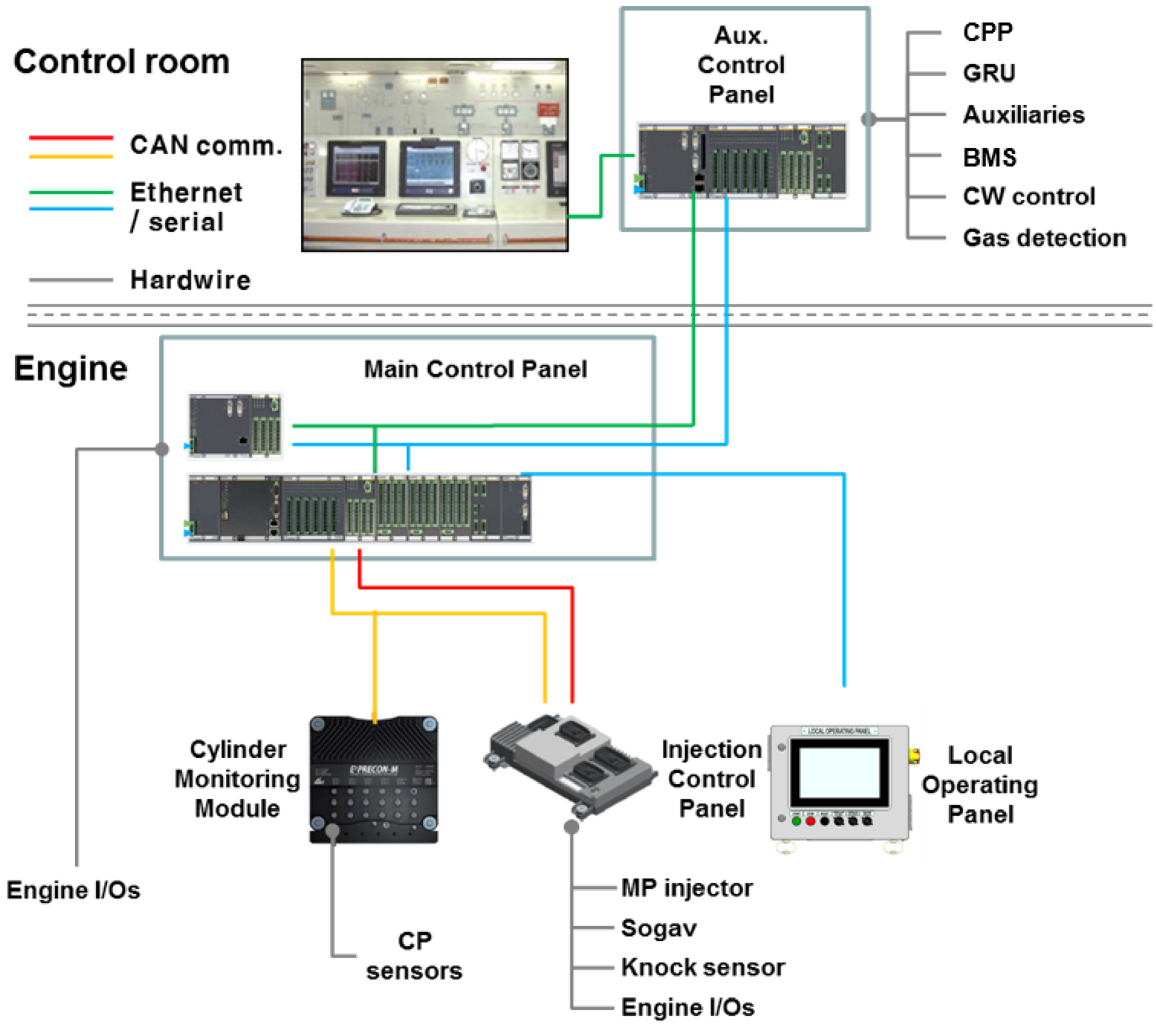

Figure 4-2-1 HIMSEN DF ECS Overview

Hardware description

- **Main Control Panel (MCP)**

The MCP is the central control unit of HiMSEN DF ECS. It consists of integrated a main controller and a safety module. The safety module can shut down the engine independently from main controller.

Location : Mounted on the engine or hull side (1 set for all cylinder of each engine)

Consist of

- Powerful main control module
- Independent safety module
- I/O modules and terminals
- Communication switches

Responsible for

- Main control of DF engine
- Engine safety control
- Engine control and safety parameter tuning
- Independent engine shutdown

IP grade: IP44

Operating condition : Adequate for all temperature, vibration and humidity condition for engine direct installation specified in Classification.

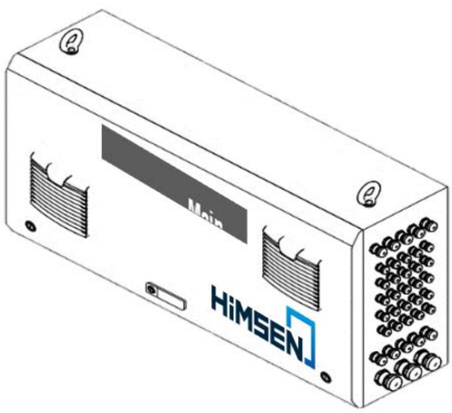

Figure 4-2-2 Main Control Panel

- **Injection Control Module (ICM)**

The ICM controls a gas admission valve and pilot injectors on each cylinder. In order to regulate the timing and duration of each valve and injector, the MCP sends global and individual offset signals to ICM. Also, some of engine signals are connected and processed in ICM. Then, the ICM shares processed data with the MCP for knock control.

When knock sensors are installed, they are connected to ICM and it calculates the knock intensity and sends the information to MCP for knock control.

Location : Mounted on an engine (1 or 2 set per engine)

Responsible for

- Actuating gas admission valve
- Actuating pilot fuel oil injector
- Knock monitoring
- Actuating high pressure pump for pilot fuel oil injection

Figure 4-2-3 Injection Control Module

- **Local Operating Panel (LOP)**

The LOP provides operation and monitoring of the engine. All engine status can be monitored through the LOP.

Location : Mounted on an engine or hull side (1 set per engine)

Consist of

- HMI touch panel PC
- Switches, buttons and lamps for engine operation

Responsible for

- Operation on an engine through hardwired contacts
- Local display of engine measurement and status
- Trend display and logging
- Alarm/event display and handling
- Alarm/event logging
- Test of actuators and valves

Figure 4-2-4 Local Operating Panel

- **Cylinder Monitoring Module (CMM)**

In order to achieve higher thermal efficiency and more stable engine operation, the combustion of individual cylinder has to be controlled. For this, the CMM can be optionally integrated. CMM monitors both the combustion characteristics and knock intensity of each cylinder. It communicates with the MCP for control and monitoring.

Location : Mounted on engine (1 or 2 set per engine)

Consist of

- Cylinder pressure monitoring module

Responsible for

- Combustion data monitoring
- Combustion data transmitted to MCP for anti-knocking and cylinder balancing control

Figure 4-2-5 Cylinder Monitoring Module

- **Auxiliary Control Panel (ACP)**

The ACP is installed in ECR(Engine Control Room) as a self-standing cabinet. The ACP is in charge of auxiliary equipment such as GRU and CW(Cooling Water) control. In addition, the ACP has interface functions to VCS(Vessel Control System), PCS through communication and hard-wire.

Location : Standalone in engine control room (1 set per engine)

Consist of

- Aux. control module
- Switches, 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 Vessel Control System
- Interface with PMS, etc.

Figure 4-2-6 Aux. Control Panel

Local and Remote Operation of Engine

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

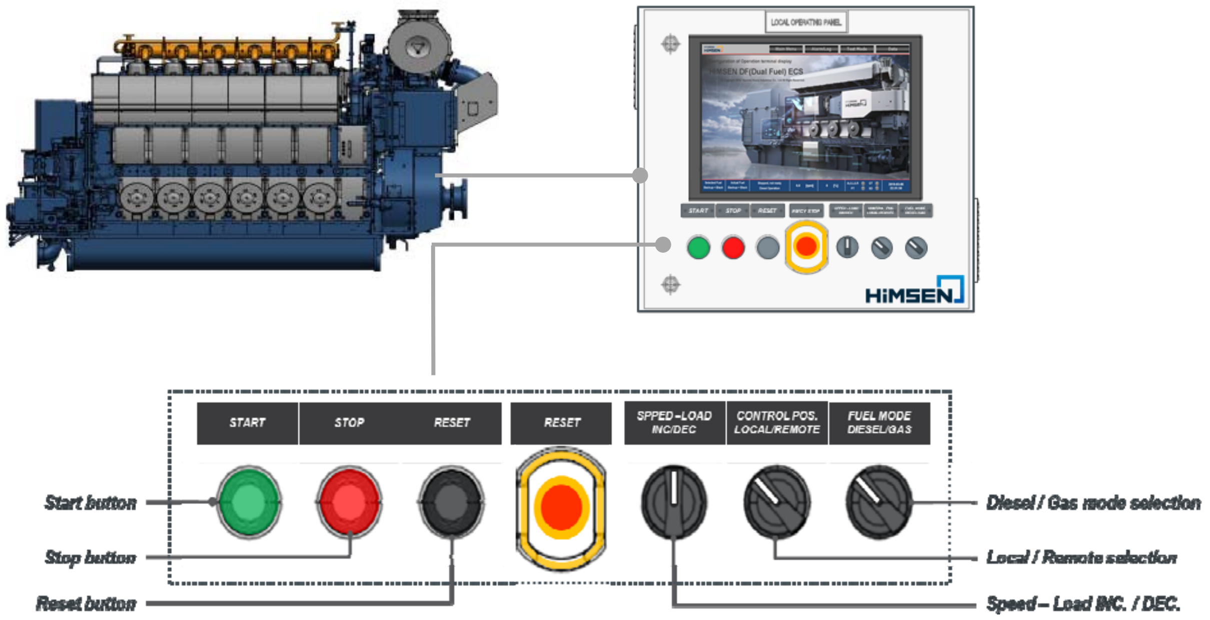

Figure 4-2-7 Engine operation at local (Engine side)

- **Engine operation at remote (Engine control room)**

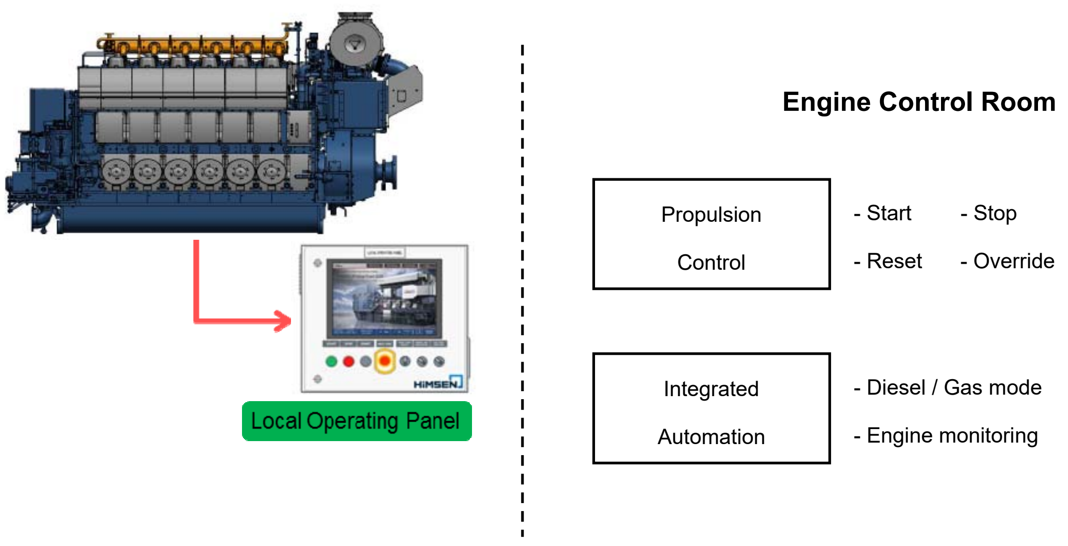

Figure 4-2-8 Engine operation at remote (Engine control room)

Functional Description

- **Speed control**

  In gas mode, the ECS regulates the duration of gas admission valve for speed & power control. In diesel mode, ECS regulates a diesel actuator of main fuel oil system to adjust the amount of main fuel oil injected from main fuel injectors.

- **Air Fuel Ratio Control**

  The AFR is controlled by adjusting the opening ratio of an exhaust waste gate. The exhaust waste gate controls the amount of the exhaust gas for turbocharger(s). The operating point shall be defined by charged air pressure at each engine rpm and load point

- **Micro Pilot Common Rail Control**

  In HiMSEN DF engine, pilot fuel oil injection is the ignition source of combustion. Pilot fuel oil injection system is a type of common rail system. The HiMECS-DF-A controls injection timing and injection duration of electronic pilot fuel oil injectors. In addition, it controls HP pump for pilot fuel oil injection pressure.

- **Fuel Gas Pressure & Valve Control**

  The HiMSEN DF A controls fuel gas pressure regulating, sequential gas valve operation, and gas admission valve operation.

- **Knocking and Cylinder Balancing Control**

  Knock detection system and cylinder pressure monitoring system are integrated in HiMECS DF A. Cylinder pressure and knocking signal are monitored by CMM and ICM. This system configuration will guarantee sophisticated anti-knocking control and cylinder combustion balancing.

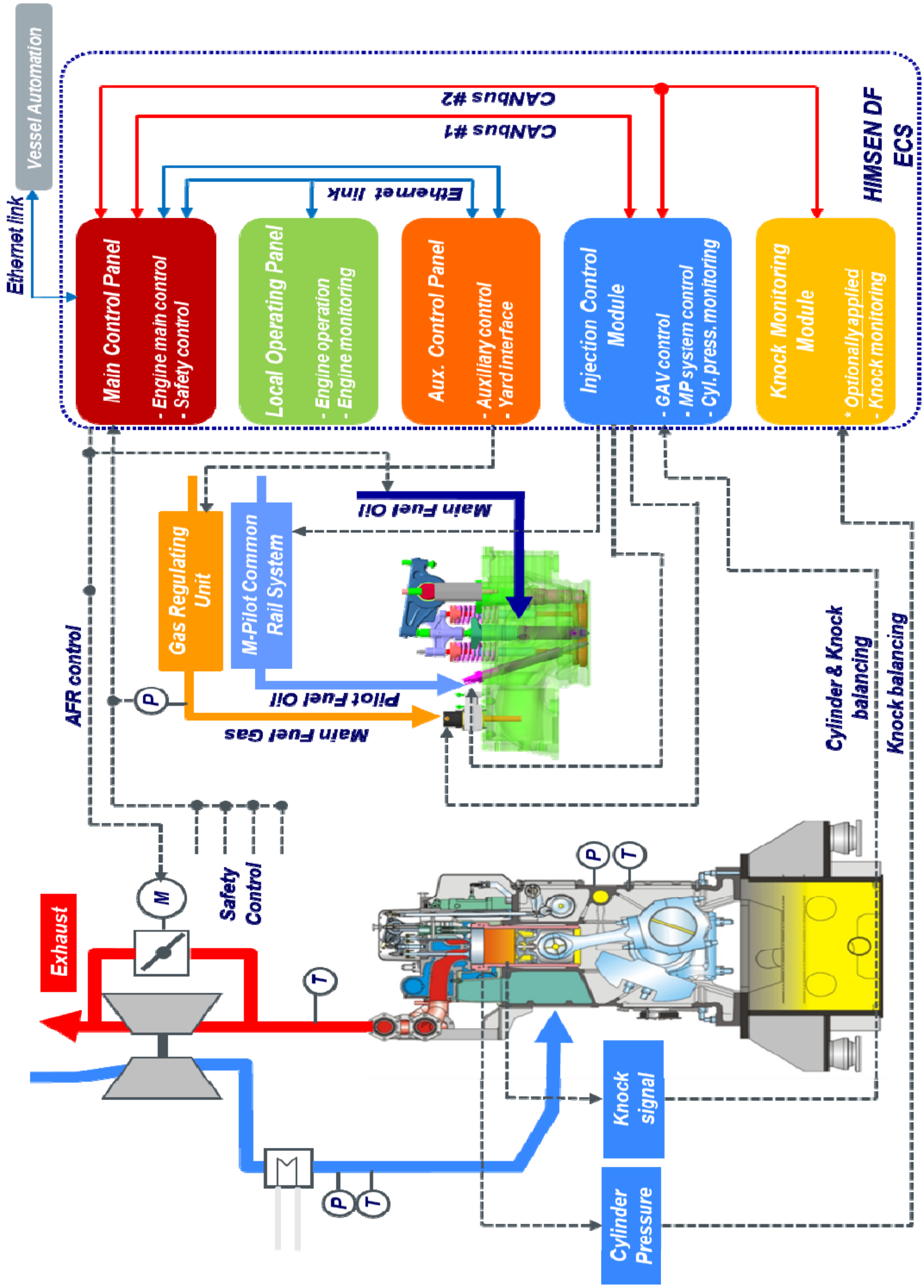

Figure 4-2-9 Functional description of HiMSEN DF Engine

General

The HiMSEN DF ECS is closely interfaced with the external system and provides full capability for optimum operation in different fuel mode.

Engine operating characteristic of diesel and gas mode is different. Therefore, the external system should identify current fuel mode and take proper actions.

For the details of interface schematic, refer to Figure 4-3-1

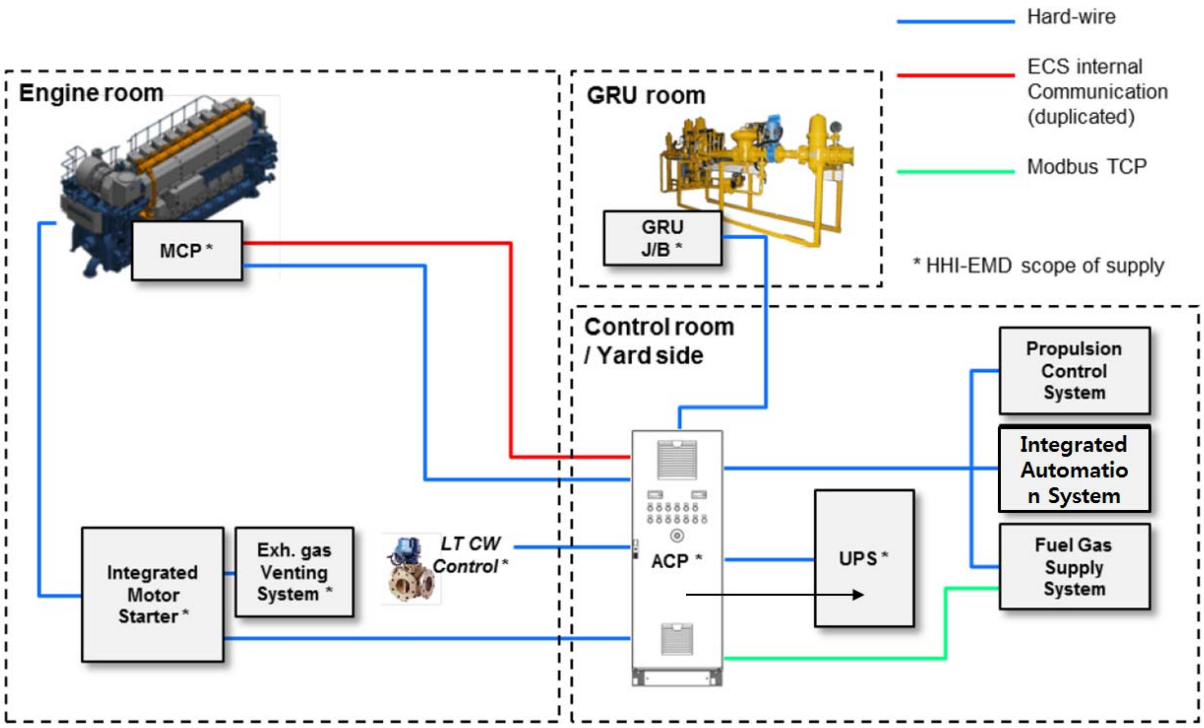

Figure 4-3-1 Yard interface (system layout)

Hardwire Interface

- **Signal input from Propulsion Control System**

  Emergency stop from remote

  Remote stand-by signal

  Remote speed + (backup, option)

  Remote speed – (backup, option)

  Remote engine start

  Remote reset

  Remote engine stop

  Remote start blocking

Clutch engaged

Clutch engage command

Speed reference signal active (back-up, option)

Shutdown override

Speed reference signal (4…20 mA)

- **Signal output to Propulsion Control System**

Ready to clutch

Engine ready for start

Engine running

Indication remote control

Load reduction request

Shutdown pre-warning to remote

Engine shutdown

Engine stopped

Start failure

Max. available load (4…20 mA)

Engine speed indication (4…20 mA)

Engine load (4…20 mA)

- **Signal input from Vessel Control System**

Diesel mode request from remote

Gas mode request from remote

Backup mode request from remote

Emergency start mode request from remote

- **Signal output to Vessel Control System**

Diesel mode activated

Gas mode activated

Backup mode activated

Engine ready for gas operation

Engine under fuel transfer

Engine common alarm

UPS common alarm

Motor starter common alarm

Engine shutdown

Slow turning pre-warning

Gas trip request from remote

- **Signal input from Gas & Fire Detection System**

  Emergency shutdown from Gas & Fire detection system

  Gas detection alarm

  Gas trip request 1 : active when gas level > over limit in defined place #1

  Gas trip request 2 : active when gas level > over limit in defined place #2

- **Signal output to Gas & Fire Detection System**

  Gas operation mode : active during gas mode operation

- **Signal input from Fuel Gas System**

  Yard main gas valve limit switch open/close

Communication Interface

The HiMSEN DF ECS provides all of engine information including engine status, monitored values and operation condition to ECR(Engine Control Room) and the external system via Ethernet (Modbus TCP).

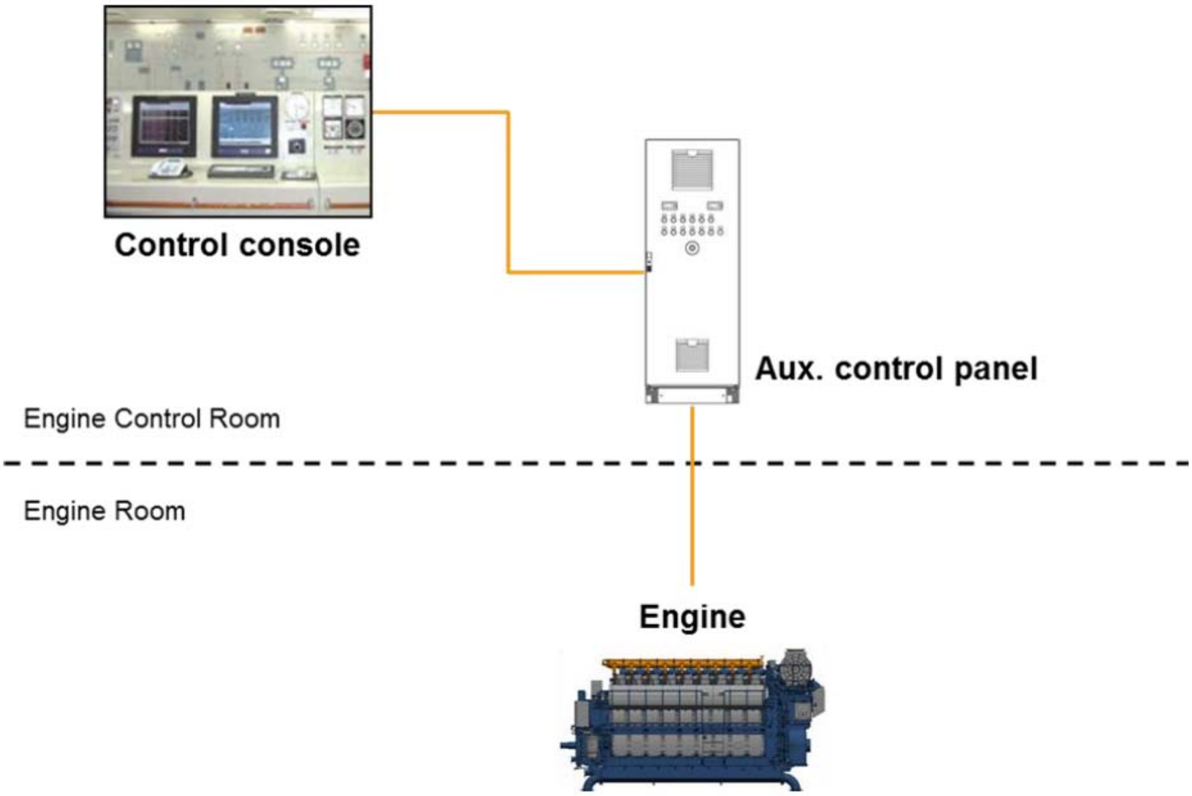

Figure 4-3-2 Communication interface

Power Distribution

Two redundant 220 VAC, 1 phase 60 Hz should be supplied to UPS(Uninterrupted Power Supply). The UPS converts 220 VAC to 24VDC for engine control. A battery for 30 min of engine running in diesel mode is installed in UPS.

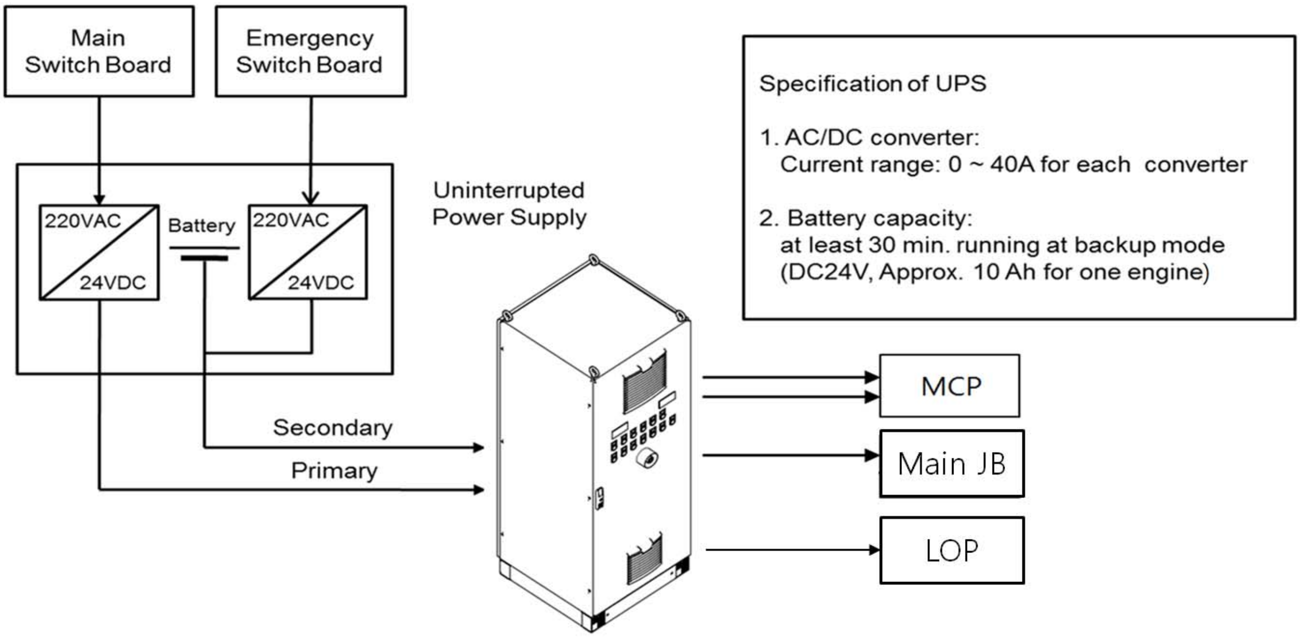

Figure 4-3-3 HiMSEN DF ECS Power Distribution

Cabling Layout

Engine internal cables are pre-wired to engine terminal box. External cabling shall be installed by shipyard.

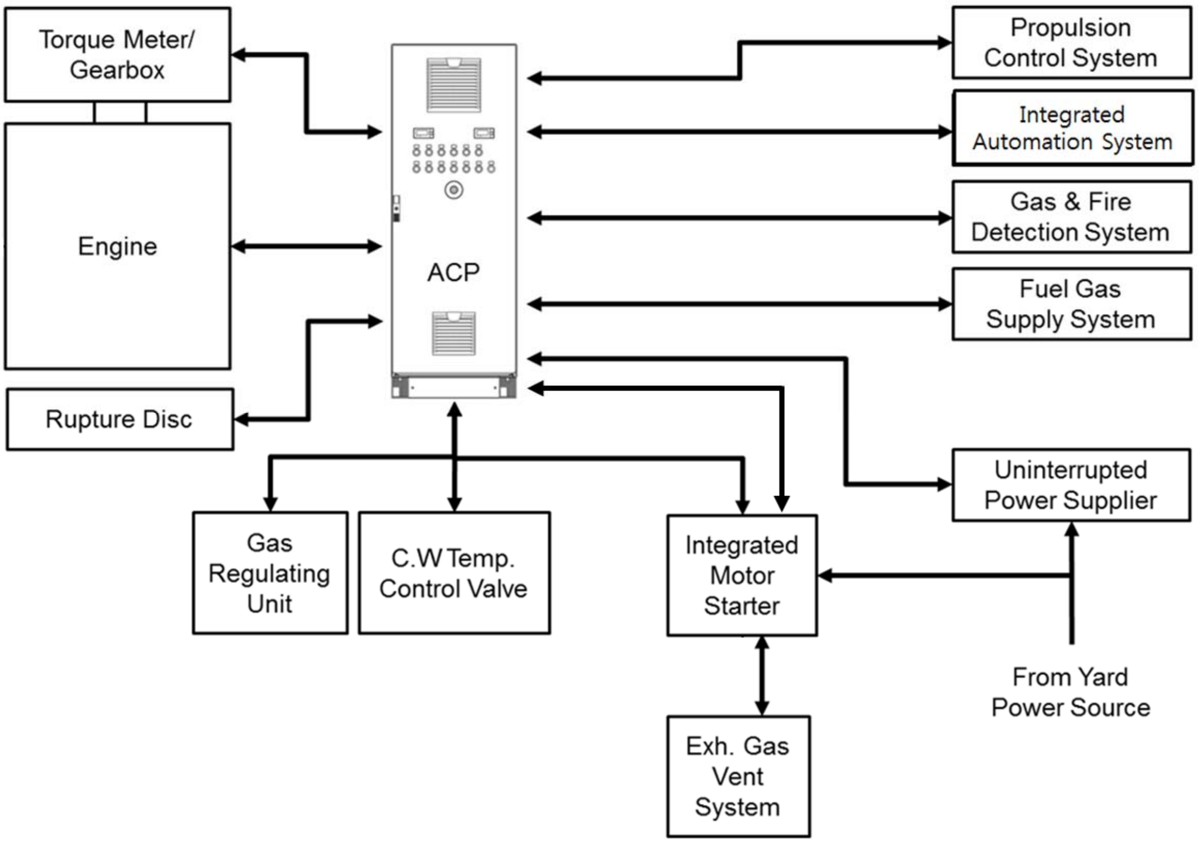

Figure 4-3-4 HiMSEN DF ECS Cabling Layout

Operating Data & Alarm Points

System	Descriptions	Normal operation range (refer to rated power)		Alarm set points		Action points	
Speed control	Engine speed -Gas mode -Diesel & Back up mode	SE11	750 rpm	SSH11	109% MCR	SSH11	109% MCR
	Engine speed & TDC	SE12	750 rpm				
	Turbocharger speed	SE14		SAH14 4)	T/C maker		
Fuel oil system	Main FO safety filter ΔP			PDAH51-52	↑ 1.5 bar		
	Main FO Press. engine inlet (for continuous HFO) - HFO - MDO	PT52	 7…10 bar 4…6 bar	 PAL52 4) PAL52 4)	 ↓ 6.0 bar ↓ 4.0 bar		
	Main FO Press. engine inlet (for continuous MDO/MGO) - MDO/MGO	PT52	 7…8 bar	 PAL52	 ↓ 6.0 bar		
	Main FO Press. filter inlet	PT51					
	Main FO Temp. filter inlet - HFO - MDO/MGO	TE51		 TAH51 4) TAH51 4)	 ↑ 155°C ↑ 50°C		
	Main FO clean leakage tank level	LS54		LAH54	High level		
	Pilot FO filter ΔP			PDAH30-31	↑ 1.5 bar		
	Pilot FO press. filter inlet	PT30					
	Pilot FO press. HP pump inlet	PT31	4…6 bar			PPTL31 PPTH31	↓ 3 bar ↑ 8 bar
	Pilot FO press. engine inlet	PT32	800…1000 bar			PPTL32 PPTH32 PDPTH32	↓ 500 bar ↑ 1300 bar (E) ± 200 bar
	Pilot FO temp, engine inlet	TE31	30…45°C	TAH31	↑ 50 °C		
Fuel Gas system	Fuel gas press. engine inlet	PT87	(E)	PDAH87	(E) ± 0.5bar	PDGTH87 PDGTH21-87	(E) ± 0.5 bar (C) ± 1.5 bar
	Fuel gas press. filter inlet(GRU)	PT80	6…9 bar				
	Fuel gas press. filter outlet(GRU)	PT81	6…9bar	PAL81	↓ (C) + 1.8 bar	PGTL81 PGTH81	↓ (C) + 1.5 bar ↑ 9 bar
	Fuel gas filter ΔP			PDAH80/81	↑ 0.05 bar		
	Fuel gas press. regulator outlet(GRU)	PT82	(E)	PDAH82	(E) ± 0.5 bar	PDGTH82	(E) ± 0.5 bar
	Fuel gas temp.	TE80	15…25°C	TAL80 TAH80	↓ 5°C ↑ 65 °C	TGTL80 TGTH80	↓ 0 °C ↑ 70 °C
	GRU control air	PT83	6…10 bar	PAL83	↓ 4.5 bar	PGTL83	↓ 4 bar
	Inert gas press.	PT89	6.5…8 bar	PAL89	↓ 6 bar		
Lubricating oil system	LO Press. drop across filter 7)			PDAH61-62	↑ 1.5 bar		
	LO Press. filter inlet	PT61	3.2…5.2 bar				
	LO Press. engine inlet	PT62	3.0…5.0 bar	PAL62	1.8 bar	PSLR62	1.6 bar
	LO Temp. engine inlet	TE62	60…70°C	TAH62	80°C		
	LO Press. T/C inlet - start phase	PT63	3) 3)	PAL63 PAL63	↓ 1.25 bar ↓ 0.5 bar		
	- Pre/Post lubrication		0.5…1.0 bar3)	PAH634)	↑ 1.1 bar 4)		
	LO Temp. T/C outlet	TE64	70…100˚C8)	TAH64	120˚C8)		

System	Descriptions	Normal operation range at rated power		Alarm set points		Action points	
Lubricating oil system	Oil mist detector	LS92		LAH92	High level	LLRH92 LSH92	High level High level
	Temp. main bearing [4]			LAH05 [4]	95°C	LLRH05 [4]	98°C
						LSH05 [4]	100°C
	LO stand-by press.					STAT62 [4]	2.0 bar
Cooling water system	L.T water press. CAC inlet	PT71	1.0…4.5 bar	PAL71 [4]	↓ 0.4 + α [5] bar		
	L.T water temp. engine inlet	TE71	30…40°C	TAH71 [4]	↑ 55°C		
	L.T water temp. CAC outlet	TE72	35…50°C				
	L.T stand-by press. [4]					STAT72 [4]	0.6 + α [5] bar
	H.T water press. engine inlet	PT75	1.5…4.5 bar	PAL75	↓ 0.4 + α [5] bar	PLRL75	0.2 + α [5] bar
	H.T water temp. engine jacket inlet	TE75	65…75°C	TAL75	↓ 50°C		
	H.T water temp. engine jacket outlet	TE76		TAH76	↑ 90°C	TLRH76	↑ 92°C [4]
						TSH76	↑ 95°C [4]
	H.T water temp. CAC outlet [4]	TE78		TAH78	↑ 105°C	TSH78	↑ 110°C [4]
	H.T stand-by press.[4]					STAT76	0.6 + α [4] bar
Combustion gas / air system	Intake air temp. before Compressor	TE29		TAH29	↑ 50°C		
	Charge air pressure air cooler outlet	PT21	depends on load				
	(At gas mode)					PGTH21 PGTH21	5.0 barA 0.5 bar ± (G)
	(At diesel mode)			PALH21 PALH21	6.0 barA Dev. ± (G)		
	Charge air temp. air cooler outlet - Gas mode - Diesel mode	TE21	43…47°C	 TAH21 TAH21	 ↑ 50°C ↑ 60°C	 TGTH21 TLRH21	 ↑ 55°C ↑ 65°C
	Exh. gas temp. cylinder outlet	TE25	350…580°C	TAH25	↑ 610°C	TLRH25 TGTH25 TLRH25 TGTH25	↑ 620°C ↑ 615°C 100°C ± (F) mapped ± (F)
	Exh. gas temp. T/C inlet	TE26	480…590°C	TAH26	↑ 600°	TLRH26	↑ 620°C
	Exh. gas temp. T/C outlet	TE27	300…500°C	TAH27 [4]	↑ 500°C		
	Intake air temperature before T/C compressor	TE29		TAH29	↑ 50°C		
Compressed air system	Starting air pressure, engine inlet	PT40	30 bar	PAL40	↓ 18 bar		
	Instrument air pressure (after press. reducing valve)	PT41	4.5…8.0 bar	PAL41	↓ 4 bar	PGTL41	↓ 3.5 bar
	DVT control air pressure	PT43		↓ PAL43	3 bar	PLLH43	↑ 3 bar
Cylinder Monitoring System	Knock sensor cylinder	LT94		LAH94	(D) > 6°CA	LGTH94	(D) > 10°CA
	Cylinder pressure sensor - Gas mode - Diesel mode	PT24 [4]		 PAH24 PAH24	 ↑ 190 bar ↑ 180 bar	 PGTH24 PLRH24	 ↑ 200 bar ↑ 190 bar
	Main & thrust bearing temp.	TE05 [4]				TLRH05 TSH05	↑ 95°C ↑ 100°C

System	Descriptions	Normal operation range at rated power		Alarm set points		Action points	
Miscellaneous System	Crankcase pressure	PT03	1...4 mbar				
	- Gas mode			PAH03	↑ 6 mbar	PGTH03	↑ 10 mbar
	- Diesel mode			PAH03	↑ 12 mbar		

[1] *The pressure should not be maintained below 6 bar in any case to avoid gasification of the hot fuel.*

[2] *The temperature inlet engine (MDO/MGO) at normal operation at rated power is determined in order to be satisfied with the recommended viscosity in P.05.310 and P.05.320.*

[3] *The pressure inlet T/C should be in the recommended range by turbocharger maker.*

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

[4] *Can be applied as an option*

[5] *α should depend on the height of the expansion tank (static pressure).*

[6] *The alarm may be only activated with sufficient level of Exhaust gas temperature.*

[7] *See P.02.200 / 210 / 220 Engine Capacity data*

[8] *Depends on the model of turbocharger*

Table 4-4-1 Operation data of an engine

Remark:

1. These data of Table 4-4-1 is only for guide.
   The data can be subjected to change and shall be informed separately for the specific project.
2. (A) depends on DVT on / off condition
3. (B) is control target value
4. (C) is charge air pressure
5. (D) is total retardation of ignition timing in order to avoid knocking
6. (E) is reference of each part load
7. (F) is average exhaust temperature
8. (G) is predefined Charge air pressure at Diesel / Gas mode

SGTH	High speed gas trip	PLRL	Low press load reduction
SAH	High speed alarm	PSL	Low pressure shutdown
SSL	Low speed alarm	PSBL	Low press start block
LAH	High level switch alarm	PLLH	High press load limitation
LGTH	High level gas trip	TAL	Low temp alarm
LLRH	High level load reduction	TAH	High temp alarm
LSH	High level switch shutdown	TSH	High temp shutdown
PAL	Low press alarm	TGTL	Low temp gas trip
PAH	High press alarm	TGTH	High temp gas trip
PDAH	High delta press alarm	TDGTH	High delta temp gas trip
PGTL	Low press gas trip	TLRH	High temp load reduction
PGTH	High press gas trip	TSBL	Low temp start block
PDGTH	High delta press gas trip	TSBH	High temp start block
PPTL	High press pilot trip		

Description		Symbol No.	Measuring Range
Pressure	Main fuel oil, engine inlet	PI 52	0 ... 16 bar
	Fuel gas supply pressure, filter inlet	PI 80	0 ... 10 bar
	Fuel gas pressure at regulator outlet	PI 82	0 ... 10 bar
	Lubricating oil, filter inlet	PI 61	0 ... 10 bar
Temperature	Main fuel oil, engine inlet	TI 52	0 ... 200 °C
	LT water temp, Charge air cooler inlet	TI 71	0 ... 120 °C
	LT water temp, Charge air cooler outlet	TI 72	0 ... 120 °C
	Fuel gas temperature, filter inlet	TI 80	0 ... 50 °C

Table 4-5-1 Local Instruments

General Information	**P.00.000**
Structural Design and Installation	**P.01.000**
Performance Data	**P.02.000**
Dynamic Characteristics and Noise	**P.03.000**
Operation and Control System	**P.04.000**
Fuel System	**P.05.000**
Lubricating Oil System	**P.06.000**
Cooling Water System	**P.07.000**
Air and Exhaust Gas System	**P.08.000**
Engine Maintenance	**P.09.000**
Theoretical Performance	**P.10.000**
Electric Control System	**P.11.000**
	Appendix

Operating modes

A HiMSEN Dual fuel engine can be operated by using fuel gas(natural gas) or fuel oil including HFO, MDO and MGO as main fuel oil. The operating mode can be changed without any interruption while the engine is running.

