PROJECT GUIDE

HiMSEN H25/33P

FOR PROPULSION

2023 1st EDITION

HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY

HiMSEN

DISCLAIMER

General

This project guide provides necessary information and recommendations for the application of HYUNDAI's HiMSEN H25/33P 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 H25/33P 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 'H25/33P' and 'Sheet No.' for easier communications

Engine model designation

6 H 25 / 33 P

- 6 – No. of Cylinders (6, 7, 8, 9)
- H – HYUNDAI's HiMSEN
- 25 – Cylinder Bore in cm
- 33 – Piston Stroke in cm
- P – Propulsion application

Sheet number

P . XX . XXX

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

Copy right

Publication : December, 2022

Contents

Sheet No.	Description

Sheet No.	Description

Cylinder numbering

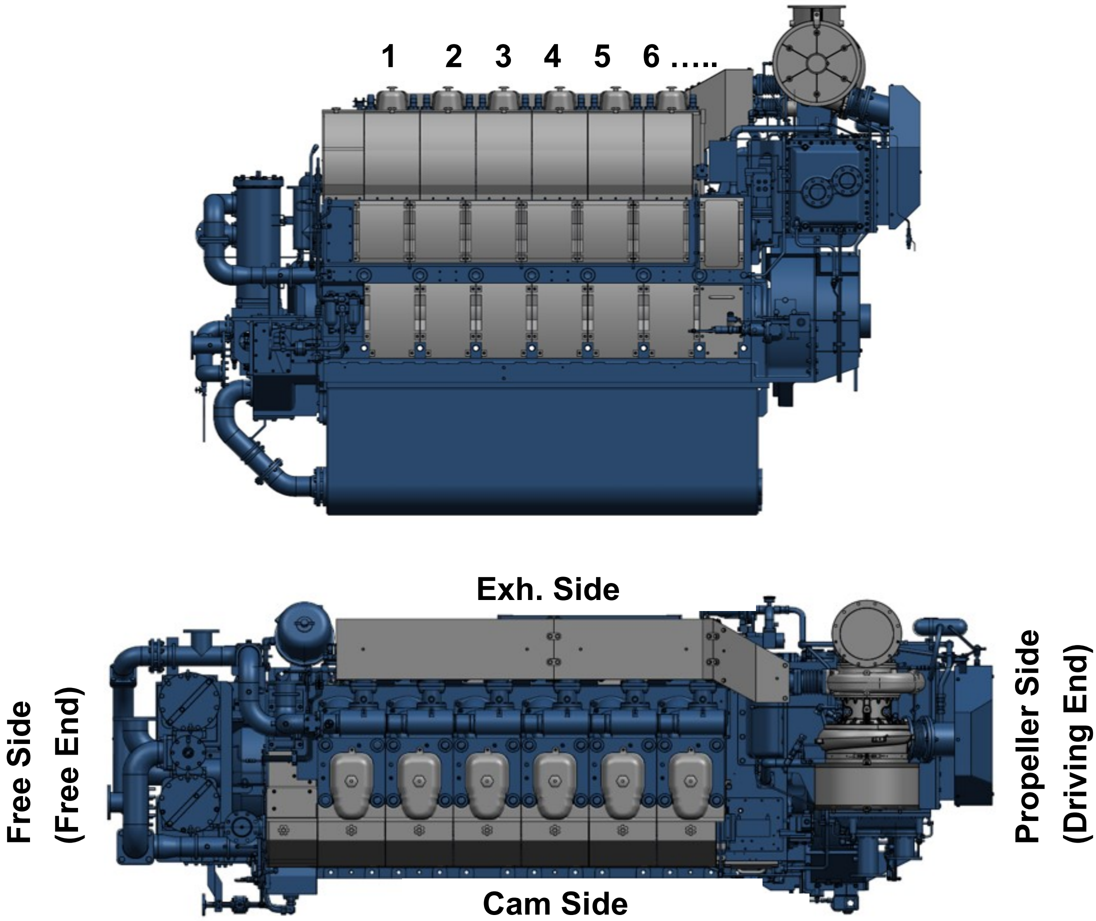
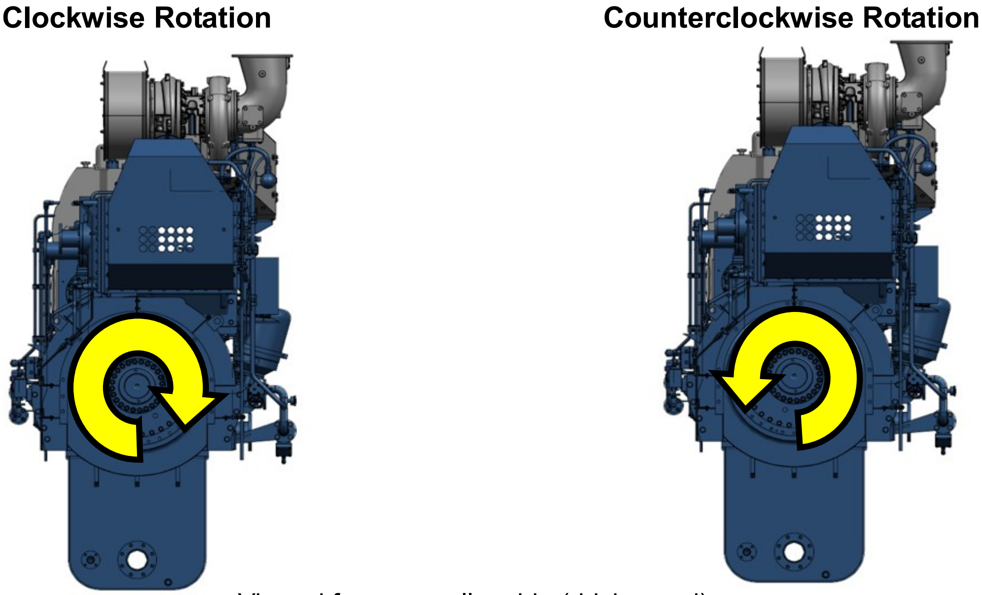


Figure 0-3-1: Engine definition

Direction of the engine rotation



Viewed from propeller side (driving end)

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

Type of engine		4-stroke, vertical, direct injection, Single acting and trunk piston type with turbocharger and inter-cooler
Cylinder configuration		In-line
Number of cylinder		6, 7, 8, 9
Rated speed	rpm	900
Power per cylinder	kW	290
Cylinder bore	mm	250
Piston stroke	mm	330
Swept volume per cylinder	dm^3	16.2
Mean piston speed	m/s	9.9
Mean effective pressure	bar	23.9
Compression ratio		17 : 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

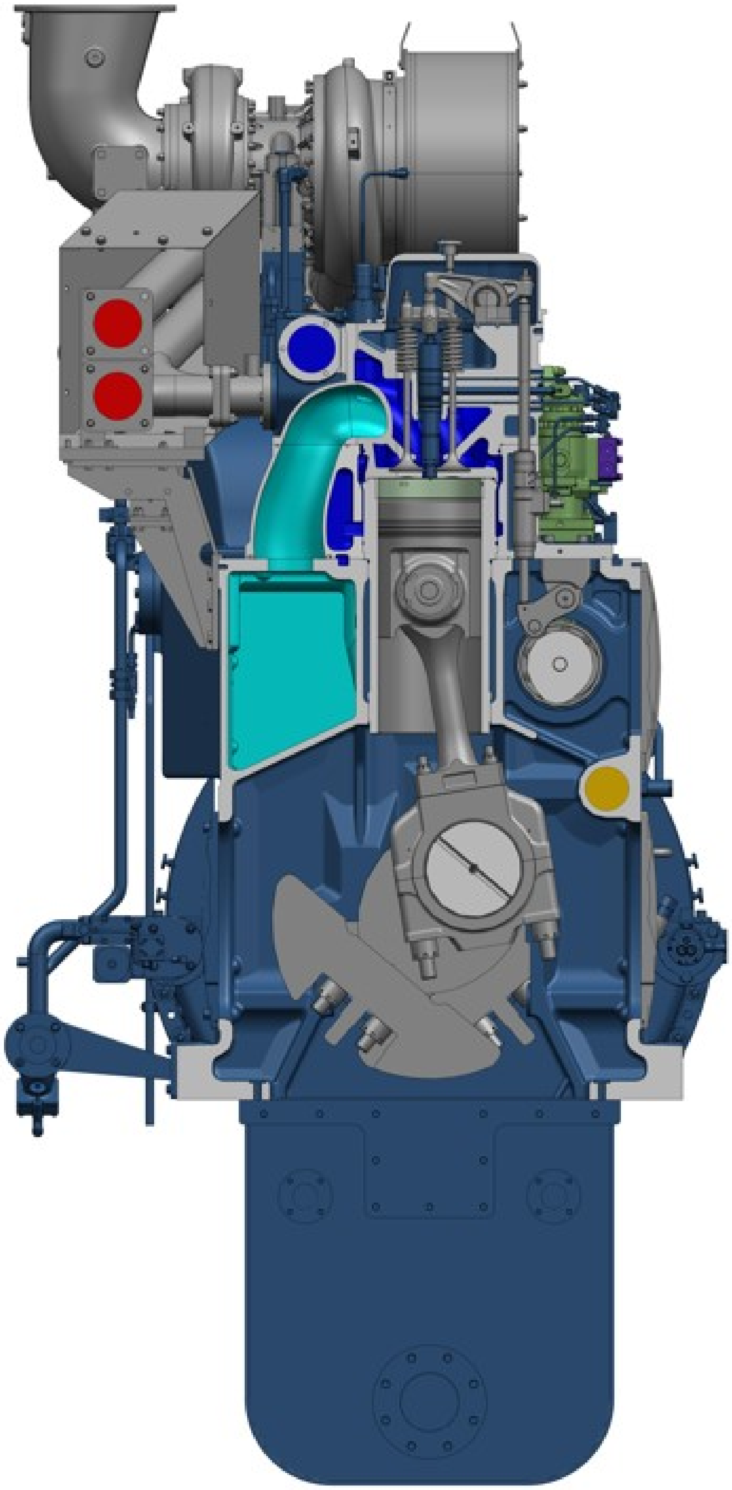


Figure 1-2-1: Engine cross section

General

Hyundai's 'HiMSEN H25/33P' Family Engine has simple and smart design suitable for marine propulsion with high reliability and performance, which is available for FPP or CPP or Azimuth thruster or Electric propulsion. The key features are summarized as follows.

Tailored design for propulsion engine with practical functions

- Excellent transient operation with pulse charging turbocharger
- Low smoke operation with pulse charging turbocharger
- Front Power Take Off up to 67%~100% nominal power
- Optimized load control with electronic or hydraulic governor

Economical and ecological engine with the lowest fuel consumption, low NOx emission and smoke, etc., based on the following design features

- High stroke to bore ratio
- High compression ratio
- Optimized valve timing based on the miller cycle
- High fuel Injection pressure

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 easy maintenance.
- Both maintenance concepts 'Individual part' and 'Cylinder unit' are provided.
- Feed system is fully modularized with direct accessibility.

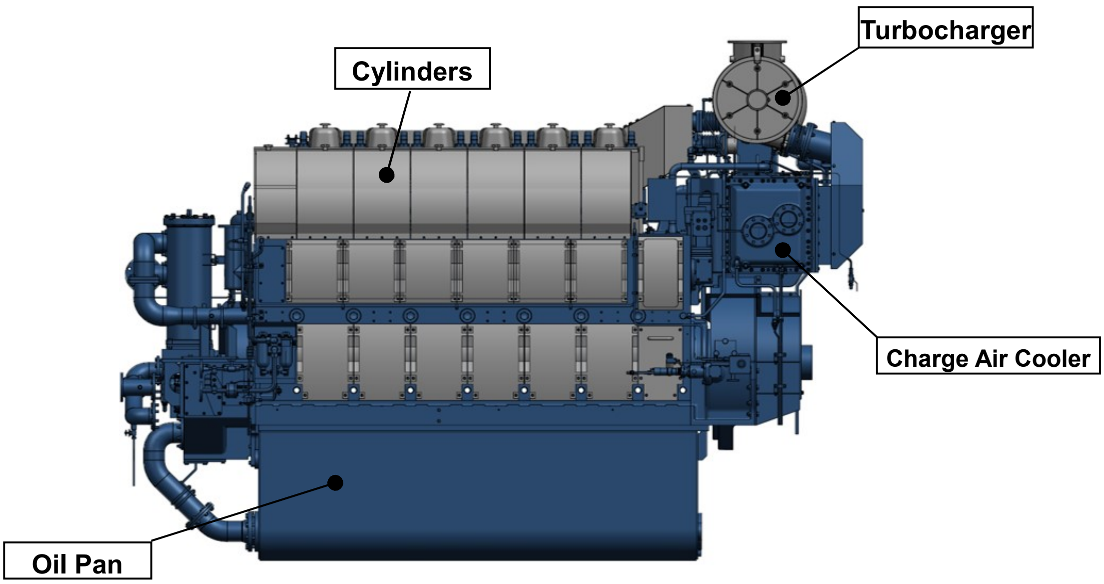


Figure 1-3-1: Engine outline

Design of main components

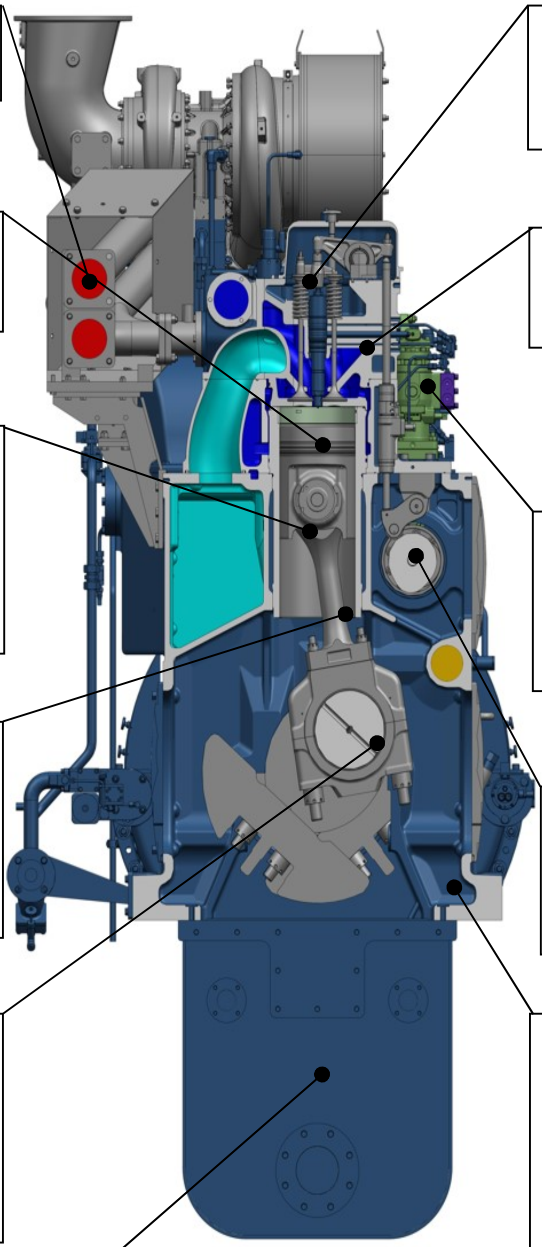
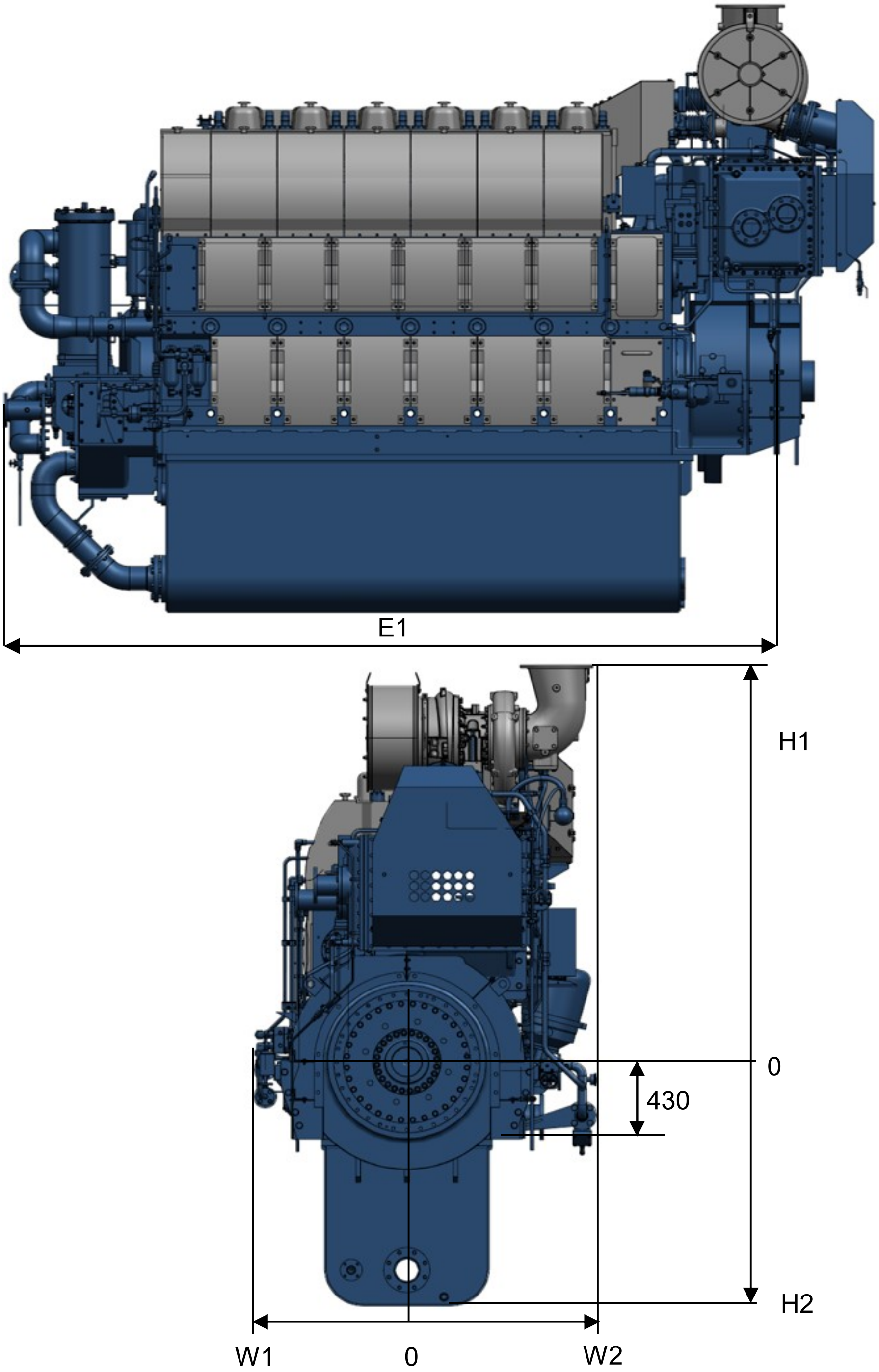


Figure 1-3-2: Main components of the engine

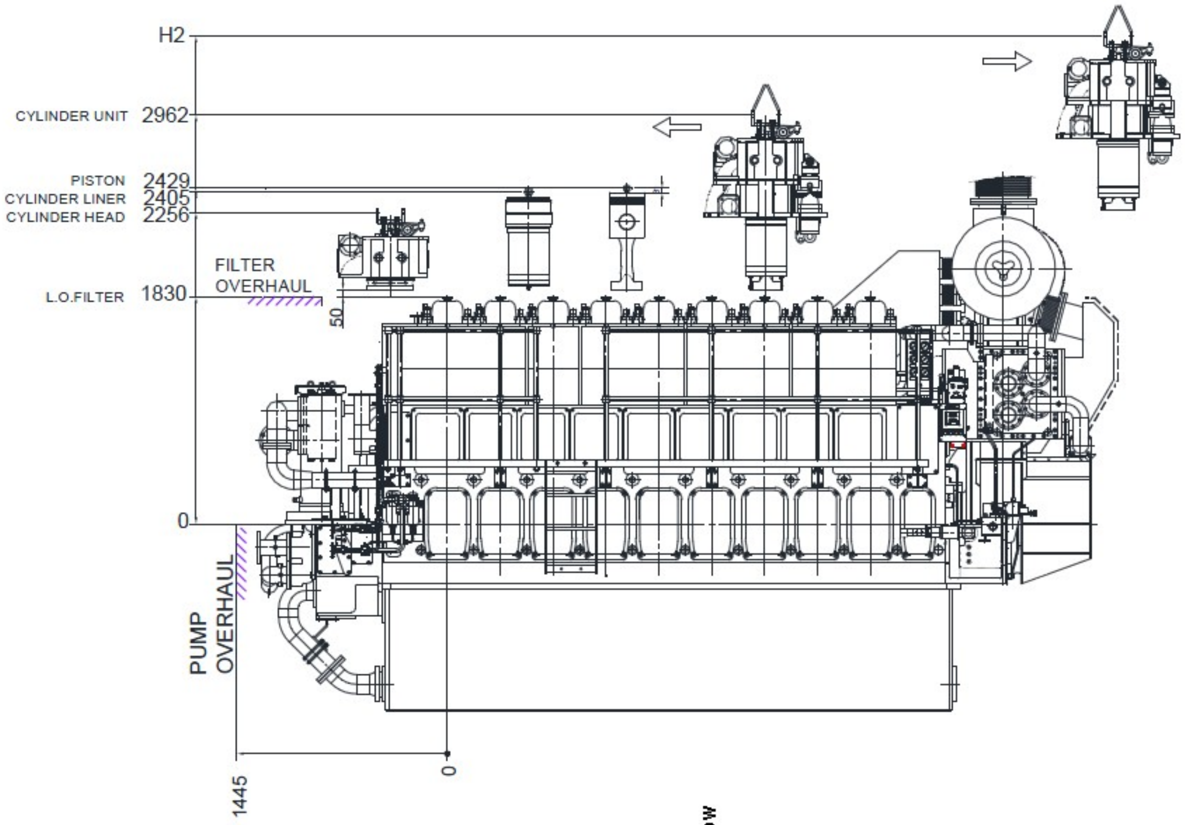


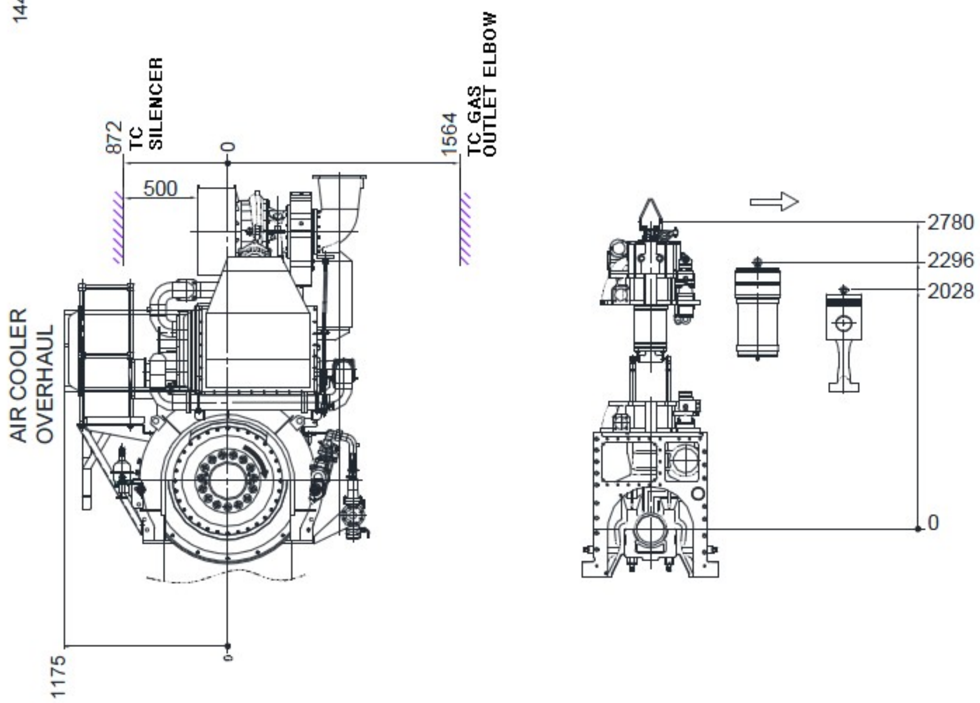
Engine type	Dimensions [mm]					Dry weigh [ton]
	E1	H1	H2	W1	W2	
6H25/33P	4,238	2,209	1,360	812	998	23.0
7H25/33P	4,618	2,209	1,360	812	998	25.0
8H25/33P	4,998	2,331	1,360	812	1,068	26.9
9H25/33P	5,378	2,331	1,360	812	1,068	29.3

E1 : Dimension between engine flywheel and engine free end

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

Overhaul Dimension





H2 Dimensions [mm]			
6H25/33P	7H25/33P	8H25/33P	9H25/33P
3475	3475	3597	3597

H2 : When carrying the cylinder unit away along the engine over the turbocharger

General

The engine can be rigidly mounted to the 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 free side of the engine by keeping the order. The number and location of stoppers are to be in accordance with the 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.

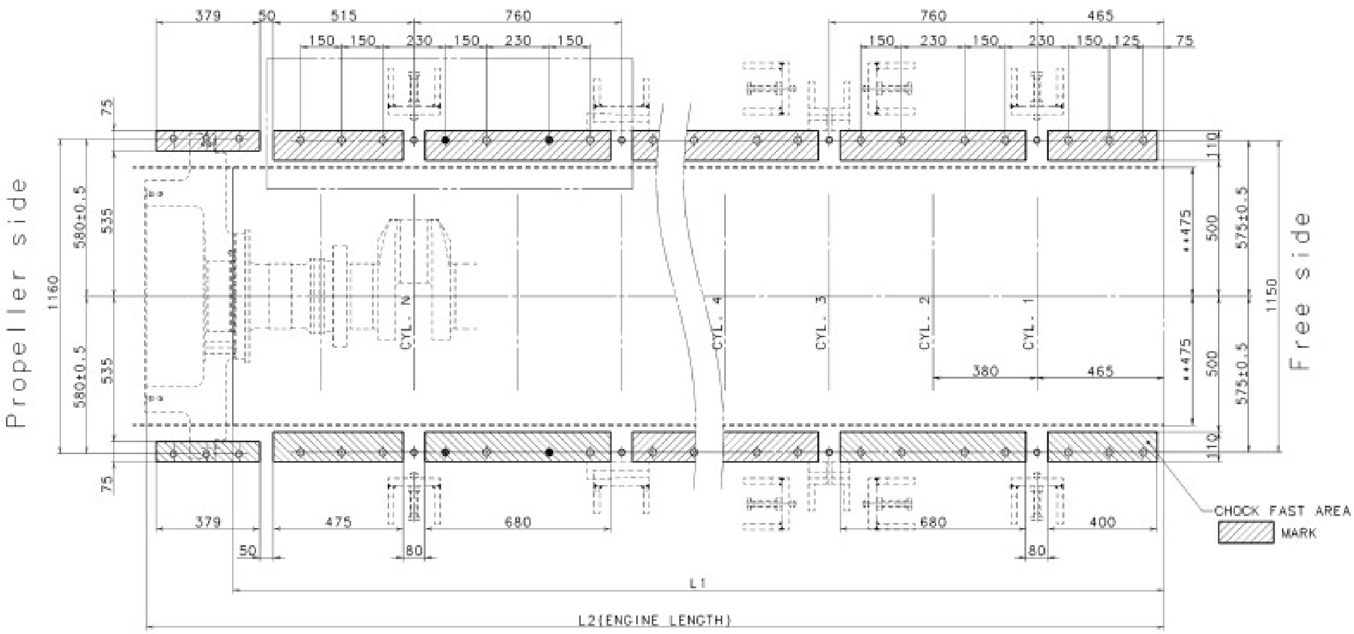
Fitting on synthetic resin chock

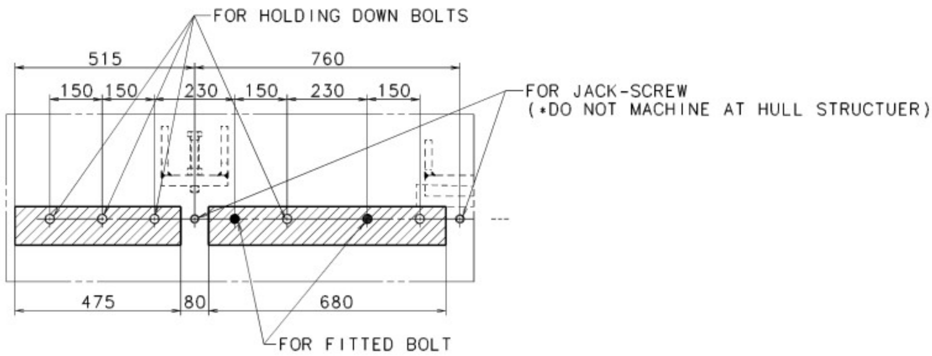
The synthetic resins chock is used for mounting engine and other machinery. The classification society responsible has approved the synthetic resin chock to be used for a specific pressure (engine deadweight + foundation bolt tension).