The operating mode can be chosen by an operator depending on the condition of vessels or plants. Also if there is any abnormal condition in gas mode, the engine will be automatically transferred to diesel mode without power de-rating.

The engine operating modes are as follows:

- Gas mode: Fuel gas + Pilot oil (MDO/MGO)
- Diesel mode: HFO or MDO/MGO + Pilot oil (MDO/MGO)
- Backup mode: MDO/MGO

Remark:

1. For diesel mode and backup mode with MGO, the external fuel oil system has to supply the main fuel oil which satisfies the quality of fuel oil such as viscosity. In addition, The internal fuel oil system should be adjusted for MGO operation.

2. The combination of using HFO and MGO as main fuel oil for long time operation is not strongly recommended because of the difference between the layout and components of the fuel oil system for each fuel oil.

Gas mode

In gas mode, main fuel gas is injected to the intake port of each cylinder through a gas admission valve. In each cylinder, the fuel gas is ignited by the pilot oil (MDO or MGO) which is injected through a pilot injector to the main chamber.

The gas admission valve and the pilot injector are a solenoid operated type which is electronically controlled. The injection timing and the amount of the fuel gas and pilot oil can be adjusted at each cylinder by ECS(Engine control system).

Diesel mode

In diesel mode, it is the same as conventional diesel engine operation, i.e. HFO, MDO or MGO can be used as main fuel. When charge air is compressed in the combustion chamber, the fuel oil is injected through a mechanical controlled main injector in each cylinder.

The pilot oil system also will be activated in diesel mode to keep the pilot fuel oil injector nozzles clean and ready for gas mode.

Backup mode

The backup mode is for safety operation. When the safety system or blackout detection system of ECS(Engine control system) is activated, the engine will be transferred to the backup mode.
In backup mode, the engine can be operated just by the main fuel oil (MDO/MGO) while the pilot oil system is not operating. The operating time of the backup mode shall be limited to the maximum 30 minutes.

Diagram for the internal fuel oil system

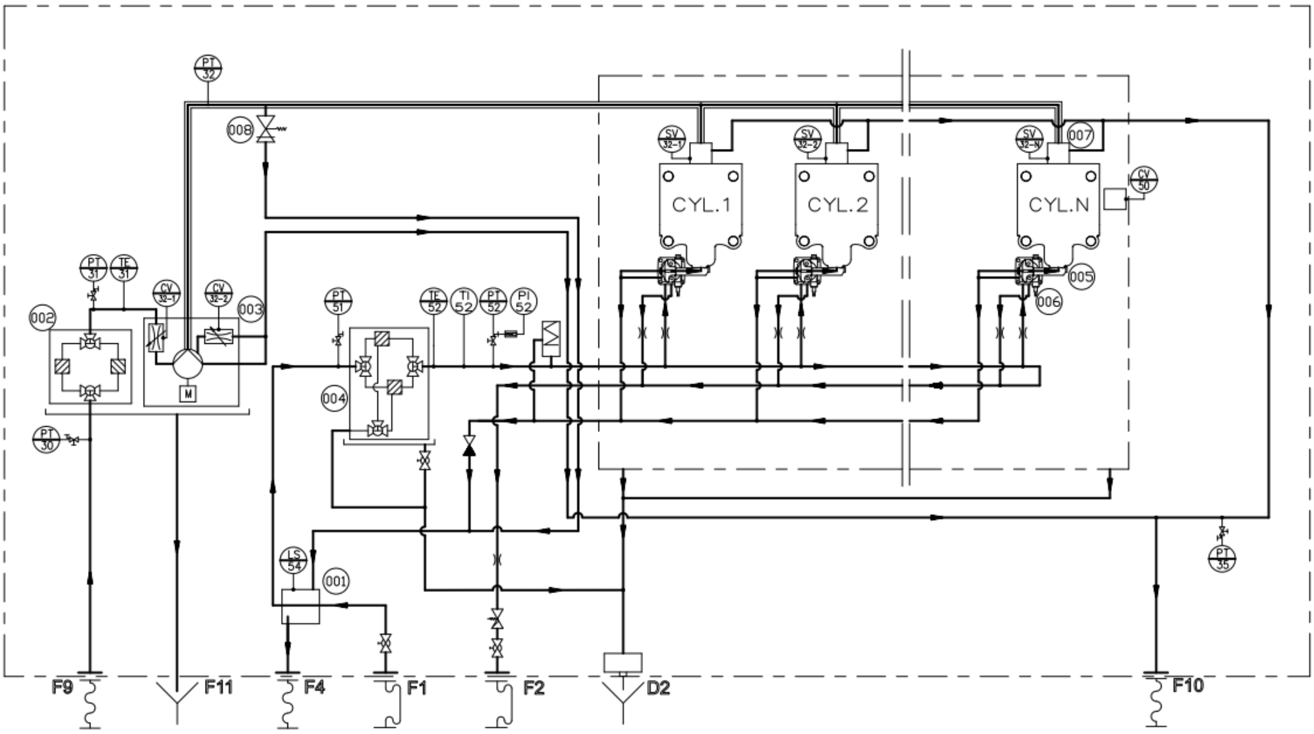

Figure 5-1-1: In-line engine internal fuel oil system

System components

No.	Description	Remark
001	Fuel oil recycling alarm tank	
002	Pilot fuel oil filter	
003	Pilot fuel oil pump	
004	Fuel oil filter	
005	High pressure block	
006	Fuel oil injection pump	
007	Pilot fuel oil injector	
008	Pilot fuel oil safety valve	

Sizes of the external pipe connections

Code	Description	Size	Standard
F1	Fuel oil inlet	16K - 25A	JIS B 2220
F2	Fuel oil outlet	16K - 25A	JIS B 2220
F4	Clean fuel oil drain	5K - 15A	JIS B 2220

Code	Description	Size	Standard
F9	Pilot fuel oil inlet	10K - 15A	JIS B 2220
F10	Pilot fuel oil outlet	5K - 15A	JIS B 2220
F11	Leak pilot fuel oil drain, dirty	OD 15	
D2	Oil drain	OD 25	

Remark:

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

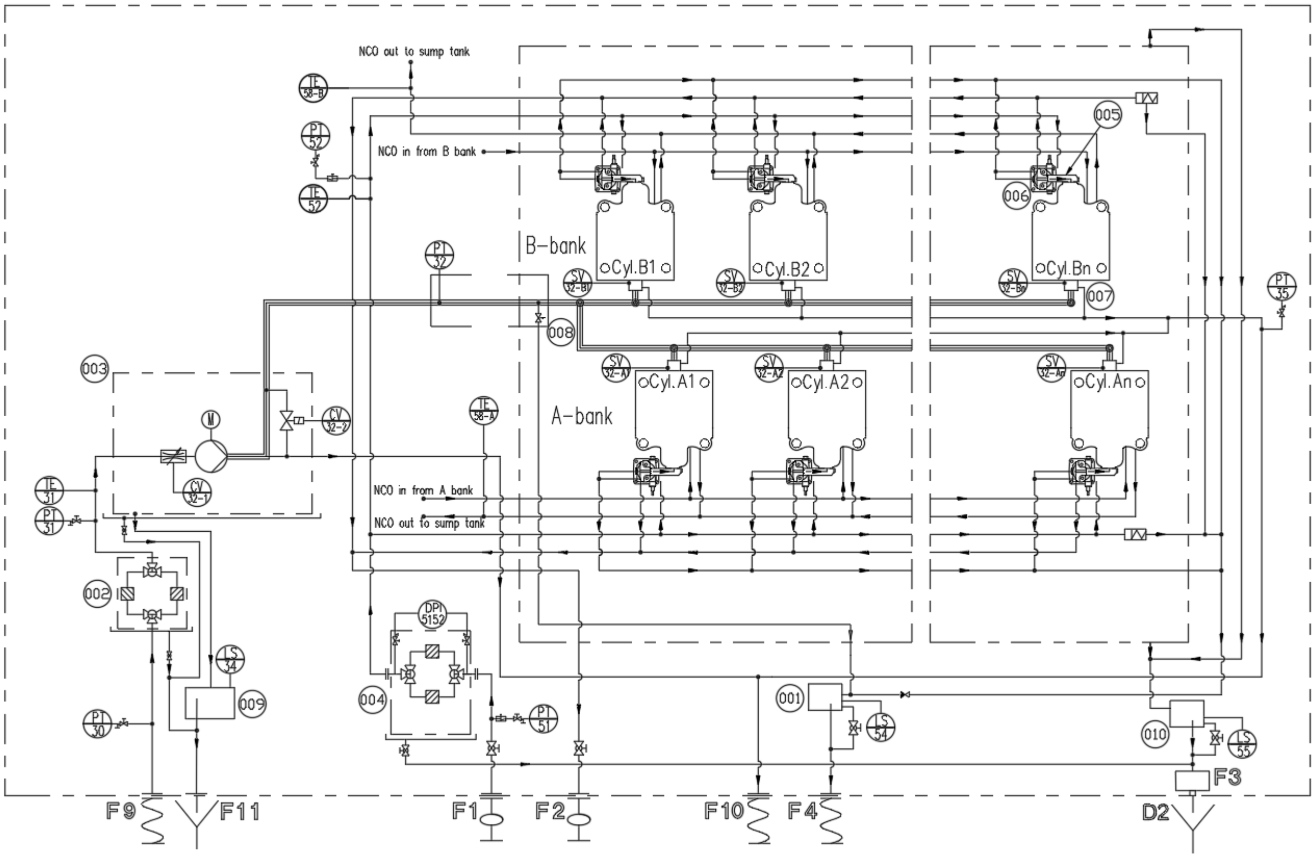

Figure 5-1-1: V-type engine internal fuel oil system

System components

No.	Description	Remark
001	Fuel oil recycling alarm tank	
002	Pilot fuel oil filter	
003	Pilot fuel oil pump	
004	Fuel oil filter	
005	High pressure block	
006	Fuel oil injection pump	
007	Pilot fuel oil injector	
008	Pilot fuel oil safety valve	
009	Pilot fuel oil leakage alarm tank	
010	Fuel oil leakage alarm tank	

Sizes of the external pipe connections

Code	Description	Size	Standard
F1	Fuel oil inlet	16K - 40A	JIS B 2220
F2	Fuel oil outlet	16K - 40A	JIS B 2220
F4	Clean fuel oil drain	5K - 15A	JIS B 2220
F9	Pilot fuel oil inlet	10K - 15A	JIS B 2220
F10	Pilot fuel oil outlet	5K - 15A	JIS B 2220
F11	Leak pilot fuel oil drain, dirty	OD 15	
D2	Oil drain	OD 25	

Remark:

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

General

The fuel system of the dual fuel engine is designed for reliable combustion of HFO (heavy fuel oil) or MDO (marine diesel oil) as well as fuel gas (natural gas). Therefore, it is possible to change over fuel modes between HFO, MDO and natural gas without a reduction in the rated output. Furthermore, it is not needed to change over from HFO to MDO except for cold starting, flushing of the system, maintenance and long-term stand still.

The pilot fuel oil system is designed to supply ignition power in gas mode, but it is also activated in diesel mode to prevent the clogging of pilot injectors. For the pilot fuel oil system, MDO (DMA, DMB, DMZ) can be used.

Main fuel oil system

The fuel oil injection equipment comprises an injection pump, a connection block, an injection pipe and an injection valve, which are installed on each cylinder. The system is designed for the high pressure of fuel injection with better combustion.

The fuel injection quantity is controlled by ECS(engine control system) via a common regulating shaft and spring loaded linkages. The control system can maintain the engine speed at the preset-value by continuously positioning of the fuel pump racks.

The clean leaked oil from an injection pump, a high pressure connection block, etc. in each cylinder is drained and collected to the recycling fuel oil leakage alarm tank. It can be led to the external tank and reused without an additional separation process.

The recycling fuel oil leakage alarm tank is a modularized box for the external connections, which provides:

- Connection for the fuel oil outlet (25A)
- Connection for the clean leaked oil drain (15A)
- Alarm switch and tank for an excessive leakage

The dirty leak and waste oil are collected to the common drain pipes and shall be led to the sludge tank.

The total leak rate from the main fuel oil system can be estimated as following formula:

$Q = \quad 0.30 \times C_f$

Q [Liter / cyl. hour] = clean fuel leak rate per cylinder at MCR
C_f = weighting factor for different fuel (0.5 for HFO, 1.0 for MDO, 2.0 for MGO)

Remark:

1. ±50% tolerance should be considered depending on the operating conditions.
2. The fuel oil safety filter can be mounted on a request as an option.
3. The clean fuel oil can be reused.

Pilot fuel oil system

The pilot fuel oil system comprises a pilot fuel pump(s), a duplex filter and pilot injectors, etc. The system is a type of common rail system which can control the injection of the small amount of pilot fuel oil with suitable timing and duration.

After the pilot fuel pump, the pilot fuel oil is pressurized up to approximate 1,000 bar and conveyed to each injector via the high pressure pipes made of the double walled structure for safety.

The return pilot fuel oil from the injectors and the pilot fuel pump are collected to the common return pipes and can be reused. The return rate of the pilot fuel oil can be estimated as following formula:

Q = 15.4 x No. of cylinder + 30

Q [Liter / hour] = clean pilot fuel oil return rate at MCR

Remark:

1. ±50% tolerance should be considered depending on the operating conditions and the layout of pilot fuel oil system.

The leak rate of the pilot fuel oil system is normally very small. However, if the pilot fuel oil is leaked due to any system failure, the leaked fuel oil will be collected to the pilot fuel oil leakage alarm tank for dirty fuel oil. Then it shall be led to the sludge tank.

If pilot fuel oil leaks from the high pressure pipes, it will be drained via the intermediate spaces of the double walled pipes and collected to the recycling fuel oil alarm tank for clean fuel oil. The clean leaked pilot fuel oil will be joined to the recycling main fuel oil drain and can be reused.
For the pilot oil system, the fuel oil with MDO and MGO can be used. Generally, MGO is more recommended.

For detail fuel oil specification, see P.05.300 “Fuel Oil specification.

General

The external fuel oil system for the engine can be in a common system with other engines or an independent system. In case of the common system, it should be able to ensure the sufficient fuel oil supply to every engine and cut off the fuel oil supply and the return lines connected to each engine individually.

The fuel oil specifications which will be used for the engine must be very carefully considered since the following information is based on the fuel oil grades in P.05.300.

According to ISO 8217:2012, DMC grade in ISO 8217:2005 is not MDO, it is RMA 10, one of marine residual fuels. If RMA10 (DMC) is used for the engine, the fuel oil system has to follow the guide for HFO, since ISO 8217:2012 is the reference of this project guide including P.05.300.

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

- The solid particles and water in fuel oil can cause over-wear and frequent maintenance for the engine itself as well as the external fuel oil system. Therefore, the qualified separation equipment should be included in the external fuel oil system not only for HFO but also for MDO/MGO which can be easily contaminated on board.
- The proper viscosity, temperature and pressure are necessary for proper operation of the system. Therefore, the preheating, the insulation with heat tracing and pressurizing equipment should be included in the external fuel oil system for HFO treatment.

  For MDO/MGO treatment, the cooling, other equipment should be installed on the external fuel oil system. The layout and equipment such as a preheater for a separator are variable depending on the fuel oil quality and engine operational condition.

  In addition, for the engine, the external system should provide the proper quality of fuel oil for the pilot fuel oil system.
- In order to prevent an excessive pressure loss and minimize a pressure pulse in the piping system, the flow velocity of fuel oil should be the following range:
  - MDO/MGO suction: 0.5…1.0 m/s
  - MDO/MGO discharge: 1.5…2.0 m/s
  - HFO suction: 0.3…0.8 m/s
  - HFO discharge: 0.5…1.2 m/s

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

Fuel oil treatment system

The fuel oil treatment system is required for the commercial engine operation with the lowest fuel oil cost, minimized repair cost of engine components, extended wearing limit, optimized fuel oil injection, etc.

For fuel oil treatment, fuel oil should be transferred from the bunker tanks to the settling tanks first while being initially separated from particles and water. And then the fuel oil in the settling tanks should be transferred to the day tanks after being cleaned by separators. The fuel oil in the settling tank shall be heated up to the required temperature by the pre-heater for efficient separation.

The system mainly consists of a feed pump, a pre-heater and a separator, etc. and it is required to be redundant so that one unit can be overhauled while the other one is in service.

- **Settling tank for HFO**

  The settling tanks should be provided for HFO. They shall satisfy the regulations issued by the classification societies and the following requirements.

Capacity of each tank	:	minimum 24 hours fuel oil feed of total fuel oil consumption at MCR
Temperature in the tanks	:	typically 50…70°C as stable as possible (It should depend on the viscosity of the fuel oil.) Heating coils and insulation should be provided to the tanks. The heating source can be a steam or an electric power.
Design	:	Sludge/water spaces and systems for drain, overflow and ventilation Internal baffles to achieve a settling efficiency Level switches with high and low alarm The tank bottom should be a sloped design for good drainage and equipped with drain valves at the lowest position.

- **Settling tank for MDO**

  The settling tanks for MDO shall satisfy the regulations issued by the classification societies and the following requirements.

Capacity of each tank	:	minimum 24 hours fuel oil feed of total fuel oil consumption at MCR
Temperature in the tanks	:	typically 20…40°C as stable as possible (It should depend on the viscosity of the fuel oil.) In general, the heating coils and insulations are not required for the MDO settling tank.
Design	:	Sludge/water spaces and systems for drain, overflow and ventilation Level switches with high and low alarm The tank bottom should be a sloped design for good drainage and equipped with drain valves at the lowest position.

- **Separator**

The separators for HFO should be designed for proper cleaning of fuel oil considering the total fuel oil consumption of the vessel (or the plant). They are recommended to be centrifuges and a self-cleaning type.

The separators for MDO are recommended because there can be particles, sludge and water depending on the bunkering situation and/or condensation in the storage tank. In this case, the system for MDO should be separated from HFO.

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

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

Q [liter/h] = required flow rate for the separation
P [kW] = maximum continuous output of the engine(s)
b [g/kWh] = specific fuel oil consumption at MCR + 20% safety margin (Remark 2)
ρ [kg/m^3] = fuel oil density at the separating temperature (approx. 930 for HFO, 870 for MDO)
t [h] = daily operating time for the separator depending on the manufacturer's recommendation (Usually 22…24hr)

Remark:

1. If the fuel oil treatment system is common with other engines, the fuel oil consumption of them should be included.

2. 20% safety margin for the specific fuel oil consumption is considered due to the followings:
   - Engine driven pumps
   - Fuel oil consumption tolerance
   - Operation conditions including tropical condition
   - Fluctuation of the fuel oil calorific value
3. The actual capacity of the separator should be considered with the throughput (%) additionally.

The separator should have the capability to purify the worst grade of fuel oil. Normally, the fuel oil grade of H380 to H700 requires the capability up to 1,010kg/m^3 at 15°C.

It is required to ensure proper cleaning of HFO as follows:

- Selection and operation of the separator according to the manufacturer's recommendation
- Correct HFO temperature at inlet to the separator
- Correct throughput of the fuel oil through the separator
- Proper density of HFO in the conformance with the separator specifications
- Proper maintenance of the separator according to the manufacturer's recommendation

Without gravity disc, the continuously operating separators with monitoring of cleaned fuel can handle fuel with densities exceeding 911kg/m^3. The main and stand-by separators should be run in parallel.

With gravity disc, each stand-by separator should be operated with another separator in series. Then, the first separator runs as a purifier and the second as a clarifier.

In order to achieve the maximum separation efficiency, it is recommended to always use all available separators. This will ensure the long retention time of the separators and the optimal efficiency for the removal of catalytic fines.

- **Feed pump for the separator**

The feed pump should be electrically driven and dimensioned for the required flow rate for separation. It is recommended to be a screw type and it should be protected by the suction strainers with a mesh size of approximate 0.5…0.7mm with a magnet.

The specifications of each pump should be as follows:

Delivery capacity	:	Same as the required flow for the separation	
Delivery head	:	2.5 bar (Depends on the location of Pump and separator)	
Design temperature	:	100°C for HFO	50°C for MDO
Viscosity (for electric motor)	:	1,000 cSt for HFO	100 cSt for MDO

- **Pre-heater for the separator**

The pre-heater should be provided to reach and maintain the separating temperature. It has to be designed considering the delivery capacity of the feed pump and the required temperature increase in the pre-heater.

The separating temperature is typically 98°C for HFO and 20…40°C for MDO. It should depend on the viscosity of fuel oil and be recommended by the manufacturer of the separator. In order to avoid fuel oil being cracked, the temperature of the pre-heater surface must not be too high.

The minimum required capacity of the pre-heater can be estimated as the following formula:

$$P = 0.55 \times Q \times dT$$

P [kW] = required capacity of the pre-heater
Q [m^3/h] = delivery capacity of the feed pump
dT [℃] = temperature increase in the pre-heater

Fuel oil feed system for HFO

The fuel oil feed system for HFO is to supply cleaned fuel oil from the day tank to the engine(s) with the required viscosity and pressure. For the efficient operation of the system, it is recommended to be a closed system with a mixing tank and additional circulation pumps.

The system mainly consists of supply pumps, circulation pumps, heaters / viscosity controller and a main filter, etc.

- **Day tank for HFO (TK-501)**

  At least two day tanks should be provided for HFO and always filled with cleaned fuel oil by continuous separation. The settling tank is not used for the day tank. Each day tank shall satisfy the regulations issued by the classification societies and the following requirements.

Capacity of each tank	:	minimum 8 hours fuel oil feed of total fuel oil consumption at MCR of propulsion and vital system of a vessel
Temperature in the tanks	:	typically 90°C as stable as possible (It should depend on the viscosity of the fuel oil.) Heating coils and insulation should be provided to the tanks. The heating source can be a steam or an electric power.
Design	:	Sludge/water spaces and systems for drain, overflow and ventilation Level switches with high and low alarm The tank bottom should be a sloped design for good drainage and equipped with drain valves at the lowest position. The accumulated sludge in the tank bottom should be prevented from entering into the suction line of supply pumps.

- **Day tank for MDO (TK-502)**

  At least two day tanks should be provided for MDO and always filled with cleaned fuel oil by a continuous separation. Each day tank shall satisfy the regulations issued by the classification societies and the following requirements.

Capacity of each tank	:	minimum 8 hours fuel oil feed of total fuel oil consumption at MCR of propulsion and vital system of a vessel of propulsion and vital system of a vessel
Temperature in the tanks	:	typically 20…40°C as stable as possible (It should depend on the viscosity of the fuel oil.)
Design	:	Sludge/water spaces and systems for drain, overflow and ventilation Level switches with high and low alarm The tank bottom should be a sloped design for good drainage and equipped with drain valves at the lowest position. The accumulated sludge in the tank bottom should be prevented from entering into the suction line of supply pumps.

- **Changeover valve (CV-501)**

When the engine load is lower than 20% or flushing operation is necessary, the fuel oil feed must be changed from HFO to MDO by the changeover valve.

The sequence and control of the fuel oil changeover should ensure that fuel oil will be changed smoothly in the temperature and viscosity. And the fuel oil viscosity of the engine inlet should be in the recommended range in order to avoid high risk of plunger seizure and leakage in the fuel injection pump.

The valve can be a manual or an electro-pneumatic remote control type depending on the vessel design. And it is required to be provided with indication device for the valve opening on the control station.

- **Supply pump (PP-501)**

The supply pump should be dimensioned to maintain the pressure in the fuel oil supply system. The pump should be electrically driven and it is recommended to be a screw or a gear type. It should be protected by the suction strainers with a mesh size of approximate 0.5..0.7mm with a magnet and the minimum positive static pressure of 0.5bar is required on the suction side of the pump.

At least another supply pump is required to be redundant so that one can be overhauled while the other one is in service. The specifications of each pump should be as follows:

Delivery capacity	:	minimum 1.5 times of total fuel oil consumption at MCR including a back flushing quantity of the automatic filter
Delivery head	:	6 bar The delivery head can be variable to meet engine inlet target, 8^{+2}_{-1} bar with HFO operation. (See. P.04.800) Pressure drop is to be considered in pipe and fuel oil system.
Design temperature	:	100°C
Viscosity (for electric motor)	:	1,000 cSt

- **Pressure control valve (PV-501)**

The pressure control valve is required to maintain constant fuel oil pressure in the mixing tank. The valve should be provided in the by-pass line of the supply pump and the surplus fuel oil should return to the suction side of the pump.

Set pressure	:	6 bar

- **Cooler for supply pump (HE-501)**

When fuel oil is not consumed in the engine(s) and the supply pump is operating, the fuel oil has to be prevented from overheating. Therefore, it is recommended to provide the cooler in the by-pass line of the supply pump and the returned surplus fuel oil to be cooled appropriately.

In case of MDO operation, the cooler should maintain the temperature of MDO below 40 °C. For very light fuel oil, this temperature must be even lower.

- **Flow-meter (FM-501)**

If a measuring device for fuel oil consumption is required, it should be installed between the supply pump and the mixing tank. A by-pass line has to be provided in parallel with the flow-meter to ensure fuel oil supply in case the flow-meter is clogged.

- **Mixing tank (TK-503) with auto de-aerating valve (AV-501) and flushing valve (CV-502)**

The main purpose of the mixing tank is to remove gas from fuel oil through the de-aerating valve and maintain a gradual temperature balance while mixing the heated return oil from the engine(s) and the oil from the day tank. The tank should be dimensioned to ensure fuel oil supply for 5…10 minutes at the full load operation and not less than minimum 50 liters in any case. The fuel oil outlet of the mixing tank shall be located at least 200mm above the circulation pumps.

It is recommended to install the automatic de-aerating valve on the mixing tank to remove gas from the fuel oil system.

The flushing valve is required to change fuel oil from HFO to MDO in the system in case of the emergency stop during HFO operation. In this case, fuel oil will be changed from HFO to MDO by the changeover valve (CV-501) and circulated in the system through the supply/circulation pumps. And then, the flushing valve will change the flow to make the remaining HFO in the mixing tank to return into the day tank for HFO. When fuel oil in the system is changed to MDO completely, the flushing valve should be back to the normal position in which the fuel oil returned from the engine(s) can flow into the mixing tank. When it is required to return the fuel oil into the tank for the system overhaul, the fuel oil flow shall be led to the tank through this flushing valve.

- **Circulation pump (PP-502)**

As the heated HFO has to be continuously re-circulated, the circulation pump should ensure fuel oil circulation with the required pressure in the system. This pump should be electrically driven and recommended to be a screw or a gear type.

Another pump is required to be redundant so that one can be overhauled while the other one is in service. The specifications of each pump should be as follows:

Delivery capacity	:	minimum 4 times of total fuel oil consumption at MCR including a back flushing quantity of the automatic filter

Delivery head	:	6 bar The delivery head can be variable to meet engine inlet target, 8±1.bar with HFO operation. (See. P.04.800) Pressure drop is to be considered in pipe and fuel oil system.
Design temperature	:	150℃
Viscosity (for electric motor)	:	500 cSt

- **Heater (HE-502) and viscosity controller (VC-501)**

The heater should be provided to maintain the correct injection viscosity of 12…18 cSt at the engine(s).

At least another heater is required to be redundant so that one can be overhauled while the other one is in service. Therefore, each heater should have the sufficient capacity for heating fuel oil at the full load operation.

The minimum required capacity of each heater can be estimated as the following formula:

$$P = 0.55 \times Q \times dT$$

P [kW] = required capacity of the heater
Q [m^3/h] = delivery capacity of the circulation pump
dT [℃] = temperature increase in the heater

The operation of the heater should be controlled by the viscosity controller. The set point of the viscosity controller shall be a little lower than the required injection viscosity at the engines in order to compensate for heat loss during the transfer-process.

In order to avoid fuel oil being cracked, the temperature of the heater surface must not be too high.

- **Main filter (FT-501 / FT-502)**

The automatic back-flushing filter should be provided in order to achieve the better cleaning effect of the fuel oil supplied to the engine(s).

Nowadays fuel oil contains much cat fines(catalytic fines) which are small, very hard particles derived from the refining process. If the removing process of cat fines is insufficient, it causes wearing problem on engine parts. It is hard to remove the cat fines only by the centrifugal separators, because the cat fine has a specific gravity equal or lower than fuel oil.

Generally, 34μm absolute is chosen for the mesh size of the automatic back-flushing filter. However, a 10μm absolute is strongly recommended for the mesh size of the filter under operation with low sulfur fuel oil which is produced by catalytic hydro desulfurization process in order to protect the engine from cat fines.

The by-pass filter with a 10 absolute is recommended to be provided so that it can be operated manually while the main filter is overhauled or cleaned.

It is generally recommended to install an automatic filter between the engine and the heater in the circulation system. If the automatic filter is installed in the supply line after the supply pump, the safety filter of the duplex manual type has to be placed between the engine and the heater.

The automatic filter should be provided with a pressure differential indication and switch in order to check the filter clogging

Oil viscosity	:	Depends on fuel specification
Design temperature	:	150
Delivery pressure	:	16bar
Design flow	:	Same as the circulating pump (PP-502)
Fineness	:	
- Automatic filter	:	10 (absolute size)
- Manual by-pass filter	:	10 (absolute size)

- **Pressure control valve (PV-502)**

The pressure control valve is required to maintain constant fuel oil pressure at the engine inlet. The valve should be located as close as possible to the engine inlet and ensure that the surplus fuel oil feed will flow to the return line after the engine(s) through the by-pass line.

Set pressure : 8…10 bar

- **MDO cooler (HE-503) and changeover valve (CV-503)**

The MDO cooler is required to prevent fuel oil from overheating and being with a very low viscosity in the circulation system in MDO operation. It shall be installed to the return line after the engine(s) or the inlet line before the engine(s). It should be provided with a by-pass pipe and a changeover valve.

If the viscosity of MDO in day tanks drops below the minimum value of recommended viscosity range, it is required to install the MDO Cooler into the engine supply line for the reliable viscosity of fuel oil.

When the engine is changed over from HFO to MDO operation, the changeover valve shall make the fuel oil returned from the engine(s) to flow through the MDO cooler. In this way, MDO which was heated by the injection pumps of the engine(s) in the circulation system can be cooled and return to the mixing tank.

The cooler should maintain the temperature of MDO below 40 °C. For very light fuel oil, this temperature must be even lower and it depends on the actual fuel oil specification.

The minimum required capacity of MDO cooler can be estimated as the following formula:

$$P = \frac{Q \times \rho \times c \times dT}{3600}$$

P [kW] = required capacity of the cooler
Q [m^3/h] = max. delivery quantity of fuel oil (equal to the flow capacity of circulating pump)
ρ [kg/m^3] = fuel oil density at 15℃ (Typical value: 900kg/m^3)
c [kW/kg℃]=Specific heat of fuel oil (Typical value: 2 kJ/kg℃)
dT[℃] = Temperature difference between engine inlet and outlet. (Typical value: 12…15℃)

Remark:

1. The engine inlet temperature should be obtained in order to meet the minimum value of the recommended viscosity range.

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

- **Waste fuel oil tank (TK-504)**

  The dirty leak fuel oil which is drained from the engine(s) by gravity should be continuously collected into the sludge tank through the inclined pipes. The tank should be provided with a heating coil and insulation for good drainage, unless the fuel oil system is for the MDO operation only.

- **Clean leak fuel oil tank, HFO (TK-505)**

  The clean leak fuel oil which is drained from the engine(s) by gravity should be continuously collected into the clean leak fuel oil tank through the inclined pipes. It can be transferred to the day tank for HFO and reused without separation. The tank should be provided with a heating coil and insulation.

Fuel oil feed system for MDO

If the engine(s) always operates with MDO, the fuel oil feed system can be an open system without the mixing tank and additional circulation pumps. In this case, the cleaned fuel oil of the day tank will be fed to the engine(s) through supply pumps and returned into the day tank.

- **Day tank for MDO (TK-502)**

  At least two day tanks should be provided for MDO and always filled with cleaned fuel oil by continuous separation. Each day tank shall satisfy the regulations issued by the classification societies and the following requirements.

Capacity of each tank	:	minimum 8 hours fuel oil feed of total fuel oil consumption at MCR of propulsion and vital system of a vessel
Temperature in the tanks	:	typically 20…40°C as stable as possible (It should depend on the viscosity of the fuel oil.)
Design	:	Sludge/water spaces and systems for drain, overflow and ventilation Level switches with high and low alarm The tank bottom should be a sloped design for good drainage and equipped with drain valves at the lowest position. The accumulated sludge in the tank bottom should be prevented from entering into the suction line of supply pumps.

- **Supply pump (PP-503)**

  The supply pump should ensure fuel oil circulation in the system and maintain the required pressure at the engine inlet. The pump should be electrically driven and it is recommended to be a screw or gear type. It should be protected by the suction strainers with a mesh size of approximate 0.5…0.7mm with a magnet and the minimum positive static pressure of 0.5 bar is required on the suction side of the pump.

  At least another supply pump is required to be redundant so that one can be overhauled while the other one is in service. The specifications of each pump should be as follows:

Delivery capacity	:	minimum 4 times of total fuel oil consumption at MCR
Delivery head	:	8 bar
Design temperature	:	50℃
Viscosity (for electric motor)	:	100 cSt

- **Flow-meter (FM-502)**

  If a measuring device for the fuel oil consumption is required, it should be installed before and after the engine(s) respectively to check the measurement difference. A by-pass line has to be provided in parallel with the flow-meter to ensure fuel oil supply in case the flow-meter is clogged.

- **Pressure control valve (PV-503)**

  The pressure control valve is required to maintain constant fuel oil pressure at the engine inlet. The valve should be located as close as possible to the engine inlet and ensure that the surplus fuel oil feed will flow to the return line after the engine(s) through the by-pass line.

  Set pressure : 8 bar

- **MDO cooler (HE-503)**

  The MDO cooler is required to prevent fuel oil from overheating and being with a very low viscosity in the circulation system. It shall be installed to the return line after the engine(s) or the inlet line before the engine(s).

- If the viscosity of MDO in day tanks drops below the minimum value of recommended viscosity range, it is required to install the MDO Cooler into the engine supply line for the reliable viscosity of fuel oil.

  The cooler should maintain the temperature of MDO below 40 °C. For very light fuel oil, this temperature must be even lower and it depends on the actual fuel oil specifications.

  It should be installed to the return line after the engine(s) and provided with the by-pass pipe and manual valve to ensure a fuel oil circulation while the cooler is overhauled.

  The minimum required capacity of the MDO cooler can be estimated as the following formula:

$$P = \frac{Q \times \rho \times c \times dT}{3600}$$

P [kW] = required capacity of the cooler
Q [m^3/h] = max. delivery quantity of fuel oil (equal to the flow capacity of Supply pump)
ρ [kg/m^3] = fuel oil density at 15℃ (Typical value: $900kg/m^3$)
c [kW/kg℃]=Specific heat of fuel oil (Typical value: 2 kJ/kg℃)
dT[℃] = Temperature difference between engine inlet and outlet. (Typical value: 12…15℃)

Remark:
1. The engine inlet temperature should be obtained in order to meet the minimum value of the recommended viscosity range.
2. These parameters are typically only for reference. When dimensioning the MDO cooler capacity, the parameters must be taken into account based on actual fuel oil properties.

- **Pressure control valve (PV-504)**

  The pressure control valve is required to increase and maintain constant fuel oil pressure in the return line to the day tank.

  Set pressure : 2 bar

- **Waste fuel oil tank (TK-504)**

  The dirty leak fuel oil which is drained from the engine(s) by gravity should be continuously collected into the sludge tank through the inclined pipes. In case of the engine operation with MDO only, a heating coil and insulation are not required for the tank.

- **Clean leak fuel oil tank, MDO (TK-506)**

  The clean leak fuel oil which is drained from the engine(s) by gravity should be collected continuously into the clean leak fuel oil tank through the inclined pipes. It can be transferred to the day tank for MDO and reused without separations. In case of the engine operation on MDO only, a heating coil and insulation are not required for the tank.

- **Main filter (FT-503)**

  The automatic back-flushing filter is recommended to be provided in order to achieve the better cleaning effect of the fuel oil supplied to the engine(s).

  It is generally recommended to install an automatic filter between the engine and the heater in the circulation system or the supply system. The automatic filter should be provided with a pressure differential indication and switch in order to check the filter clogging.

  Generally, 34 absolute is chosen for the mesh size of the automatic back-flushing filter.

  A by-pass filter with a same fineness as the main filter is recommended to be provided so that it can be operated manually while the main filter is overhauled.

  If the engine is operated with MGO / MDO only, the main automatic filter (FT-503) can be replaced by a duplex filter with the fineness 25㎛ absolute on external side. However, it shall be better to install the automatic back-flushing type in order to avoid too frequent filter cleaning in manual.

- **Duplex safety filter**

  In general, the duplex safety filter with 50㎛ absolute will be equipped on engine side. If this filter is not installed on engine side, the installation place for the filter is to be as close as the engine.

Fuel oil feed system for Pilot fuel oil

Pilot oil is supplied from the MDO/MGO day tank through the pilot fuel oil supply pump and fine filter, which the system can be common with other engines. The feed pressure of pilot fuel oil should be constant and HFO is not allowed to enter the pilot fuel oil system. The pilot fuel oil returned from the engine can be led to the MDO/MGO day tank directly.

The back pressure in the return line is allowed maximum 1 bar to ensure the function and reliability of the pilot fuel oil system.

When the vessel has only the MDO or MGO feed system, the main and pilot fuel oil system can be combined as a unified system.

- **Day tank for pilot fuel oil (TK-511)**

  Pilot fuel oil must be of type MGO or MDO and stored in the day tank. The tank location and system layout have to satisfy the requirements of the pilot fuel oil supply pump. The tank shall satisfy the regulations issued by the classification societies and the following requirements.

  Alternatively, a vessel (plant) has a day tank for MDO or MGO, and the fuel oil is satisfied with pilot fuel oil system, the day tank for MDO or MGO can replace the day tank for pilot fuel oil. In this case, please contact to HHI-EMD.

Capacity of each tank	:	minimum 8 hours fuel oil feed of total pilot fuel oil consumption at MCR
Temperature in the tanks	:	typically 20…40°C as stable as possible (It should depend on the viscosity of the pilot fuel oil.)
Design	:	Sludge/water spaces and systems for drain, overflow and ventilation Level switches with high and low alarm The tank bottom should be a sloped design for good drainage and equipped with drain valves at the lowest position. The accumulated sludge in the tank bottom should be prevented from entering into the suction line of supply pumps.

- **Pilot fuel oil supply pump (PP-511)**

  The pilot fuel oil supply pumps are required if the MDO/MGO supply pump does not satisfy the requirements for the pilot fuel oil system. Pumps supply MDO/MGO to the pilot fuel oil system. It should be protected by the suction strainers with a mesh size of approximate 0.5…0.7mm with a magnet and the minimum positive static pressure of 0.5 bar is required on the suction side of the 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 Depending on the temperature of pilot fuel oil at the pump

- **Fine filter for Pilot fuel oil (FT-511)**

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

- **Pressure control valve for Pilot fuel oil (PV-511)**

The pressure control valve maintains the constant pressure in the pilot oil supply line. The surplus pilot oil returns to the MDO/MGO day tank.

Set pressure : 5…6 bar

- **Pilot fuel oil cooler (HE-511)**

If the viscosity of MDO/MGO in day tanks drops below the minimum value of recommended viscosity range for the pilot fuel oil system, it is required to install the pilot fuel oil cooler into the engine supply line for the reliable viscosity of fuel oil.

The cooler should maintain the MDO temperature below 40 °C. For very light fuel oil, this temperature must be even lower and it depends on the actual fuel oil specifications.

It should be installed to the supply line before the engine(s) and manual valve to ensure fuel oil circulation while the cooler is overhauled.

The minimum required capacity of the pilot fuel oil cooler can be estimated as the following formula:

$$P = \frac{Q \times \rho \times c \times dT}{3600}$$

P [kW] = required capacity of the cooler
Q [m^3/h] = max. 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: 900kg/m^3)
c [kW/kg℃]=Specific heat of fuel oil (Typical value: 2 kJ/kg℃)
dT[℃] = Temperature difference between the fuel oil of MDO/MGO day tank and the cooler outlet

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

Diagram for the external fuel oil system (HFO), a single engine installation

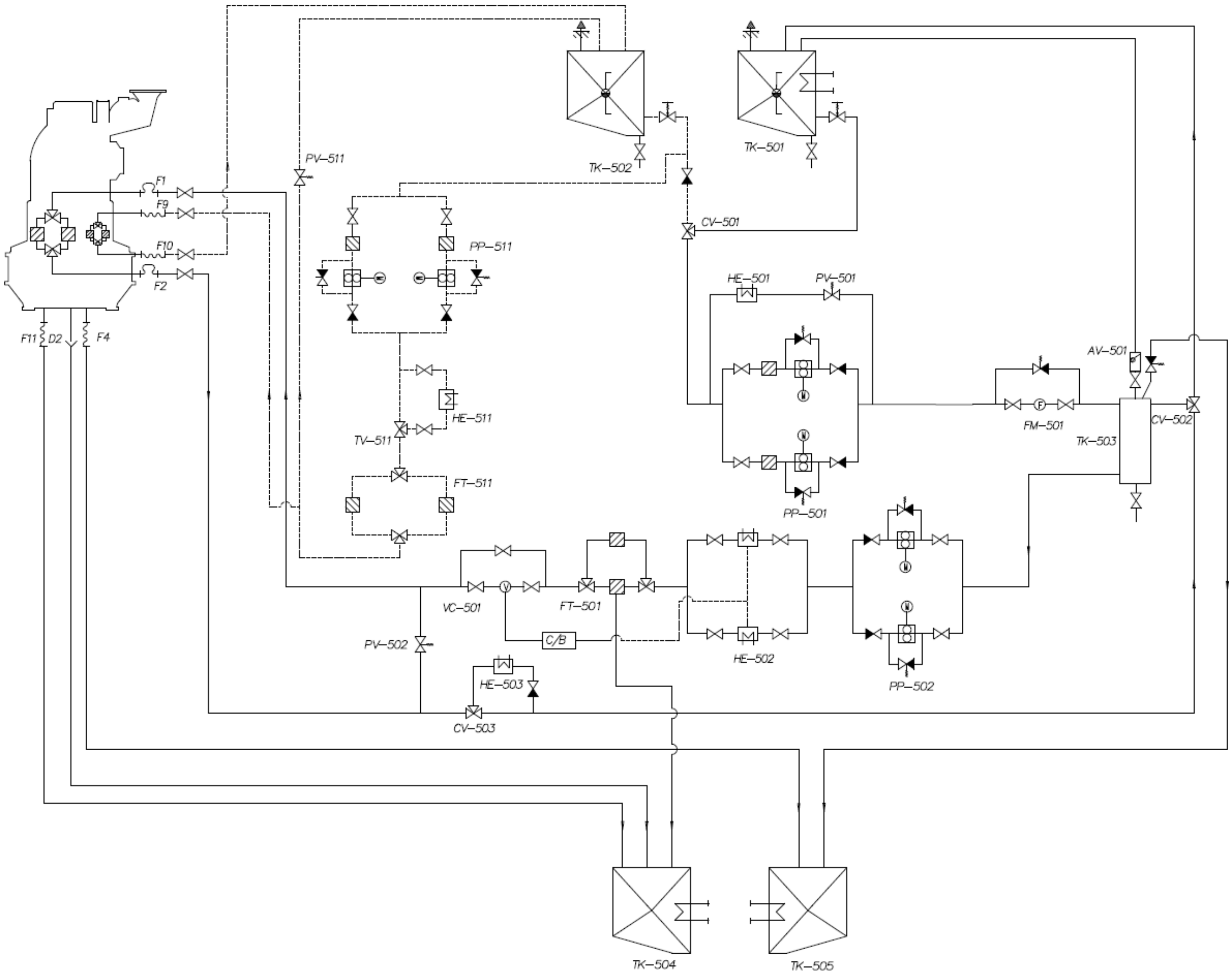

Figure 5-2-1: External fuel oil system (HFO) for a single engine installation

System components			
Code	Description	Code	Description
TK-501	Day tank for HFO	PP-501	Supply pump
TK-502	Day tank for MDO	PP-502	Circulation pump
TK-503	Mixing tank	PP-511	Pilot fuel oil supply pump
TK-504	Waste fuel tank	CV-501	Changeover valve
TK-505	Clean leak fuel tank, HFO	CV-502	Flushing valve
FT-501	Main filter	CV-503	Changeover valve (MDO cooler)
FT-511	Fine filter for Pilot fuel oil	HE-501	Cooler for supply pump
FM-501	Flow-meter	HE-502	Heater
VC-501	Viscosity controller	HE-503	MDO cooler
AV-501	Auto de-aerating valve	HE-511	Pilot fuel oil cooler

System components			
Code	Description	Code	Description
PV-501	Pressure control valve	PV-511	Pressure control valve for Pilot fuel oil
PV-502	Pressure control valve		

Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F9	Pilot fuel oil inlet
F2	Fuel oil outlet	F10	Pilot fuel oil outlet
D2	Waste oil drain	F11	Leak Pilot fuel oil drain, dirty
F4	Clean fuel oil drain		

Diagram for the external fuel oil system (HFO), multi-engine installation,

- **With a day tank for Pilot fuel oil**

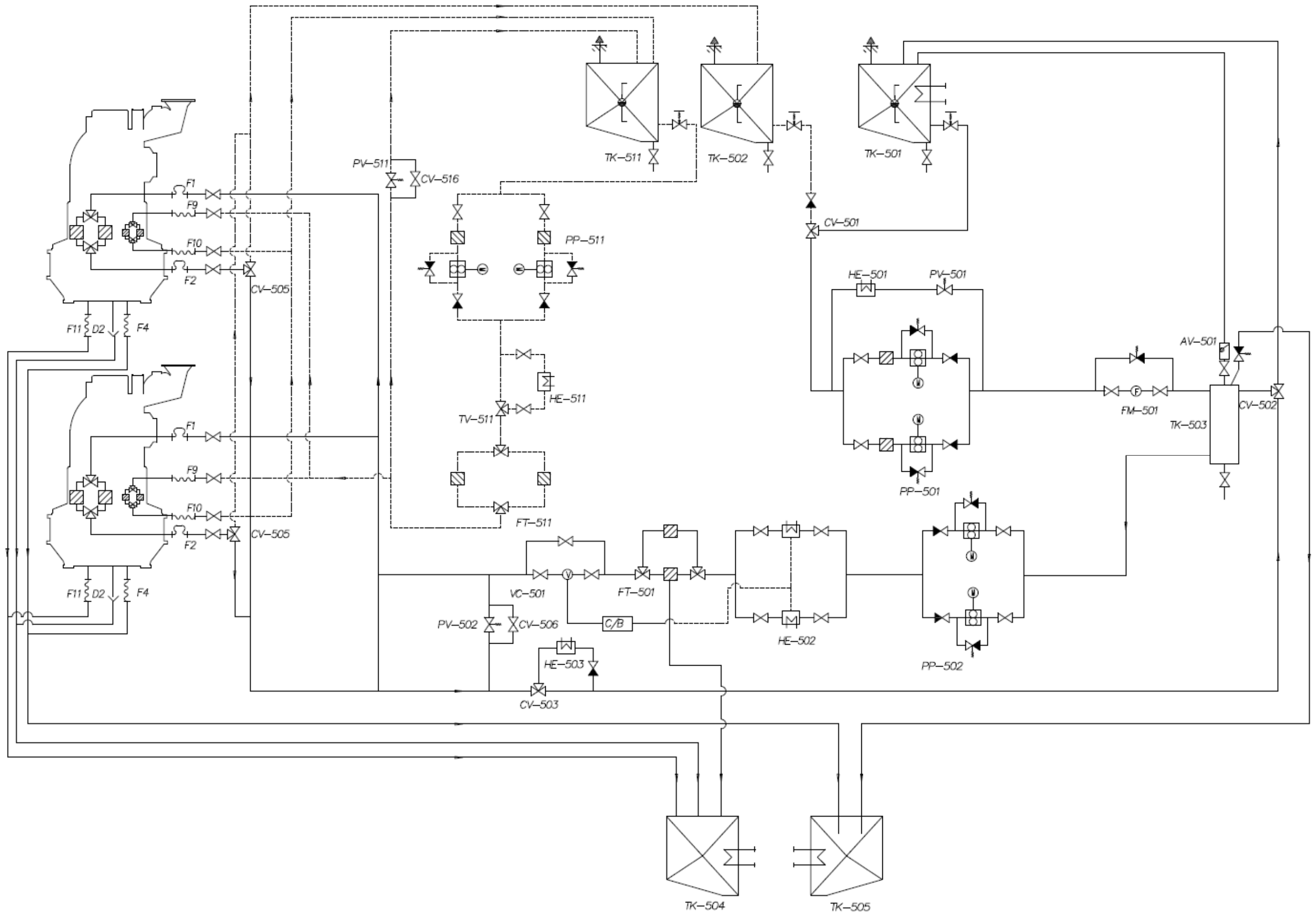

Figure 5-2-2: External fuel oil system (HFO) for multi-engine installation with a day tank for Pilot fuel oil

System components			
Code	Description	Code	Description
TK-501	Day tank for HFO	PP-501	Supply pump
TK-502	Day tank for MDO	PP-502	Circulation pump
TK-503	Mixing tank	PP-511	Pilot fuel oil supply pump
TK-504	Waste fuel tank	CV-501	Changeover valve
TK-505	Clean leak fuel tank, HFO	CV-502	Flushing valve
TK-511	Day tank for Pilot fuel oil	CV-503	Changeover valve (MDO cooler)
FT-501	Main filter	HE-501	Cooler for supply pump
FT-511	Fine filter for Pilot fuel oil	HE-502	Heater
FM-501	Flow-meter	HE-503	MDO cooler
VC-501	Viscosity controller	HE-511	Pilot fuel oil cooler
AV-501	Auto de-aerating valve	PV-501	Pressure control valve

System components			
Code	Description	Code	Description
PV-511	Pressure control valve for Pilot fuel oil	PV-502	Pressure control valve

Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F9	Pilot fuel oil inlet
F2	Fuel oil outlet	F10	Pilot fuel oil outlet
D2	Waste oil drain	F11	Leak Pilot fuel oil drain, dirty
F4	Clean fuel oil drain		

Diagram for the external fuel oil system (MDO), a single engine installation

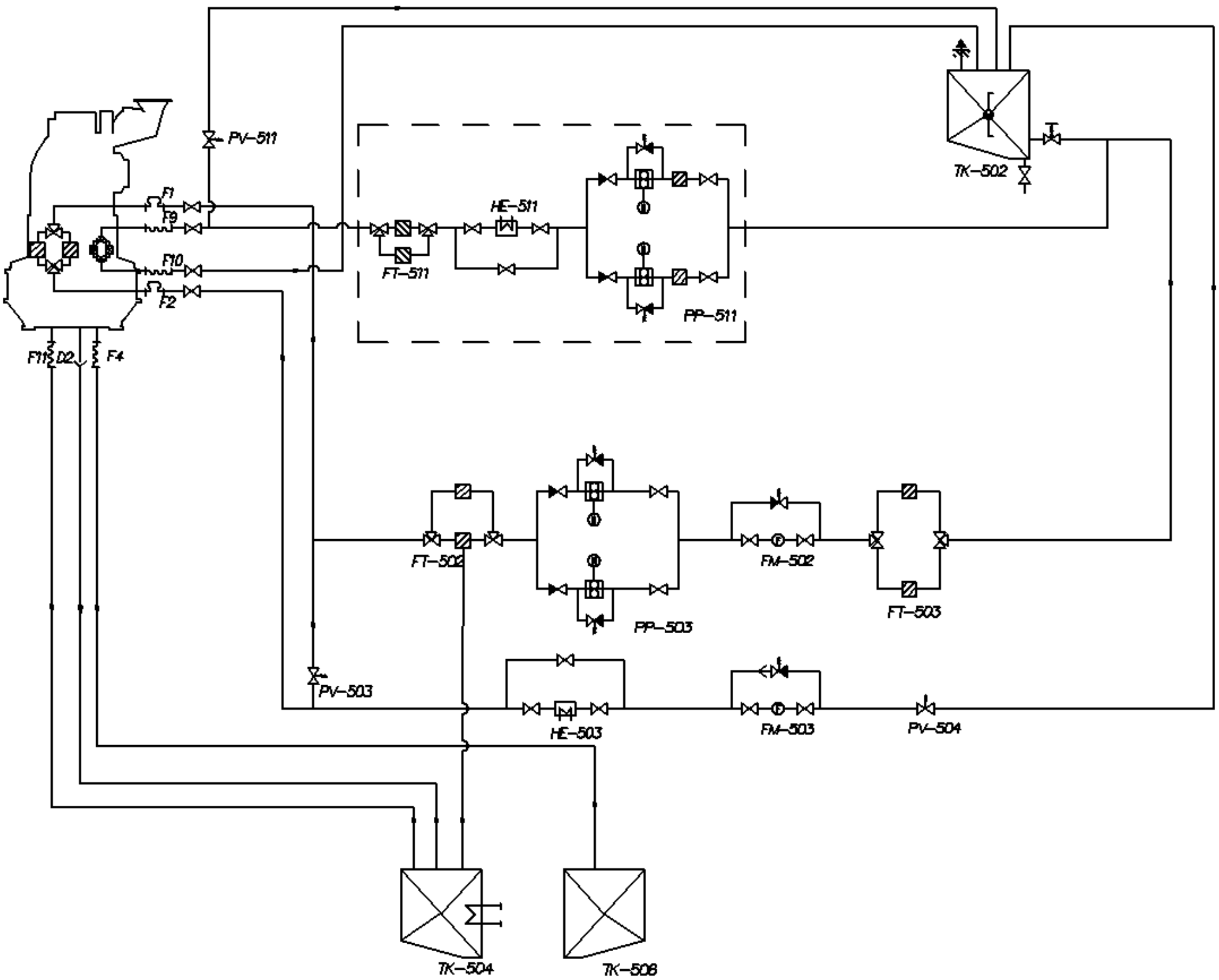

Figure 5-2-3: External fuel oil system (MDO) for a single engine installation

System components			
Code	Description	Code	Description
TK-502	Day tank for MDO	PP-511	Pilot fuel oil supply pump
TK-504	Waste fuel tank	HE-503	MDO cooler
TK-506	Clean leak fuel tank, MDO	HE-511	Pilot fuel oil cooler
FT-503	Main filter	PV-503	Pressure control valve
FT-504	Suction strainer	PV-504	Pressure control valve
FT-511	Fine filter for Pilot fuel oil	PV-511	Pressure control valve for Pilot fuel oil
FM-502	Flow-meter (supply line)		
FM-503	Flow-meter (return line)		
PP-503	Supply pump		

Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F9	Pilot fuel oil inlet
F2	Fuel oil outlet	F10	Pilot fuel oil outlet
D2	Waste oil drain	F11	Leak Pilot fuel oil drain, dirty
F4	Clean fuel oil drain		

Diagram for the external fuel oil system (MDO), multi-engine installation
With a day tank for Pilot fuel oil

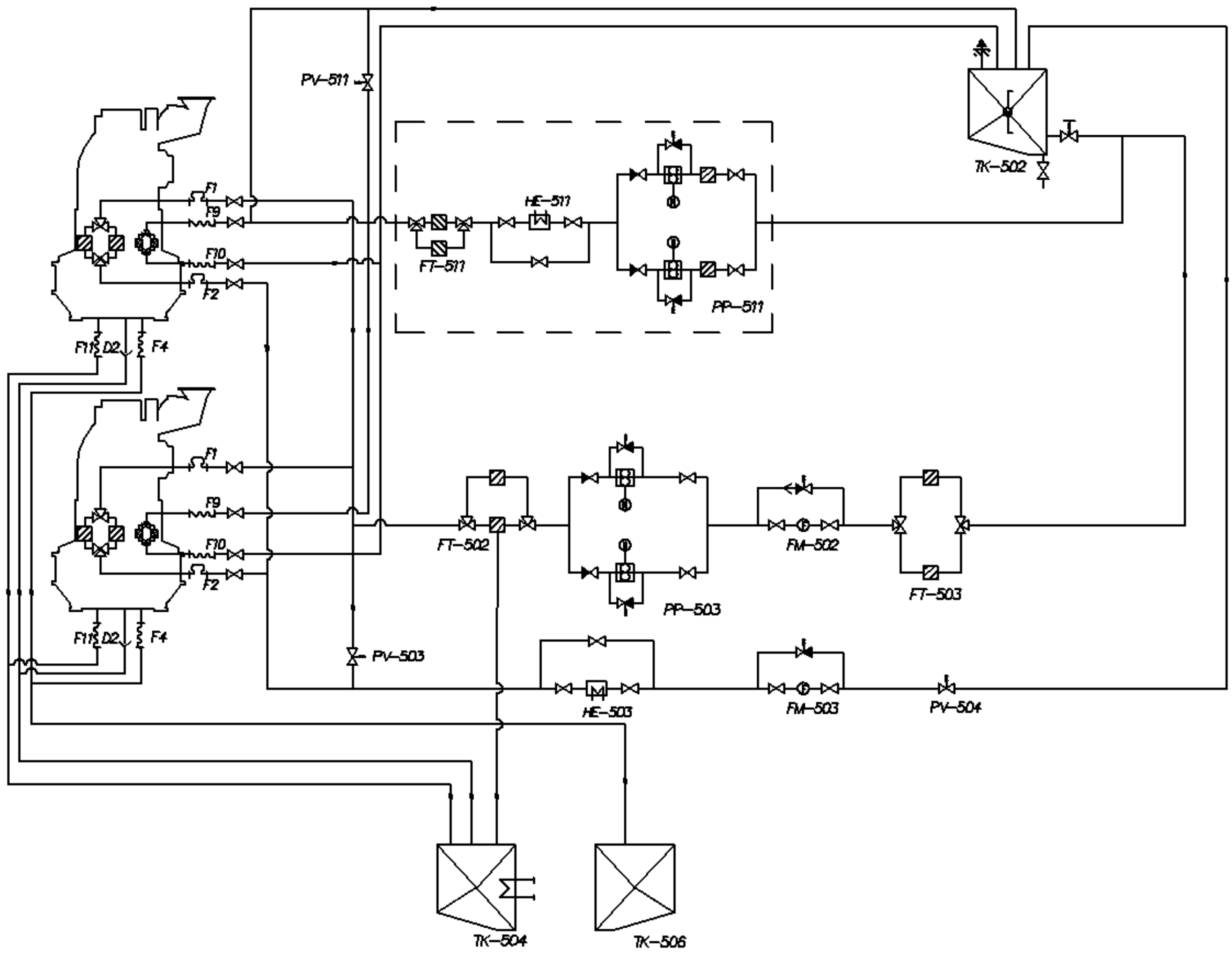

Figure 5-2-4: External fuel oil system (MDO) for multi-engine installation, with a day tank for Pilot fuel oil

System components			
Code	Description	Code	Description
TK-502	Day tank for MDO	PP-511	Pilot fuel oil supply pump
TK-504	Waste fuel tank	HE-503	MDO cooler
TK-506	Clean leak fuel tank, MDO	HE-511	Pilot fuel oil cooler
FT-503	Main filter	PV-503	Pressure control valve
FT-504	Suction strainer	PV-504	Pressure control valve
FT-511	Fine filter for Pilot fuel oil	PV-511	Pressure control valve for Pilot fuel oil
FM-502	Flow-meter (supply line)		
FM-503	Flow-meter (return line)		
PP-503	Supply pump		

Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F9	Pilot fuel oil inlet
F2	Fuel oil outlet	F10	Pilot fuel oil outlet
D2	Waste oil drain	F11	Leak Pilot fuel oil drain, dirty
F4	Clean fuel oil drain		

General

The fuel specifications are based on ISO 8217:2012. The fuels are largely classified into two categories as distillate fuels and residual fuels. Distillate fuels are divided into DMX, DMA, DFA, DMZ, DFZ, and DMB. Residual fuels are divided 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 consensus of the marine market is a simplified terminology for fuels used in the market after 1st January 2020, in accordance with the most relevant characteristics.

HiMSEN is able to operate with all fuels specified in the below table.2 And, using the simplified terminology as listed Table 5-3-1 allows easy determination if a fuel is fit for the purpose near in time.

HiMSEN designates the fuel grades threeas the following table:

Table 5-3-1 : Designation of fuel grades

Fuel grade		Sulfur content(%)	Typical viscosity(cSt) (at 50°C for residual fuels & 40°C for distillate fuels)		ISO 8217:2017
			Minimum	Maximum	
HFO (Heavy Fuel Oil)	HSFO (High Sulfur Fuel Oil)	1.0 < S ≤ 3.5 (or even higher)	10	700	Residual marine fuels (RMB,RMD,RME,RMG, RMK)
	LSFO (Low Sulfur Fuel Oil)	0.5 < S ≤ 1.0			
	VLSFO (Very Low Sulfur Fuel Oil)	0.1 < S ≤ 0.5	2 ~ 380 (Not decided yet)		Not defined
	ULSFO (Ultra Low Sulfur Fuel Oil)	S ≤ 0.1	9 ~ 67 (Not decided yet)		
MGO (Marine Gas Oil)		S ≤ 1.0	2	6	Distillate marine fuels (DMA, DMZ)
MDO (Marine Diesel Oil)		S ≤ 1.5	2	11	Distillate marine fuels (DMB) Residual marine fuels (RMA10)

Distillate fuels

Table 5-3-2 : Specification of Distillate fuels

Characteristics		Unit	Limit	Category ISO-F-							Test Method Reference
				DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Kinematic viscosity at 40°C		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°C		kg/m^3	max.	-	890.0		890.0		900.0		ISO 3675 or ISO 12185
Cetane index		-	min.	45	40		40		35		ISO 4264
Sulfur [b)]		mass %	max.	1.0	1.0		1.0		1.5		ISO 8754 ISO 14596 ASTM D4294
Flash point		°C	min.	43.0	60.0		60.0		60.0		ISO 2719
Hydrogen sulfide		mg/kg	max.	2.0	2.0		2.0		2.0		IP 570
Acid number		mg KOH/g	max.	0.5	0.5		0.5		0.5		ASTM D664
Total sediment by hot filtration		mass %	max.	-	-		-		0.10 [c)]		ISO 10307-1
Oxidation stability		g/m^3	max.	25	25		25		25 [d)]		ISO 12205
Fatty acid methyl ester(FAME)[e)]		Volume %	max.	-	-	7.0	-	7.0	-	7.0	ASTM D7963 or IP579
Carbon residue: micro method on the 10% volume distillation residue		mass %	max.	0.3	0.30		0.30		-		ISO 10370
Carbon residue: micro method		mass %	max.	-	-		-		0.30		ISO 10370
Cloud point [f)]	Winter	°C	max.	-16	report		report		-		ISO 3015
	summer	°C	min	-16	-		-		-		
Cold filter plugging point [f)]	Winter	°C	max.	-	report		report		-		IP 309 OR IP 612
	summer	°C	min	-	-		-		-		
Pour point (upper) [f)]	Winter	°C	max.	-	-6		-6		0		ISO 3016
	summer	°C	max.	-	0		0		6 [c)]		
Appearance		-	-	Clear and bright [g)]							
Water		volume %	max.	-	-		-		0.30 [c)]		ISO 3733
Ash		mass %	max.	0.01	0.01		0.01		0.01		ISO 6245
Lubricity, corrected wear scar diameter (WSD 1,4) at 60°C [h)]		μm	max.	520	520		520		520 [d)]		ISO 12156-1

a) *1 mm2/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) *This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0.050 mass %).*

Residual fuels

Table 5-3-3: Specifications of residual fuels

Characteristics	Unit	Limit	Category ISO-F-											Test method reference
			RMA	RMB	RMD	RME	RMG				RMK			
			10	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50°C	mm²/s a)	max.	10.0	30.0	80.0	180.0	180.0	380.0	500.0	700.0	380.0	500.0	700.0	ISO 3104
Density at 15°C	kg/m³	max.	920.0	960.0	975.0	991.0	991.0				1,010.0			ISO 3675 or ISO 12185
CCAI	-	max.	850	860	860	860	870				870			
Sulfur b)	mass %	max.	Statutory requirements *)											ISO 8754 ISO 14596 ASTM D4294
Flash point	°C	min.	60.0	60.0	60.0	60.0	60.0				60.0			ISO 2719
Hydrogen sulfide	mg/kg	max.	2.0	2.0	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	2.5				2.5			ASTM D664
Total sediment aged	mass %	max.	0.1	0.1	0.1	0.1	0.1				0.1			ISO 10307-2
Carbon residue: micro method	mass %	max.	2.5	10.0	14.0	15.0	18.0				20.0			ISO 10370
Pour point (upper) d) winter	°C	max.	0	0	30	30	30				30			ISO 3016
Pour point (upper) d) Summer	°C	max.	6	6	30	30	30				30			ISO 3016
Water	volume %	max.	0.30	0.50	0.50	0.50	0.50				0.50			ISO 3733
Ash	mass %	max.	0.04	0.07	0.07	0.07	0.10				0.15			ISO 6245
Vanadium	mg/kg	max.	50	150	150	150	350				450			IP 501, IP 470 or ISO 14597
Sodium	mg/kg	max.	50	100	100	50	100				100			IP 501, IP 470
Aluminum plus silicon	mg/kg	max.	25	40	40	50	60				60			IP501, 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

i) 1 mm²/s=1 cSt

j) The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations.

k) See Annex H of ISO 8217:2017.

l) The purchaser should confirm that this pour point is suitable [or the ship's intended area of operation.

*) *International statutory requirements*

This document specifies allowable minimum flash point limits following the provisions given in the SOLAS convention. MARPOL Annex VI, which controls air pollution from ships, includes a requirement that either the fuel shall not exceed a specified maximum sulfur content 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 5-3-4 and Table 5-3-5.

- ✓ When using biofuels included in quality standards Table 5-3-4 and Table 5-3-5, you need to get confirmation from HiMSEN.

Biodiesel / Fatty Acid Methyl Ester (FAME)

Biodiesel (FAME) is derived from Crude 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 5-3-4)

Table 5-3-4 Specification 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
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 14018 / EN 14109 / EN 14538
Group II metals (Ca+Mg)	mg/kg	-	5	EN 14538
Phosphorus content	mg/kg	-	4	EN 14107

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 5-3-5)

Table 5-3-5 Specification of HVO (EN 15940)

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 / EN 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	-	EN 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	EN ISO 2160
Oxidation stability	hours	20	-	EN 14112
Oxidation stability	g/m3	-	25	EN 14112
Carbon residue : on the 10% volume distillation residue	Mass %	-	0.30	ISO 10370
Ash	% (m/m)	-	0.010	ISO 6245
Lubricity HFRR at 60°C	μ m	-	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	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 5-3-4 and the bioblends(B##) except for biodiesel-blends(BD##) are referred to the Table 5-3-6.