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

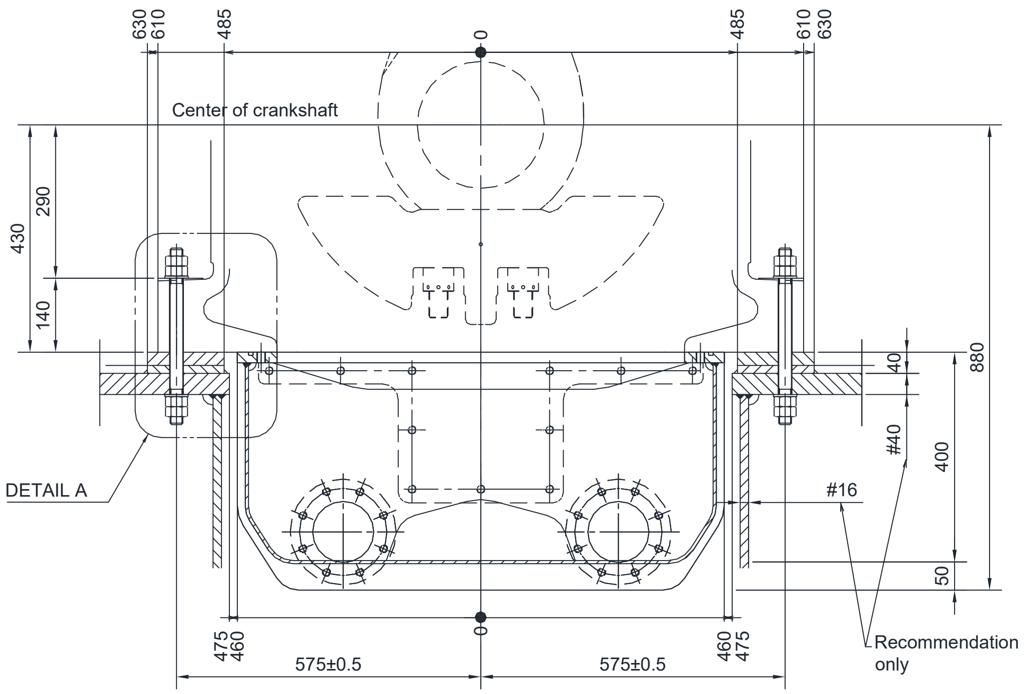


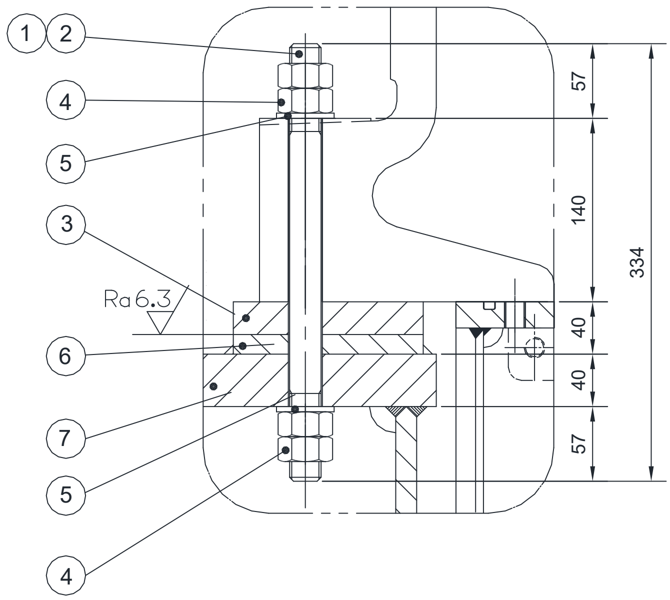


Engine type	Quantities [EA]			Length [mm]	
	Fitted bolt	Holding down bolt	Jack screw	L1	L2
6H25/33P	4	28	8	3028	3345
7H25/33P	4	32	8	3408	3725
8H25/33P	4	36	8	3788	4105
9H25/33P	4	40	10	4168	4485

Figure 1-5-1: Foundation seat arrangement

Foundation – cross section





Code	Description	Code	Description
01	Holding down bolt	05	Plain washer
02	Fitted bolt	06	Steel liner
03	Epoxy chock	07	Top plate
04	Nut		

General

A resilient mounting can be provided for the 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 the vessel. Therefore, the final specification of the mounts shall be decided based on the information from the shipyard for the case by case.

Connections to the engine

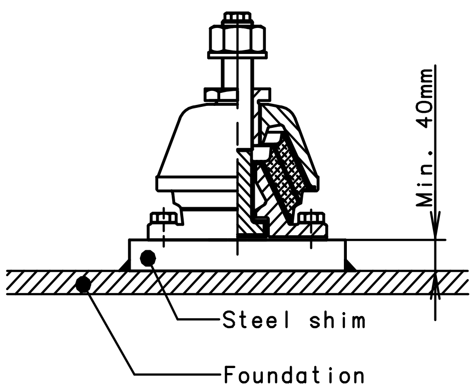
The engine mounted on the resilient mounts usually has some relative motions to the hull structure. Any rigid fixing between the engine and hull structure causes damages of the engine or hull structure.

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

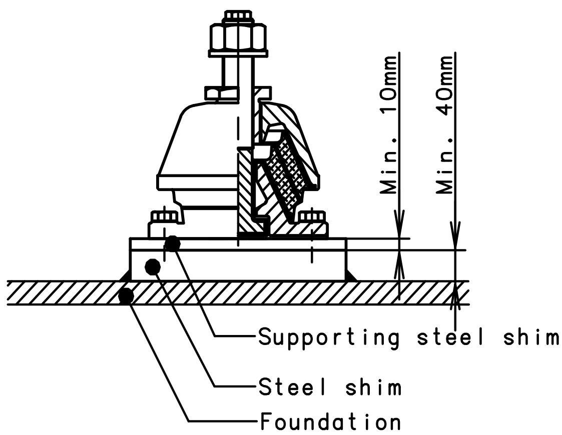
Recommendations for seating design and adjustment

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

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



Method 1



Method 2

Figure 1-6-1: Resilient mounting adjustments

H25/33P foundation for reference

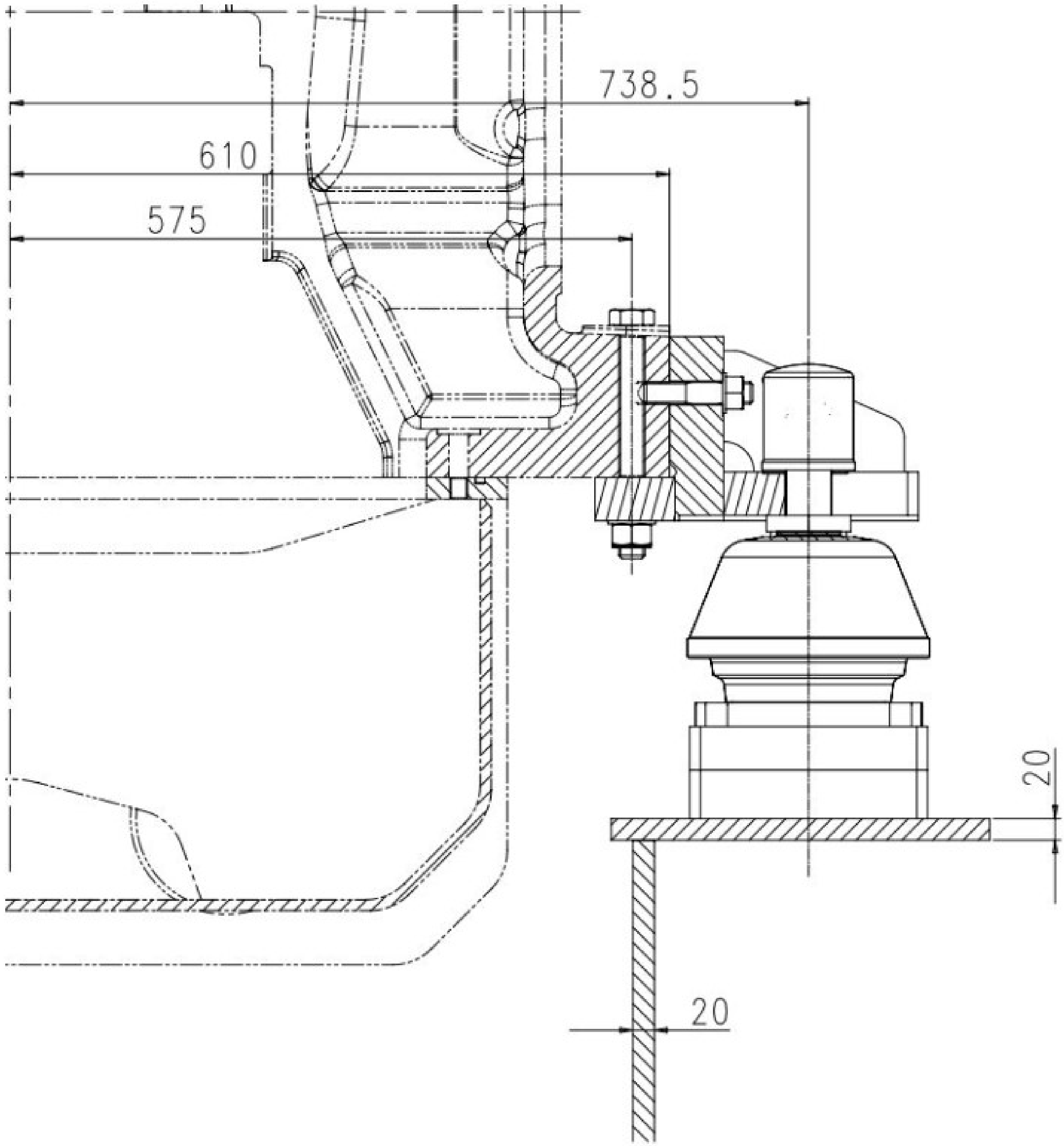


Figure 1-6-2: H25/33P Engine foundation (only for reference)[1)]

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

Rated power

Engine type	Rated output at 900rpm			
	kW		PS [3]	
	FPP [1]	CPP [2]	FPP [1]	CPP [2]
6H25/33P	1,740 / 1,800		2,366 / 2,448	
7H25/33P	2,030		2,760	
8H25/33P	2,320		3,155	
9H25/33P	2,610		3,550	

[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. 110% mechanical output shall be confirmed only for shop test.
2. Power adjusting (derating 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 a diesel main engine rating is specified in accordance with ISO 3046-1:2002. However, the engine outputs are available within tropical condition without de-rating.

ISO conditions

Total barometric pressure	: 1 bar
Air temperature	: 298 K (25°C)
Relative humidity	: 30%
Charge air coolant temperature	: 298 K (25°C)

Tropical conditions

Total barometric pressure	: 1 bar
Air temperature	: 318 K (45°C)
Charge air coolant temperature [1]	: 309 K (36°C)

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

Rated Power : 290 kW/cyl. at 900 rpm / 1-stage air cooler

Tier-II Tier-III (Tier-III with SCR)

Engine MCR	Cyl / kW	6 / 1,740	7 / 2,030	8 / 2,320	9 / 2,610
Cooling Capacity					
Charge Air					
Heat dissipation [1)]	kW	665	775	885	1,000
LT-cooling water flow	m^3/h	60	60	70	70
LT-cooling water temperature, engine in	℃	36	36	36	36
Lubricating Oil					
Heat dissipation [1),3)]	kW	295	345	395	445
Lubricating oil temperature, engine in	℃	65	65	65	65
LT-cooling water flow	m^3/h	60	60	70	70
LT-cooling water temperature, cooler in/out	℃	45 / 50	47 / 52	47 / 52	48 / 54
Cylinder Jacket					
Heat dissipation [1)]	kW	300	350	400	450
HT-cooling water flow	m^3/h	60	60	70	70
HT-cooling water temperature, engine in/out	℃	77 / 82	77 / 82	77 / 82	77 / 82
External L.T / H.T System					
Capacity of L.T central cooler [1)]	kW	960	1,120	1,280	1,445
L.T-water temperature, after central cooler	℃	36	36	36	36
Capacity of H.T central cooler [1)]	kW	300	350	400	450
H.T-water temperature, after central cooler	℃	77	77	77	77
Exhaust Gas Data[2)]					
Combustion air consumption	kg/h	11,710	13,660	15,610	17,560
Exhaust gas flow	kg/h	12,030	14,040	16,040	18,050
Exhaust gas temperature after turbine, approx.	℃	295	295	295	295
Allowable exhaust gas back pressure, max	mbar	30	30	30	30
HEAT RADIATION					
Engine radiation [1)]	kW	35	45	50	55
STARTING AIR[4)]					
Air consumption per start, disengaging propeller shaft (excluding Jet air)	Nm^3	2.2	2.4	2.6	2.8
Jet air consumption at sudden load up	Nm^3	1.1	1.1	1.1	1.1
Starting air source, pressure (max.)	bar	30	30	30	30
Starting air source, pressure (min.)	bar	15	15	15	15
Required vessels [5)]	liter	Refer to P.08.200			
Air compressor	m^3/h	Refer to P.08.200			

Engine MCR	Cyl kW	6 1,740	7 2,030	8 2,320	9 2,610
PUMP CAPACITIES, ENGINE DRIVEN PUMP					
Lubricating oil pump (6 bar)	m^3/h	82	82	94	94
HT-Cooling water pump (3 + static bar)	m^3/h	60	60	70	70
LT-Cooling water flow at engine inlet (3 + static bar)	m^3/h	60	60	70	70
PUMP CAPACITIES, EXTERNAL PUMP					
HFO supply pump [6)] (6 bar)	m^3/h	0.62 + Z	0.73 + Z	0.83 + Z	0.93 + Z
HFO booster pump [6)] (6 bar)	m^3/h	1.25 + Z	1.45 + Z	1.66 + Z	1.87 + Z
MDO supply pump [6)] (8 bar)	m^3/h	1.25 + Z	1.45 + Z	1.66 + Z	1.87 + Z
Stand-by lub. oil pump [6)] (6 bar)	m^3/h	82	82	94	94
Stand-by HT-cooling water pump (3 + static bar)	m^3/h	60	60	70	70
Circulation pump for fresh water (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%, LT(Low temperature)-cooling water temperature 36°C)
Heat dissipation tolerance ±10%, Fuel oil based on MDO, LCV (Low calorific value) 42,700 kJ/kg

A margin (0…15%) 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%, LT(Low temperature)-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) *Mentioned value for starting air source is for reference and based on the following conditions;*
A single engine: 6 starts and 1 margin start without engaging propeller shaft
Twin engines: 12 starts and 1 margin start without engaging propeller shaft
However, the required capacity of starting air source could be variable depending on the rules of classification and the arrangement of engines, reduction gear and etc. Therefore, the capacity of the starting air source must be satisfied with the rules of classification for each project.
The starting air source must be split up into at least two starting vessels of about equal capacity.

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 shaft and propeller 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. All above capacity is for IMO NOx Tier-II application and also can be used for SCR application against Tier-III.

4. If the engine capacity data for 6H25/33P(1,800kW) is necessary, please contact to HHI-EMD.

1. Engine Performance Data

Rated Power: 290 kW/Cyl. at 900 rpm

Tier-II / Tier-III (Tier-III with SCR)

Performance Data		Engine Load (%) 110	100	85	75	50
CYLINDER DATA						
Cylinder Output	kW/Cyl.	319	290	246.5	217.5	145
Mean Effective Pressure	bar	26.3	23.9	20.3	17.9	11.9
COMBUSTION AIR DATA 1)						
Mass Flow	kg/kWh	6.6	6.7	6.9	7.0	7.3
Air temperature after Cooler	℃	45	45	45	45	45
EXHAUST GAS DATA 1)						
Mass Flow	kg/kWh	6.8	6.9	7.0	7.2	7.4
Gas Temperature after Turbine	℃	310	295	305	315	350
HEAT BALANCE DATA 2)						
Charge Air	kJ/kWh	1405	1370	1235	1145	905
Lubricating Oil 3)	kJ/kWh	625	615	645	710	870
Jacket Cooling Water	kJ/kWh	615	620	625	655	780
Exhaust Gas	kJ/kWh	1910	1870	2010	1990	2280
Radiation	kJ/kWh	90	80	85	100	130
FUEL OIL CONSUMPTION 4)						
Specific Fuel Oil Consumption	g/kWh	182	181	181	182	188

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

2) *Reference condition based on tropical condition (Turbocharger inlet air pressure 1 bar, Intake air temperature 45 ℃, Relative humidity 30%, LT(Low temperature)-cooling water temperature 36 ℃)*
Heat dissipation tolerance ±10%

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

4) *Reference condition based on ISO 3046-1:2002 (Turbocharger inlet air pressure 1 bar, Intake air temperature 25 ℃, Relative humidity 30%, LT(Low temperature)-cooling water temperature 25 ℃), under IMO Tier II NOx condition*
SFOC tolerance for warranty +5%
Engine driven pumps detached: Lub. oil pumps, HT-pump, LT-pump
Fuel oil based on MDO, LCV 42700 kJ/kg
Warranted at 85% MCR load only

Remark

1. Engine performance data is for IMO NOx Tier-II application and also can be used for SCR application against Tier-III.
2. If the engine performance data for 6H25/33P (300kW/Cyl.) is necessary, please contact to HHI-EMD.