General biofuels

The quality standards of general liquid biofuels except biodiesel(FAME) are as shown below Table 5-3-6 (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 5-3-6)

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 5-3-6 Specification 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℃	mm^2/s	-	700	
Density at 15℃	kg/m^3	-	1010	ISO 3675 / ISO 12185
Sulfur	Mass %	Statutory requirements		ISO 8754 / ISO 14596 / ASTM D4294
Flash point	°C	60	-	ISO 2719
Cloud point	°C	-	a)	ISO 3015
Cold filter plugging point(CFPP)	°C	-	a)	IP 309
Pour point	°C	-	a)	ISO 3016
Total sediment by hot filtration	mass %	-	0.1	ISO 10307-1
Total sediment aged	Mass %	-	0.1	ISO 10307-2
Ash	% (m/m)	-	0.15	ISO 6245
Carbon residue (a) : on the 10% volume distillation residue	Mass %	-	0.30	ISO 10370

Characteristics	Unit	Min. limit	Max. limit	Test method reference
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)		30	-	
- Zinc (Zn)		15	-	
- Phosphorus (P)		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
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.*

Fuel oil viscosity according to the temperature

The viscosity of residual fuels from RMB 30 to RMK 700 should be kept in the range of 12…18 cSt before the engine(s). A typical fuel oil viscosity diagram regarding temperature is as follows:

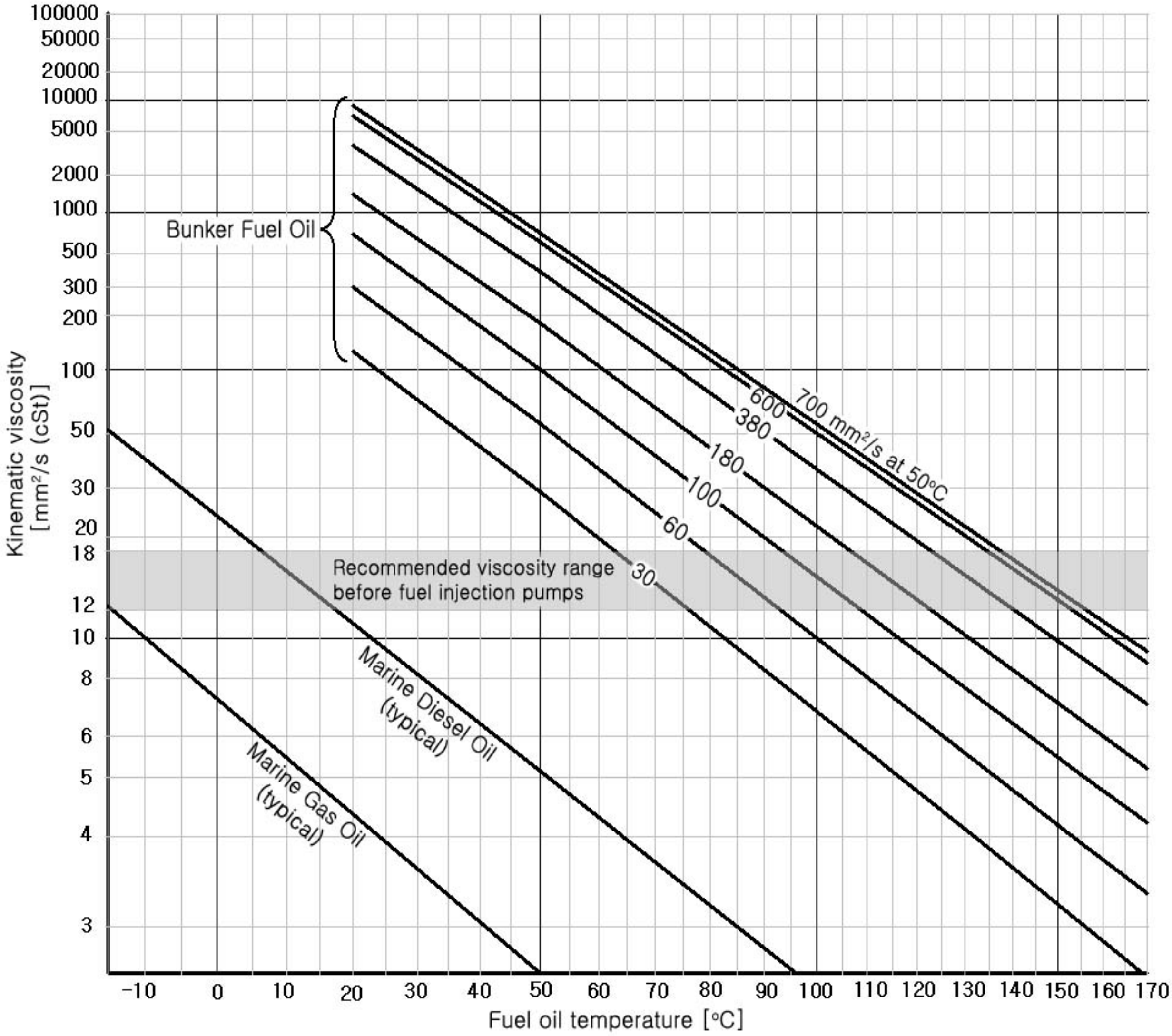

Figure 5-3-1: Fuel oil viscosity-temperature diagram

Remark:

1. The maximum pre-heating temperature of HFO shall be limited up to 155°C to avoid vaporization in the fuel oil system.
2. The viscosity of distillate fuels and RMA 10 should be kept in the range of 2 ~ 14 cSt in order to prevent possible sticking of the fuel injection pump due to a low lubricity.

Fuel characteristics

- **Viscosity**

  The viscosity of the fuel oils should be kept in the range of 12…18 cSt before the engine(s). It could be achieved by a proper heating recommended by fuel suppliers as the viscosity varies depending on the properties of the fuel oil.

- **Density**

  If the density of the fuel oil is above the maximum density (991 kg/m^3 at 15°C), the fuel cannot be used because of water and solid contaminants which are not removed by a centrifuging. A special centrifuging system should be installed to use the fuel oil with the maximum density (1010 kg/m^3 at 15°C).

- **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 corrosions in the combustion chamber and contribute to the formation of high temperature deposits. It is also recommended to keep the proper alkalinity of the lubricating oil for neutralizing.

- **Ash**

  The ash content comes from a natural crude oil and also from contaminations during the treatment of the fuel. The solid ingredients can be mostly removed 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 a crude oil mostly. However, sodium is water-soluble and comes from a crude oil as well as a contaminated fuel by salt water.

  As the 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 residue (CCR)**

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

- **Asphaltenes**

  High asphaltenes content may contribute to deposit formation in combustion chamber as well as exhaust system at low load 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 in the fuel injection pump and fouling of the exhaust system and turbochargers. The water contents should be reduced to maximum 0.2% by centrifuging.

- **Abrasive particles**

  Fuel oil can be contaminated by abrasive particles composed of aluminum (Al) and silicon (Si) oxides called catalyst fines. If the efficient fuel treatment is not applied, these catalysts fines can cause abnormal wear on injection system and cylinder liners / piston rings.

  In order to avoid the abnormal wear and malfunction of injection system and other engine parts and operate engine(s) in accordance with good practice, the amount of aluminum and silicon contents must be reduce to below 15 mg/kg. For the measurement of these catalyst fines, test method is ISO 10478, IP 501 or IP 470. The reference test method shall be IP 501.

Ignition quality

The ignition quality is related to the ignition delay that is the intervals between the fuel injection and the 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 first operating, the engine can be damaged by the low ignition quality without sufficient preheating. The following equation of CCAI (Calculated Carbon Aromaticity Index) developed by Shell can be used to get the ignition quality of the heavy fuel oil.

$$CCAI = \rho - 81 - 141 \times \log\left[\log\left(v + 0.85\right)\right]$$

ρ [kg/m^3] = density at 15℃
v [cSt] = viscosity at 50℃

Remark:

1. If the value of CCAI is increased, the value of the ignition quality is decreased.

The CCAI guidelines are as follows:

- The fuel oil with CCAI < 840 can be used without any troubles for any application.
- The fuel oil with 840 ≤ CCAI ≤ 870 can be used when its viscosity is lower than 180 cSt at 50°C. If its viscosity is higher than 180 cSt at 50℃, it may be happened a combustion problem at the part load operation and variable speed.
- The fuel oil with CCAI > 870 can cause damages after a short time. It is strongly recommended not to be used.

To prevent any troubles about a poor ignition quality, the engine should be pre-heated sufficiently before starting and has proper functions of the cooling and injection systems.

Specific Energy

For residual fuels, net and gross specific energy can be calculated with a degree of accuracy acceptable for normal purposes as the following formulas:

$$N_r = \left(46.704 - 8.802 \times \rho^2 \times 10^{-6} + 3.167 \times \rho \times 10^{-3}\right) \times \left[1 - 0.01 \times \left(w + a + s\right)\right] + 0.094 \times 2s - 0.024 \times 49w$$

$$G_r = \left(52.190 - 8.802 \times \rho^2 \times 10^{-6}\right) \times \left[1 - 0.01 \times \left(w + a + s\right)\right] + 0.094 \times 2s$$

N_r [MJ/kg] = net specific energy of the residual fuel

G_r [MJ/kg] = gross specific energy of the residual fuel

ρ [kg/m^3] = density at 15℃

w [mass %] = water content

a [mass %] = ash content

s [mass %] = sulfur content

For distillate fuels,

$$N_d = \left(46.423 - 8.792 \times \rho^2 \times 10^{-6} + 3.170 \times \rho \times 10^{-3}\right) \times \left[1 - 0.01 \times \left(w + a + s\right)\right] + 0.094 \times 2s - 0.024 \times 49w$$

$$G_d = \left(51.916 - 8.792 \times \rho^2 \times 10^{-6}\right) \times \left[1 - 0.01 \times \left(w + a + s\right)\right] + 0.094 \times 2s$$

N_d [MJ/kg] = net specific energy of the distillate fuel

G_d [MJ/kg] = gross specific energy of the distillate fuel

ρ [kg/m^3] = density at 15℃

w [mass %] = water content

a [mass %] = ash content

s [mass %] = sulfur content

Diagram for the internal fuel gas system

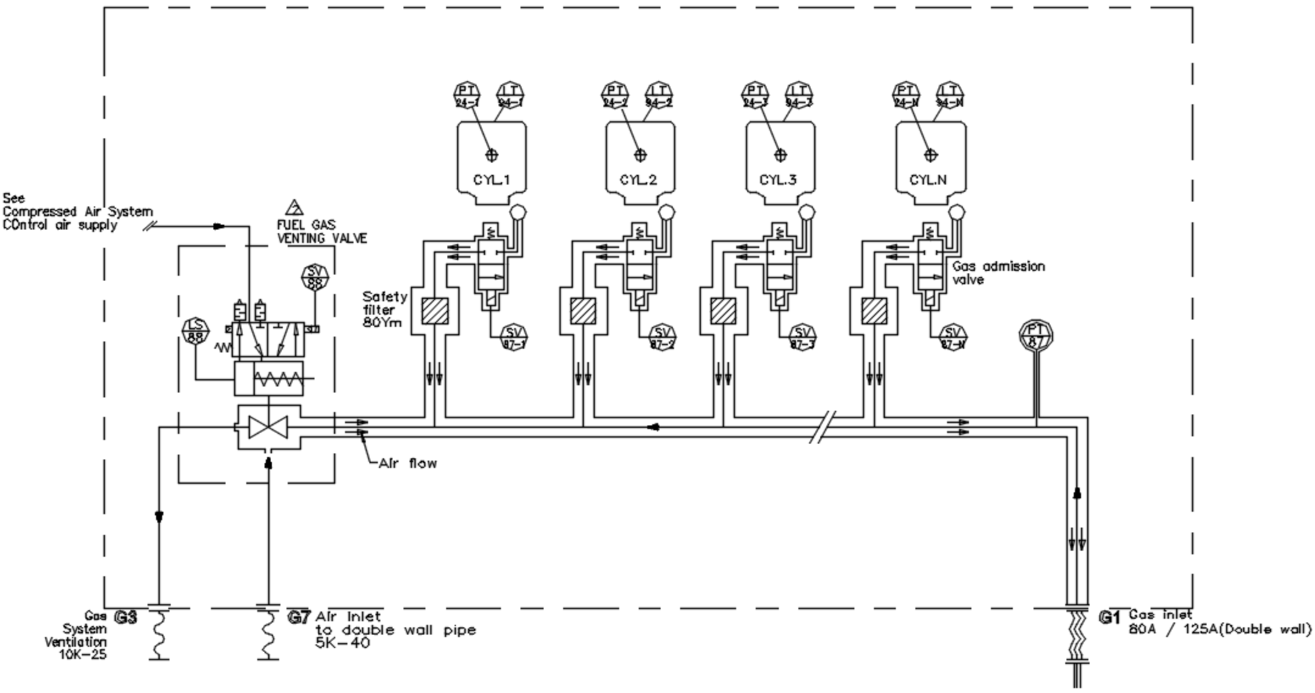

Figure 5-4-1: L-type engine internal fuel gas system

System components

No.	Description	Remark
001	Gas admission valve	
002	Safety filter	
003	Gas ventilation valve	

Sizes of the external pipe connections

Code	Description	Size	Standard
G1	Gas inlet	80A/125A	Double wall
G3	Gas system ventilation	10K - 25A	JIS B 2220
G7	Air inlet to double wall pipe	5K – 40A	JIS B 2220

Remark:

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

Diagram for the internal fuel gas system

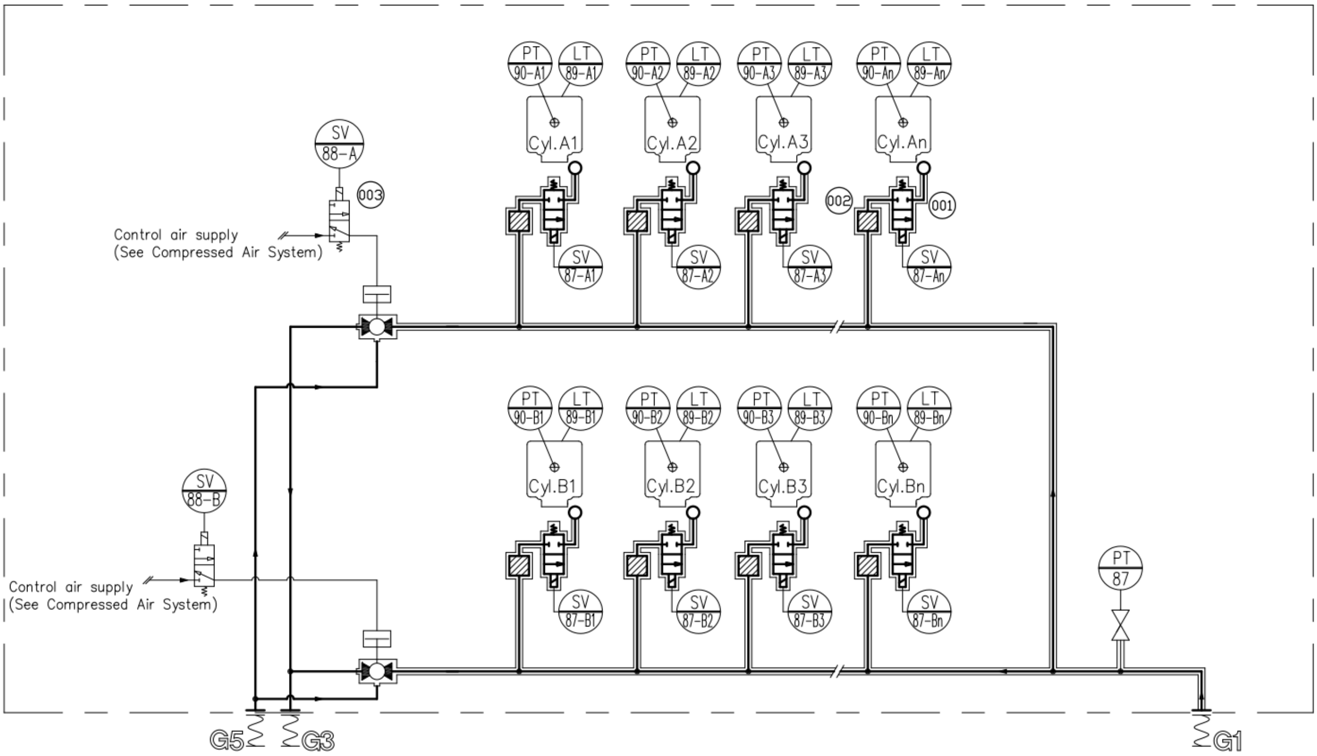

Figure 5-4-2: V-type engine internal fuel gas system

System components

No.	Description	Remark
001	Gas admission valve	
002	Safety filter	
003	Gas ventilation valve	

Sizes of the external pipe connections

Code	Description	Size	Standard
G1	Gas inlet	80A/125A	Double wall
G3	Gas system ventilation	10K - 25A	JIS B 2220
G5	Air inlet to double wall pipe	5K – 40A	JIS B 2220

Remark:

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

General

In gas mode, the regulated fuel gas from the external fuel gas system is to be injected to the 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 a pilot fuel oil.

When change over from gas to diesel, the residual gas is ventilated naturally through a gas ventilation valve. But at emergency stop in gas mode, fuel gas should be purged out with inert gas (Nitrogen), which is supplied from the gas regulating unit.

The fuel gas pipes on the engine are made of the double walled structure up to the gas admission valves for safety from the gas leakage. The annular intermediate space of double walled pipes shall be continuously ventilated under the negative pressure by 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 signal 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 valve, a safety filter with a fineness of approx. 80㎛ is installed at downstream of each 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.

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 5.4.1).

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.

Engine type	Double walled gas pipe external volume (Annular space) (liter)	Remark
6H35DFP	66.3	
7H35DFP	74.4	
8H35DFP	82.4	
9H35DFP	90.5	

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

Supply pressure : minimum 3 barg / maximum 6 barg

Alarm set point : 3.5 barg

Recommended : 4.0 barg

Engine type	Double walled gas pipe internal volume (liter)	Remark
6H35DFP	73.0	
7H35DFP	83.3	
8H35DFP	93.6	
9H35DFP	103.9	

Inert gas to crankcase

Connection code : L6 (see the lubricating oil system Figure 6-1-1)

Supply pressure : minimum 3 barg / maximum 6 barg

Required inert gas volume : 20.5 Nm^3 (atm, 0˚C)

Engine type	Crankcase volume (liter)	Remark
6H35DFP	7,890	
7H35DFP	8,995	
8H35DFP	10,099	
9H35DFP	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*

Gas Regulating Unit

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

- **Installation**

  The gas regulating 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 unit is recommended within 10m.

- **Type of gas regulating unit**

  - ✓ Open type gas regulating unit (GRU)

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

  - ✓ Enclosed type gas regulating 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 unit**

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

- **The comprisal of gas regulating 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 (option)

Open type Gas Regulating Unit

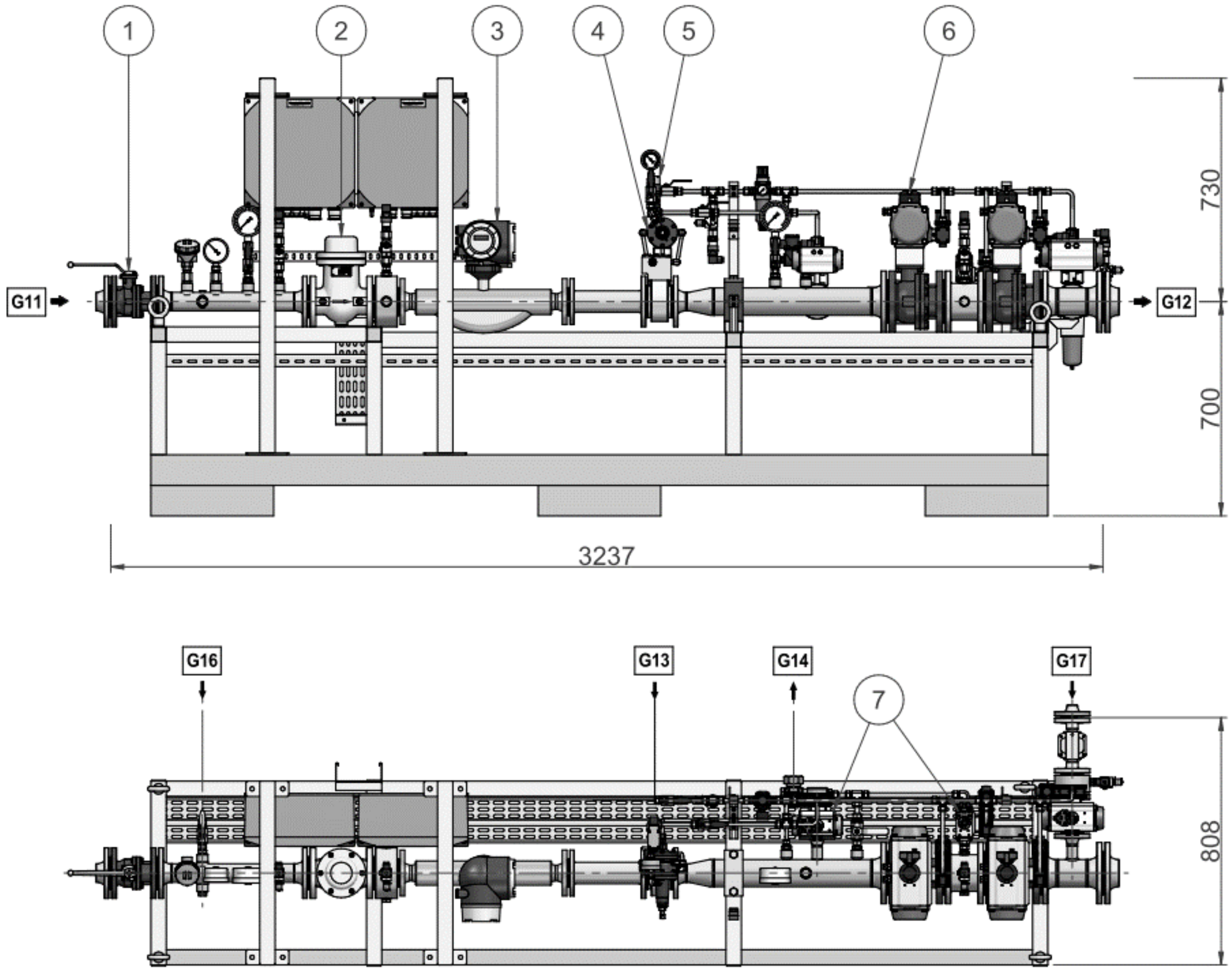

Figure 5-5-1: Typical drawing of open type Gas Regulating Unit

System components

No.	Description	Remark
001	Manual shut-off valve	DN 50, PN 16, Ball valve
002	Gas filter with magnetic insert	DN 50, PN 16
003	Gas flow meter	DN 80, PN 16
004	Gas pressure regulating valve	DN 50, PN 16
005	I/P-converter	¼"NPT
006	Double block valves	DN 50, PN 16, Electro-pneumatic valves

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

Enclosed type Gas Regulating Unit

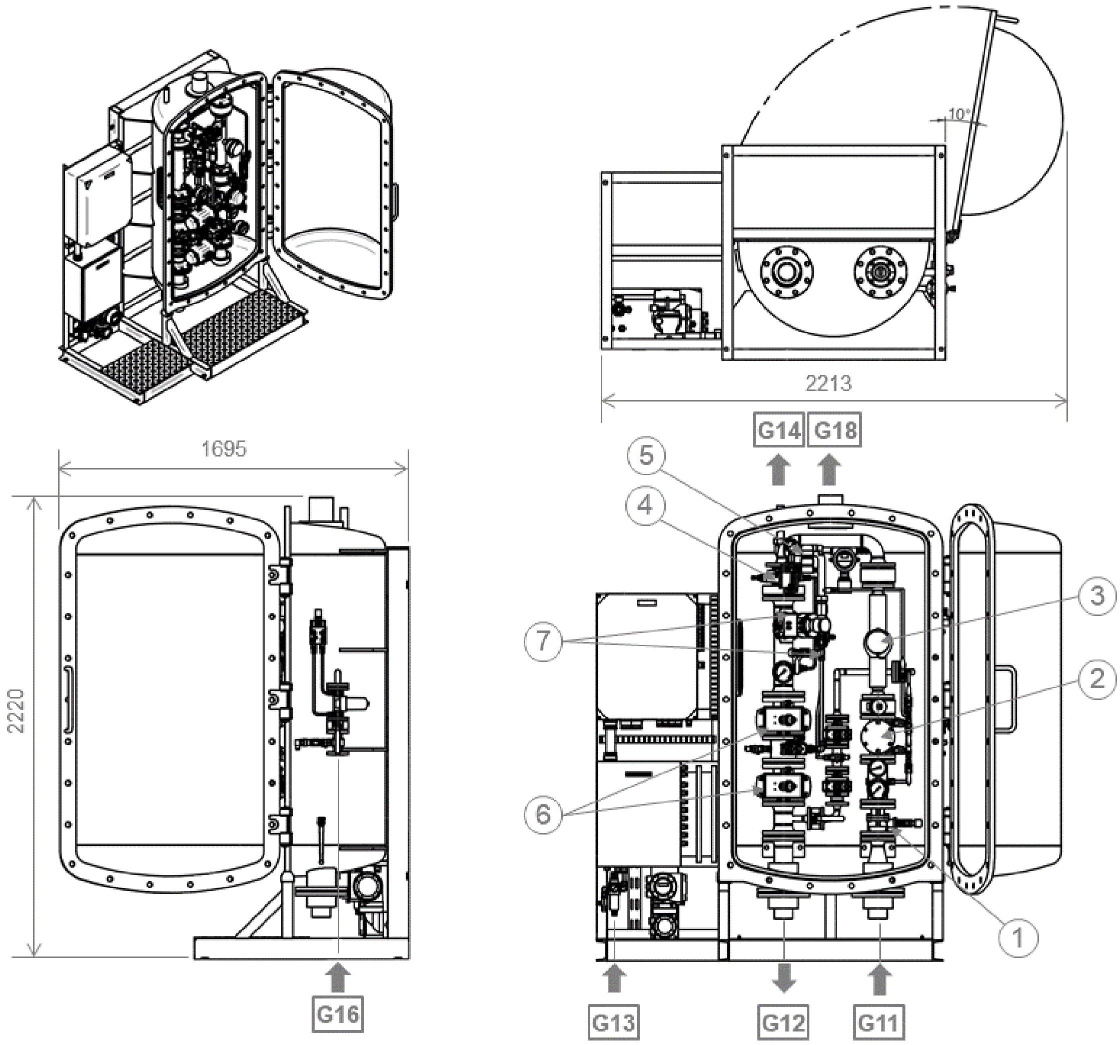

Figure 5-5-2: Typical drawing of enclosed type Gas Regulating Unit

System components

No.	Description	Size
1	Manual shut off valve	
2	Fuel gas filter	2μm
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 unit figure. The exact dimension shall be consulted to HHI-EMD.
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 unit

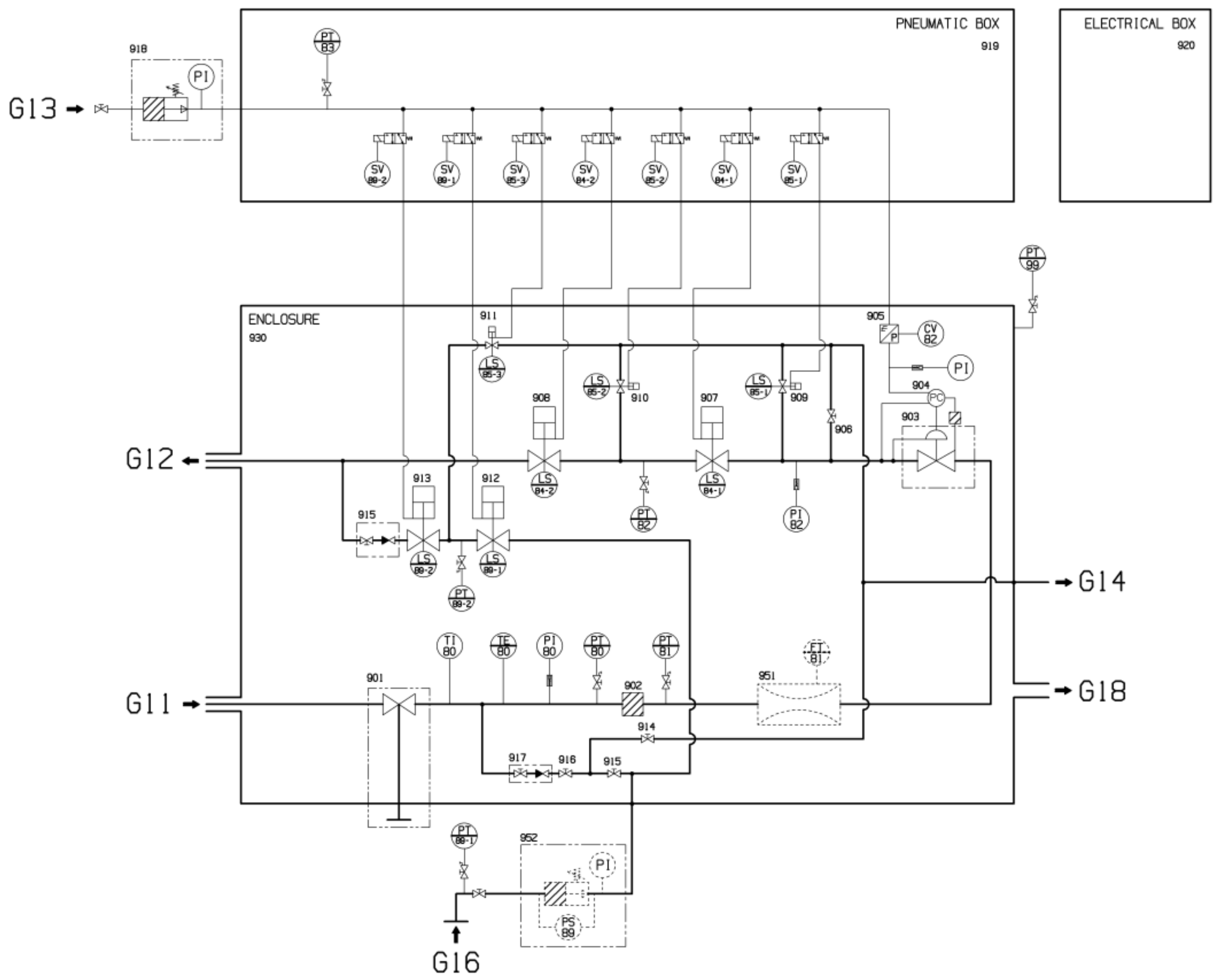

Figure 5-5-3: Enclosed type gas regulating unit

Size of the external pipe connection

Code	Description	Size	Standard
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 as regulating unit	10K-20A	JIS B 2220
G18	Ventilation on enclosure	100A	Welded type(pipe end)

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	Fist 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
914	Manual vent valve	Normal open
915	Manual first block valve	Normal close
916	Manual second block valve	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)	Option

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

Diagram for the external fuel gas system

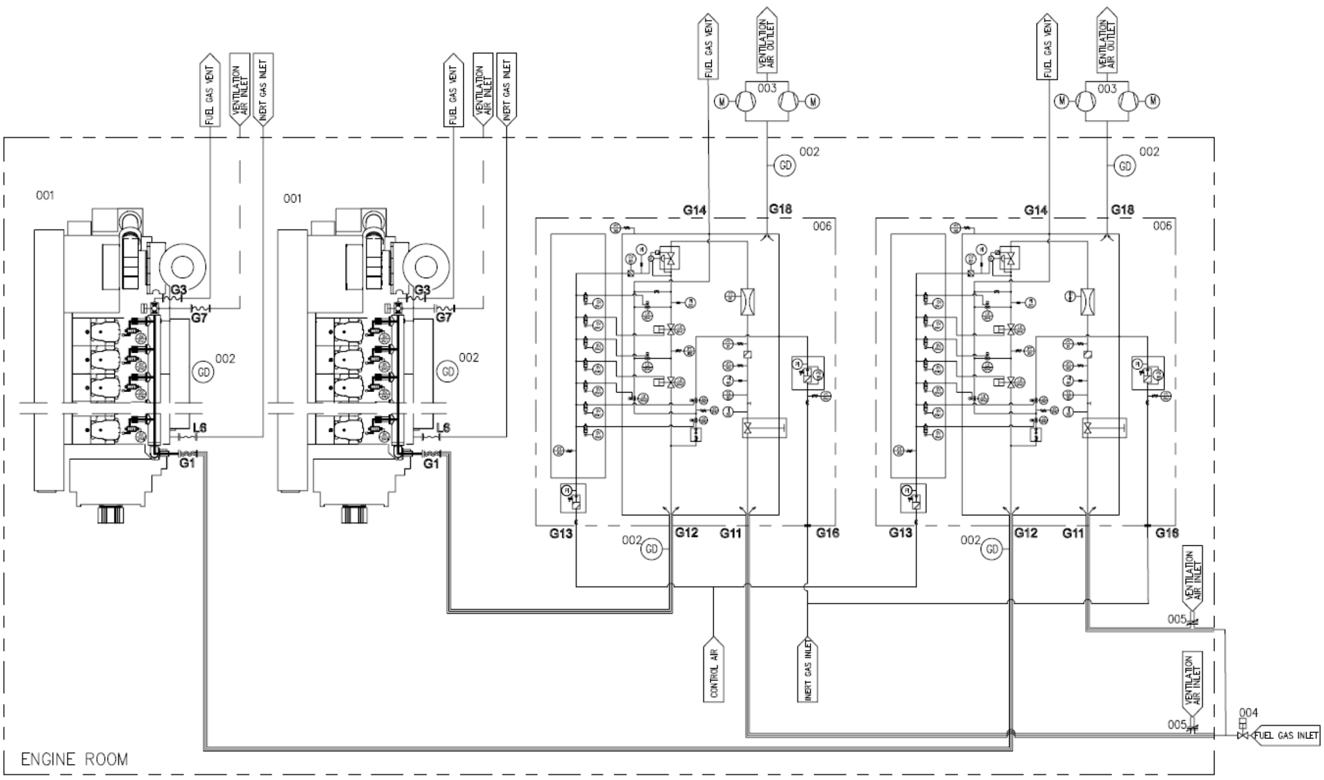

Figure 5-5-4: Typical drawing of External Fuel Gas System

System components

No.	Description	Remark
1	HiMSEN DF Engine	
2	Gas detector	
3	Ventilation fan	
4	Master fuel gas valve	
5	Adjustable orifice for air inlet	
6	Enclosed type gas regulating unit	

General

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

Double walled gas piping

The fuel gas supply pipes in the engine room are to be double walled and connected to the gas regulating unit space. The design of the gas piping should be satisfied with the requirements of classification societies.

The annular intermediate space of double walled pipes is to be continuously ventilated by negative pressure in the gas regulating unit room. The gas leakage from inner pipes is to be monitored by the gas detectors at all times.

Its ventilation system should be equipped with the min. capacity of 30 air changes per hour, and the differential pressure of ventilation flow is to be monitored to check possible loss of the negative pressure.

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 5-5-4 : 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.

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 6.4 (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.

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.

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.

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 2-6-3 De-rating due to gas lower calorific value and gas feed pressure' for detail information.

Fuel Gas Characteristics

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

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

Property	Unit	Value
Lower calorific value (LCV), minimum 3)	MJ/Nm³ 1)	28
Methane number (MN), minimum 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, maximum	㎛	5
Particles or solids at engine inlet	mg/Nm³	50
Hydrogen sulfide content (H_2S), maximum	mg/Nm³	30
Gas inlet temperature	°C	0 … 50
Oil content, maximum	mg/Nm³	0.01
Water or liquids	Condensate not allowed at engine inlet	

1) Reference condition for the volume designation Nm³ (Temp. 0℃, Atmospheric press. 1.013 bar)

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

2) 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.