1. Engine Performance Data

Rated Power: 290 kW/Cyl. at 900 rpm — Tier-II Tier-III (Tier-III with SCR)

Performance Data		Engine Load (%) 110 (929rpm)	100 (900rpm)	85 (852rpm)	75 (817rpm)	50 (714rpm)
CYLINDER DATA						
Cylinder Output	kW/Cyl.	319	290	246.5	217.5	145
Mean Effective Pressure	bar	25.4	23.9	21.4	19.7	15.0
COMBUSTION AIR DATA 1)						
Mass Flow	kg/kWh	6.6	6.7	6.5	6.4	5.7
Air temperature after Cooler	℃	45	45	45	45	45
EXHAUST GAS DATA 1)						
Mass Flow	kg/kWh	6.8	6.9	6.7	6.5	5.9
Gas Temperature after Turbine	℃	305	295	300	320	400
HEAT BALANCE DATA 2)						
Charge Air	kJ/kWh	1395	1370	1165	1025	650
Lubricating Oil 3)	kJ/kWh	635	615	630	690	870
Jacket Cooling Water	kJ/kWh	625	620	610	635	780
Exhaust Gas	kJ/kWh	2035	1870	1930	1920	2535
Radiation	kJ/kWh	90	80	80	95	130
FUEL OIL CONSUMPTION 4)						
Specific Fuel Oil Consumption	g/kWh	184	181	181	177	188

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

2) *Reference condition based on tropical condition (Turbocharger inlet air pressure 1 bar, Intake air temperature 45 ℃, Relative humidity 30%, LT(Low temperature)-cooling water temperature 36 ℃)*
Heat dissipation tolerance ±10%

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

4) *Reference condition based on ISO 3046-1:2002 (Turbocharger inlet air pressure 1 bar, Intake air temperature 25 ℃, Relative humidity 30%, LT(Low temperature)-cooling water temperature 25 ℃), under IMO Tier II NOx condition*
SFOC tolerance for warranty +5%
Engine driven pumps detached: Lub. oil pumps, HT-pump, LT-pump
Fuel oil based on MDO, LCV 42700 kJ/kg
Warranted at 85% MCR load only

Remark

1. Engine performance data is for IMO NOx Tier-II application and also can be used for SCR application against Tier-III.
2. If the engine performance data for 6H25/33P (300kW/Cyl.) is necessary, please contact to HHI-EMD.

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

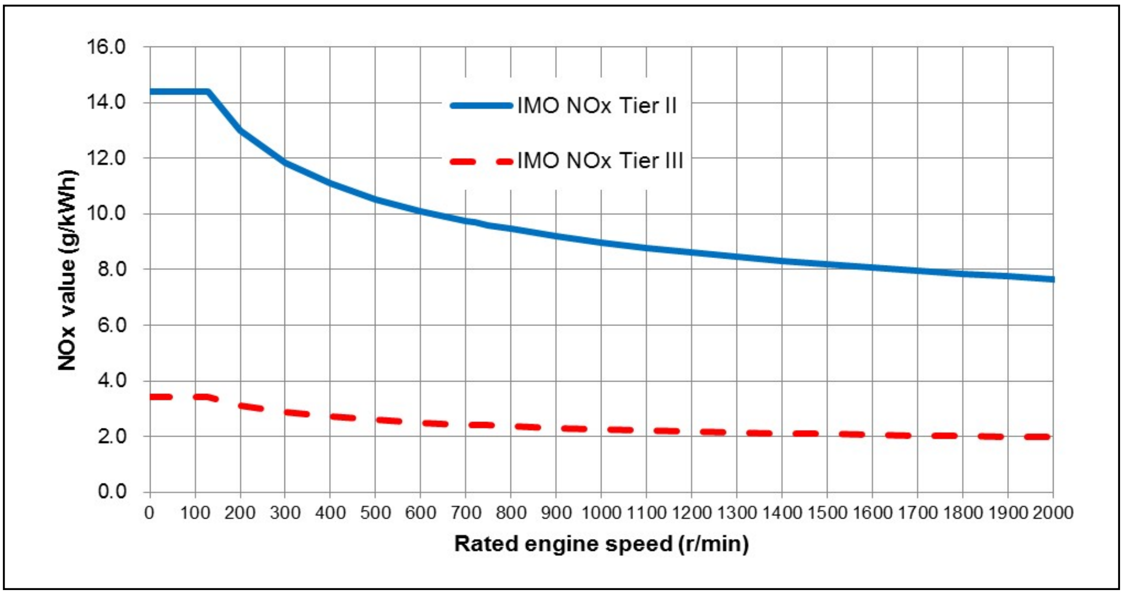


Figure 2-5-1: NOx emission from marine propulsion engine

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.

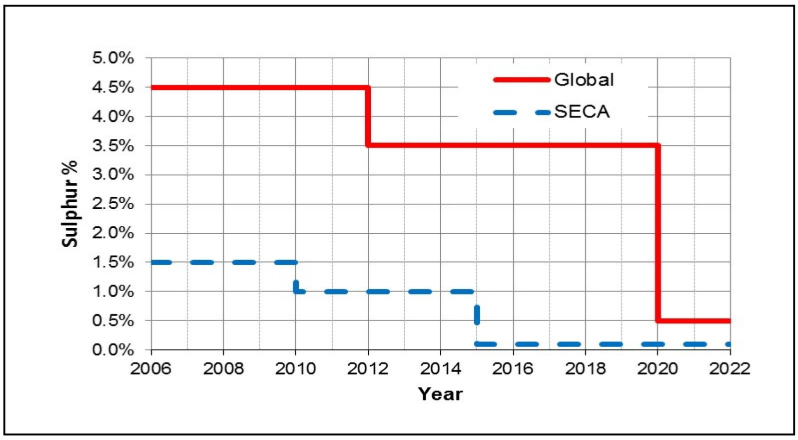


Figure 2-5-2: Sulphur limits in fuels

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, or Tier III emission level with SCR (Selective Catalytic Reduction) system 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:

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

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

$SFOC_{amb}$ [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(Low Temperature)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}): 1000 mbar
- LT(Low Temperature) Cooling water temperature (T_{CW}): 30°C
- Lower calorific value (LCV): 42700 kJ/kg
- $SFOC_{ISO}$: 183 g/kWh at 720 rpm, MCR

  Then, dSFOC = 1.006 and SFOC at site condition will be increased to 184.1 g/kWh.

Correction for engine driven pump

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]
Lubricating oil pump	+ 2.0
H.T Cooling water pump	+1.0
L.T Cooling water pump	+1.0
Fuel oil feed pump	Please contact to HHI-EMD
Charge air pressure control device	Please contact to HHI-EMD
Operation on MGO	+ 2
Exhaust gas back pressure after turbine > 300mmWC	+ 0.5 / 100 mmWC

L.T & H.T Pump attached engine (Genset & Propulsion)
Additional SFOC by water pump =
Additional SFOC at 100% load * (100/Load)^x * (actual rpm/rated rpm)^3 [g/kWh]

L.O Pump attached engine (Genset & Propulsion)
Additional SFOC by L.O pump =
Additional SFOC at 100% load * (100/Load)^x * (actual rpm/rated rpm)^3 [g/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] = LT(Low Temperature) Cooling water temperature before Charge Air Cooler(CAC) on actual operating condition

Example

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

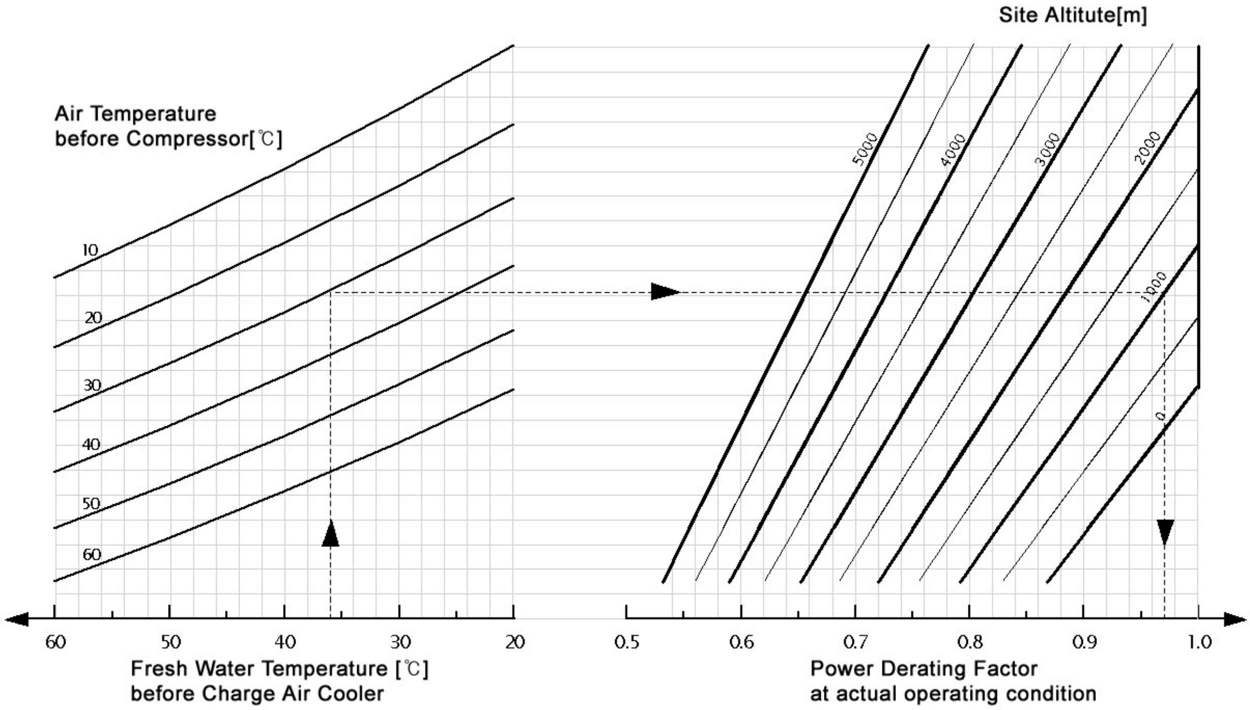
  then, dT_{aturb} = 22°C and the $T_{aturb,\ exh}$ on actual operating condition will be increased to 312°C.

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”.

Power derating

Engine output power at MCR shall be reduced depending on the Intake air temperature, LT(Low Temperature) cooling water temperature and site altitude.



Example

- LT(Low Temperature) Cooling water temperature before 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 actual operating condition is 0.97. Therefore the engine output power at actual operating condition should be de-rated to the 97% of the standard engine power.

External forces and couples

Engine Type	Speed	External Forces and Moments						Guide Force Moments		
		Order		Free Force		Moment		Order		Moment
				Horizontal	Vertical	Horizontal	Vertical			
	1/min	No.	Hz	kN	kN	kNm	kNm	No.	Hz	kNm
6H25/33P	900	1	15.0	0	0	0	0.0	3	45.0	15.0
		2	30.0	0	0	0	0.0	6	90.0	10.0
7H25/33P	900	1	15.0	0	0	0	12.0	3.5	52.5	36.0
		2	30.0	0	0	0	12.0	7	105.0	7.0
8H25/33P	900	1	15.0	0	0	0	0.0	4	60.0	31.0
		2	30.0	0	0	0	0.0	8	120.0	4.0
9H25/33P	900	1	15.0	0	0	0	9.0	4.5	67.5	29.0
		2	30.0	0	0	0	6.0	9	135.0	3.0

Table 3-1-1: External forces and couples

Moment of inertia

Engine Type	Speed	Rating	Moments of Inertia ; J 1)			
			Engine MOI	Flywheel 2)		Total MOI
				MOI	Mass	
	1/min	kW	kg㎡	kg㎡	kg	kg㎡
6H25/33P	900	1740	132.7	230	1,229	362.7
7H25/33P	900	2030	150.0	230	1,229	380.0
8H25/33P	900	2320	167.3	230	1,229	397.3
9H25/33P	900	2610	184.8	230	1,229	414.8

Table 3-1-2: Moments of inertias

Remark:

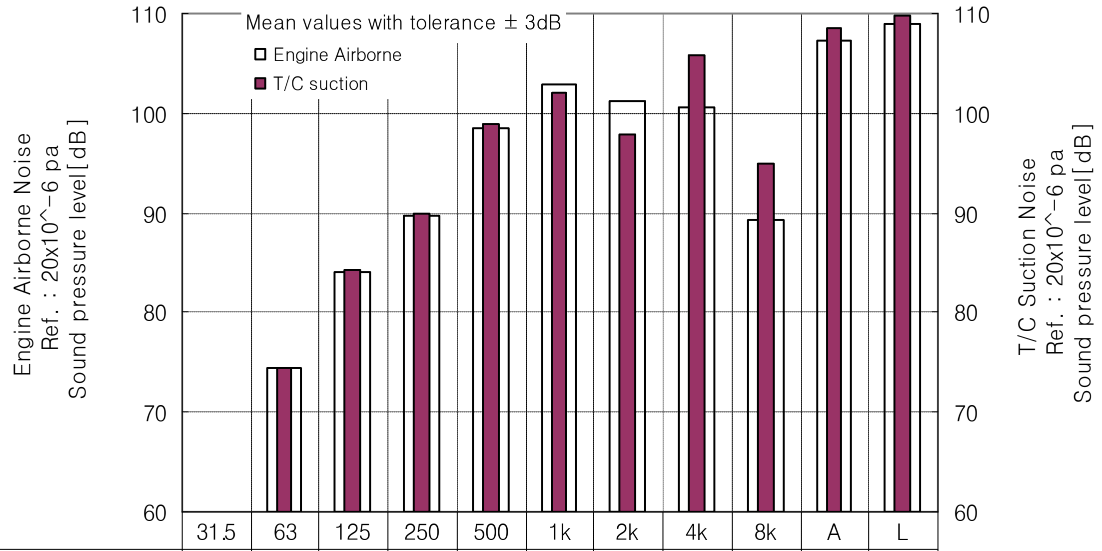
1) Moment of Inertia : $GD^2 = 4 \times J$ (kg㎡) 100% load
2) Finalizing of MOI of engine flywheel should be confirmed by a torsional vibration analysis.
3) The moment of inertia and mass data of the engine flywheel should be dimensioned depending on specific project specifications.

General

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

A typical measured result of each rated speed is as shown below. The values are average with linear and A-weighting in one octave band.

900 RPM (9Cyl.)



	31.5	63	125	250	500	1k	2k	4k	8k	A	L
Engine Airborne	51.8	74.5	84.2	89.8	98.5	102.8	101.2	100.5	89.4	107.2	109.0
T/C suction	55.0	74.5	84.2	89.9	98.9	102.1	97.8	105.8	94.8	108.6	109.7

Octave band center frequency[Hz]

Figure 3-2-1: Typical sound pressure level of the engine airborne noise

Remark:

1) The above measured result can be changed depending on 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.