General Information **P.00.000**

Structural Design and Installation **P.01.000**

Performance Data **P.02.000**

Dynamic Characteristics and Noise **P.03.000**

Operation and Control System **P.04.000**

Fuel System **P.05.000**

Lubricating Oil System **P.06.000**

Cooling Water System **P.07.000**

Air and Exhaust Gas System **P.08.000**

Engine Maintenance **P.09.000**

Theoretical Performance **P.10.000**

Electric Control System **P.11.000**

Appendix

Diagram for the internal lubricating oil system

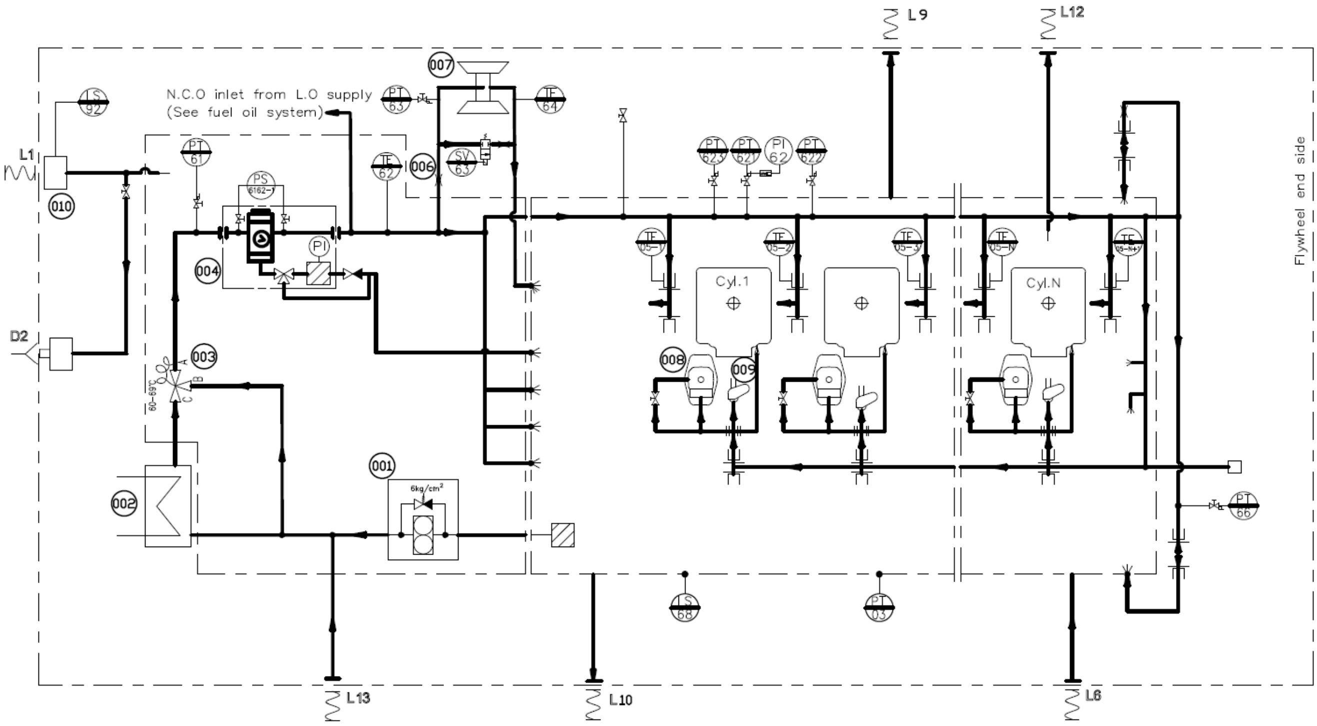

Figure 6-1-1: In-line engine internal lubricating oil system

System components

No.	Description	Remark
001	Engine driven lubricating oil pump	
002	Lubricating oil cooler	
003	Lubricating oil thermostatic valve	
004	Lubricating oil Automatic main filter	
006	Turbocharger inlet orifice	
007	Turbocharger	
008	Fuel oil pump and drive	
009	Valve drive	
010	Oil Mist Detector	

Sizes of the external pipe connections

Code	Description	Size	Standard
L1	Oil vapor discharge	5K-125A	JIS B 2220
L6	Inert gas supply to crank chamber	5K-50A	JIS B 2220

Code	Description	Size	Standard
L9	Lub. oil outlet to system oil tank, flywheel side	5K-250A	JIS B 2220
L10	Lub. oil outlet to system oil tank, free end side	5K-250A	JIS B 2220
L12	Lub. oil to stand-by pump	5K-150A	JIS B 2220
L13	Lub. oil from stand-by pump	10K-150A	JIS B 2220

Remark:

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

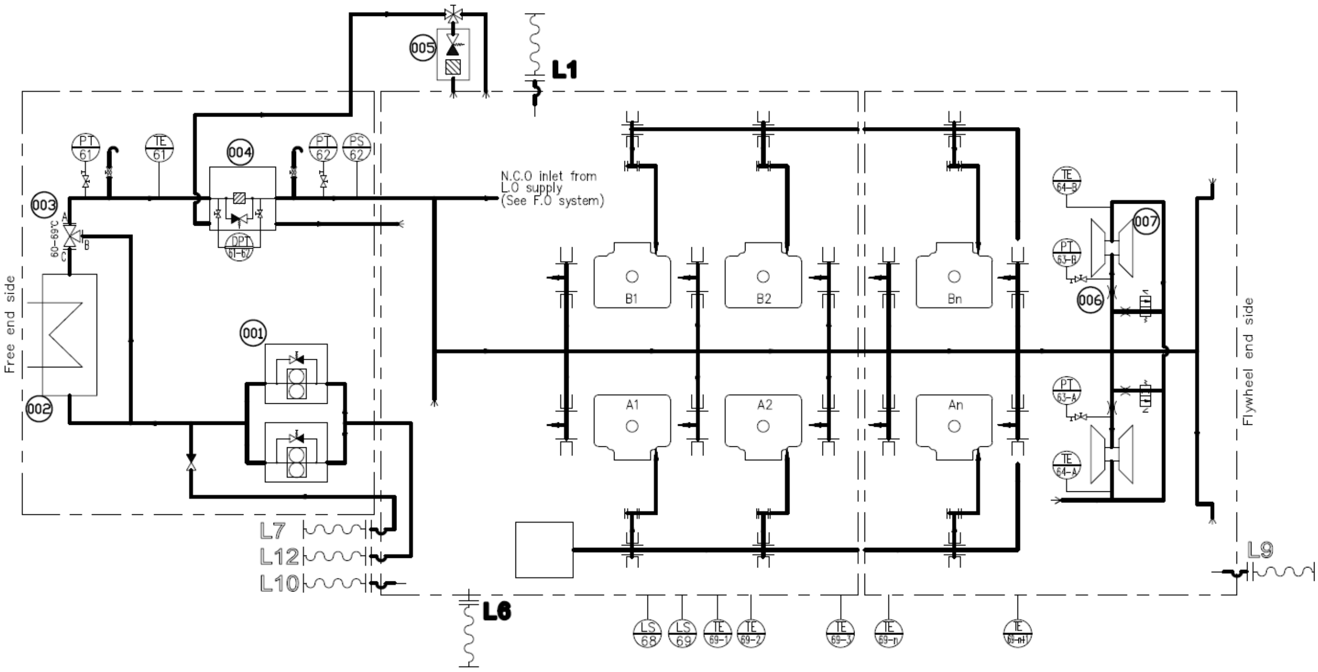

Figure 6-1-2 : V-type engine internal lubricating oil system

System components

No.	Description	Remark
001	Engine driven lubricating oil pump	
002	Lubricating oil cooler	
003	Lubricating oil thermostatic valve	
004	Lubricating oil Automatic main filter	
006	Turbocharger inlet orifice	
007	Turbocharger	
008	Fuel oil pump and drive	
009	Valve drive	
010	Oil Mist Detector	

Sizes of the external pipe connections

Code	Description	Size	Standard
L1	Oil vapor discharge	5K-125A	JIS B 2220
L6	Intert gas supply to crank chamber	5K-50A	JIS B2220
L7	Lub. oil from stand-by pump	10K-150A	JIS B 2220
L9	Lub. oil outlet to system oil tank, flywheel side	5K-250A	JIS B 2220
L10	Lub. oil outlet to system oil tank, free end side	5K-250A	JIS B 2220
L12	Lub. oil to engine driven Lub. oil pump	5K-150A	JIS B 2220

Remark:

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

General

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

The lubricating oil main pump(s) is driven by the engine. The pump is of a gear type with the pressure regulating valve. For the flow rate at MCR, see P.02.200/210 “Engine Capacity Data”.

The lubricating oil main filter(s) is built on the free side of the engine. The filter is of an automatic back-flushing type with the fineness of 34㎛ absolute.

The lubricating oil sump of the engine is of a dry sump type. It has the lubricating oil outlet connections which shall lead the lubricating oil to a bottom tank in the external system.

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

- Lubricating oil main pump, engine driven
- Lubricating oil cooler
- Lubricating oil thermostatic valve
- Lubricating oil main filter
- Oil mist detector

Lubricating oil consumption

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

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

Remark:

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

General

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

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

- Even though the automatic back-flushing type filter is built on the engine(s) to remove particles by filtration, a centrifugal purification is commonly required for the engine(s) in order to remove water, carbon residuals and particles by separation.
- The solid particles and water in the lubricating oil can cause wear and frequent maintenance for the engine itself as well as the external lubricating oil system. Therefore, the qualified separation equipment should be included in the external system not only for HFO operation but for MDO operation.
- In order to prevent excessive pressure losses in the piping system, it is recommended that the flow velocity of the lubricating oil should be the following values:
  - Suction pipe: 0.5 ~ 1.5 m/s
  - Pressure pipe: 1.0 ~ 2.5 m/s
- The actual required quantity of the lubricating oil should depend on the tank geometry and total volume of the system including pipes.

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

Lubricating oil treatment system

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

The system mainly consists of a feed pump, a pre-heater and separator, etc.

- **Separator (SP-601)**

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

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

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

Q [liter/h] = required flowrate for the separation
P [kW] = maximum continuous output of the engine(s)
n [-] = number of oil circulation per day (4 for MDO operation, 5 for HFO operation)
t [h] = actual separation time per day
(23 hours for normal operation, 24 hours for continuous separator operation

Remark:

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

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

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

The specification of the pump should be in accordance with the recommendation of a separator manufacturer. To dimension the mover for pump, the lowest temperature in the system oil tank or the oil pan (if wet type is applied) should be taken into account.

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

The lubricating oil in the system oil tank or the oil pan (if wet type is applied) shall be warmed up to 40°C before engine starting and heated up to approx. 65…75°C during engine running. The preheater for the separator is designed to heat the lubricating oil to a recommended temperature for efficient separation. The recommended temperature is typically 95°C, but the temperature should be consulted by a separator maker and lubricating oil maker. However, the temperature of heater surface must not exceed 150°C in order to avoid the cooking of lubricating oil.

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

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

- **Separator installation**

A separator should be in continuous operation for each main engine in order to ensure removal of contaminants (If a common separator is installed in multi-engine application, it must be consulted by HHI-EMD.). And if the engine is operated in MGO/MDO/Gas only, the intermittent separation might be sufficient.

Lubricating oil feed system

The lubricating oil feed system shall supply cleaned lubricating oil from the system oil tank to the engine(s) with the required temperature and flow.

At that case, the system mainly consists of strainer, a stand-by pump, etc.

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

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

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

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

- **System oil tank (TK-601)**

  The system oil tank is to be arranged below engine foundation and the pipe connection between an engine and the tank must be flexible in order to prevent the damage from thermal expansion.

  The tank location should be ensured to be not cooled down and keep the operating temperature. If necessary, the heater shall be considered for the tank in order to warm up the temperature of lubricating oil to 40°C before the engine starting and maintain at approx. 65°C during the engine operating.

  In order to supply the clean lubricating oil to the engine(s), suction pipes for main and stand-by pumps are required to be close to the separator return pipe and to be kept with the distance to the discharge pipes from the engine(s). In addition, suction pipe for the separator should be close to the discharge pipes from the engine(s).

  The height of suctions from the tank bottom is recommended to be minimum half of the pipe diameter. And the position of suctions for main and standby pumps should be aligned at the tank level that is filled with the lubricating oil every time.

  Total quantities of lubricating oil in the system oil tank are as follows:

Engine type	Oil quantities [L]
6H35DFP	4,000
7H35DFP	4,300
8H35DFP	4,500
9H35DFP	5,000
12H35DFVP	8,100
14H35DFVP	9,450
16H35DFVP	10,800
18H35DFVP	12,150
20H35DFVP	13,500

Table 6-2-1: Required volumes for the system oil tank

The value(s) above is only provided preliminary information purpose. It would be changed without any notice to improve the engine. In order to construct a commercial engine project, please contact HHI-EMD.

- **Design parameter : Please refer to section P.06.230**

- **Suction strainer**

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

- **Stand-by pump (PP-601)**

  It is recommended to install a stand-by pump for each engine in order to ensure lubricating engines although the stand-by pump may be omitted in some case according to the rule of classification societies. The stand-by pump is an electrical driven a gear type or a screw type pump. It is required to be protected by the suction strainers with a mesh size of approx. 0.5…1.0 mm with a magnet.

  The recommended specifications of the pump are as follows and it must be satisfied with the requirement of classification:

Delivery capacity	:	See P.02.200 “Engine Capacity Data”
Delivery pressure	:	6 bar (set by a safety valve)
Design temperature	:	100°C
Lubricating oil viscosity	:	SAE 40
Viscosity (for electric motor)	:	500 cSt (SAE 40)

Crankcase and tank ventilation

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

The arrangement should be as follows:

- When two or more engines are installed, the crank case vent pipe from each engine shall be kept independently. Lubricating oil drain pipes are also to be independent in order to avoid interaction between crankcases.
- The crankcase vent pipes from each engine shall be led independently to the top of the funnel. The pipes should not be connected with any other branch such as a tank vent, etc.
- Corrosion resistant flame screen shall be applied to each vent pipe.
- Vent pipes should have a continuous upward gradient of minimum 10° without high or low point.
- A condensate trap with draining facilities shall be applied to each vent pipe.

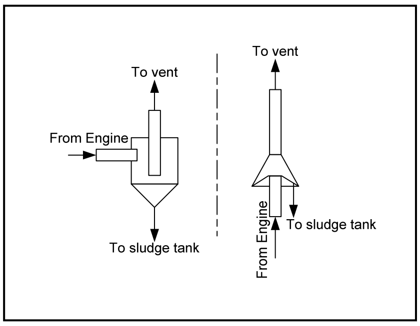

Figure 6-2-2 : an example of condensation trap

- The connection between the engine and vent pipe of the external system should be flexible, if a resilient mounting is applied.
- Size of crankcase vent pipe shall be equal or larger than engine side vent pipe.
  (See the P.06.100 “Internal Lubricating Oil System”, L1 connection.)
- The venting pipe on the tank should be arranged at the corners of the tank or at the ends of the tank to secure venting at any trim of the vessel. It shall be recommended to have minimum two lines with opposite corner each other.
- For Gas and DF engine, the ventilation pipe are to lead to a safe location outside of engine room, which is distant place from any source of ignition. A flame arrestor must be equipped at the end of the vent pipe. In addition, the arrangement of the system must be satisfied with the rules of classification societies or other related authorities.

Diagram for the external lubricating oil system (dry sump), a single engine installation

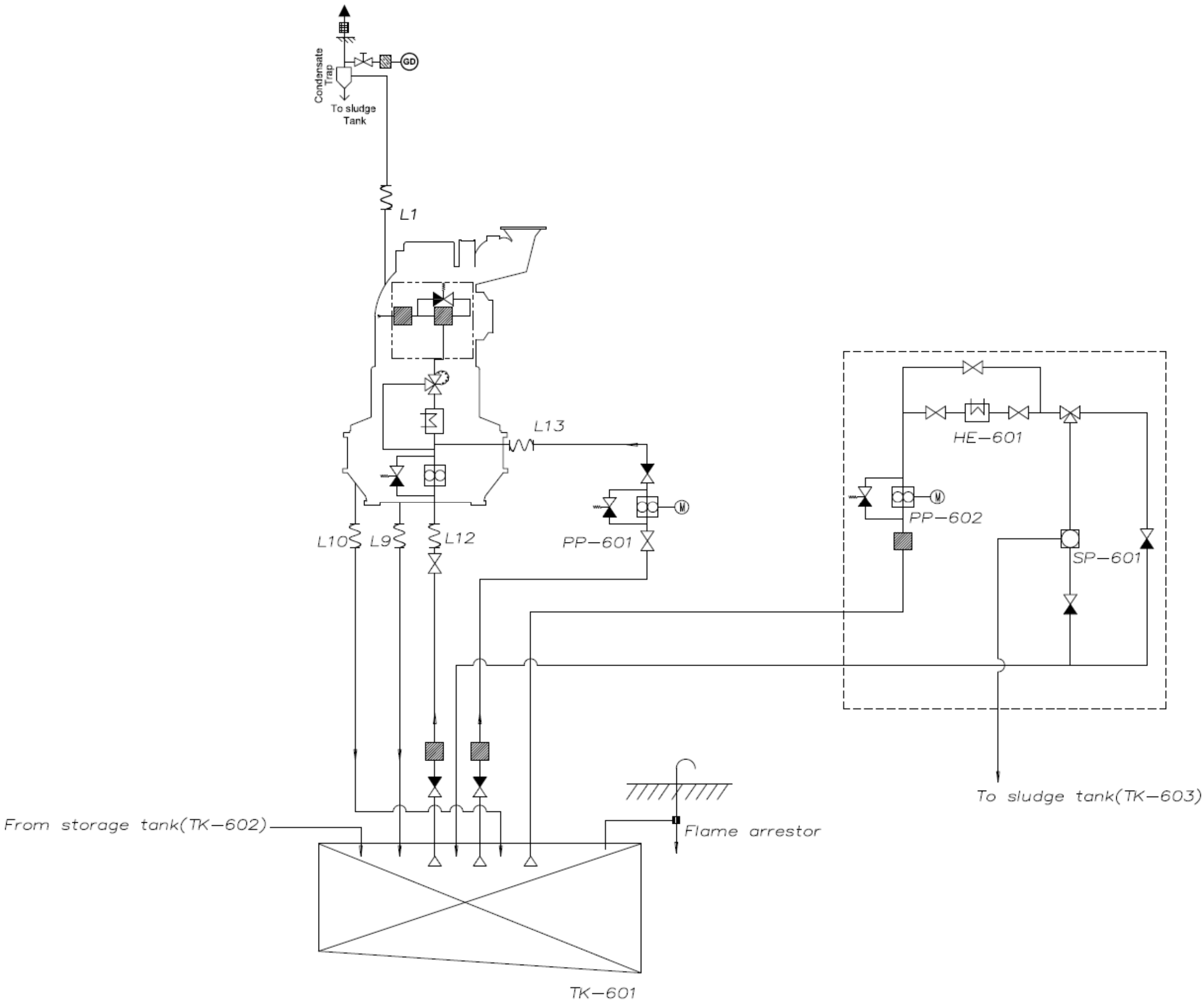

Figure 6-2-1: External lubricating oil system (Dry Sump) for a single engine installation

System components		Pipe connections	
Code	Description	Code	Description
TK-601	System oil tank	HE-601	Pre-heater for the separator
TK-602	Storage tank	PP-601	Stand-by pump
TK-603	Sludge tank	PP-602	Feed pump for the separator
SP-601	Separator		
Pipe connections			
Code	Description	Code	Description
L1	Oil vapor discharge	L12	Lubricating oil to engine drive pump
L9	Lubricating oil outlet to system oil tank (flywheel side)	L13	Lubricating oil from standby pump
L10	Lubricating oil outlet to system oil tank (free end side)		

- **Design parameter:**

The suction pipe shape is to be trumpet shape or conical, the length of suction pipe is to be as short and straight as possible and the suction pipe has a sufficient diameter in order to minimize the pressure losses. The suction height between a pump and a tank is most important in order to avoid a pump cavitation. The suction pipe also be equipped the non-return valve of flap type without spring to be self-closing. The inclination angles should be considered in accordance with classification society.

Trumpet shape (St) = 1.25 x S

Distance between tank bottom and trumpet shape pipe end = 0.5 x St

Suction and return shall be not located in the same corner of the tank and it shall be designed that drain oil should not be sucked in at once to supply clean lubricating oil to engine. In addition, suction for the separator is recommended to be close to the return lube oil from engine.

Drain pipe end should be below minimum oil level in any condition including dynamic inclination conditions of vessel.

The distance of pipe end and tank bottom: 0.5 x D

The space between maximum oil level and tank top surface is minimum 150mm or the space have to obtain the sufficient space to continuously vent via ventilation line under dynamic inclination conditions of vessel.

The minimum level alarm should be placed at a suitable height to ensure the suction of pump, Net Positive Suction Head (NPSH) of pump, free of air and inclinations of vessel. Lubricating oil must always be higher than minimum level alarm under all operating condition. The signal from low oil alarm will be delayed (Max. 30sec.) in order to prevent the wrong signal from heavy sea condition.

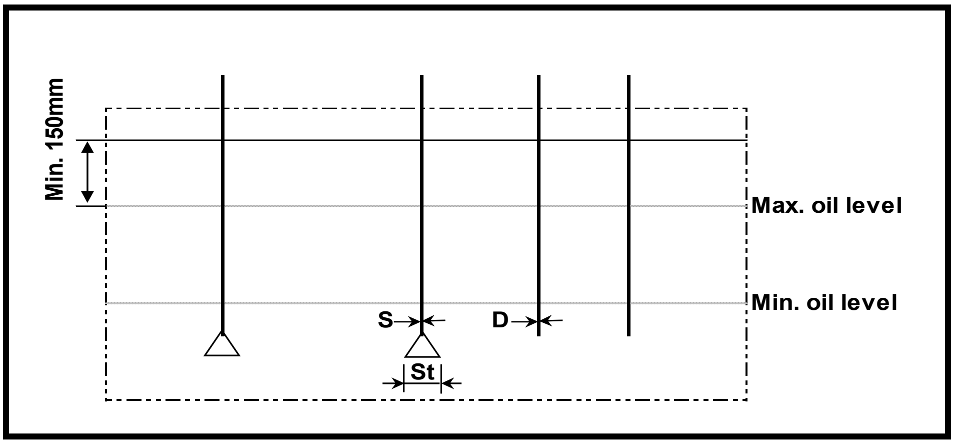

Figure 6-2-1: Example of System oil tank design

A back flushing oil from automatic filter must be discharged to sludge tank, when a further filtration is not consisted in the back flushing line. If it is considered to recycle a back flushing oil, this back flushing oil must be filtered by sludge checker or centrifugal filter.

When the back flushing oil is recycled, it is recommended to have a small drain chamber in the system oil tank. The back flushing oil from automatic filter is led to this small drain chamber and separator can also suck in the small drain chamber. Its details and principle is shown figure 6-2-1-1 and figure 6-2-1-2.

If it is impossible to consist of a small drain chamber in system oil tank, the flushing oil pipe from automatic filter and separator suction pipe should be located as close as possible. And these two lines should also be positioned as far away as possible from the engine suction line.

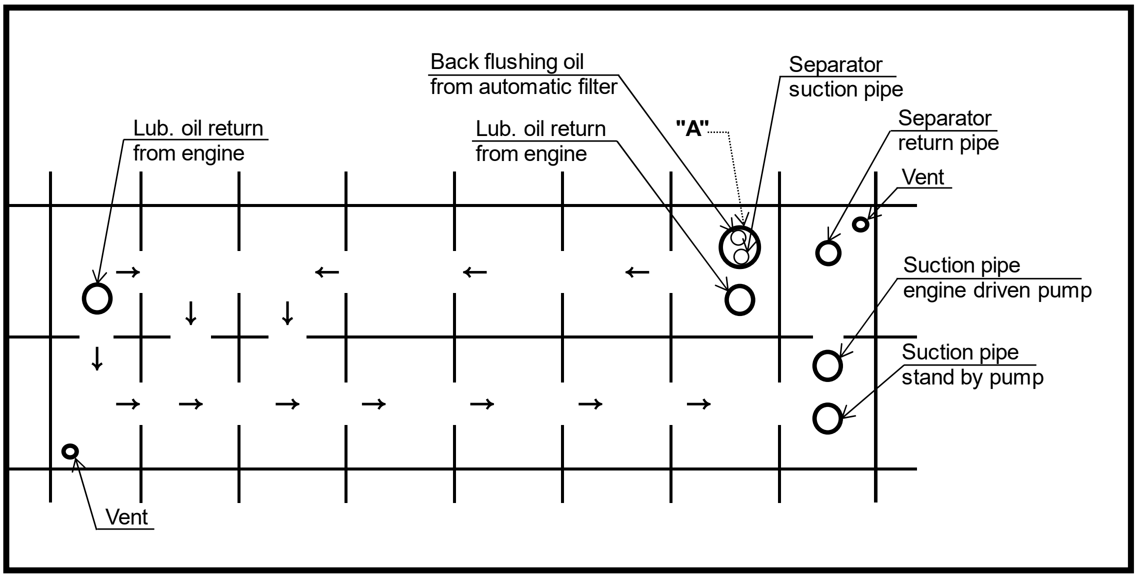

Figure 6-2-1-1: Example of System oil tank design

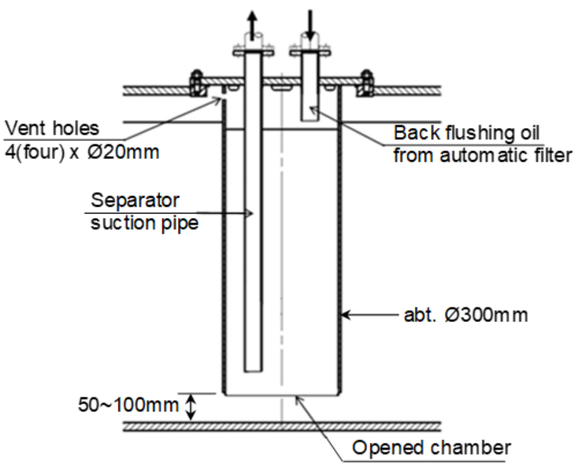

Figure 6-2-1-2: Example of "back-flushing drain tank, Detail "A"

Oil grade

The medium-alkaline, heavy duty (HD) oil in API-CD class has to be used for HiMSEN engine including the turbocharger lubrication. Please see the table “List of Lubricants”.

Oil viscosity

The oil viscosity is based on SAE 40 oil and recommended to be 145 mm^2/sec at 40°C. The initial heating of the oil up to 40°C is required prior to the engine starting.

Governor Oil Grade

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

Base number

BN (Base Number) is a measure of the alkalinity of 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.

The base number (BN) shall be carefully selected depending on the fuel grade and sulfur contents. It is important that proper balance should be maintained between the BN coming from the lubricating oil and the fuel sulfur level by choosing the proper lubricating oil in order to avoid the following problems:

- 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

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 sheet No. P.05.300 / P.05.600 for specification of fuel oil and fuel gas.

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)

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

Approved lubricating oils

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

Oil brand	Engine system lubricating oil			Governor oil
Oil company	Brand name	SAE	BN*)	
Shell	Mysella S3 N40	40	5	1) Same as Engine system L.O 2) Refer to the governor manual for detailed L.O 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 2)		50	
TOTAL (Lubmarine)	Aurelia LNG	40	5	
	Nateria X 405		5.2	
	DISOLA M 4012		12	
	DISOLA M 4015		14	
	AURELIA TI 4020		20	
	AURELIA TI 4030		30	
	AURELIA TI 4040		40	
	AURELIA TI 4055 2)		55	
Chevron (Taxaco, Caltex)	Geotex LA	40	5.2	
	DELO SHP 40		12	
	DELO 1000 Marine 40		12	
	TARO 20 DP 40(X)		20	
	TARO 30 DP 40(X)		30	
	TARO 40 XL 40(X)		40	
	TARO 50 XL 40(X) 2)		50	
ExxonMobil	Pegasus 705	40	5.3	
	Pegasus 805		6.2	
	Pegasus 905		6.2	
	Pegasus 1		6.5	
	Mobilgard ADL 40, Mobil Delvac 1640		12	
	Mobilgard 412		15	
	Mobilgard M420		20	
	Mobilgard M430		30	
	Mobilgard M440		40	
BP	CASTROL Duratex L	40	4.5	
	CASTROL MLC 40		12	

Oil brand	Engine system lubricating oil			Governor oil
Oil company	Brand name	SAE	BN*)	
BP	CASTROL MHP 154	40	15	1) Same as Engine system L.O 2) Refer to the governor manual for detailed L.O specification, volume of governor. 3) Initial filling: Oil filled 4) Electrical (Digital) Governor: Not applied
	CASTROL TLX Xtra 204		20	
	CASTROL TLX Xtra 304		30	
	CASTROL TLX Xtra 404		40	
	CASTROL TLX Xtra 504		50	
	CASTROL TLX Xtra 554		55	
SK Lubricants	SUPERMAR 13TP 40	40	13	
	SUPERMAR 24TP 40		24	
	SUPERMAR 30TP 40		30	
	SUPERMAR 40TP 40		40	
LUKOIL	Navigo TPEO 12/40	40	12	
	Navigo TPEO 15/40		15	
	Navigo TPEO 20/40		20	
	Navigo TPEO 30/40		30	
	Navigo TPEO 40/40		40	
	Navigo TPEO 50/40 2)		50	
	Navigo TPEO 55/40 2)		55	
Gulf Oil Marine	GulfSea Power MDO 4012, SeaLub Power MDO 4012	40	12	
	GulfSea Power MDO 4015, SeaLub Power MDO 4015		15	
	GulfSea Power MDO 4020, SeaLub Power MDO 4020		20	
	GulfSea Power 4030, SeaLub Power 4030		30	
	GulfSea Power 4040, SeaLub Power 4040		40	
	GulfSea Power 4055, SeaLub Power 4055 2)		55	
ENI S.p.A.	AGIP CLADIUM 120	40	12	
	AGIP CLADIUM 300		30	
	AGIP CLADIUM 400		40	
	AGIP CLADIUM 500S 2)		50	
Petronas	PETRONAS Disrol 50	40	6	
	PETRONAS Disrol 120		12	
	PETRONAS Disrol 300		32	
	PETRONAS Disrol 400		42	
	PETRONAS Disrol 500		51	
AEGEAN	ALFAMAR 430	40	30	
	ALFAMAR 440		40	
	ALFAMAR 450 2)		50	
	ALFAMAR 455 2)		55	

Oil brand	Engine system lubricating oil			Governor oil
Oil company	Brand name	SAE	BN[*)]	
SINOPEC TPEO	SINOPEC TPEO 4012	40	12	1) Same as Engine system L.O 2) Refer to the governor manual for detailed L.O specification, volume of governor. 3) Initial filling: Oil filled 4) Electrical (Digital) Governor: Not applied
	SINOPEC TPEO 4015		15	
	SINOPEC TPEO 4020		20	
	SINOPEC TPEO 4030		30	
	SINOPEC TPEO 4040		40	
	SINOPEC TPEO 4050 [2)]		50	
Hyundai Oilbank	Hyundai XTeer HGSL 40	40	4.5	
	Hyundai XTeer TPEO 4012		12	
	Hyundai XTeer TPEO 4015		15	
	Hyundai XTeer TPEO 4020		20	
	Hyundai XTeer TPEO 4030		30	
	Hyundai XTeer TPEO 4040		40	
	Hyundai XTeer TPEO 4050 [2)]		50	
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 Europa : 1.5 Liter

[1)] See P.06.300 "Lubricating Oil Specification" when selecting the BN value.

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

Remark:

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

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Performance Data **P.02.000**

Dynamic Characteristics and Noise **P.03.000**

Operation and Control System **P.04.000**

Fuel System **P.05.000**

Lubricating Oil System **P.06.000**

Cooling Water System **P.07.000**

Air and Exhaust Gas System **P.08.000**

Engine Maintenance **P.09.000**

Theoretical Performance **P.10.000**

Electric Control System **P.11.000**

Appendix

Diagram for the internal cooling water system

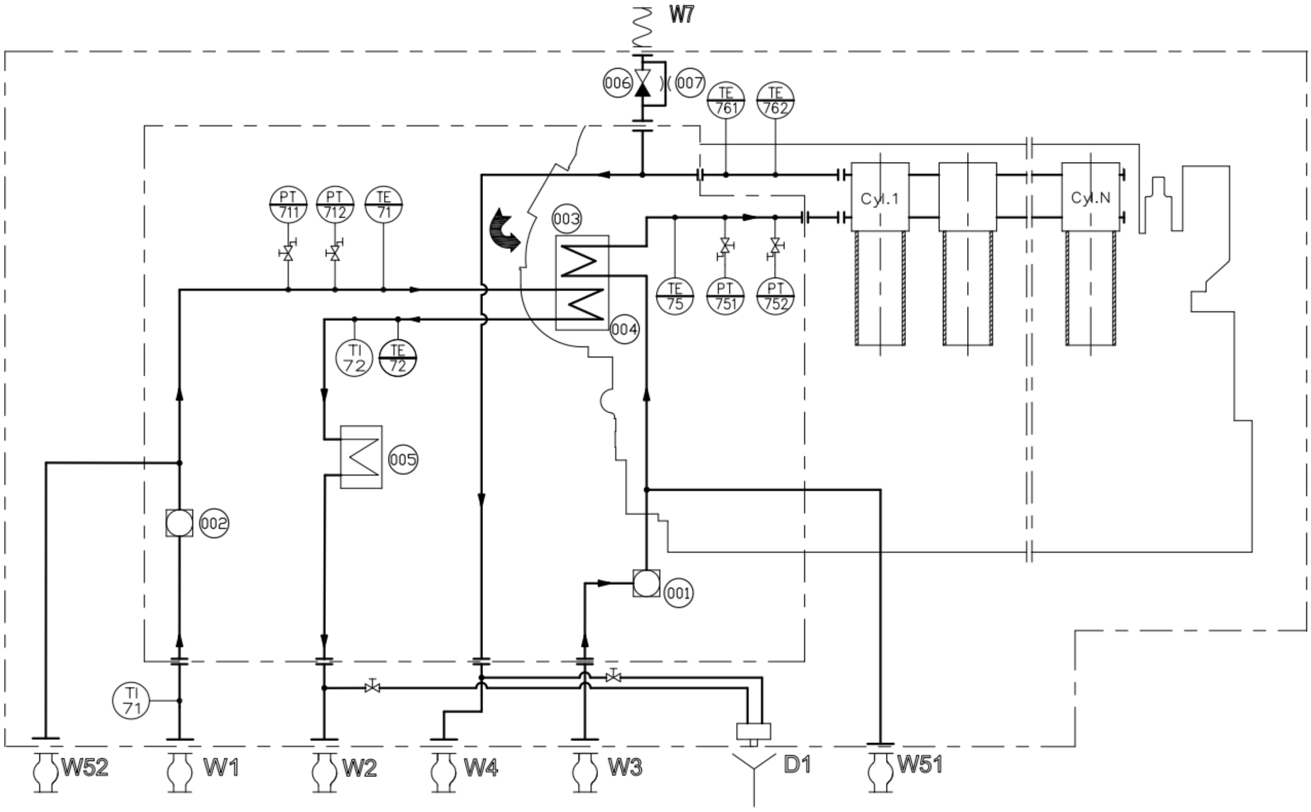

Figure 7-1-1 : In-line engine internal cooling water system

System components

No.	Description	Remark
001	H.T. Cooling water pump	
002	L.T. Cooling water pump	
003	H.T. Charge air cooler	
004	L.T. Charge air cooler	
005	Lubricating oil cooler	
006	Non-return valve	
007	Orifice	

Sizes of the external pipe connections

Code	Description	Size	Standard
W1	L.T cooling water inlet	5K - 125A	JIS B 2220
W2	L.T cooling water outlet	5K - 125A	JIS B 2220
W3	H.T cooling water inlet	5K - 125A	JIS B 2220
W4	H.T cooling water outlet	5K - 125A	JIS B 2220

Code	Description	Size	Standard
W5	L.T cooling water Stand-by inlet	5K – 125A	JIS B 2220
W6	H.T cooling water Stand-by inlet	5K – 125A	JIS B 2220
W7	Venting to expansion tank	5K - 25A	JIS B 2220

Remark:

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

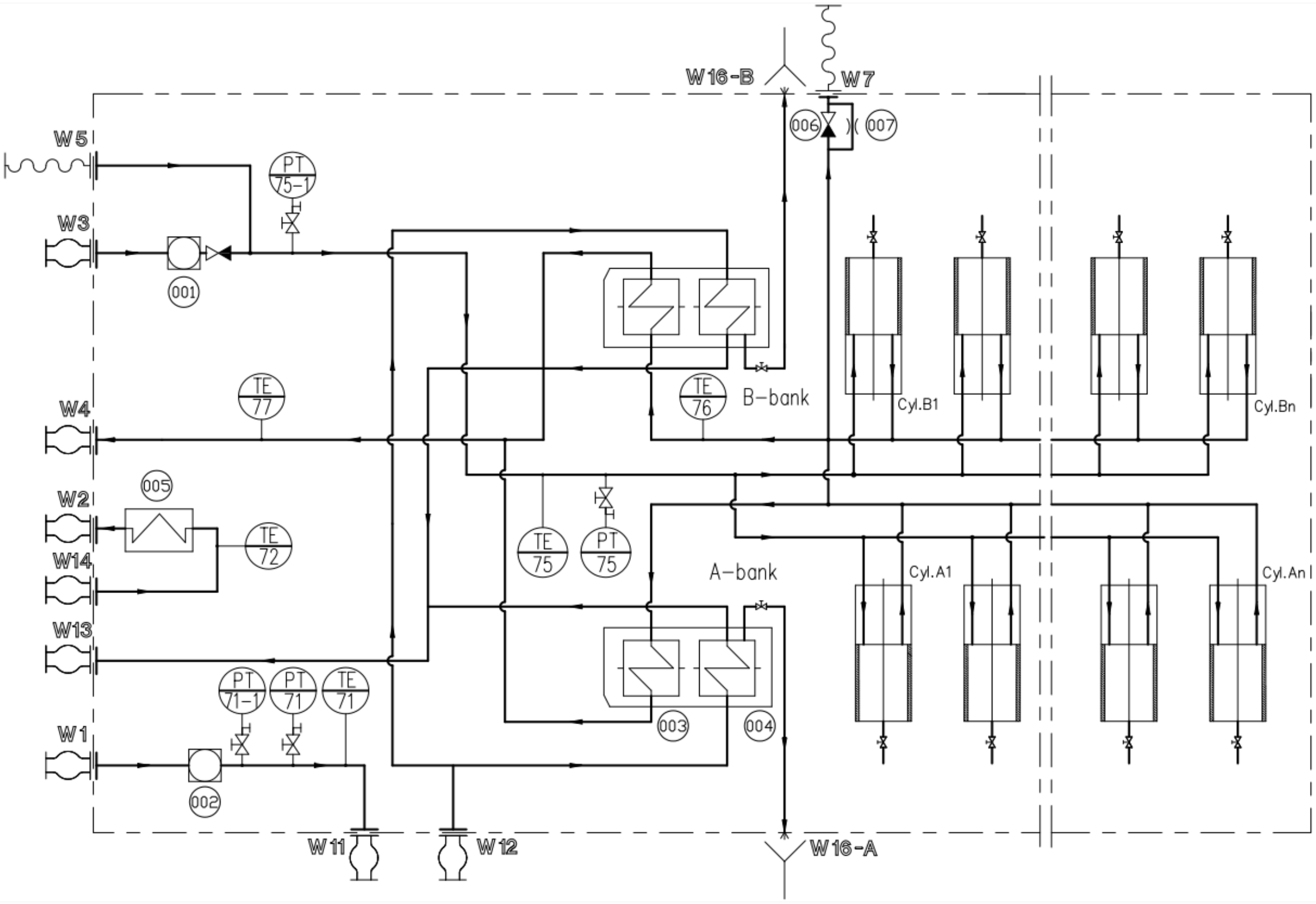

Figure 7-1-2 : V-type engine internal cooling water system

System components

No.	Description	Remark
001	H.T. Cooling water pump	
002	L.T. Cooling water pump	
003	H.T. Charge air cooler	
004	L.T. Charge air cooler	
005	Lubricating oil cooler	
006	Non-return valve	
007	Orifice	

Sizes of the external pipe connections

Code	Description	Size	Standard
W1	L.T cooling water inlet	5K - 125A	JIS B 2220
W2	L.T cooling water outlet	5K - 125A	JIS B 2220

Code	Description	Size	Standard
W3	H.T cooling water inlet	5K - 125A	JIS B 2220
W4	H.T cooling water outlet	5K - 125A	JIS B 2220
W5	L.T cooling water Stand-by inlet	5K – 125A	JIS B 2220
W6	H.T cooling water Stand-by inlet	5K – 125A	JIS B 2220
W7	Venting to expansion tank	5K - 40A	JIS B 2220
W11	L.T cooling water outlet to CAC	5K – 125A	JIS B 2220
W12	L.T cooling water inlet to CAC	5K – 125A	JIS B 2220
W13	L.T cooling water outlet to L.O cooler	5K – 125A	JIS B 2220
W14	L.T cooling water inlet to L.O cooler	5K – 125A	JIS B 2220

Remark:

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

General

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

The L.T cooling water circulates through an air cooler(s) and a lubricating oil cooler built on the engine. It should be circulated with the sufficient flow and proper temperature by the L.T cooling water pump.