General

The engine is designed for a reliable combustion of HFO (Heavy Fuel Oil) and MDO (Marine Diesel Oil) / MGO (Marine Gas Oil). Therefore, it is not required to change over from HFO to MDO at any operating conditions such as the low load running operation, engine starting and stopping, etc.

In order to maintain the good performance and reliability of the engine consistently, the general requirements are as follows:

Normal starting condition

- **Lubricating oil**

  The continuous pre-lubrication is required.

  Temperature : above 40°C(preheated)

- **Cooling water for the engine jacket**

Temperature	:	above 40°C for the starting on MDO/MGO (preheated)	above 60℃ for the starting on HFO (preheated)

- **Combustion air**

  Temperature : between 0°C and 45°C

- **Fuel oils**

  Pre-circulation is required.

Viscosity at engine inlet	:	2…14 cSt for MDO/MGO	12…18 cSt for HFO

Emergency cold starting

- **Lubricating oil**

  The pre-lubrication is required.

  Temperature : min. 10°C(Pre-lubricated)

  Viscosity : approx. 1,000 cSt based on SAE 40

- **Cooling water for the engine jacket**

  Temperature : min. 15°C

- **Combustion air**

  Temperature : min. 0

- **Fuel oil**

  Only MDO/MGO is acceptable.

Restrictions for the low load operation

There are no restrictions basically if the engine is running at above 15% load on MDO/MGO or above 20% load on HFO. In case the engine load is lower than the above values depending on the fuels, the engine operation should be limited.

The pre-heating operation with the closed charge air cooling flow valve is recommended to improve a clean combustion during the long term low load operation. At that time, a by-pass circuit or an appropriate circuit should be provided in order to ensure supply cooling water to a lubricating oil cooler.

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

- **Long term low load operation**

  Marine diesel oil and marine gas oil operation

  - Over 15% load operation : no restriction
  - Below 15% load operation : load up over 70% load at every limited time at corresponding load in Figure 5.1

  Heavy fuel oil operation

  - Over 20% load operation : no restriction
  - Below 0% load operation : load up over 70% load at every limited time at corresponding load in Figure 5.1

  Duration of flushing operation (See ‘Figure 5.1)

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

Example

1. Time limits for low load operation (line A, A')

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

2. Duration of flushing operation (line B, B')

   Engine should be operated for roughly 1.15 hours (heavy fuel oil) and 0.75 hours (marine diesel oil / marine gas oil) at not less than 70 % of full load.

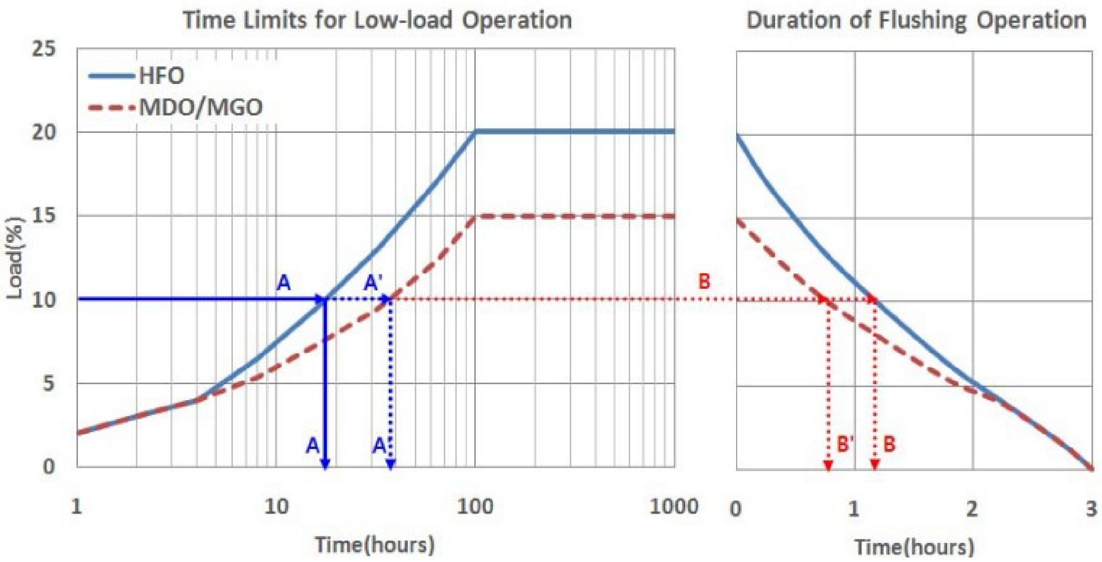


Figure 5.1 Time limits for low load operation

- **Around 15% load on HFO**

  The short time operation of 20…30 hours is recommended. After this operation, the MDO flushing operation of one hour should be done.

Stopping and restarting on HFO

- **Stopping on HFO**

  The engine can be stopped while running on HFO. In this case, the temperature of the fuel oil should not drop below the pour point. Otherwise, the change over from HFO to MDO should be done.

- **Restarting on HFO**

  In order to restart on HFO, the following requirements should be met:

  - Jacket water pre-heating up to 60°C to ensure the pre-lubrication
  - Fuel pre-heating up to the temperature corresponding to 12…18 cSt at the engine inlet

Change over from HFO to MDO

If the following services are necessary, the change over from HFO to MDO should be done.

- Cold starting
- Flushing operation of the fuel system
- Long term low load operation
- Long term stand still
- Maintenance work of the engine
- Emergency situations such as black-out, trip and shut-down, etc.

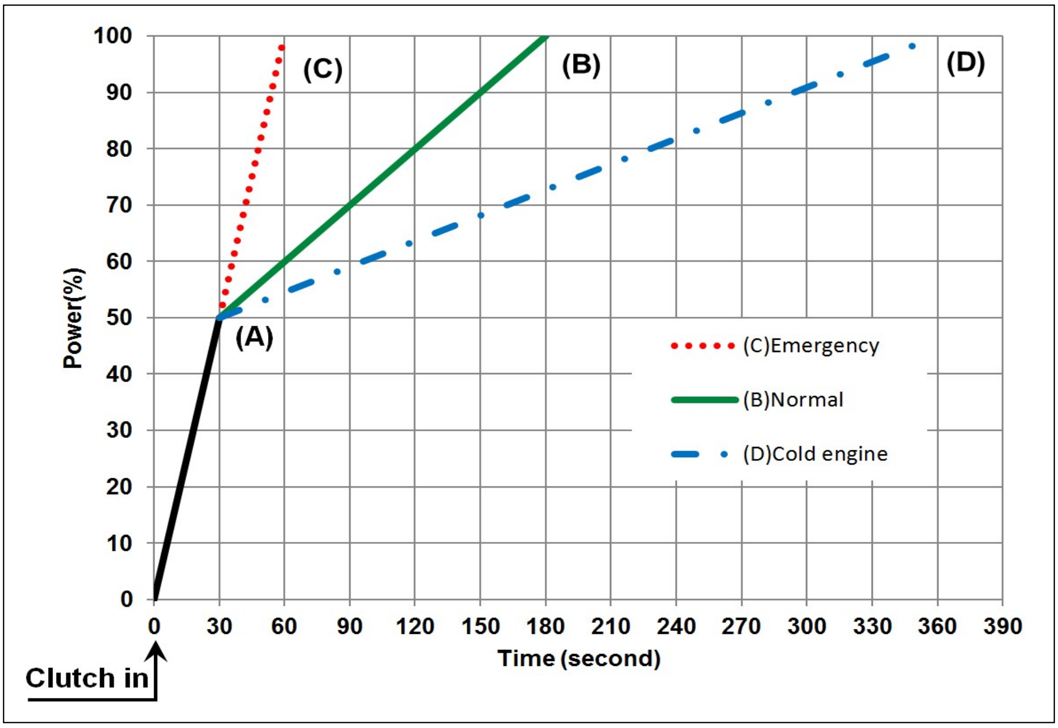


Table 4-2-1: Load-up rate depending on the engine conditions

Load-up of the warm engine

The conditions for the warm engine are generally as follows:

Temperature of the lubricating oil	:	above 40°C	
Temperature of the jacket water	:	above 40°C for the starting on MDO/MGO	over 60℃ for the starting on HFO
Temperature of the combustion air	:	approx. 0…45	

As the warm engine, the typical load-up times for the mechanical propulsion shall be in accordance with the following procedure.

- **Starting time**

  For the shortest starting time of the warm engine, the ready time for load-up is approx. 20 seconds from the starting order to the idle running.

- **Half load-up**

  The normal load-up from the idle running (clutch in) to the half load (A) takes maximum 30 seconds. If the smoke reduction is important as priority during load up, it should be considered to apply the slower loading time than the indicated curve.

- **Emergency load-up of the warm engine**

  The maximum loading capacity of the warm engine can be achieved from the half load (A) to full load (C). It takes approx. 30 seconds.

- **Normal load-up**

  For the normal loading while the vessel is on a maneuvering mode, the load-up takes approx. 150 seconds from the half load (A) to full load (B).

Load-up of the cold engine

The conditions for the cold engine are generally as follows:

Temperature of the lubricating oil	:	min. 10°C
Temperature of the jacket water	:	min. 15°C
Temperature of the combustion air	:	min. 0
Fuel oil	:	only MDO/MGO acceptable

As the cold engine on the limited conditions, the load up should not be faster than 330 seconds from half load (A) to full load (D) in order to achieve the enough heating-up time.

Programmable load-up

An automatic load-up can be achieved by the bridge or the CPP control system, which is recommended to be provided as an option.

Remark:

1. If there are the special requirements for the loading capacity, it should be consulted with the engine builder.

Engine starting

The starting system comprises a starting module including motor, relay valve and normal/emergency start valve. When the engine is started, a compressed air with the pressure of maximum 30 bar flows through a relay valve for starting the engine by turning flywheel with gears.

The main starting valve module is of an electro-pneumatic type and controlled by the engine control system. The signals for the start interlock are as follows:

- Turning gear engaged
- "BLOCKING" switch on
- “STOP ENGINE” activated
- Low pressure of the pre-lubricating oil (It can be different depends on system configuration)
- Common shut-down
- Clutch engaged
- Start fail

Engine stop

Two types of stop functions are provided to the engine for a safety: normal stop and emergency stop.

In case of normal stop, governor terminal shaft goes to zero fuel and thus fuel control shaft makes fuel rack “0” position. Normal stop is activated by pressing stop button in local or remote as per select control position (local/remote).

When manual emergency stop order or automatic shutdown is activated, emergency stop air cylinder pushes the stop lever. Consequently, fuel rack is moved to zero position. It is an independent function from governor’s action to zero fuel.

Both stop functions are activated by the following shutdown signals:

- Engine over-speed
- High temperature of the H.T cooling water at the engine outlet
- Low pressure of the lubricating oil at the engine inlet
- Manual emergency stop order
- High concentration of the oil vapor in the crankcase (if applied)
- Others (depends on each project)

Engine automation

- **Slow down (The function is conducted by FPP control system)**

  The engine speed decreases to a preset value in the following abnormal conditions:

  - Low pressure of the lubricating oil at the engine inlet
  - High temperature of the H.T cooling water at the engine outlet
  - Low pressure of the H.T cooling water at the engine inlet
  - High temperature of the exhaust gas at the cylinder outlets
  - Others (depends on each project)

- **Load reduction (The function is conducted by CPP control system)**

  It is same function as the slow down operation. The engine load shall be reduced by the propeller pitch control.

Speed control

When the select control position is on remote, the speed setting signal is transmitted from the propulsion control system. The governor compares the engine speed to the remote speed setting signal and then adjusts the fuel control shaft.

General

The engine control & safety system provides the protection, monitoring and control functions utilizing a reliable PLC (programmable logic controller). One control cabinet contains the independent subsystems as safety system, control system, etc. The subsystems work independently each other. The information and data are exchanged via communication.

For HiMSEN propulsion engine, two types of engine control & safety system are applied as below.

Engine built-on type

The engine built-on type is that most engine control modules and safety modules are installed in the Engine Control Panel (ECP) which is attached on engine. Therefore, all sensors and solenoid valves are directly hardwired to the ECP.

The Local Operating Panel (LOP) provides engine operation and monitoring functions by interfacing with ECP. All sensor data and engine condition are shown on HMI of LOP; for example ready to start, temperature values, pressure values, engine & T/C rpm, etc.

Self-standing type

The self-standing type is that PLC for control and safety are installed in separate Engine Control Panel (ECP). Accordingly, all sensors and solenoid valves are hardwired to terminal box or junction box on engine. And, it is to be connected to ECP which is installed in hull side.

The Local Operating Panel (LOP) shows engine status and engine & T/C rpm. The engine operation is available by pressing the buttons on LOP.

The other data from sensors are shown on HMI of ECP.

System	Descriptions	Normal operation range (refer to rated power)		Alarm set points		Load reduction	Shut-down
Speed control	Engine speed	SI11		SAH11	109% MCR		109% MCR
	Turbocharger speed	SI14		SAH14	97%-T/C max[9]		
Fuel oil system	For continuous HFO						
	Press. engine inlet(HFO)	PI52	8^{+2}_{-1} bar [1]	PAL52	6.0 bar		
	For continuous MDO/MGO						
	Press. engine inlet (MDO/MGO)	PI52	7…8 bar	PAL52	6.0 bar		
	Temp. engine inlet(HFO)	TI52	[2]	TAH52 [4]	155°C		
	Temp. engine inlet (MDO/MGO)	TI52	[2]				
	Fuel leakage			LAH54	High level		
	F.O safety filter ΔP			PDAH51-52 [4]	1.5 bar		
Lubricating oil system	Press. drop across filter	PI61-62		PDAH61-62	1.5 bar		
	Press. filter inlet	PI61 [4]	3.2…5.2 bar				
	Press. engine inlet	PI62	3.0…5.0 bar	PAL62	1.8 bar	1.6 bar	1.4 bar
	Temp. engine inlet, SAE40	TI62	60…70°C	TAH62	80°C		
	Press. T/C inlet	PI63	[3]	PAL63	[3]		
	Temp. T/C outlet	TI64	70…100°C[9]	TAH64	120°C[9]		
	Oil mist detector [4]			LAH92 [4]	High level		Hi-High[4] level
	Temp. main bearing [4]			TAH05 [4]	95°C	98°C [4]	100°C [4]
	Lub. oil stand-by press.			STAT62 [4]	2.0 bar		
Cooling water system	L.T water press. air cooler inlet	PI71	1.0…4.5 bar	PAL71	0.4 + α [5] bar		
	L.T water temp. engine inlet	TI71	30…40°C	TAH71 [4]	45°C		
	L.T stand-by press.			STAT72 [4]	0.4+ α [5] bar		
	H.T water press. engine inlet	PI75	1.5…4.5 bar	PAL75	0.4 + α [5] bar	0.2 + α [5] bar	
	H.T water temp. engine inlet	TI75 [4]	65…75°C				
	H.T water temp. engine outlet	TI76	75…85°C	TAH76	90°C	92°C	95°C
	H.T stand-by press.			STAT75	0.5 + α [5] bar		
Combustion gas / air system	Charge air press. air cooler outlet	PI21	3.3…4.3 bar[8]				
	Charge air temp. air cooler outlet	TI21	35…55°C	TAL21 [4] TAH21 [4]	25°C 70°C		
	Exh. gas temp. cylinder outlet	TI25	350…550°C	TAH25	530°C	540°C	
	deviation from average of cylinder		±50°C	TDAH25	±70°C [6]	[10]	
	Exh. gas temp. T/C inlet	TI26	420…580°C	TAH26	580°C		
	Exh. gas temp. T/C outlet	TI27	230…410°C	TAH27	480°C		
Compressed air system	Starting air pressure, engine	PI40	15…30 bar[9]	PAL40	15 bar [9]		

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 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.*

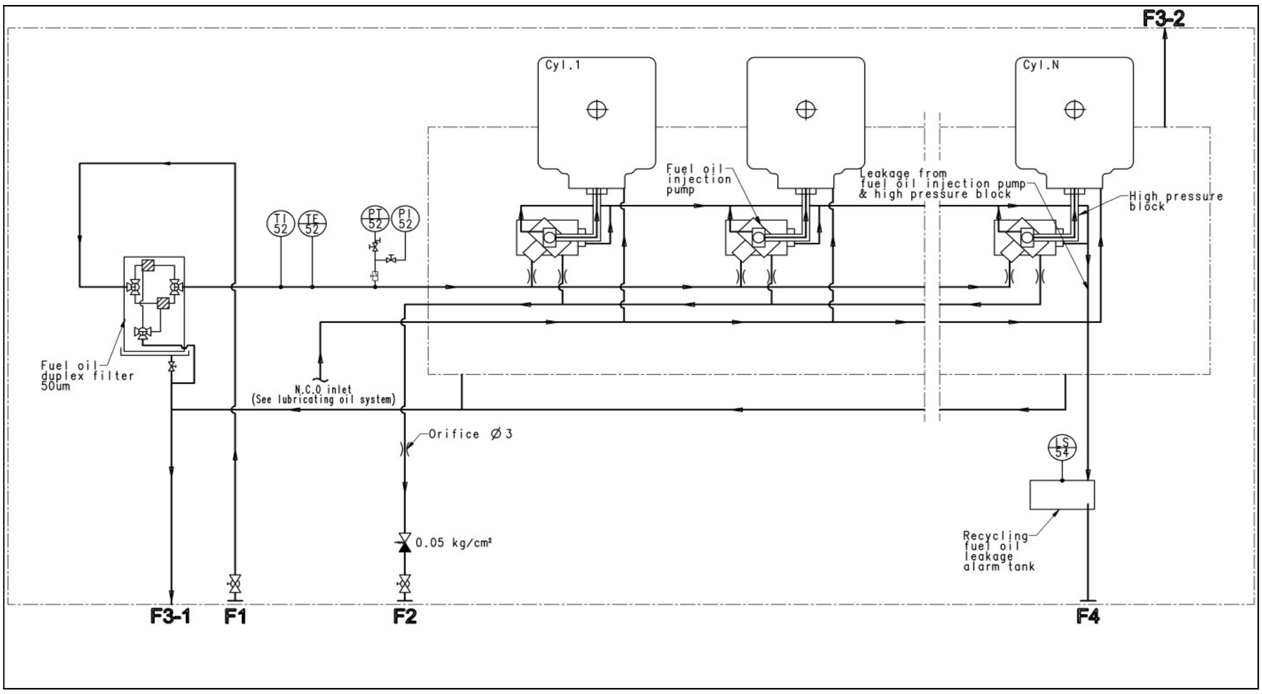
7) *See. Engine capacity, P.02.200 and P.02. 210*

8) *Depends on the engine load*

9) *Depends on the model of maker*

10) *If required by torsional vibration calculations, load reduction shall be added.*

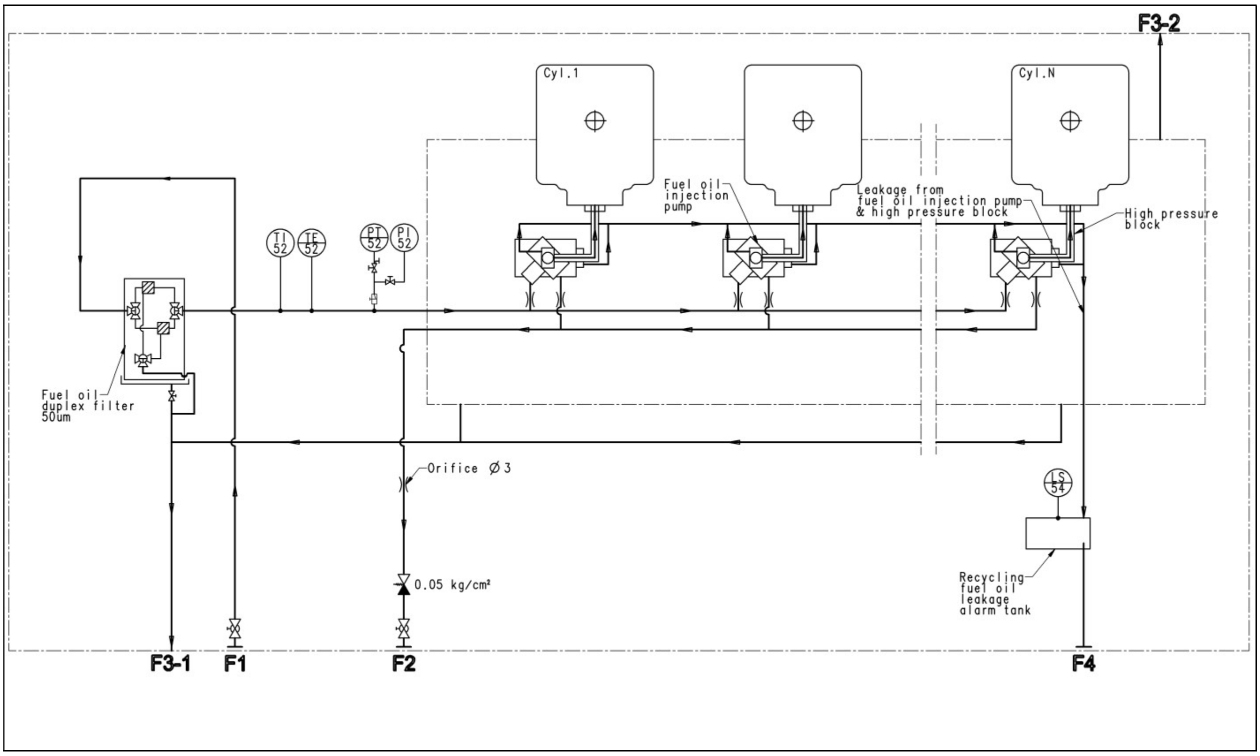
Diagram for Internal Fuel Oil System (HFO operation)



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

Figure 5-1-1: Internal fuel oil system (HFO operation)

Diagram for Internal Fuel Oil System (MDO operation)



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

Figure 5-1-2: Internal fuel oil system (MDO operation)

Sizes of External Pipe Connections

Code	Description	Size	Standard
F1	Fuel oil inlet	25A	JIS B 2220
F2	Fuel oil outlet	25A	JIS B 2220
F3-1	Waste oil drain(cam side)	OD15	
F3-2	Waste oil drain(exh. side)	OD10	
F4	Clean fuel oil drain	15A	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 fuel oil system designed for a reliable combustion of HFO (Heavy Fuel Oil) or MDO. (Marine Diesel Oil) Therefore, it is not recommended to change over fuel except for cold starting, flushing of the system, maintenance and long-term stand still.

The nozzles of fuel injection valves are cooled by the lubricating oil for the HFO operation, while they are not cooled for the MDO operation.

Fuel injection quantity is controlled by governor via a common regulating shaft and spring loaded linkage, which maintain engine speed set point by continuous positioning of the fuel pump rack.

The fuel oil duplex filter can be built on the fuel oil inlet in the engine as an option. It is of a manual cleaning type and works as a safety filter. The fineness of the filter is 50㎛ absolute.

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

- Fuel oil injection pump
- Fuel oil injection valve
- High pressure block
- Clean fuel oil leakage alarm tank
- Fuel oil duplex Filter

Clean fuel oil drain

The clean fuel can leak from the fuel oil injection pumps and the high pressure blocks. It is drained by gravity through the clean fuel oil leakage alarm tank. This clean fuel drainage shall be led to the clean leak fuel tank and can be reused without a separation.

The total leak rate from the fuel oil injection pumps and the high pressure blocks can be estimated as following formula:

$$Q = 0.3 \times C_f$$

Q [L/cyl.hour] = Clean fuel leak rate per cylinder
C_f = Weighing 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.

Waste oil drain

When the engine is overhauled, the waste oil can be drained. And in case the engine is designed for a continuous MDO operation, the waste oil leakage from the fuel oil injection pumps can be drained. These waste drainage flows by gravity and shall be led to the sludge tank.

General

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

Fuel oil specification which will be used for an 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) will be used for an engine, fuel oil system has to follow the guide for HFO, since ISO 8217:2017 is a reference of this project guide including P.05.300.

In any case, the condition of fuel oils (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 the fuel oils 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.
- Therefore, the proper viscosity, temperature and pressure are necessary for a proper operation of the system, the pre-heating, insulation with heat tracing and pressurizing equipment should be included in the external fuel oil system.
- In order to prevent an excessive pressure loss and minimize a pressure pulse in the piping system, the flow velocity of the 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 system should be provided with a backup for HFO system especially for emergency situations and flushing operation with MDO/MGO before the engine stop in case of a long period standstill or an event of the major overhaul.

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

Fuel treatment system

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

For a fuel treatment, the fuel oil should be transferred from the bunker tanks to the settling tanks first while it is 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 an efficient separation.

The system mainly consists of a feed pump, a pre-heater and 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 meet the following requirements and satisfied with the regulations issued by classification societies.

Capacity of each tank	:	minimum 24 hours fuel feed of total fuel 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.) The 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 meet the following requirements and satisfied with the regulations issued by classification societies.

Capacity of each tank	:	minimum 24 hours fuel feed of total fuel 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 a proper cleaning of the fuel oil considering the total fuel consumption of 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 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 consumption at MCR + 20% safety margin (Remark 2)
ρ [kg/m^3] = fuel 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 treatment system is common with other engines, the fuel consumption of other engines should be included.
2. 20% safety margin for the specific fuel consumption is considered due to the followings:
   - Engine driven pumps
   - Fuel consumption tolerance
   - Operation conditions including tropical condition
   - Fluctuation of the fuel calorific value
3. The actual capacity of the separator should be considered with the throughput (%) additionally

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

It is required to ensure a 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

The separators should be operated in parallel, unless they comprise manually operated separators with purifier followed by 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 flowrate for the separation. It is recommended to be a screw type and it should be protected by the suction strainers with a mesh size of approx. 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 the fuel oil and be recommended by the manufacture of the separator. In order to avoid making a fuel oil to be 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 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 feed system for HFO

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

The system mainly consists of a supply pump, a circulation pump, a heater / 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 a cleaned fuel oil by a continuous separation. The settling tank is not used for the day tank.

  Each day tank shall meet the following requirements and satisfied with the regulations issued by classification societies.

Capacity of each tank	:	minimum 8 hours fuel feed of total fuel 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.) The 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 a cleaned fuel oil by a continuous separation. Each day tank shall meet the following requirements and satisfied with the regulations issued by class societies.

Capacity of each tank	:	minimum 8 hours fuel feed of total fuel 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.

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

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

The sequence and control of the fuel changeover should ensure that the fuel oil will be changed smoothly in the temperature and viscosity. And the viscosity of the fuel oil 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 pumps.

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 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 approx. 0.5…0.7mm with a magnet and the positive static pressure of minimum 0.5 bar is required on the suction side of the pump.

The 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 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 a constant 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 the fuel 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 to be cooled appropriately.

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

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

  If a measuring device for the fuel 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 a fuel 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 gases from the fuel through a 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 a fuel supply for 10…15 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 circulation pumps.

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

  The flushing valve is required to change the fuel oil from HFO to MDO in the system in case of the emergency stop during HFO operation. In this case, first the fuel oil will be changed from HFO to MDO by the changeover valve (CV-501) and circulated in the system via 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 the fuel oil in the system is changed with MDO completely, the flushing valve should be back to the normal position in which the fuel 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 via this flushing valve.

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

  As the heated HFO has to be continuously re-circulated, the circulation pump should ensure a fuel 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 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	:	150°C
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).

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 a sufficient capacity for heating the fuel oil at full load operation.

The minimum required capacity of each heater can be estimated as 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 a viscosity controller. The set point of the viscosity controller shall be a little lower than the required injection viscosity at the engine(s) in order to compensate for heat losses during a transfer-process.

In order to avoid making a crack of a fuel oil, the temperature of the heater surface must not be too high.

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

The automatic back-flushing filter should be provided in order to achieve a better cleaning effect of a 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 catalytic hydrodesulphurization 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 by only centrifugal separators, because the cat fine has a specific gravity equal or lower than the fuel oil.

Generally, 34㎛ absolute is chosen for the mesh size of the automatic back-flushing filter. However, a 10㎛ absolute is strongly recommended for the mesh size of the filter under operation with low sulfur fuel oil which is produced by catalytic hydrodesulphurization 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 on supply line after 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 the pressure differential indication and switch in order to check the filter clogging.

Oil viscosity	:	Depends on fuel specification
Design temperature	:	150°C
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)

- **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 of filter is to be as close as the engine.

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

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

Set pressure : 8…10 bar

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

The MDO cooler is required to prevent the fuel oil from overheating and being with a very low viscosity in the circulation system at 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 by-pass pipe and changeover valve.

If the viscosity of MDO in day tanks drops below the minimum value of recommended viscosity range, it is required to install a MDO cooler into the engine supply line for 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 fuels, this temperature must be even lower and it depends on the actual fuel oil specification.

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

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

P [kW] = required capacity of the cooler
Q [m³/h] = max. delivery quantity of fuel oil (equal to the flow capacity of circulating pump)
ρ [kg/m³] = fuel density at 15℃ (Typical value: 900kg/m³)
c [kW/kg℃]=Specific heat of fuel (Typical value: 2 kJ/kg℃)
dT[℃] = Temperature difference between 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 MDO cooler capacity, the parameters must be taken into account based on actual fuel properties.

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

The dirty leak fuel which is drained from the engine(s) by gravity should be collected into the sludge tank via the pipes continuously inclined. 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 tank, HFO (TK-505)**

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

Fuel feed system for MDO

If the engine(s) are always operated with MDO, the fuel feed system can be an open system without a mixing tank and an additional circulation pump. In this case, the cleaned fuel oil of the day tank will be fed to the engine(s) via a supply pump 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 a cleaned fuel oil by a continuous separation. Each day tank shall meet the following requirements and satisfied with the regulations issued by class societies.

Capacity of each tank	:	minimum 8 hours fuel feed of total fuel 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 a fuel 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 approx. 0.5…0.7mm with a magnet and the positive static pressure of minimum 0.5 bar is required on the suction side of the pump.

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 consumption at MCR
Delivery head	:	8 bar
Design temperature	:	50°C
Viscosity (for electric motor)	:	100 cSt

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

If a measuring device for the fuel 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 a fuel supply in case the flow-meter is clogged.

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

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

Set pressure : 8 bar

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

The MDO cooler is required to prevent the 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 a MDO Cooler into the engine supply line for reliable viscosity of fuel oil.

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

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 circulation while the cooler is overhauled.