The H.T cooling water circulates through cylinder jackets and a charger air cooler(s), and heads by the H.T cooling water pump. The temperature of the H.T cooling water circulation in the engine should be regulated by the thermostatic valve.

The L.T and H.T cooling water pump are driven by the engine. They are of a centrifugal type and built on the free side of the engine. For the pump flow rate at MCR, see P.02.200 "Engine Capacity Data".

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

- Charge air cooler
- Lubricating oil cooler
- L.T cooling water pump, engine driven
- H.T cooling water pump, engine driven

Pressure drops

The pressure drops over the engine are as follows:

H.T circuit: approx. 1.0 bar

L.T circuit: approx. 0.8 bar

Water volumes

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

Engine type	Volumes of the H.T and L.T cooling water [L]
6H35DFP	582
7H35DFP	617
8H35DFP	651
9H35DFP	686
12H35DFVP	1,164
14H35DFVP	1,234
16H35DFVP	1,302
18H35DFVP	1,372
20H35DFVP	1,460

Table 7-1-1 Total water volumes in an engine

The value(s) above is only provided preliminary information purpose. It would be changed without any notice to improve the engine. In order to construct a commercial engine project, please contact HHI-EMD.

Preheating system

In order to ensure the engine initial start on HFO/MDO and quick load-up, the H.T cooling water in the engine is required to be pre-heated up to the required minimum temperature.

The preheating system must be provided on the external cooling water system.

Preheating for all engines is recommended.

For an external preheating system, please see “Preheating system” in P.07.200 External cooling water system

Operation

Before the initial engine start on HFO/MDO, the preheating system should be always running when the engine is positioned at the initial start. It is recommended that the preheater should be arranged for automatic operation, so that the pre-heater is disconnected during engine running and it is connected during engine being in stand-by condition.

Remark

1. When the engine is in standstill, external valves connected to the cooling water inlet must be shut off.

General

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

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

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

Cooling water circulation system

- **LT Circulation pump (PP-701)**

  The circulation pump should be of centrifugal type and electrically driven. The pump is required to be redundant so that the one can be overhauled while the other one is in service.

  Except the application with constant speed operation only, it is recommended for the vessel to have circulation pumps in order to keep the fresh water flow.

- **LT Central cooler (HE-701)**

  The central cooler can be of shell & tube or plate type. It can be in common with other engines or an independent cooler for each engine.

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

  The specifications of each cooler should be as follows:

Required heat dissipation	:	See P.02.200 "Engine Capacity Data". (It should include the margin of 15% for fouling.)
Temperature of the fresh water after the cooler	:	max. 36°C

Flow rate of the fresh water	:	same as the total delivery capacity of the LT system
Flow rate of the sea water	:	typically 1.5 times of the fresh water flow (It should be recommended by the manufacturer of the cooler.)
Pressure drop on the fresh water side	:	max. 0.5 bar
Pressure drop on the sea water side	:	typically 1.0…1.5 bar (It should depend on the specifications of the sea water pump.)

- **Charge air temperature control valve (TV-701)**

The temperature control valve should be installed after each engine to maintain the temperature of charge air by L.T cooling water at the engine lube oil cooler outlet. It is required to be as a dividing three-way valve and should be of a motor-operated or an electric pneumatic type.

The valve shall be actuated via an electric signal from the engine control system which will monitor the temperature of the charge air continuously.

- **H.T Thermostatic valve (TV-702)**

The thermostatic valve should be installed after each engine to maintain the temperature of H.T cooling water at the engine jacket outlet. It is required to be as a dividing three-way valve and should be of a motor-operated or an electric pneumatic type.

The valve shall be actuated via an electric signal from the engine control system which will monitor the temperature of the engine jacket outlet continuously.

- **Thermostatic valve for L.T central cooler (TV-703)**

In order to control the temperature of the fresh water before the engine(s), the thermostatic valve should be provided after the L.T central cooler. It is required to be as a mixing three-way valve and can be of a motor-operated type, an electric pneumatic, or a wax thermostat.

- **Thermostatic valve for H.T central cooler (TV-704)**

In order to control the temperature of the fresh water after the engine(s), the thermostatic valve should be provided before the H.T central cooler. It is required to be as a dividing three-way valve and can be of a motor-operated type, an electric pneumatic, or a wax thermostat.

- **Stand-by pump for H.T cooling water circuit (PP-702)**

The H.T stand-by pump is required for the vessel with a single propulsion engine which is provided with an engine driven H.T pump. It is also can be applied in multi engine.

The pump should have the same capacity as the required H.T cooling water flow of the engine. And it should be of a centrifugal type and electrically driven.

The specification of the pump should be as follows:

Delivery capacity	:	See P.02.200 “Engine Capacity Data”.
Delivery Head	:	3 bar

- **Stand-by pump for L.T cooling water circuit (PP-704)**

The L.T stand-by pump is required for the vessel with a single propulsion engine which is provided with an engine driven L.T pump. It is also can be applied in multi engine.

The pump should have the same capacity as the required L.T cooling water flow of the engine. And it should be of a centrifugal type and electrically driven.

The specification of the pump should be as follows:

Delivery capacity	:	See P.02.200 “Engine Capacity Data”.
Delivery Head	:	3 bar

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

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

In order to avoid a cavitation, the tank should provide the positive static pressure of minimum 0.5 bar (5 meters above the crankshaft of the engine) on the suction side of the pump(s).

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

For DF(dual fuel)/Gas engine, the arrangement and structures of the expansion tank and vent system should be satisfied with the requirement of classification society, or other applicable standards.

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

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

Preheating system

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

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

- **Pre-heater for H.T cooling water (HE-703)**

  The H.T cooling water in the engine should be able to be heated from 10°C up to minimum 60°C within 4…10 hours by the pre-heater. The heating source can be steam or electric power.

  The specification of the pre-heater should be as follows:

Heat capacity	:	min. 6 kW per cylinder depending on the heater's operation hours
Temperature of the cooling water after the heater	:	min. 40°C (Marine Diesel Oil operation) min. 60°C (Heavy Fuel Oil operation)
Flow rate of the cooling water	:	same as the delivery capacity of the circulation pump for the preheater
Pressure drop on the cooling water side	:	max. 0.5 bar

- **Electric pre-heating element (Option for H35DFP)**

  The mount type on the cooling water pre-heating 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˚C which provides water (60˚C) to jacket water outlet.

- **Circulation pump for pre-heater (PP-703)**

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

  The specification of the pump should be as follows:

Delivery capacity	:	min. 0.4 m^3/h per cylinder depending on the heater's operation hours
Delivery Head	:	1 bar

Diagram for the external cooling water system
(Multi-engine installation with external preheater units)

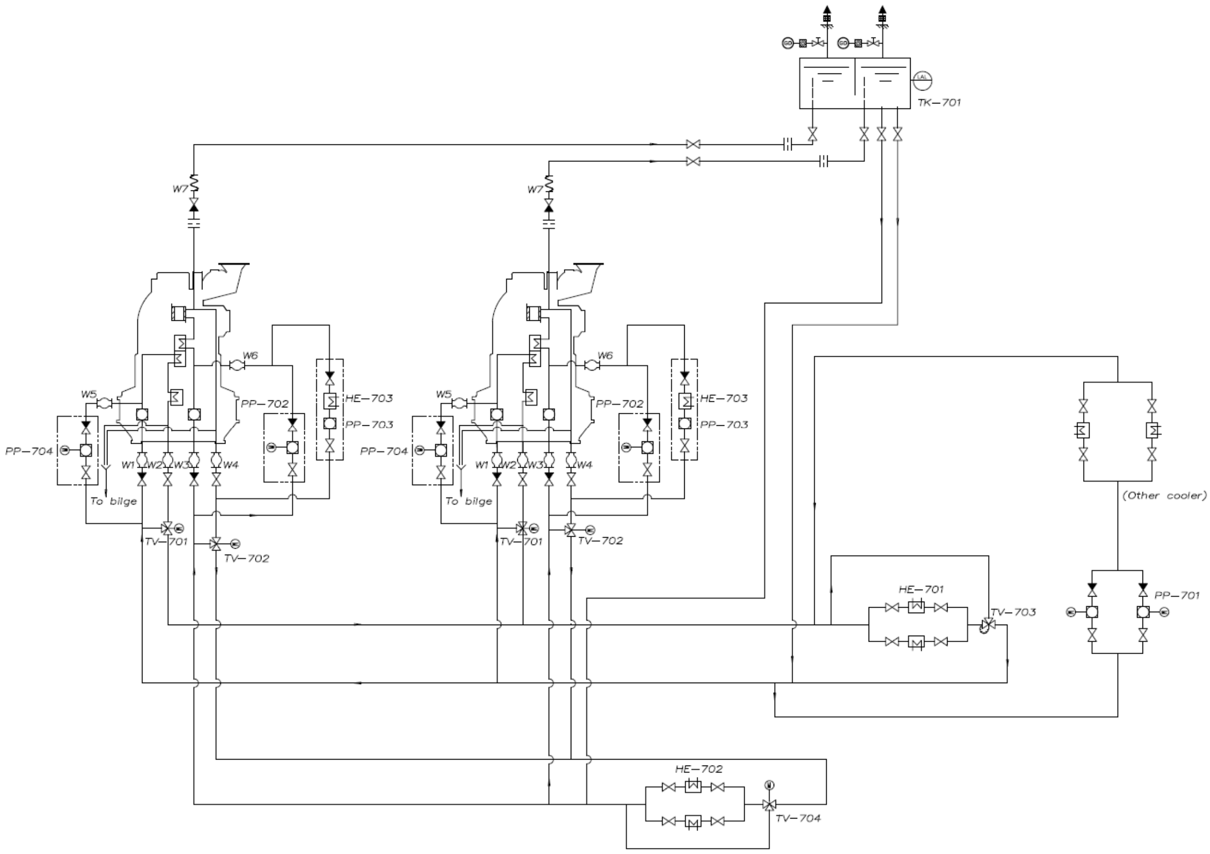

Figure 7-2-1: External cooling water system for multi-engine installation with external preheater units

System components			
Code	Description	Code	Description
TK-701	Expansion tank	TV-703	Thermostatic valve for L.T central cooler
HE-701	L.T Central cooler	TV-704	Thermostatic valve for H.T central cooler
HE-702	H.T Central cooler	PP-701	LT Circulation pump
HE-703	Pre-heater for H.T cooling water	PP-702	Stand-by pump for H.T cooling water circuit
TV-701	Charge air temperature control valve	PP-703	Circulation pump for preheating
TV-702	H.T Thermostatic valve	PP-704	Stand-by pump for L.T cooling water circuit

Pipe connections			
Code	Description	Code	Description
W1	L.T cooling water inlet	W5	L.T cooling water Stand-by inlet
W2	L.T cooling water outlet	W6	H.T cooling water Stand-by inlet
W3	H.T cooling water inlet	W7	H.T cooling water ventilation to expansion tank
W4	H.T cooling water outlet	D1	Water drain

Quality of cooling water

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

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

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

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

Remark:

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

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

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

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

Treatment of cooling water

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

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

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	Nitrite, Borate	Liquid	128 liter / 1000 liter
	TRAC100	Molybdate, silicate	Liquid	17.5 liter / 1000 liter
	TRAC108	Nitrite, Borate	Liquid	28 liter / 1000 liter
GE	CorrShield NT4200	Nitrite	Liquid	30 liter / 1000 liter
Water & Process Technologies				
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

Remark:

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

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Appendix

Diagram for the internal compressed air system

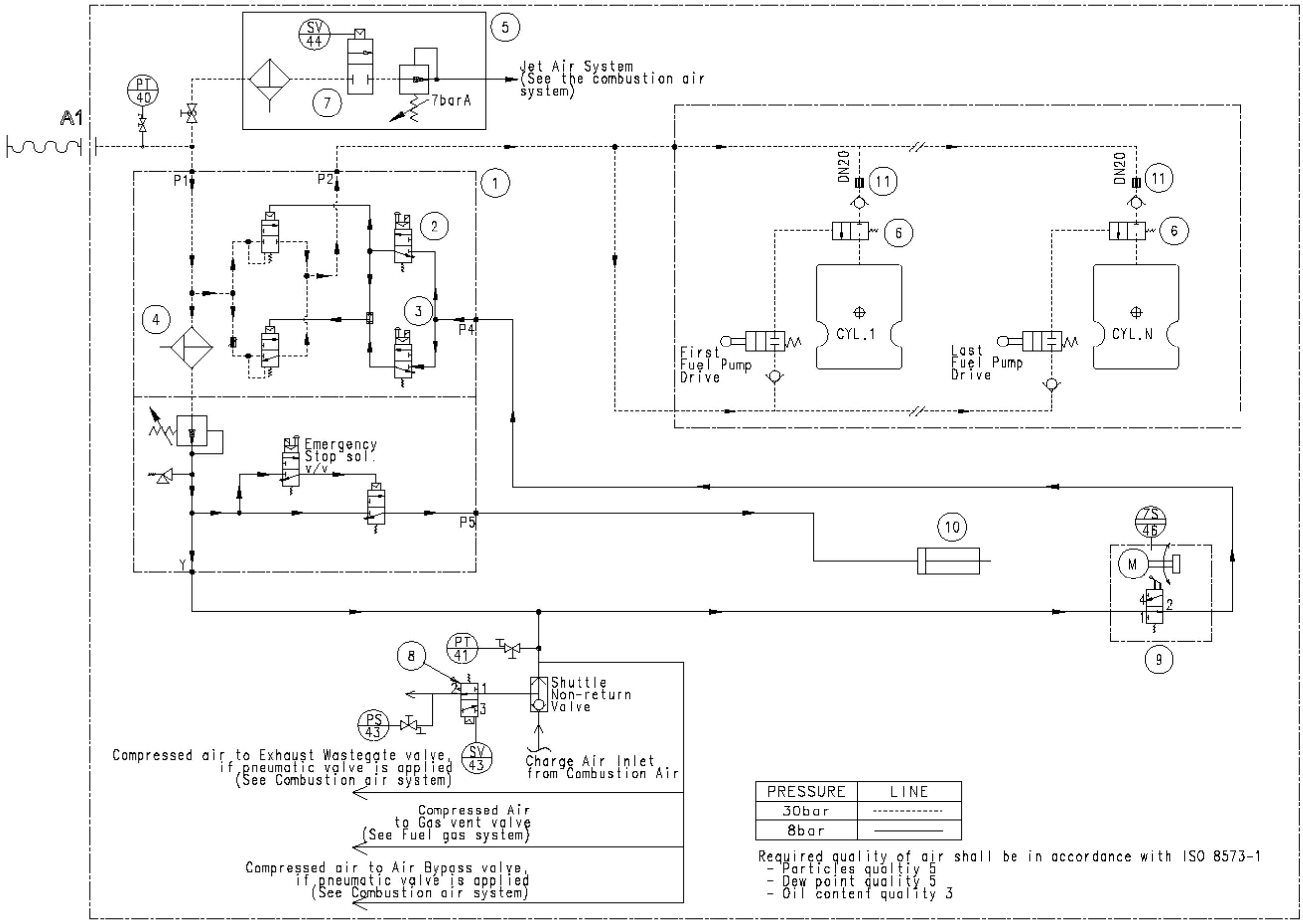

Figure 8-1-1: In-line engine internal compressed air system

System components

No.	Description	Remark
001	Main air starting valve module	
002	Starting solenoid valve	
003	Solenoid valve for slow turning	
004	Air filter	
005	Reducing valve unit	
006	Starting valve	
007	Solenoid valve for Jet assist air	
008	Solenoid valve for dual valve timing	
009	Turning gear	
010	Emergency stop cylinder	
011	Flame arrestor	

Size of external pipe connections

Code	Description	Size	Standard
A1	Compressed air inlet	30K - 50A	JIS B 2220

Remark:

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

Diagram for the internal compressed air system

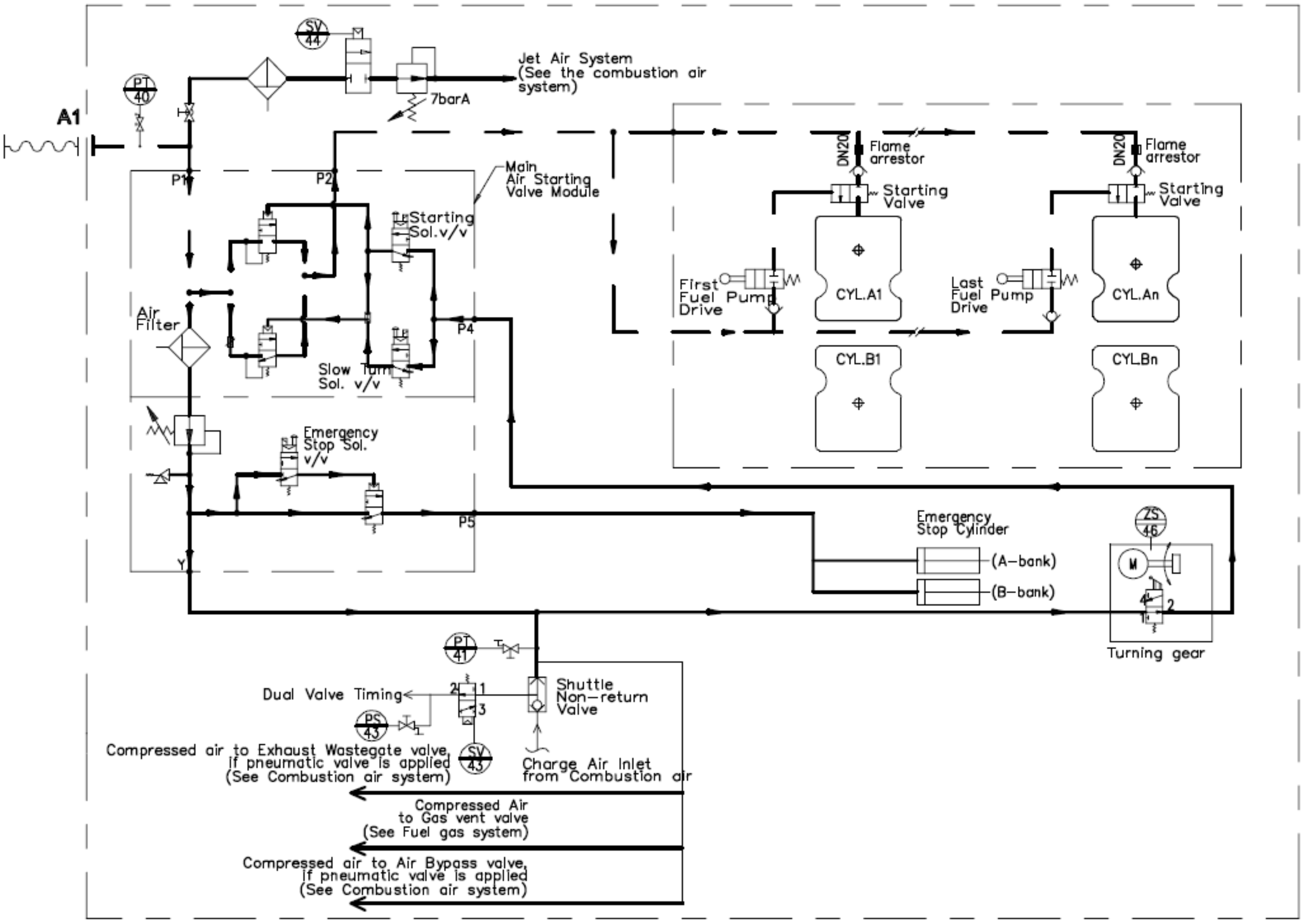

Figure 8-1-2 : V-type engine internal compressed air system

System components

No.	Description	Remark
001	Main air starting valve module	
002	Starting solenoid valve	
003	Solenoid valve for slow turning	
004	Air filter	
005	Reducing valve unit	
006	Starting valve	
007	Solenoid valve for Jet assist air	
008	Solenoid valve for dual valve timing	
009	Turning gear	
010	Emergency stop cylinder	
011	Flame arrestor	

Size of external pipe connections

Code	Description	Size	Standard
A1	Compressed air inlet	30K - 50A	JIS B 2220

Remark:

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

General

Compressed air is supplied to start the engine, stop the engine in emergency situations and actuate some pneumatic devices such as an air bypass valve and an exhaust waste gate valve. When the built-on turning gear is engaged, the compressed air for the engine start is cut-off and the engine cannot be started.

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

- Engine starter complete
- Pressure reducing valve and air filter
- Solenoid valve for the jet assist
- Solenoid valve for the dual valve timing system
- Solenoid valve for slow turning
- Air cylinder for the emergency stop

Engine start

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

Emergency stop

The emergency stop valve is incorporated into a main starting valve module. In case the emergency stop function is activated, compressed air flows through the emergency stop cyliner to an air cylinder(s) which pushes governor linkages not to move the fuel pump racks.

Jet assist

The jet assist system is used to improve the acceleration response of the engine. When the jet assist function is activated, the compressed air through a solenoid valve is injected through nozzle into the downstream right after a turbocharger compressor. It leads the acceleration of the turbocharger and consequently improves the engine response.

General

The external compressed air system should be properly designed for a nominal pressure of 30 bar and also satisfies the requirements of the corresponding classification societies. The system can supply compressed air to other engines as a common system or an independent system for one engine. In case of a common system, it should be able to ensure sufficient air supply to each engine with required flow and pressure. In general, the classification societies require that a total capacity divides into at least two equal size starting air vessels and starting air compressors.

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

- A dry and clean air is essential for the reliable functions of the engine starting and control system. And the required air quality shall be referred to the ISO 8573-1:2010 Class 5.5.3. Therefore, the appropriate separation equipment should be included in the external system.
- The air pipes and vessels should be arranged with a slope to ensure a good drainage of condensate. In addition, it is required to be equipped with the automatic or manual drain system at the lowest point.

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

External compressed air system

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

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

  The approximate volume of air vessels is as shown in the table below.

Table 8-2-1: Volume for air vessels

Engine Type	Volume [L] based on 1000 mbar, 0°C 3)	
	Single main engines 1)	Twin main engines 2)
6H35DFP	2 x 1,300	2 x 2,200
7H35DFP	2 x 1,400	2 x 2,500
8H35DFP	2 x 1,600	2 x 2,700
9H35DFP	2 x 1,700	2 x 2,900
12H35DFVP	2 x 2,100	2 x 3,600
14H35DFVP	2 x 2,300	2 x 4,100
16H35DFVP	2 x 2,600	2 x 4,500
18H35DFVP	2 x 2,800	2 x 4,900
20H35DFVP	2 x 3,100	2 x 5,300

[1] *For a single propulsion ship where one engine is coupled to a shaft through reduction gear.*

- *The number of starting: 6 starts*

[2] *For a twin propulsions ship where there are two engines and each engine is coupled to each shaft through reduction gears, or for a single propulsion ship where two engines are coupled with a shaft through clutch and reduction gear.*

- *The number of starting: 12 starts*

[3] *These values on the table are based on 1000 mbar, 0℃*
In order to fit the condition of vessel and plant, the volume can be increased depending on ambient condition such as tropical condition.

Remark:

1. The volume above is based on the condition, the gearbox and propeller shaft are disengage.
2. The volume in the table above is for guidance only and shall be satisfied with the requirement of classification societies for each project.

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

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

V_r [L] = total volume of starting air vessels for the number of starts required by classification societies
V_{st} [L] = air consumption per start
N_{st} [-] = number of starts required by classification societies
N_{margin} [-] = starts margin (option 1 start)
V_{Jet} [L] = air consumption per jet assist
N_{Jet} [-] = number of jet assist (typically 1…3 times)
t_{Jet} [s] = duration of jet assist (typically 5 seconds)
P_{max} [bar] = maximum starting air pressure
P_{min} [bar] = minimum starting air pressure. For the V_r calculation, it is highly recommended to use a minimum starting air pressure of 18bar.

For propulsion application, if the engine starts while it is engaged with a propeller shaft, the capacity of each air vessel should increase accordingly to supply enough air to the jet assist system or an additional air vessel may be required.

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

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

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

At least two air compressors are required in the external compressed air system and should be arranged to be able to charge each air vessel. At least one of the air compressors shall be independently driven of the main engine.

A total capacity of the air compressors should be sufficient for charging the air vessels from atmospheric pressure to maximum pressure within one hour. Each compressor is to have sufficient capacity to supply minimum 50% of the required total capacity.

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

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

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

V_c [m³/h] = total capacity of compressors
P_{max} [bar] = maximum starting air pressure
t [h] = air vessel filing time from empty
V_r [m³] =total volume of starting air vessels for the number of starts required by classification societies

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

- **Oil and water separator (WS-801, WS-802)**

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

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

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

Diagram for the external compressed air system, a single engine installation

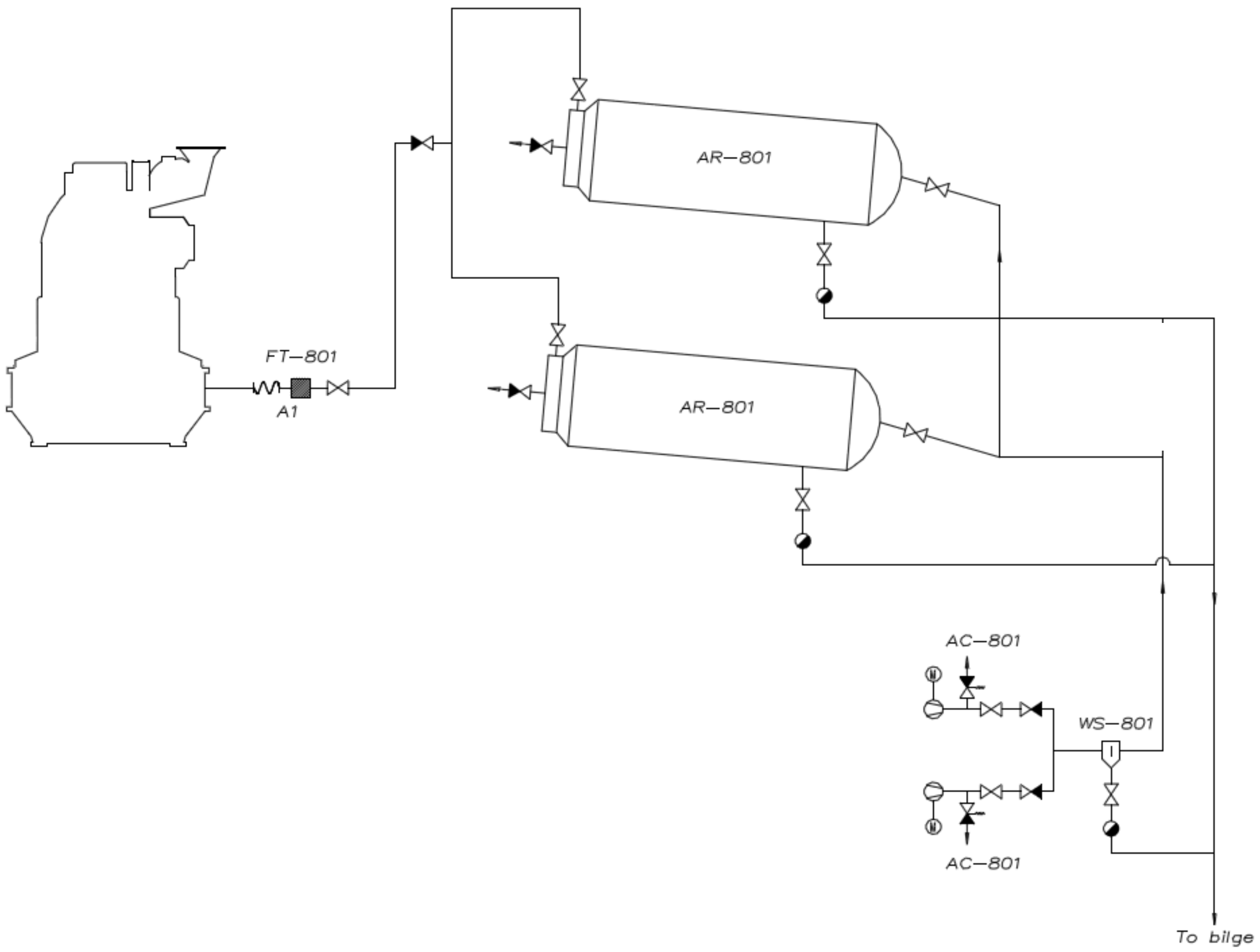

Figure 8-2-1: External compressed air system for a single engine installation

System components			
Code	Description	Code	Description
AR-801	Air vessel	FT-801	Filter with water trap
AC-801	Air compressor	WS-801	Oil and water separator
Pipe connections			
Code	Description	Code	Description
A1	Compressed air inlet		

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

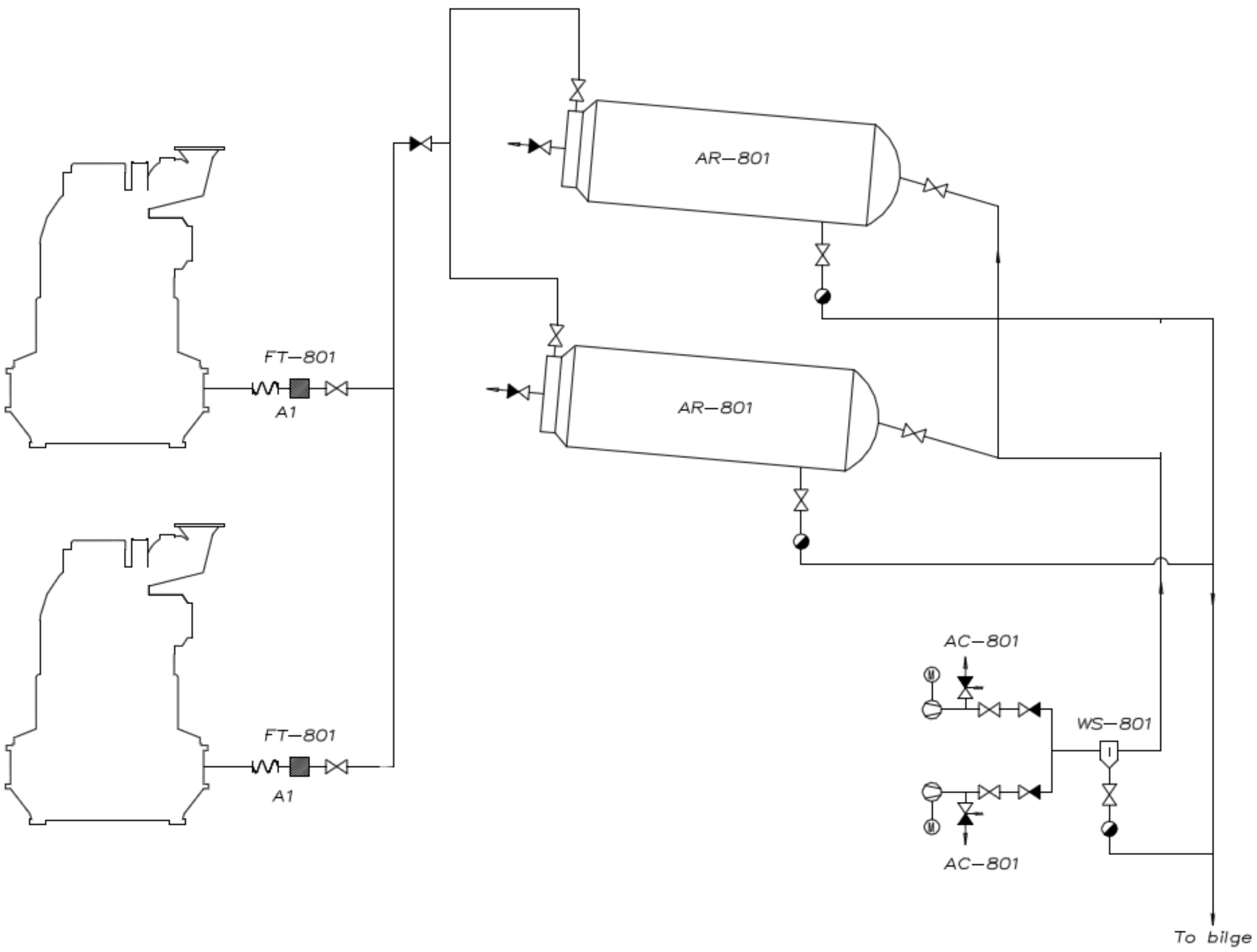

Figure 8-2-2: External compressed air system for multi-engine installation

System components			
Code	Description	Code	Description
AR-801	Air vessel	FT-801	Filter with water trap
AC-801	Air compressor	WS-801	Oil and water separator
Pipe connections			
Code	Description	Code	Description
A1	Compressed air inlet		

Diagram for the combustion air and exhaust gas system

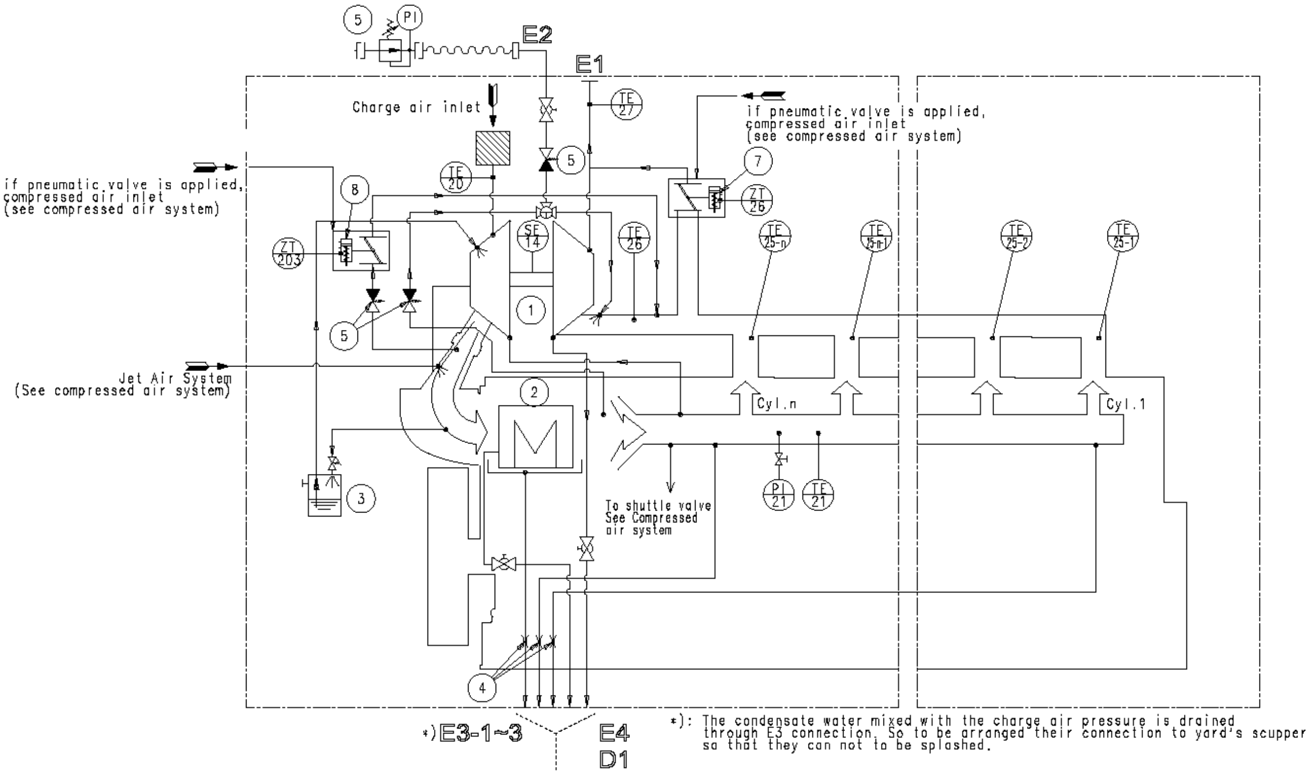

Figure 8-3-1: Internal combustion air and exhaust gas system

System components

No.	Description	Remark
001	Turbocharger	
002	Charge air cooler	
003	Water container	
004	Orifice	
005	Non-return valve	
006	Turbine cleaning hose Ass'y	
007	Exhaust Waste gate valve	
008	Air bypass valve	

Size of the external pipe connections

Code	Description	Size	Standard
E1	Exhaust gas outlet	1)	2K JIS F 7805
E2	Water inlets for the turbine washing	OD 20	Quick releasing
E3 - 1	Water drain -1	OD 25-15	Bite type Conn. Water mist catcher: Ø25 Drain: Ø15

E3 - 2	Water drain -2	OD 10	Bite type Conn.
E3 - 3	Water drain -3	OD 10	Bite type Conn.
E4	Water drain from turbine	OD 28	Bite type Conn.
D1	Water drain	OD 25	Bite type Conn.