The minimum required capacity of MDO cooler can be estimated as 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 density at 15℃ (Typical value: 900kg/m^3)
c [kW/kg℃]=Specific heat of fuel (Typical value: 2 kJ/kg℃)
dT[℃] = Temperature difference between inlet and outlet. (Typical value: 12…15℃)

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

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

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

Set pressure : 2 bar

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

  The dirty leak fuel which is drained from the engine(s) by gravity should be 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 tank, MDO (TK-506)**

  The clean leak fuel which is drained from the engine(s) by gravity should be collected into the clean leak fuel tank via the pipes continuously inclined. 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-502)**

  The automatic back-flushing filter is recommended to be provided in order to achieve a better cleaning effect of a fuel oi supplied to the engine(s). If an engine is operated on MDO only, the main automatic filter (FT-502) can be replaced by a duplex filter with the fineness 34㎛ 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.

  It is recommended to install an automatic filter with a mesh size of 34㎛ absolute between the engine and the supply pump in the supply system. The automatic filter should be provided with the pressure differential indication and switch in order to check the filter clogging.

  The 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.

- **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 of filter is to be as close as the engine.

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

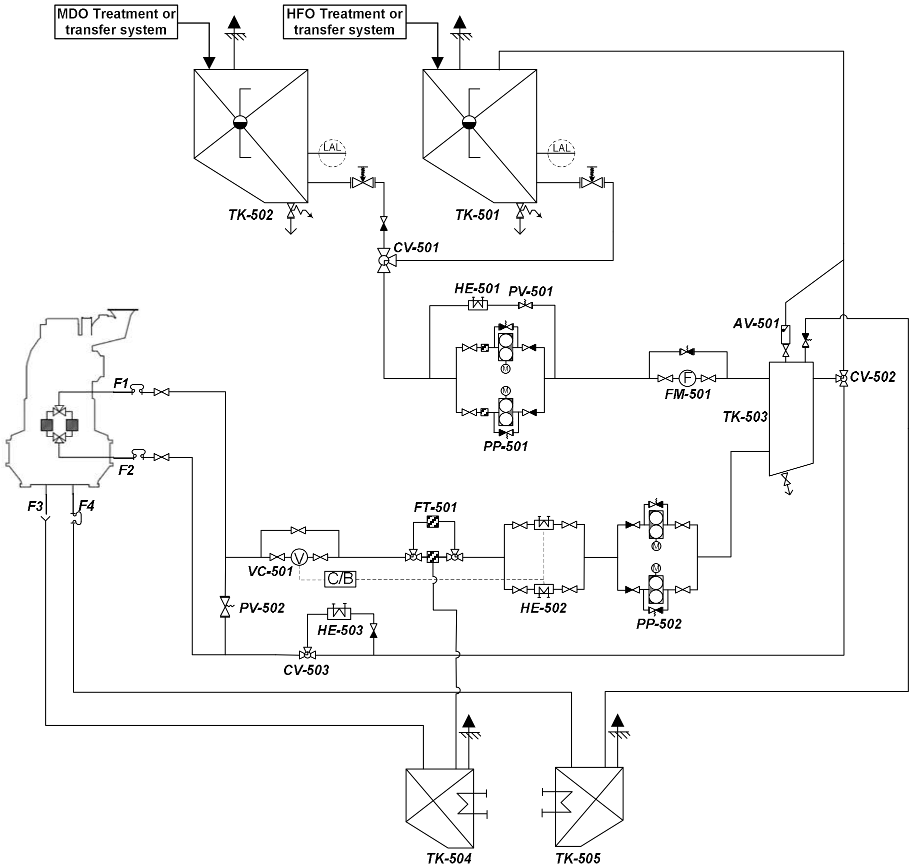


Figure 5-2-1: External fuel oil system (HFO) for a single engine installation

System components			
Code	Description	Code	Description
TK-501	Day tank for HFO	PP-502	Circulation pump
TK-502	Day tank for MDO	CV-501	Changeover valve
TK-503	Mixing tank	CV-502	Flushing valve
TK-504	Waste fuel tank	CV-503	Changeover valve (MDO cooler)
TK-505	Clean leak fuel tank	HE-501	Cooler for supply pump
FT-501	Main filter (Automatic filter)	HE-502	Heater
FM-501	Flow-meter	HE-503	MDO cooler
VC-501	Viscosity controller	PV-501	Pressure control valve
AV-501	Auto de-aerating valve	PV-502	Pressure control valve
PP-501	Supply pump		
Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F3	Waste oil drain
F2	Fuel oil outlet	F4	Recycling fuel oil drain (Clean oil)

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

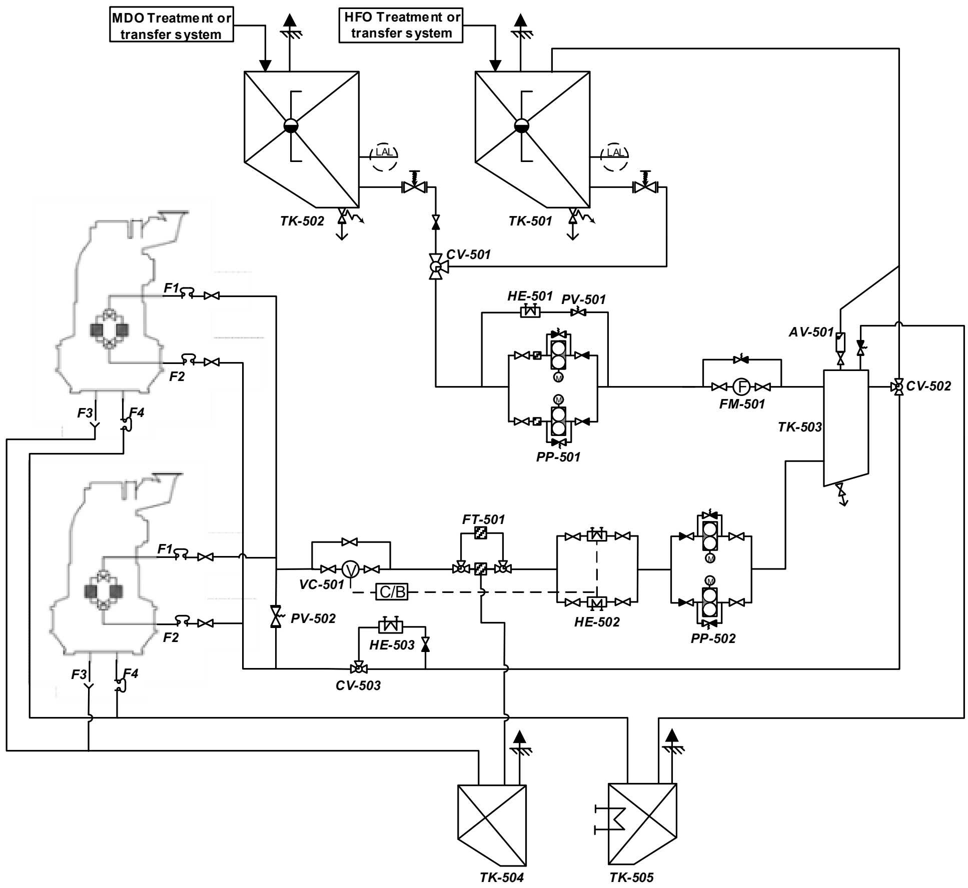
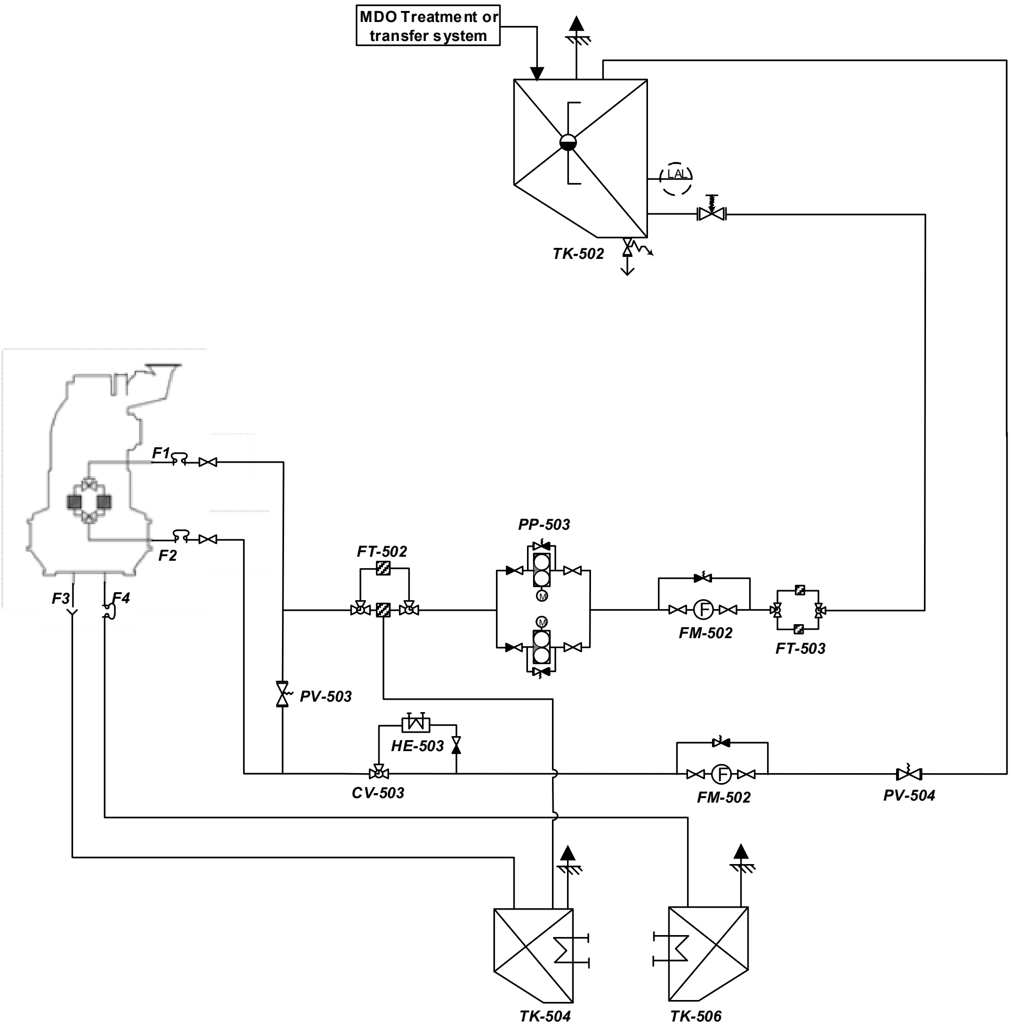


Figure 5-2-2: External fuel oil system (HFO) for a multi-engine installation

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

Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F3	Waste oil drain
F2	Fuel oil outlet	F4	Recycling fuel oil drain (Clean oil)

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



System components			
Code	Description	Code	Description
TK-502	Day tank for MDO	FT-503	Suction strainer
TK-504	Waste fuel tank	PP-503	Supply pump
TK-506	Clean leak fuel tank	HE-503	MDO cooler
FM-502	Flow-meter	PV-503	Pressure control valve
FT-502	Main filter	PV-504	Pressure control valve
Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F3	Waste oil drain
F2	Fuel oil outlet	F4	Recycling fuel oil drain (Clean oil)

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

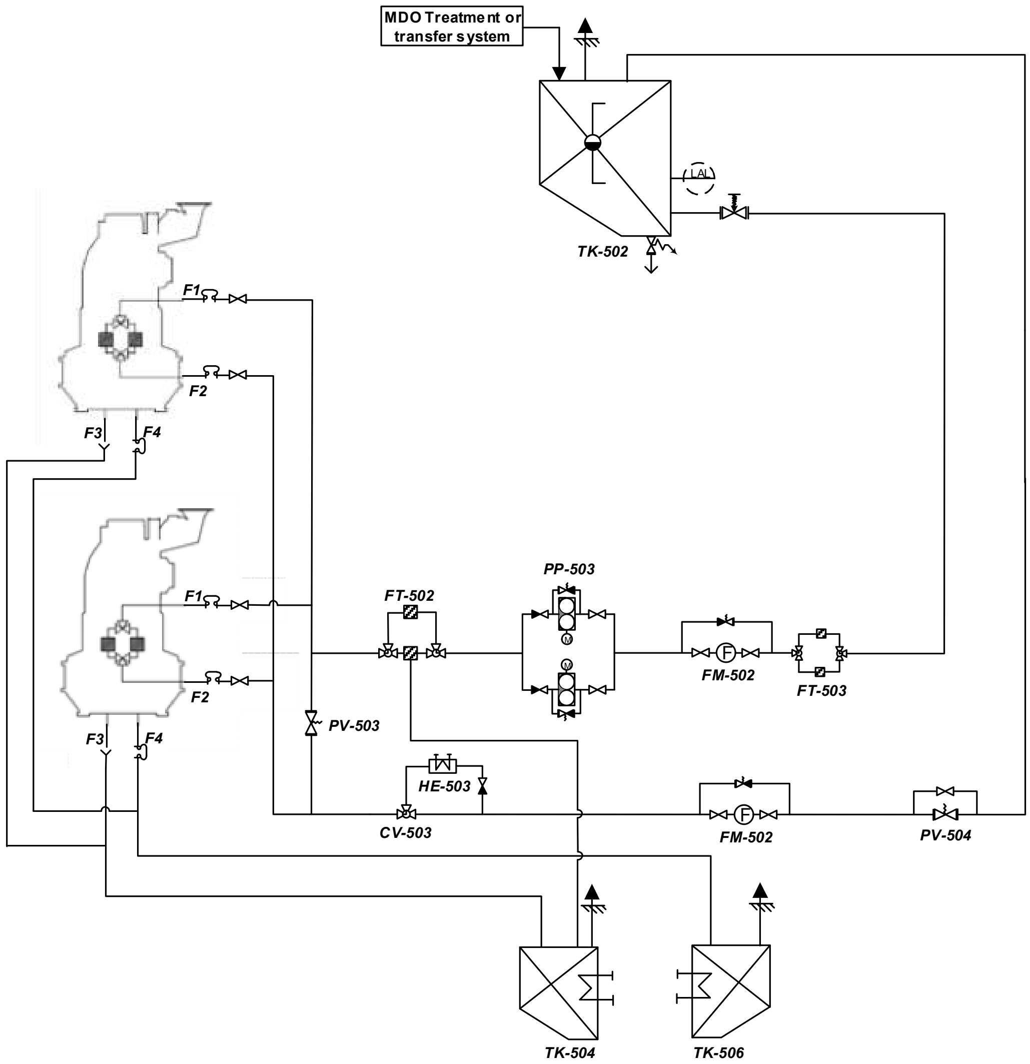


Figure 5-2-4: External fuel oil system (MDO) for a multi-engine installation

System components			
Code	Description	Code	Description
TK-502	Day tank for MDO	FT-503	Suction strainer
TK-504	Waste fuel tank	PP-503	Supply pump
TK-506	Clean leak fuel tank	HE-503	MDO cooler
FM-502	Flow-meter	PV-503	Pressure control valve
FT-502	Main filter	PV-504	Pressure control valve
Pipe connections			
Code	Description	Code	Description
F1	Fuel oil inlet	F3	Waste oil drain
F2	Fuel oil outlet	F4	Recycling fuel oil drain (Clean oil)

General

The fuel specifications are based on ISO 8217:201. 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 DB. 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. 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 as the following table:

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)

Table 5-3-1: Designation of fuel grades

Distillate fuels

Characteristics		Unit	Limit	Category ISO-F-							Test Method Reference
				DMX	DMA	DFA	DMZ	DFZ	DMB	DFB	
Kinematic viscosity at 40°C		mm²/s [a]	max.		6.0		6.0		11.0		ISO 3104
			min.		2.0		3.0		2.0		
Density at 15°C		kg/m³	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.		1.5		1.5		2.0		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/m³	max.	25	25		25		25 [d]		ISO 12205
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		
Appearance		-	-	Clear and bright [g]					[c]		
Water		volume %	max.	-	-		-		0.30 [c]		ISO 3733
Ash		mass %	max.	0.01	0.01		0.01		0.01		ISO 6245
Lubricity, corrected wear scar diameter (WSD 1,4) at 60°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, cloud point, cold filter plugging point) are suitable for the ship's design and intended voyage. See 6.11 ISO 8217:2017.*
g)	*If the sample is dyed and not transparent, then the water limit and test method as given in 6.12. ISO 8217:2017 shall apply.*
	This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0.050 mass %).