[1)] *See P.08.510 "Exh. Gas Pipe Connection".*

Remark:

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

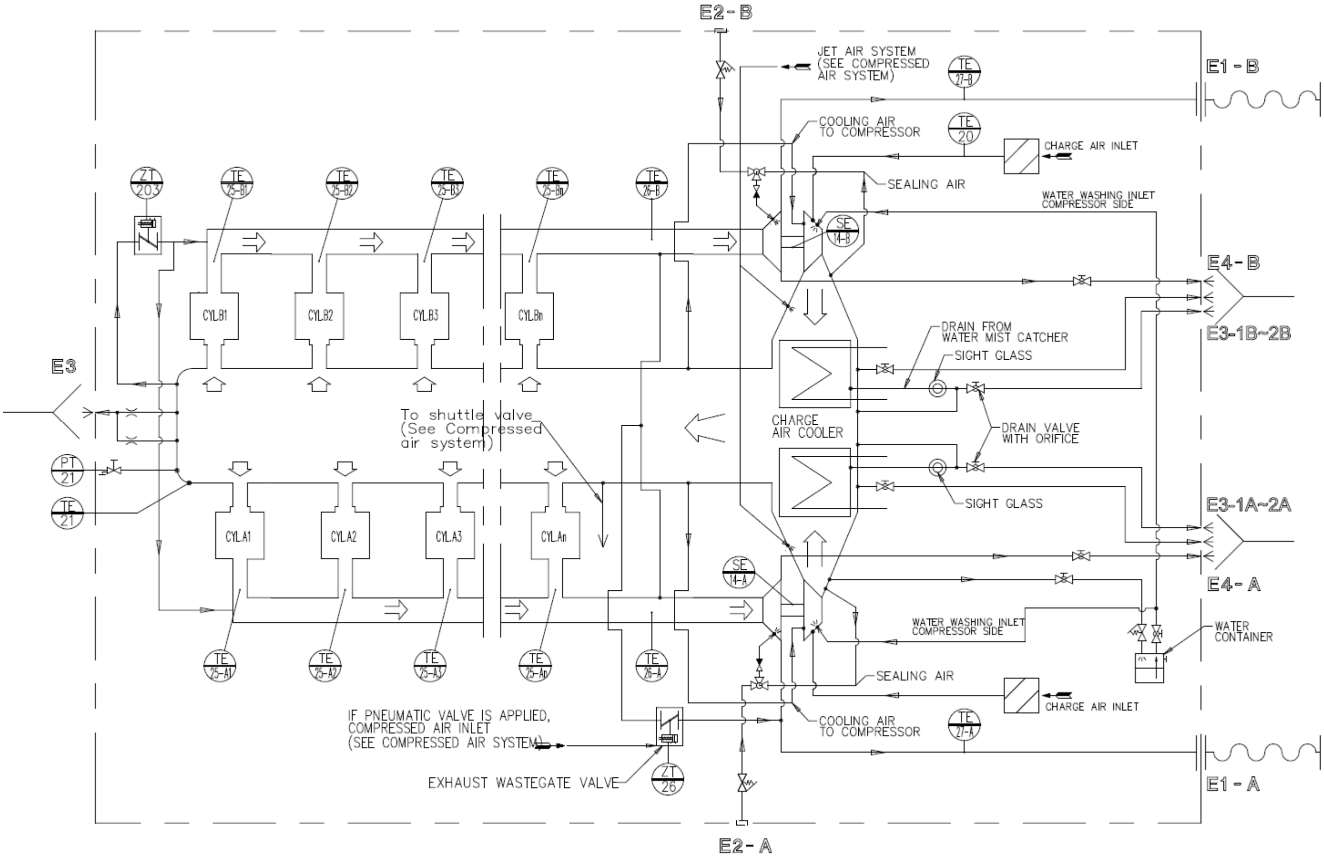

Figure 8-3-2 : V-type engine internal combustion air and exhaust gas system

System components

No.	Description	Remark
001	Turbocharger	
002	Charge air cooler	
003	Water container	
004	Orifice	
005	Non-return valve	
006	Turbine cleaning hose Ass'y	
007	Exhaust Waste gate valve	
008	Air bypass valve	

Size of the external pipe connections

Code	Description	Size	Standard
E1 – A/B	Exhaust gas outlet from a/b bank	1)	2K JIS F 7805
E2 – A/B	Water inlets for the turbine washing	OD 20	Quick releasing
E3	Charge air drain	OD 10	Bite type Conn.
E3 – 1A/B	Air cooler drain -1(A/B – Bank)	25A	Bite type Conn.
E3 – 2A/B	Air cooler drain -2(A/B – Bank)	25A	Bite type Conn.
E4 – A/B	Drain from turbine(A/B – Bank)	OD 28	Bite type Conn.

1) *See P.08.510 "Exh. Gas Pipe Connection".*

Remark:

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

General

Air required for the combustion is taken from an engine room generally through a filter(s) fitted on a turbocharger(s). The combustion air should be free from sea water, dust and fumes, etc.

The engine is equipped with a turbocharger(s) which is of a radial type with high efficiency. The turbocharger(s) can be mounted on a free end or a flywheel side of the engine. In order to maintain a reliable engine performance, it is strongly recommended to wash compressor and turbine wheels of the turbocharger periodically by the water washing systems.

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

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

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

- Turbocharger
- Charge air cooler
- Water mist catcher
- Exhaust pipe system
- Exhaust waste gate valve for DF/Gas engine, or some special case
- Air bypass valve for DF/Gas propulsion engine, or some special case

General

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

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

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

Combustion air

- **Arrangement of air intake pipes**

  The arrangement of air intake pipes should be made to supply fresh air for the reliable engine combustion, which should be free from any risk of water spray, exhaust gas, dust, oil mist and electric equipment, etc. The piping system of intake air should be considered to allow thermal expansion and harmful vibration to avoid stress of pipe. The end of deep slope position of intake pipe, cleanable waste trap and water drain should be prepared.

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

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

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

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

- **Air velocity**

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

- **Air consumption volume**

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

- **Air filtration**

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

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

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

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

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

Ventilation of the engine room

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

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

Q [m³/h] = required air amount for the ventilation of the engine room
Q_c [m³/h] = required air flow for the engine combustion
Q_e [kJ/h] = engine radiation heat
Q_a [kJ/m³] = air conditioning factor (typically 12)
Q_v [m³/h] = required air ventilation for other heat sources such as generator, exhaust gas pipes, etc.

Remark

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

General

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 exhaust 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 recommended 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 continuous rating. The maximum back pressure should not exceed 500 mm WC at maximum continuous rating. Please see the sheets '3.6 correction of fuel oil consumption' for the fuel consumption correction in case of exceeding 300 mmWC at maximum continuous rating. The measuring position is approx. 1 ~ 2 m after the turbocharger gas outlet casing.

Velocity

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

Insulation

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

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 bending 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.

Expansion joint (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 joint

- - 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.

Exhaust gas boiler

Thermal energy of exhaust gas can be utilized by boiler. Please refer to the sheets 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.

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

Silencer

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

For more information, see P.08.600 “Silencer with Spark Arrestor”, and P.08.610 “Silencer without Spark Arrestor”.

Exhaust gas ventilation unit

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 gastight.

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.

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.

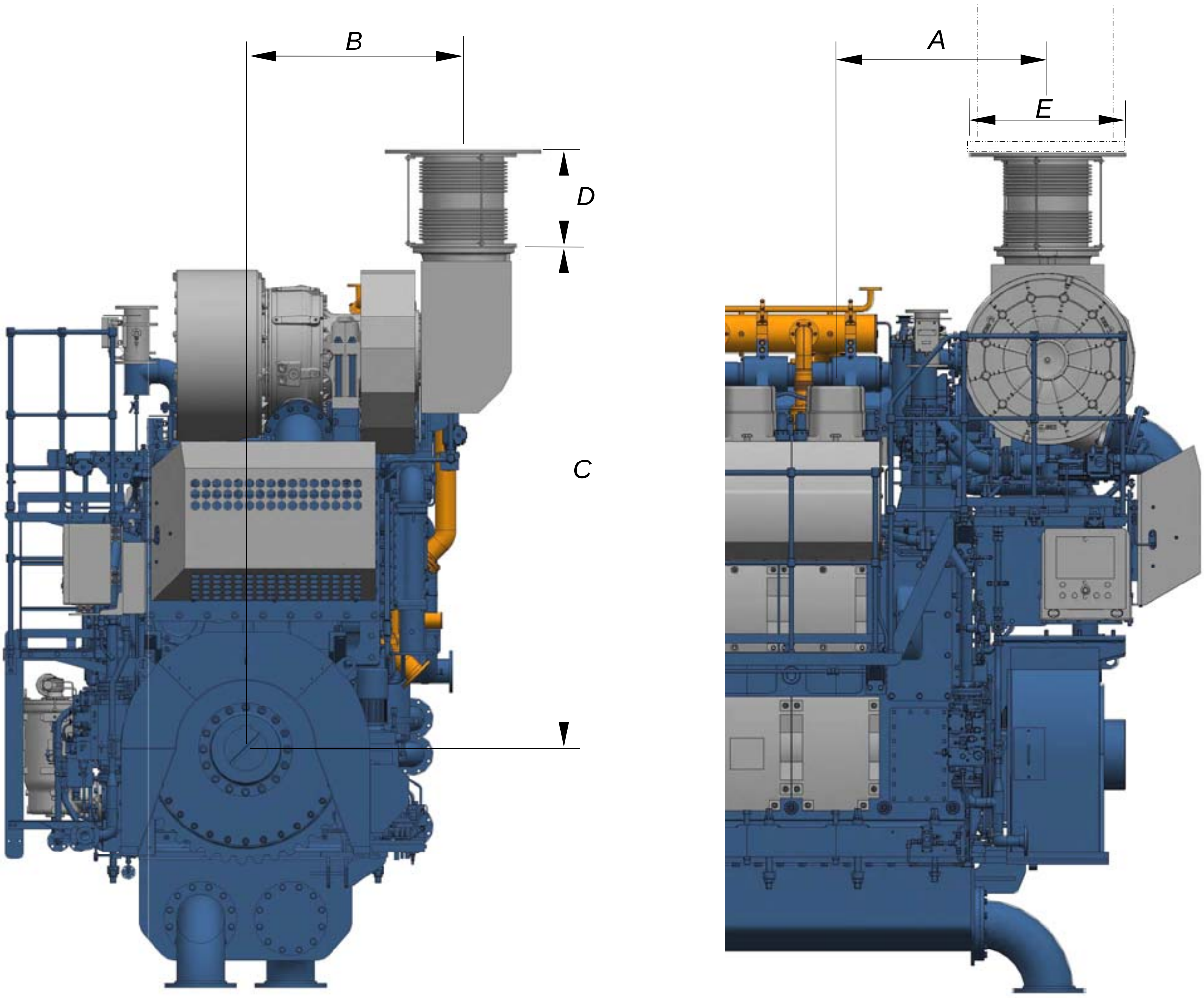

Table 8-5-1: In-line engine position and size of the exhaust gas pipe connections

Engine type	A	B	C	D	E	
	[mm]	[mm]	[mm]	[mm]	Size	Standard
6H35DFP	1254	1142	2585	470	2K – 600A	JIS F 7805
7H35DFP	1214	1200	2608	540	2K - 700A	JIS F 7805
8H35DFP	1175	1260	2631	540	2K - 700A	JIS F 7805
9H35DFP	1171	1207	2799	542	2K - 750A	JIS F 7805

In order to improve engine performance, some component of engine can be changed without any notice and the dimensions above also can be affected by the changes.

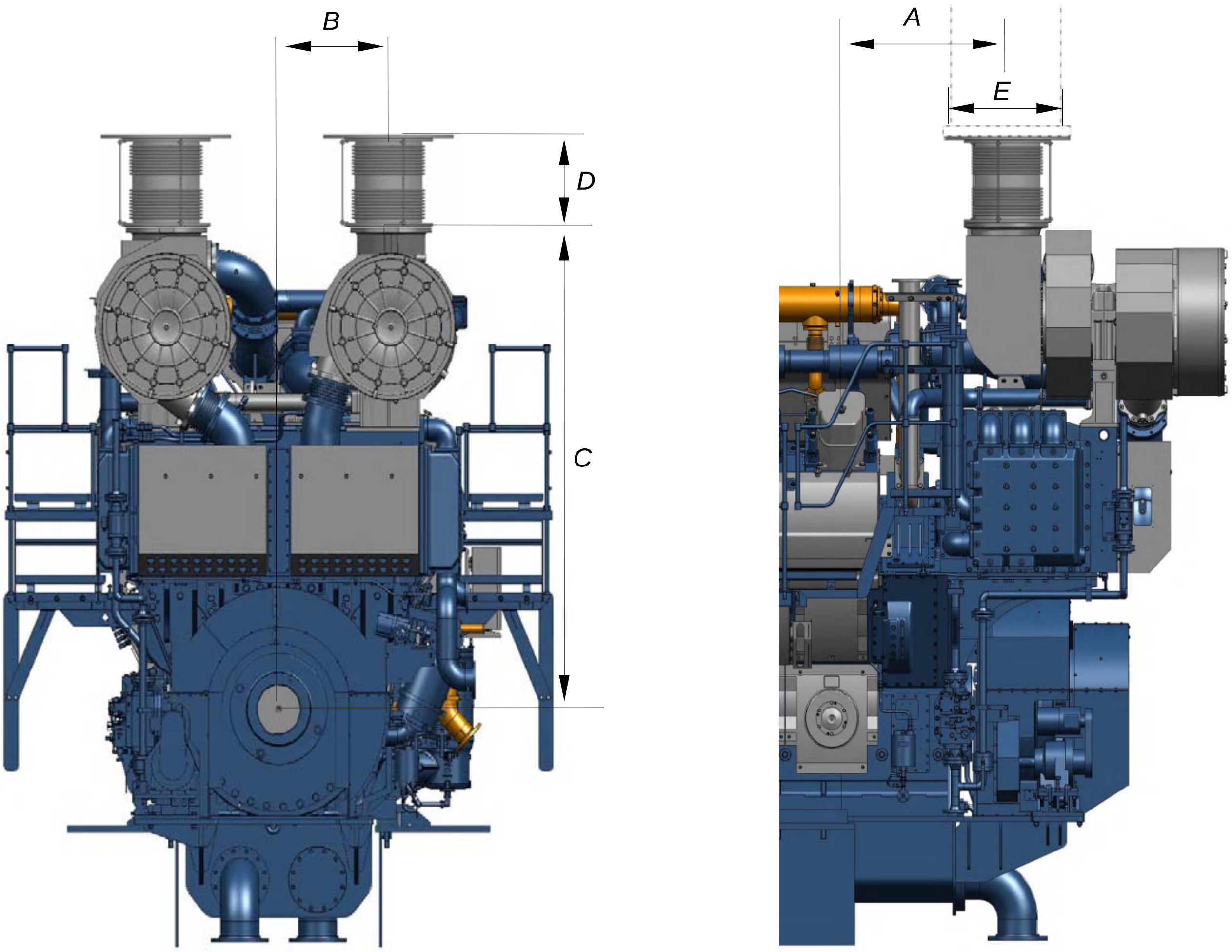

Table 8-5-2: V-type engine position and size of the exhaust gas pipe connections

Engine type	A	B	C	D	E	
	[mm]	[mm]	[mm]	[mm]	Size	Standard
12H35DFVP	1193	555	2434	470	2K – 600A	JIS F 7805
14H35DFVP	1370	780	2935	540	2K – 700A	JIS F 7805
16H35DFVP	1370	780	2935	540	2K – 700A	JIS F 7805
18H35DFVP	1370	780	2935	542	2K – 800A	JIS F 7805
20H35DFVP	1370	780	2935	542	2K – 800A	JIS F 7805

In order to improve engine performance, some component of engine can be changed without any notice and the dimensions above also can be affected by the changes.

General

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

Generally, the silencer can be mounted horizontally or vertically for diesel engines.

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

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

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

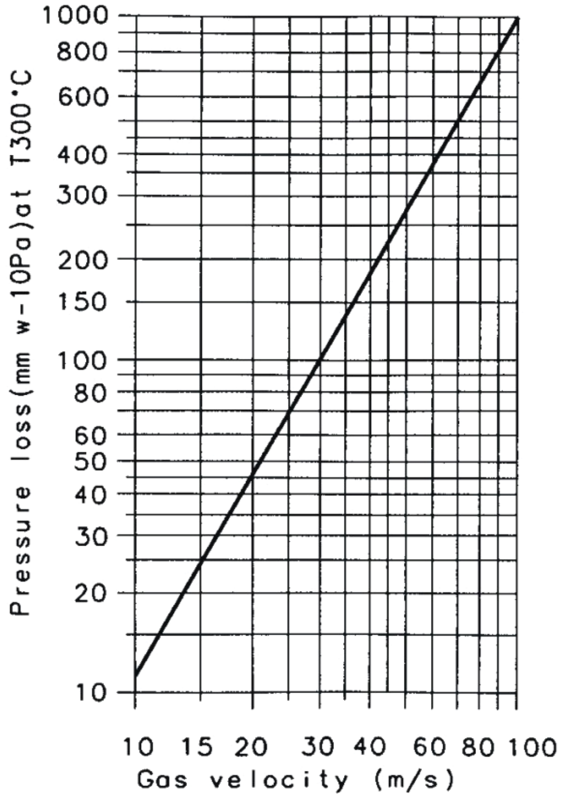

Figure 8-6-1: pressure loss in the silencer with the spark arrestor depending on the gas velocity

Silencer with the spark arrestor

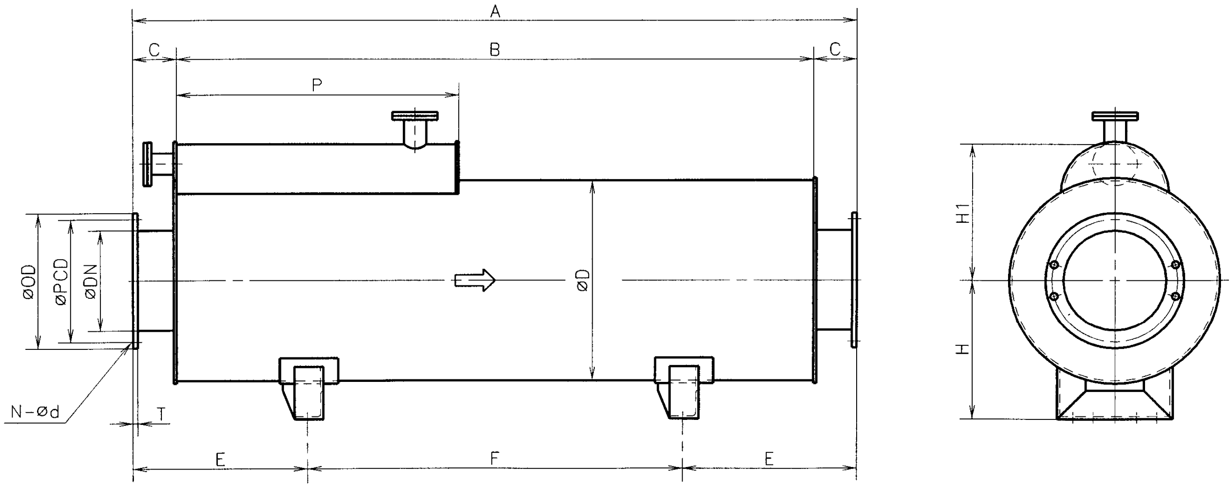

Figure 8-6-2: Layout of the silencer with the spark arrestor

Silencer of 25dB type

Engine type	A	B	C	D	E	F	H	H1	P	Flange						W
										ND	OD	PCD	T	N	d	
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[A]	[mm]	[mm]	[mm]	[-]	[mm]	[kg]
6H35DFP	4,980	4,680	150	1,060	990	3,000	700	792	1,000	600	710	670	16	16	23	1873
7H35DFP	5,680	5,380	150	1,110	1,090	3,500	730	819	1,100	650	760	720	16	16	23	2080
8H35DFP	6,220	5,920	150	1,160	1,150	3,920	750	885	1,200	700	775	775	16	16	23	2385
9H35DFP	6,660	6,360	150	1,210	1,170	4,320	780	910	1,200	750	825	825	20	20	23	2660

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

Silencer of 35dB Type

Engine type	A	B	C	D	E	F	H	H1	P	Flange						W
										ND	OD	PCD	T	N	d	
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[A]	[mm]	[mm]	[mm]	[-]	[mm]	[kg]
6H35DFP	6,230	5,930	150	1,060	990	4,250	700	792	1000	600	710	670	16	16	23	2065
7H35DFP	6,980	6,680	150	1,110	1,090	4,800	730	819	1100	650	760	720	16	16	23	2295
8H35DFP	7,570	7,270	150	1,160	1,150	5,270	750	885	1200	700	815	775	16	16	23	2615
9H35DFP	8060	7760	150	1210	1170	5720	780	910	1200	750	865	825	20	20	23	2910

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

The value(s) above is only provided preliminary information purpose. It would be changed without any notice to improve the engine. In order to construct a commercial engine project, please contact HHI-EMD

General Information	P.00.000
Structural Design and Installation	P.01.000
Performance Data	P.02.000
Dynamic Characteristics and Noise	P.03.000
Operation and Control System	P.04.000
Fuel System	P.05.000
Lubricating Oil System	P.06.000
Cooling Water System	P.07.000
Air and Exhaust Gas System	P.08.000
Engine Maintenance	P.09.000
Theoretical Performance	P.10.000
Electric Control System	P.11.000
	Appendix

Major overhaul Guidance for Main Engine

Section No.		Description	Overhaul Interval (hours)											Remark
			Others	500 *)	1,500	3,000	6,000	9,000	12,000	15,000	18,000	21,000	24,000	
		Major Fasteners - Confirmation												
M11100	LDF11100	Bolt for Base Frame and Resilient Mount		▲			◆							
G11100	-	Nut for Resilient Mount and Foundation		▲			◆							
-	LDF13000	Hyd. Nut for Engine Block and Base Frame		◆			◆							
M13250	LDF13000	Hyd. Nut for Main Bearing Cap		◆			◆							
M21100	LDF13000	Hyd. Nut for Cylinder Head		◆			◆							
M25000	LDF25000	Bolt and Nut for Camshaft		▲			◆							
M31000	LDF32000	Hyd. Nut for Con-Rod (Shaft)		◆			◆							
M31000	LDF32000	Hyd. Nut for Con-Rod (Big-end)		◆			◆							
M33200	LDF33000	Hyd. Nut for Counter Weight		◆			◆							
M35300	LDF35000	Bolt and Nut for Timing Gear		▲			◆							
-	LDF83000	Bolt and Nut for Turbocharger Mounting		▲			◆							
		Major Bearing												
M13250	LDF13250	Main Bearing					√				▣			
M13250	LDF13250	Thrust Washer : Axial Clearance					◎						▣	
M25000/M25300	LDF25300	Camshaft Bearing : Clearance					√		◎				▣	
M31000/M32120	LDF32000	Con-Rod Bearing (Big-end)					√		■		▣			
M32130	LDF32000	Con-Rod Bearing (Small-end)					√		■				▣	
M35300	LDF35000	Bearing Bush for Idle Gear : Clearance							◎				▣	
		Resilient Mount												
M11100	LDF11100	Resilient Mount	●				●							**)
		Cylinder Unit and Con. Rod												
M15100	LDF15000	Cylinder Liner					√		■					
M15100	LDF15000	Flame Ring					√		▣					
M21100	LDF15000 LDF21100	Cylinder Head & Water Jacket Cooling Water Space					√		■					
M21120/M21130 /M21200	LDF21100 LDF21200	Intake/Exhaust v/v Spindle, Seat Ring and v/v Guide: Overhaul and Reconditioning					√		■		▣			
M21210	LDF21200	Intake/Exhaust v/v : Clearance		●	●									**)
M21210	LDF21200	Rocker Arm Shaft and Bush					√		■					
M21220	LDF21200	Rotocap			○				■					
M21400	LDF21400	Starting Valve					√		■					
M24100	LDF24100	Duel Valve Timing					√		■					
M31100	LDF31100	Piston Rings					√		▣					
M31100	LDF31100	Piston and Piston Pin					√		■					
M31000/M31101	LDF32000	Con-Rod Bore (Big-end)					√		■					
M31100/M32130	LDF31100 LDF32000	Piston Pin & Con-Rod (Small-end) : Clearance					√		■					
M31000	LDF32000	Shim Plate for Con-Rod					√		▣					
M31000	LDF32000	Stud for Con-Rod Shaft											▣	
		Crankshaft and Gears												
M33100	LDF33000	Crankshaft : Deflection					◎							
-	LDF33300 LDF42300	Gear Teeth on Flywheel & Turning Gear					▲							
-	LDF33400	Torsional Vibration Damper : Fluid sampling (Only for Viscous Damper)							◎					(See Manual for T/V Damper)
-	LDF33500	Flexible Coupling	▲											(See Manual for Flex.Coupling)
M35300	LDF35000	Timing Gear and Pump Driving Gear : Clearance and Backlash							◎					

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

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

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

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

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

Major overhaul Guidance for Main Engine

Section No.		Description	Overhaul Interval (hours): Others	500 *)	1,500	3,000	6,000	9,000	12,000	15,000	18,000	21,000	24,000	Remark
		Valve Operating Mechanism												
M23000	LDF23000	Swing Arm Roller Shaft and Bush							■				▣	
M25000	LDF23000 LDF25000	Contact Faces of Cam and Swing Arm Roller Camshaft Bearing		▲			▲							
		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 (See Manual for Governor)
-	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
		Fuel System												
G05100/G05200	-	Analyze Fuel Oil Properties : Sampling	◎											Every Bunkering
M51100	LDF51000	Fuel Injection Pump												
		- Deflector : Erossion				◎	▣							
		- 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	■											Every 9,000 hrs : Injector replacement (9,000 / 18,000 hrs : reconditioning) (27,000 hrs : New Injector replacement)
-	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)
		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 Lub. Oil Properties : Sampling	◎											Every 3 month
M61000	LDF61000	Lubricating Oil Pump							■					
M62000	LDF62000	Lubricating Oil Cooler							■					(See Manual for LO Cooler)
M63000	LDF63000	Lubricating Oil Filter (Cartridge Type)	■		▣									If pressure drop reaches limit (See G01400)
-	LDF63000	Auto Backwashing Filter (If Applied)	■											(See Manual for Auto Filter)
-	LDF64000	Thermostatic Valve : Clean & Check the Elements							■					(See Manual for Thermo.v/v)
M67000	LDF67000	Lubricating Oil Centrifugal Filter	■											(See Manual for Centrifugal Filter)

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

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

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

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

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

Major overhaul Guidance for Main Engine

Section No.		Description	Others	500 *)	1,500	3,000	6,000	9,000	12,000	15,000	18,000	21,000	24,000	Remark
			Overhaul Interval (hours)											
		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 & Check the Elements							■					(See Manual for Thermo.V/v)
		Compressed Air System												
O02300	-	Air Running	○											Monthly
G40000	-	Check Starting & Stop System	○											Weekly (Over a Week Stand-still Condition)
		Supercharging System												
M80000	-	Turbocharger	■											(See Manual for Turbocharger)
		- Clean Air Filter (Only for Filter Silencer type)	■		▣									Every 500hrs running
		- Turbine : Water-washing	●											Every 200hrs running
		- Compressor : Water-washing	●											Every 24~50hrs 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

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

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

List of Consumable Parts for one engine

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

Section No.	Parts Description	set/ea	Quantity for the operating hours							
			0-3,000	0-6,000	0-9,000	0-12,000	0-15,000	0-18,000	0-21,000	0-24,000
	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
LDF13250	Thrust washer	ea	-	-	-	-	-	-	-	4
LDF25300	Camshaft bearing	ea	-	-	-	-	-	-	-	1xC+1
LDF32000	Big-end bearing (upper & lower)	set	-	-	-	-	-	1 x C	1 x C	1 x C
LDF32000	Small-end bearing	ea	-	-	-	-	-	-	-	1 x C
LDF35000	Bearing bush for idle gear	ea	-	-	-	-	-	-	-	1
	Cylinder Unit and Con-Rod									
LDF15000	Flame ring	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF15000	O-rings & gasket for cylinder liner / cooling water jacket	set	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
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
LDF21100	O-ring for cylinder head	ea	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
LDF21100	Bush & O-ring for fuel valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF21100	Bush & O-ring for MP injector	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF21100	O-rings for valve guide & exh. valve seat ring	set	-	-	-	1 x C	1 x C	2 x C	2 x C	3 x C
LDF21100 LDF21200	Intake v/v spindle, seat ring and v/v guide	set	-	-	-	-	-	1 x C	1 x C	1 x C
LDF21100 LDF21200	Exhaust v/v spindle, seat ring and v/v guide	set	-	-	-	-	-	1 x C	1 x C	1 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 DVT	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 con-rod	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LDF32000	Stud for con-rod shaft	ea	-	-	-	-	-	-	-	4 x C
	Control System									
LDF45000	Cylinder pressure sensor (if applied)	ea	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
	Fuel System									
LDF51000	Plunger assembly for fuel pump	ea	-	-	-	-	-	1 x C	1 x C	1 x C
LDF51000	O-rings & seal ring for plunger ass'y	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
LDF51000	Gaskets & seal ring for fuel pump	set	-	-	-	-	-	1 x C	1 x C	1 x C
LDF51000	Deflector & 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	3 x C	4 x C	5 x C	6 x C	7 x C	8 x C
LDF52000	O-rings & gasket for fuel injection valve	set	2 x C	4 x C	6 x C	8 x C	10 x C	12 x C	14 x C	16 x C
LDF52002	Micro pilot injector compl. (incl. nozzle)	set	-	-	-	-	1 x C	1 x C	1 x C	1 x C
LDF52002	Micro pilot injector nozzle(If not reconditioning)	set	-	1 x C	2 x C	2 x C	2 x C	3 x C	3 x C	4 x C
LDF52002	O-ring & gasket for micro pilot injector and pipe	set	-	1 x C	2 x C	2 x C	3 x C	4 x C	4 x C	5 x C
LDF52002	O-rings for high pressure pump	set	-	-	-	-	-	1 x C	1 x C	1 x C

List of Consumable Parts for one engine

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

Section No.	Parts Description	set/ea	Quantity for the operating hours							
			0-3,000	0-6,000	0-9,000	0-12,000	0-15,000	0-18,000	0-21,000	0-24,000
LDF52002	High pressure pump	set	-	-	-	-	-	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	2 x C	4 x C	6 x C	8 x C	10 x C	12 x C	14 x C	16 x C
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 & 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									
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 & gasket for main gas feed pipe	set	-	-	-	1	1	1	1	2
LDF53002	Gas admission valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
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 lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF61000	O-rings for lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF62000	O-ring for lub. oil cooler connection (Installation on engine side)	ea	-	-	-	4	4	4	4	8
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 lub. 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 & O-ring for HT and LT-pump (if applied)	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LDF74000	O-ring for C.W thermostat valve (Wax type installed on engine)	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
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 cyl.head cooling water connection	ea	-	8	8	(4xC)+ 6	(4xC)+ 6	(4xC)+ 14	(4xC)+ 14	(8xC)+ 12
LDF78000	O-ring for cyl.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 T/C connection	set	-	-	-	1	1	1	1	2
	Charge Air Cooler									
LDF84000	O-rings and gaskets for air cooler	set	-	-	-	1	1	1	1	2

List of Consumable Parts for one engine

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

Section No.	Parts Description	set/ea	Quantity for the operating hours							
			0-3,000	0-6,000	0-9,000	0-12,000	0-15,000	0-18,000	0-21,000	0-24,000
	Turbocharger									
	Spare parts for turbocharger (See manual for turbocharger)	set	-	-	-	-	-	-	-	-
	Air filter mat (Engine room air suction)	ea	2	4	6	8	10	12	14	16

* 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.

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In order to construct a commercial engine project, please contact HHI-EMD.

List of standard spare parts for each vessel

Description	Section No.	Item No.	Quantity
Engine block and cover			
Main bearing, upper	LDF13250	251	1
Main bearing, lower	LDF13250	251	1
Thrust washer	LDF13250	252	4
Main bearing stud(M48)	LDF13000	231	2
Nut for main bearing stud(M48)	LDF13000	232	2
O-ring for crankcase door	LDF19300	390	1
Cylinder Head and Cylinder Liner			
Valve spindle, intake	LDF21200	201	2
Valve spindle, exhaust	LDF21200	202	4
Conical piece	LDF21200	206	6
Valve spring	LDF21200	207	6
Valve seat, inlet	LDF21100	111	2
Valve seat, exhaust	LDF21100	112	4
Roto cap	LDF21200	204	6
Air start valve	LDF21400	400	1
O-ring for starting valve D52.87	LDF21400	410	1
O-ring for starting valve D56.83	LDF21400	411	1
O-ring for starting valve D63.76	LDF21400	412	1
O-ring for starting valve D65.74	LDF21400	413	1
O-ring for starting valve D67.72	LDF21400	414	1
O-ring for starting valve D69.70	LDF21400	415	1
O-ring for starting valve D71.68	LDF21400	416	1
O-ring for starting valve D73.66	LDF21400	417	1
O-ring for DVT G65	LDF24100	330	6
O-ring for DVT G70	LDF24100	420	6
O-ring for exhaust valve seat ring	LDF21100	118	4
O-ring for valve guide	LDF21100	291	6
Cylinder head complete with valve and rocker arm	LDF21100	100	1
O-ring for cylinder head	LDF21100	901	2
O-ring for cylinder head cover, lower	LDF21100	805	1
O-ring for cylinder head cover, upper	LDF21100	806	1
Safety valve	LDF22000	600	1
Cylinder head stud	LDF13000	311	4
Cylinder head nut	LDF13000	312	4
O-ring for cooling water jacket, D193	LDF15000	901	1

Description	Section No.	Item No.	Quantity
O-ring for cooling water jacket, D225	LDF15000	902	1
Cylinder Liner	LDF15000	111	1
Flame ring	LDF15000	120	1
O-ring for cylinder liner, D420	LDF15000	192	1
O-ring for cylinder liner, D385	LDF15000	194	1
O-ring for cylinder liner, D440	LDF15000	193	2
Sealing ring for cylinder liner	LDF15000	191	1
O-ring for cooling water connection, D128.7	LDF78000	300	4
Spare for exhaust system			
Axial compensator	LDF82000	340	1
Axial compensator	LDF82000	350	1
Piston, Connecting Rod			
Piston complete (without pin, rings, retaining ring)	LDF31100	110	1
Piston pin	LDF31100	120	1
Piston ring, top	LDF31100	151	1
Piston ring, 2nd	LDF31100	152	1
Piston ring, scraper	LDF31100	153	1
Connection rod complete	LDF32000	100	1
Big end bearing, upper & lower	LDF32000	113	1
Small end bush	LDF32000	114	1
Connecting rod big end stud, M33	LDF32000	191	4
Connecting rod shaft stud, M33	LDF32000	194	4
Nut for connecting rod, M33	LDF32000	192	8
Cylindrical pin	LDF32000	193	4
Ignition System			
Fuel injection pump	LDF51000	100	1
Fuel injection valve	LDF52000	100	For one engine
Fuel high pressure block	LDF52300	100	1
Micro pilot injector	LDF56002	201	For one engine
O-ring for micro pilot injector	LDF56002	603	10
VCV for pilot oil pump (incl. Electric connector)	LDF56002	201	1
PCV for pilot oil pump (incl. Electric connector)	LDF56002	201	1
O-ring for SOGAV D50	LDF53002	107	1
O-ring for SOGAV D88.5	LDF53002	106	1
Piping System			
Flexible connecting pipe, each type	LDF98370	-	1 set
Spare for charge air cooler			
Gasket for air cooler	LDF 84000	202	1

Description	Section No.	Item No.	Quantity
Spare O-rings			
O-ring (ø66.27x3.53)	LDF23000	405	4
O-ring (ø54x2.62)	LDF21400	409	1
O-ring (ø124.6x5.7)	LDF78000	731	4

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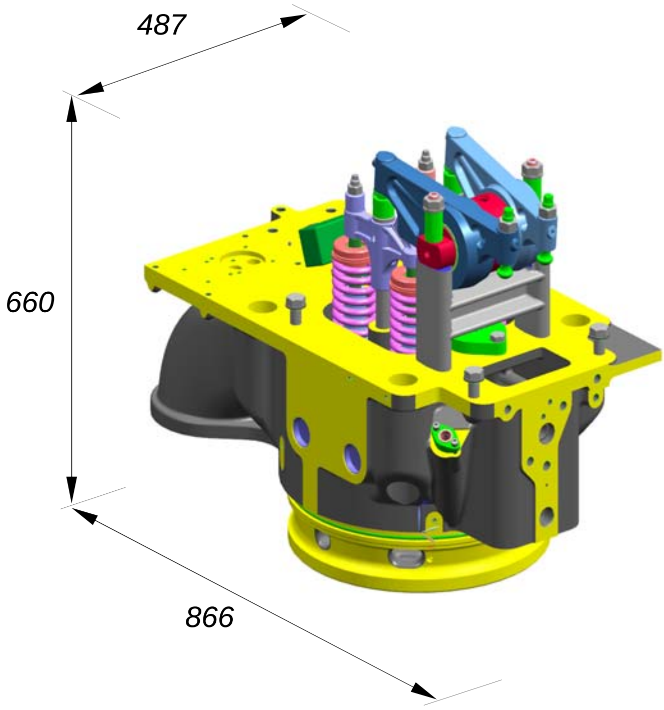
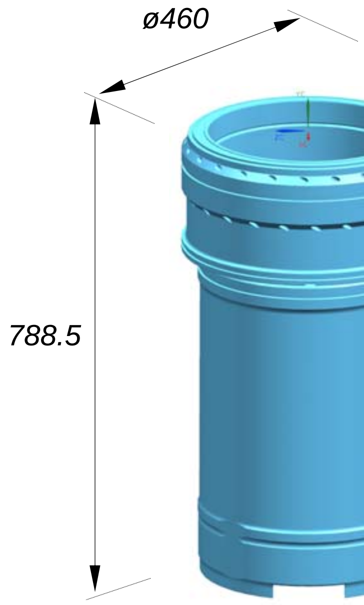
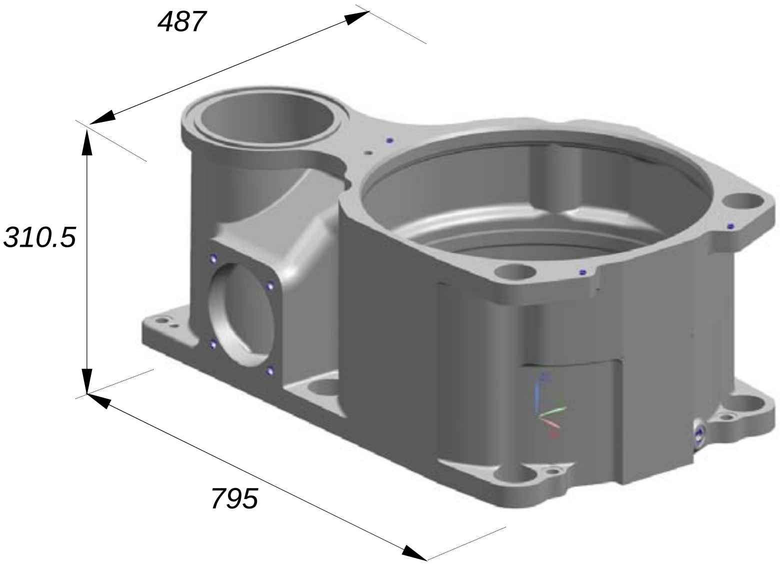


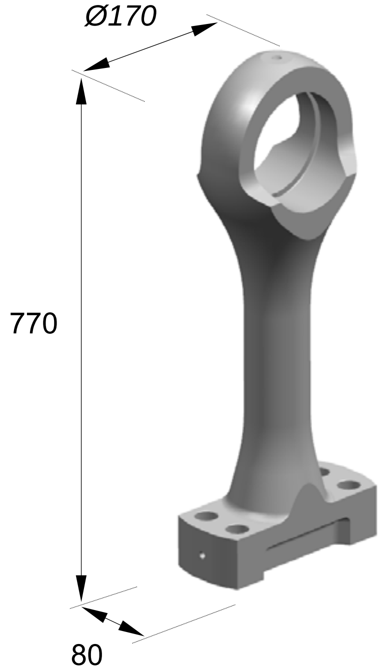
Cylinder head and rocker arms assembly
(Weight : approx. 492 kg)



Cylinder liner
(Weight : approx. 195.5 kg)

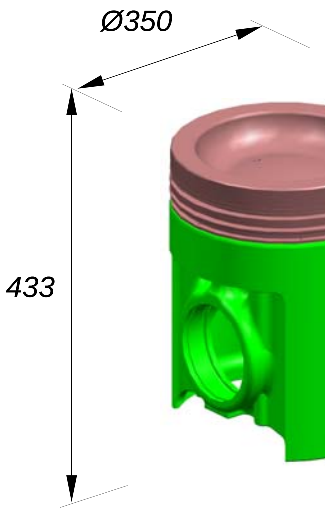


Water jacket
(Weight : approx. 118 kg)



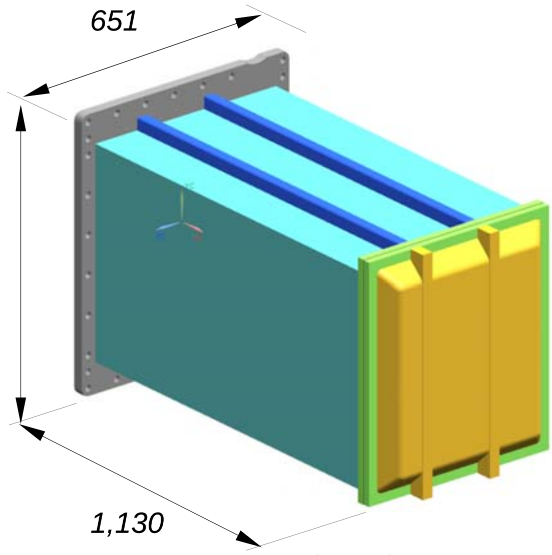
Connecting rod shaft
(Weight : approx. 73 kg)

Heavy Parts for Maintenance



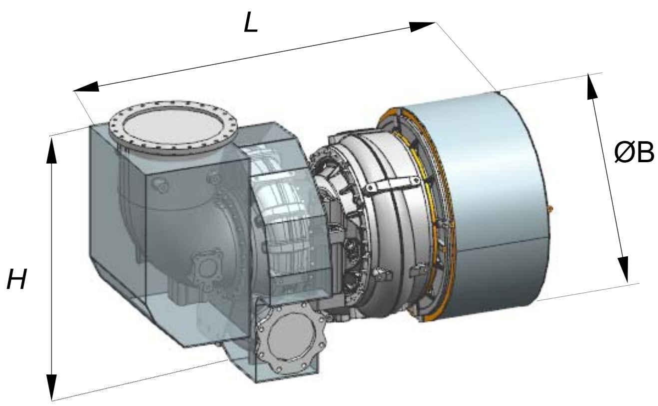
Piston

(Weight : approx. 97 kg)



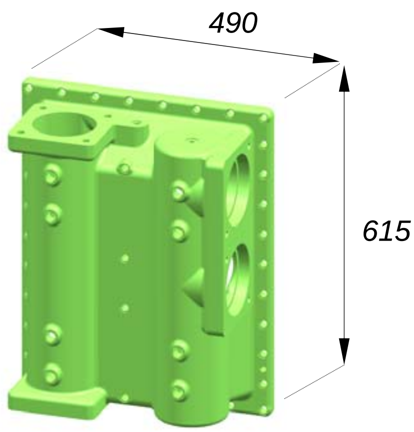
Air cooler

(Weight : approx. 527 kg)



Turbocharger

(Refer to following table)



Air cooler cover

(Weight : approx. 77 kg)

Turbocharger type	Dimensions [mm]			Weigh [kg]
	B	H	L	
A145	Ø745	855	1,570	770
A150	Ø800	910	1,840	1,010
ST7	Ø890	1,050	1,960	1,360

List of Standard Tools

Description	Quantity
For cylinder head and liner	
Lifting tool for cylinder head	1
Fitting/Removal device for v/v coni/clamping piece	1
Grinding tool for cylinder head/liner	1
Extract/suspension device for cylinder liner	1
Cylinder bore gauge	1
Removing device for flame ring	1
Removal device for valve seat	1
Lapping device for inlet & exhaust valve seat	1
Air Gun for roto cap	1
Feeler gauge for inlet & exhaust valve.	1
Plier for locking ring	1
For piston and connecting rod	
Guide for piston	1
Lifting jig for piston	1
Holding piece for crank pin bearing	2
Guide support for con-rod	1
Turning bracket for con-rod	2
Clamping support for con-rod	2
Plier 125 for piston pin looking ring	1
Piston ring expander	1
For crankshaft and main bearing	
Lifting device for main bearing	4
Fitting device for main bearing	1
Deflection gauge for crankshaft	1
For fuel injection valve	
Fitting for micro pilot injector bush	1
Removal for micro pilot injector bush	1
Test tool for fuel valve nozzle	1
Lapping device for injection valve bush	1
Removal tool for atomizer nut	1
Cleaning tool for fuel valve nozzle	1
Removal device for fuel injection valve	1
Long socket for nozzle nut	1
Removal device for injection valve bush	1
General Tools	
Removal device for C.W connection	1

Description	Quantity
Hydraulic Tools	
Hydraulic tightening devices M48(cyl.head, M.B.C)	4
Hydraulic tightening devices M39(side stud, c/weight)	2
Hydraulic tightening devices M36(coupling stud)	2
Hydraulic tightening devices M33(conrod 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(M.B.C)	2
Support for hydraulic tools M48(cyl. head)	4
Support for hydraulic tools M36(coupling stud)	2
Support for hydraulic tools M39(Side stud, c/weight)	2
Support for hydraulic tools M33(conrod shaft, big end)	2
Hydraulic Tools	
Extension screw for hydraulic tools M48(cyl. head)	4
Extension screw for hydraulic tools M39(Side stud, c/weight)	1
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
Turning pin (Φ4)	2
Turning pin (Φ8)	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 & Tool box	5
Tool for nozzle	1
Torque wrench 20-120Nm	1
Torque wrench 140-760Nm	1
Torque wrench 750-2000Nm	1
Spanner for high pressure block	1

Description	Quantity
Air Starting Valve Tools	
Lapping device for air starting valve	1
Tool for air starting valve	1

The values(s) above is only provided preliminary information purpose, and these can be changed to be satisfied with the classification rules for each project and other reasons without any notice to improve an engine.
In order to construct a commercial engine project, please contact HHI-EMD.

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Appendix

Operation range for controllable pitch propeller (CPP)

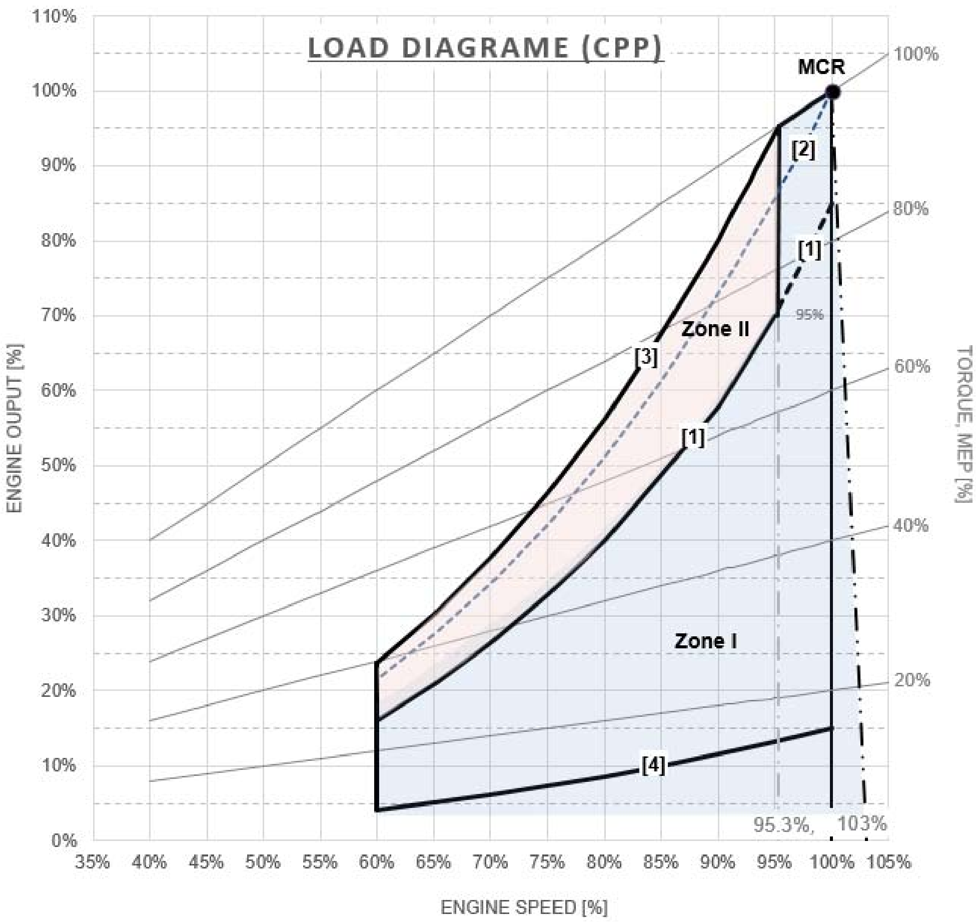

Figure 10-1-2: Load diagram for controllable pitch propeller

- **Line [1] : Combined operation curve**

Propeller design based on the combination between pitch angle and engine speed. The combination curve has to be set at a sufficient distance from the torque limit curve. And the pitch angle control has to be provided for protection against the overload. This combination curve shall be had a variation under vessel's characteristic and selected propeller configuration.

When the CPP is operated on the combination mode, the engine load shall be automatically controlled by the theory of the proportional torque control which is prepared by the electronic control logic.

Depending on the vessel’s speed and the propeller thrust, the pitch angle of the CPP shall be settled in the optimized operating pitch. It can make an energy saving operation by shifting the fuel rack against the propelling load. The operating panel and software programmed with the control logic should be provided by the CPP controller manufacturer.

- **Line [2] : Theoretical propeller curve ($P=N^3$) in propeller law & load limit on Gas mode**

  Theoretical propeller curve of fixed pitch propeller is described for reference. The engine load on gas mode must not exceed this curve at any conditions.

- **Line [3] : Torque(load) limit (1.1P) on Diesel mode**

  The load limit is the maximum thermal load of the engine's combustion process. It can be typically defined as a smoke limit, an exhaust gas temperature limit and a surging limit, etc. The load limit should be carefully set on the engine test bed through the thermal matching of the turbocharger.

  This curve related to maximum permitted overload. The engine load must not exceed this curve at any conditions.

- **Line [4] : Zero thruster**

  This curve related to zero thruster at zero pitch under speed variation.

- **Zone I : Operation range for continuous operation**

- **Zone II : Temporary operation range during maneuvering and acceleration**

- **Constant speed operation**

  Constant speed operation as one of operation mode in Controllable Pitch Propeller is complied with control of pitch angle under fixed one of engine speed (typically 100% rated speed). This operation mode provide a better manœuvrability and optimal operation for PTO (Power Take Off) generator. In this operation mode, the engine load is limited to 100% rated output at 100% rated speed.

- **Separated operation (Option)**

  This separated operation specifies the condition where pitch and engine speed can be controlled individually. The pitch is adjusted using the lever and the engine speed is adjusted using the propulsion control panel.

- **Permissible engine speed range**

  The permissible speed range for continuous operation is max. 103% of rated speed.

Power declaration

- **Maximum continuous rating (MCR)**

The MCR is the maximum output at which the engine can be operated safely and continuously. This output is the basis of calculating the strength of the engine and the nominal output of the propulsion machinery.

The engine power is guaranteed as the maximum continuous rating at 100% output, which shall be agreed on the contract between the shipyard and the engine builder. It shall be measured at the engine flywheel side as brake horsepower. The validity of the power guarantee can be determined only at the test bench by using fuel oil with the lower calorific value of 42,700kJ/kg. The power correction should be weighted in accordance with ISO 3046-1:2002 and the MCR cannot be guaranteed during an onboard operation. The unit of the power is applied SI unit and specified as kW.

- **MEP**

  If the diesel cycle is a theoretical process, the engine power can be available up to MEP of 100%. MEP of 100% is an equal process of the constant torque between the engine output and the speed. Therefore, the constant fuel admission can be nearly identified.

  100% MEP : 100% of Mean Effective Pressure ($P=N^n \propto$ Constant torque), where n=1 at 100% MEP

- **Overload power**

  The overload power is demonstrated at shop test as 110% of MCR only for the inspections of classification societies. The overload power is not allowed during an onboard operation. In order to restrict the overload operation during an onboard operation, the engine power is limited at 100% MCR by the mechanical fuel oil limiter after shop test in accordance with requirement of classification societies.

- **Available maximum power**

  The available maximum power up to 100% of MCR shall not be considered until 45°C of an ambient temperature in the engine room. If the temperature is increased above 45°C, the available maximum power should be de-rated from 100% of MCR accordingly depending on the ambient conditions.

Information of the load diagram

- **The range of the engine idling speed**

  The range of the engine idling speed is the service speed between the dead-slow speed and slow speed safely. For this range, the following is required:

  - Normal operating pressures of the oils
  - Normal operating values of the cooling water temperature and charge air pressure, etc.
  - The harmful barred range should be avoided.
  - The harbor speed of the vessel should be satisfied.
  - The clutching load should be considered.

- **Low revolution speed**

  The low revolution speed shall be applicable to idle speed or clutching speed of engine.

- **Clutching speed**

  The allowable engine speed range, i.e. a reduction gear's clutching order is capable of normal operating value between clutching and declutching as well as crash astern.

  The reduction gear shall meet the following requirements:

  The capacity of the clutch plate and the torque capacity of the reduction gear should be designed against the propelling torque of a ship's load such as a crash astern and a heavy acceleration.

  The variation of the clutch oil pressure should be minimized while the clutching order is taken place.

  The allowable engine speed for controllable pitch propeller is recommended as follows:

  N_{CPP}= above 0.6 x MCR, depends on specification of CPP.

IMO NOx certification for CPP

Propulsion engine connected to controllable pitch propeller is tested and issued to E2 (constant speed) test cycle, irrespective of combination operation in accordance with regulation of IMO NOx Technical code

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	Appendix

General

The propulsion control system for the azimuth thruster shall be designed for controlling the engine with the azimuth thrust including bridge control system, safety system and governor.

An azimuth thruster is a thruster which has the capability with a 360-degree revolution in order to develop a thrust in any direction.

The engine is equipped with the digital governor to control the engine speed. The speed adjustment is made to match the speed setting of the governor via analog signals.

The control system for the azimuth thruster typically consists of the following equipment:

- Azimuth thruster control panel
- Thruster direction indicator
- Azimuth thruster control lever

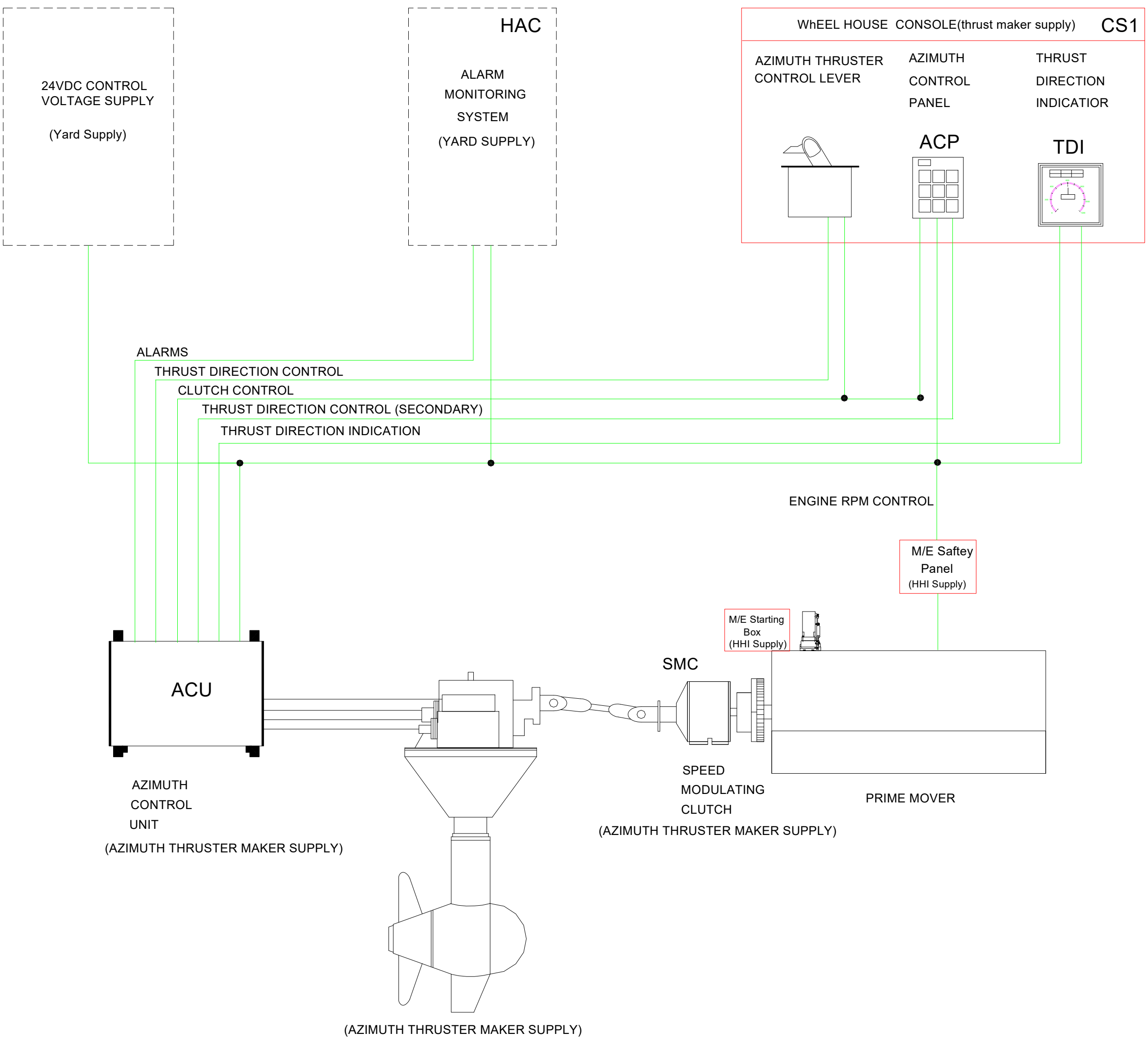

Figure 11-2-1: Diagram of the control system for the azimuth thruster

General

The propulsion control system for the CPP shall be designed for controlling the engine with the controllable pitch propeller including the bridge control system, telegraph, safety system and governor.

The control system for CPP may be connected one or several propulsion units and should be able to make reliable ship operation by controlling the propeller pitch according to the ship maneuvering status.

The control system for CPP shall consist of the following three sections for suitable ship operations:

- Bridge control
- Engine control room(ECR) control
- Local control at Engine room

In the engine control room, the central control unit must communicate each system such as the propeller pitch control system, the reduction gear system and the engine control system, etc.

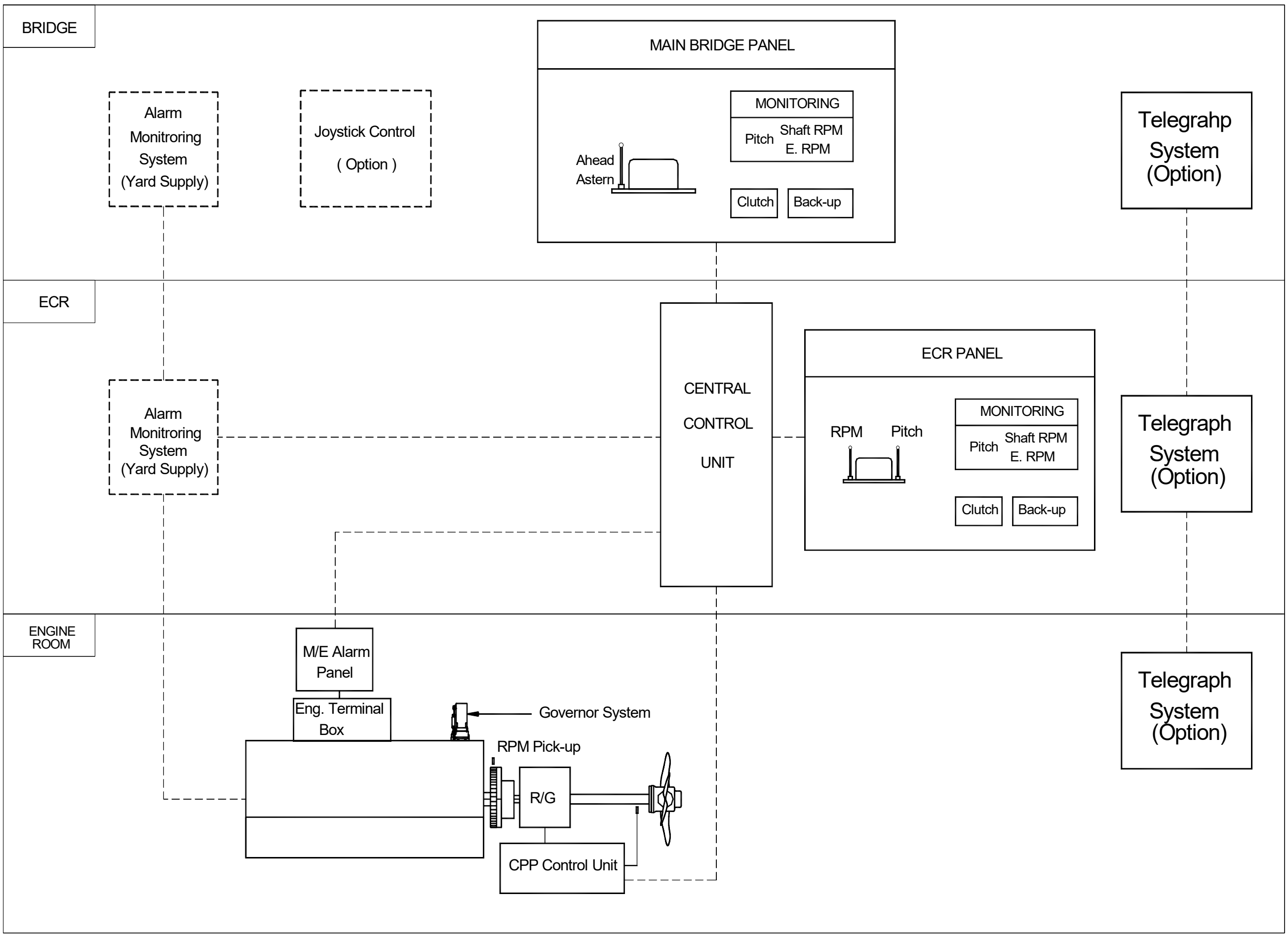

Figure 11-3-1: Diagram of the control system for the CPP

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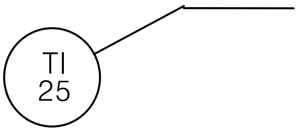
Appendix

NO.	SYMBOL	SYMBOL DESIGNATION	NO.	SYMBOL	SYMBOL DESIGNATION
1. GENERAL CONVENTIONAL SYMBOLS					
1.1		PIPE	1.6		HIGH PRESSURED PIPE
1.2		PIPE WITH INDICATION OF DIRECTION OF FLOW	1.7		TRACING
1.3		VALVES, GATE VALVES, COCKS AND FLAPS	1.8		ENCLOSURE FOR SEVERAL COMPONENTS ASSEMBLED IN ONE UNIT
1.4		APPLIANCES			
1.5		INDICATING AND MEASURING INSTRUMENTS			
2. PIPES AND PIPE JOINT					
2.1		CROSSING PIPES, NOT CONNECTED	2.13		BLANK FLANGE
2.2		CROSSING PIPES, CONNECTED	2.14		SPECTACLE FLANGE
2.3		TEE PIPE	2.15		BULKHEAD FITTING WATER TIGHT, FLANGED
2.4		FLEXIBLE PIPE	2.16		BULKHEAD CROSSING, NON-WATERTIGHT
2.5		EXPANSION PIPE (CORRUGATED) GENERAL	2.17		TEST PIECE WITH PLUG
2.6		JOINT, SCREWED	2.18		ORIFICE
2.7		JOINT, FLANGED	2.19		REDUCER
2.8		JOINT, SLEEVE	2.20		OPEN DRAIN & AIR VENT
2.9		JOINT, HOSE COUPLING	2.21		ORIFICE
2.10		EXPANSION JOINT WITH GLAND	2.22		LOOP EXPANSION JOINT
2.11		EXPANSION PIPE	2.23		SNAP-COUPLING
2.12		CAP NUT			
3. VALVES, GATE VALVES, COCKS AND FLAPS					
3.1		VALVE, STRAIGHT THROUGH	3.10		FLAP, ANGLE
3.2		VALVE, ANGLE	3.11		REDUCING VALVE
3.3		STOP VALVE (SCREW ENDED)	3.12		SAFETY VALVE
3.4		VALVE, THREE-WAY	3.13		ANGLE SAFETY VALVE
3.5		NON-RETURN VALVE(FLAP) STRAIGHT	3.14		SELF-CLOSING VALVE
3.6		NON-RETURN VALVE(FLAP) ANGLE	3.15		QUICK-OPENING VALVE
3.7		NON-RETURN VALVE(FLAP) STRAIGHT, SCREW DOWN	3.16		QUICK-CLOSING VALVE
3.8		NON-RETURN VALVE(FLAP) ANGLE, SCREW DOWN	3.17		REGULATING VALVE
3.9		FLAP, STRAIGHT THROUGH	3.18		ANGLE VALVE

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

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

Symbol explanation

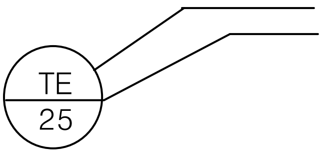


Measuring device

Locally reading

Temperature Indicator

No. 25*



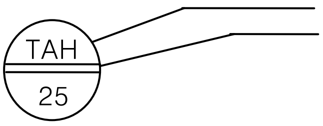
Measuring device

Sensor mounted on engine/unit

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

Temperature element

No. 25*



Measuring device

Sensor mounted on engine/unit

Reading/identification outside the engine/unit

Temperature Alarm High

No. 25*

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

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

Standard text for instruments

0. Plant outline

05 Main bearing

1. Engine Structure

11 Engine speed & position (flywheel)
12 Engine speed & position (cam)
13 Overspeed (Mechanical)
14 Turbocharger speed

2. Combustion gas system

20 Charge air air cooler inlet
21 Charge air air cooler outlet
25 Exhaust gas cylinder outlet
26 Exhaust gas turbocharger inlet
27 Exhaust gas turbocharger outlet

4. Control system compressed air system

40 Starting air engine inlet
41 Control air engine inlet
43 Control air DVT inlet
44 Jet assist air
45 Slow turn
49 Emergency stop

5. Fuel inj system

50 Fuel rack position
51 Fuel oil filter inlet
52 Fuel oil engine inlet
54 Clean fuel oil leakage tank
55 Waste oil leakage tank

6. Lub. Oil system

61 Lub. oil filter inlet
62 Lub. Oil engine inlet
63 Lub. oil turbocharger inlet
64 Lub. Oil turbocharger outlet
65 Prelubricating oil
67 Splash oil
68 Lub. oil sump tank

7. Cooling water system

70 LT water LT pump inlet
71 LT water air cooler inlet
72 LT water air cooler outlet
73 LT water Lub. oil cooler outlet
74 HT water air cooler inlet
75 HT water engine inlet
76 HT water engine outlet
77 HT water each cylinder outlet
78 HT water air cooler outlet

9. Maintenance

90 Turning gear

92 Oil mist detector

93 Vibration sensor

*** Reference**

201 Air recirculation valve

202 Air waste gate valve

203 Air by pass valve

204 Charge air shut off valve

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