Table 5-3-2: Specifications of distillate fuels

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	mm^2/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/m^3	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			
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

a) *1 mm^2/s=1 cSt*

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

c) *See Annex H of ISO 8217:2017.*

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

*) *International statutory requirement*

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.

Table 5-3-3: Specifications of residual fuels

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	μm	-	460	EN 12156-1
Evaporated at 250°C	% (v/v)	-	65	ISO 3405
Evaporated at 350°C	% (v/v)	-	85	ISO 3405
Distillation 95% (v/v)	°C	-	360	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 biofules

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
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:

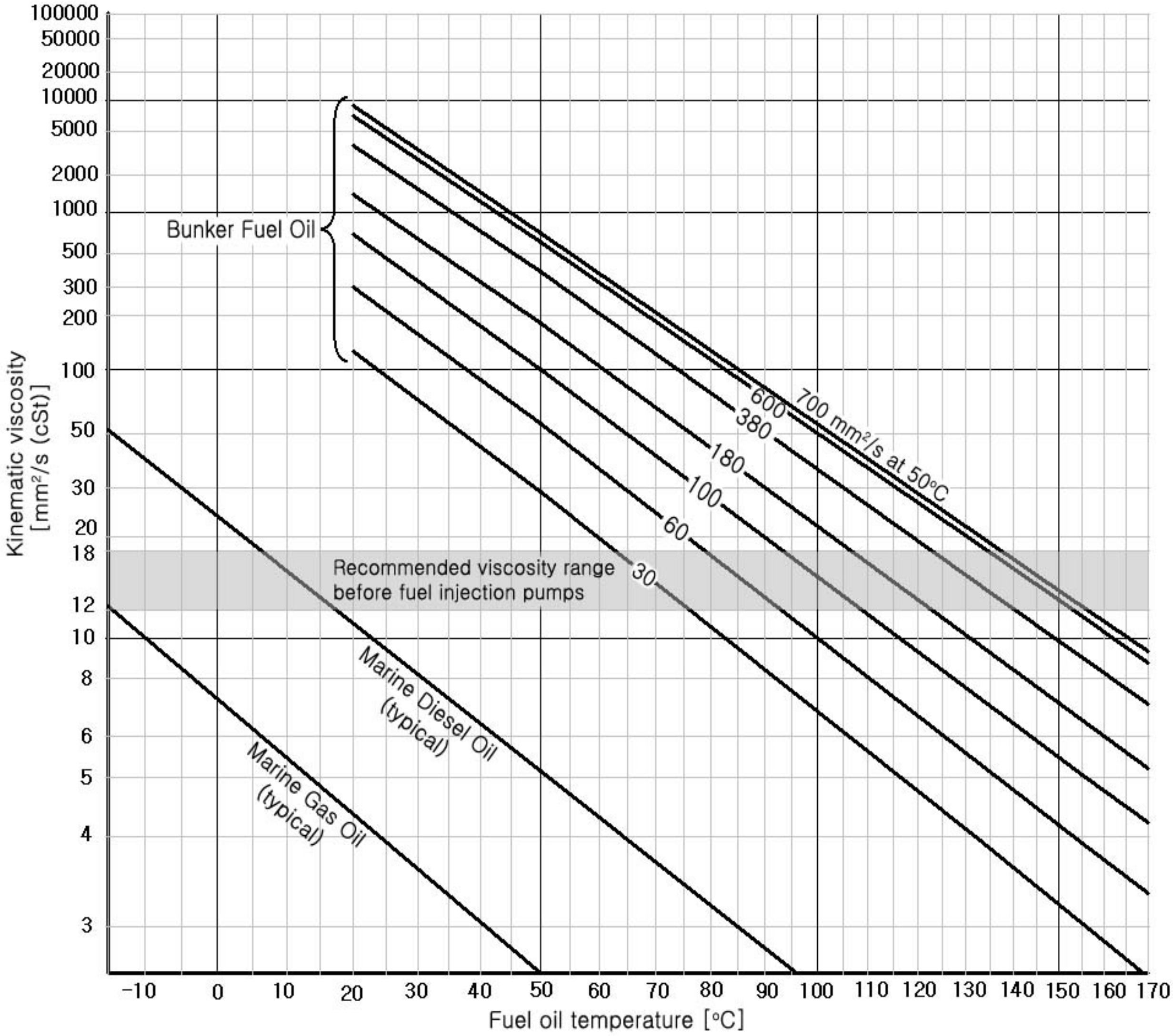


Figure 5-3-1: Fuel oil viscosity-temperature diagram

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/m³] = 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/m³] = 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/m³] = density at 15 ℃

w [mass %] = water content

a [mass %] = ash content

s [mass %] = sulfur content

Diagram for internal lubricating oil system (dry sump)

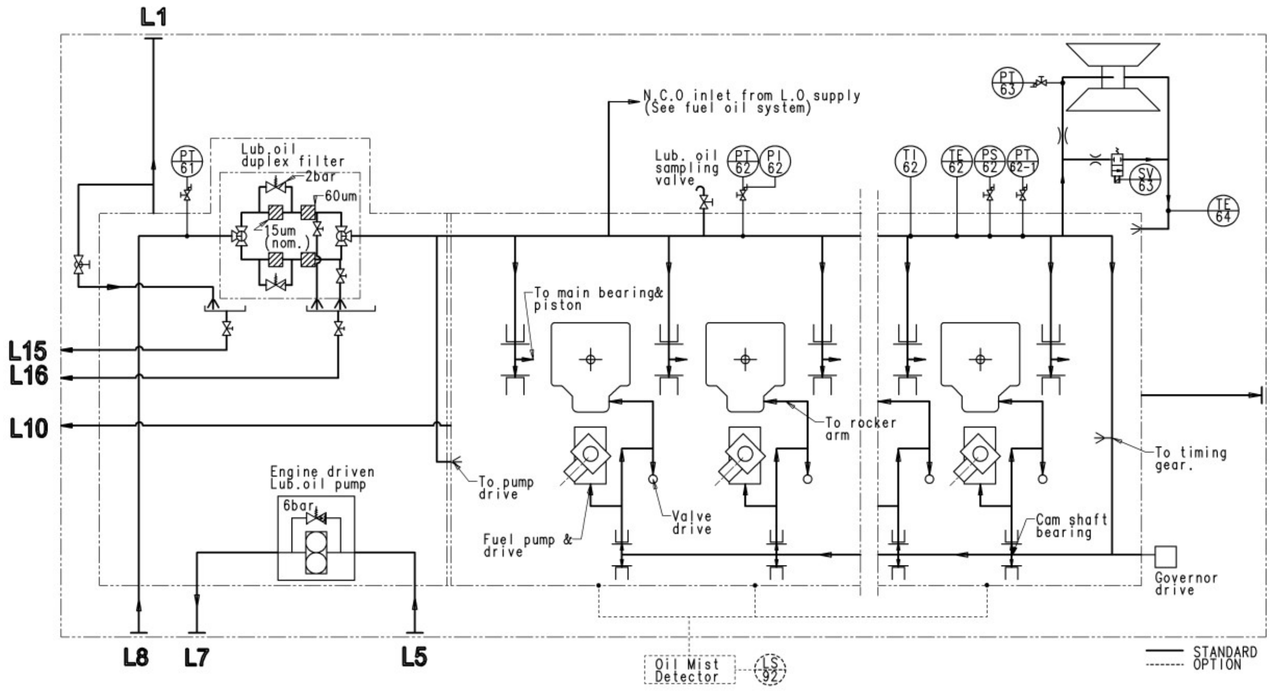


Figure 6-1-1: Internal lubricating oil system(dry sump)

Diagram for internal lubricating oil system (wet sump)

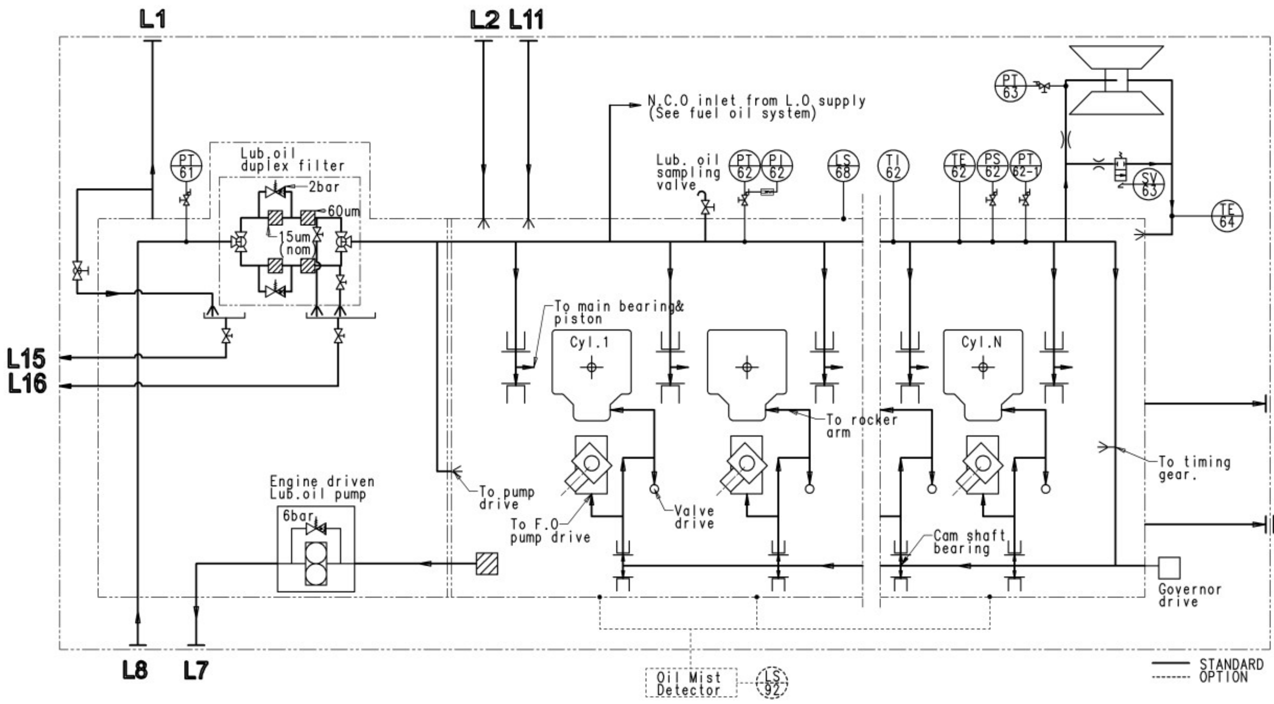


Figure 6-1-2: Internal lubricating oil system(wet sump)

Sizes of external pipe connections

Code	Description	Size	Standard
L1	Oil vapor discharge	5K-100A	JIS B 2220
L2	Lub. oil from separator/filling	5K-50A	JIS B 2220
L4	Lub. oil to separator	5K-50A	JIS B 2220
L5	Lub. oil to engine driven pump	10K-125A	JIS B 2220
L6	Lub. oil to stand by pump	10K-125A	JIS B 2220
L7	Lub. oil to L.O cooler	10K-125A	JIS B 2220
L8	Lub. oil from L.O cooler	10K-125A	JIS B 2220
L9	Lub. oil to bottom tank(flywheel end side)	5K-150A	JIS B 2220
L10	Lub. oil to bottom tank(free end side)	5K-100A	JIS B 2220
L11	Back flushing lub. oil to oil pan	5K-50A	JIS B 2220
L15	Waste oil drain from oil vapor discharge pipe	OD 10	
L16	Lub. oil drain from L.O filter	OD 10	

General

The main engine has its own internal lubricating oil system with wet or dry oil sump, which supplies lubricating oil to all moving parts for lubricating as well as for cooling. Most of the oil passages are incorporated into the engine components including a turbocharger(s).

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

- Engine driven lubricating oil pump(with pressure regulating valve)
- Main lubricating oil filter
- Oil mist detector (Option on 8 and 9 cylinder H25/33P)
  Oil mist detector shall be applied to all engines of 2250kW and above or with cylinder bore later than 300mm as standard.

Wet sump

Engine wet sump for lubricating oil is to be separate the air and particles from lubricating oil before engine inlet. And its design shall be taken in the consideration by requirement of classification of society.

Engine type	Oil quantities in litter	
	Min.	Max.
6H25/33P	1,210	1,460
7H25/33P	1,340	1,630
8H25/33P	1,490	1,800
9H25/33P	1,620	1,970

Lubricating oil consumption

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

SLOC = approx. 0.6

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

Remark:

1. +25% tolerance should be considered depending on the operating conditions.

General

The external lubricating oil system is required for not only cleaning but 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 filter is installed in system 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 Distillate fuel oil 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 Distillate fuel oil, the intermittent separation might provide sufficient capacity.

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 Distillate fuel oil 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**

  The separator should be in continuous operation for each engine in order to ensure removal of contaminants. (If one separator is installed in multi-engine plats, it must be consulted by HHI-EMD.) And if the engine is operated in Distillate fuel oil/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. The system mainly consists of an automatic filter, a cooler, a thermostatic valve, a stand-by pump and 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.

- **Separated oil tank (TK-604)**

  The separated oil tank contains the separated oil from separation to ready the replacement.

- **Transfer pump (PP-604)**

  The transfer pump shall transfer the lubricating oil between engine and tank. The transfer pump should be dimensioned for the required filling amount and location of engine, tank and separator. 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.

- **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 in liter
6H25/33P	1,800
7H25/33P	2,000
8H25/33P	2,200
9H25/33P	2,400

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

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

- **Automatic filter (FT-601)**

  It is recommended to apply the automatic filter with back-flushing filter. The back flushed oil with sludge is finally led to system oil tank via back-flushing filter. Sludge checker or centrifugal filter can be used as back-flushing filter. The centrifugal filter's interval of cleaning and/or replacement will be normally longer than sludge checker. But if back-flushing flow rate is not enough, sludge checker is recommended. Final selection of filter type should be consulted by an automatic filter maker.

  The back flushing of filter elements should be arranged to be not affected the lube oil flow and pressure. The differential pressure indicator shall be installed to protect the filter element and indicate the abnormal condition of filter. A high differential pressure has to be indicated as an alarm.

Oil viscosity	:	50cSt (SAE40)
Design temperature	:	100°C
Delivery pressure	:	10bar
Design flow	:	See P.02.200 "Engine Capacity Data"
Fineness	:	
- Automatic filter	:	34㎛ (absolute size)
- Sludge checker	:	60㎛ (Nominal size)
- Manual by-pass filter	:	34㎛ (absolute size)

- **Suction strainer**

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

- **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 head	:	6 bar (set by a safety valve)
Design temperature	:	100°C
Lubricating oil viscosity	:	SAE 40
Viscosity (for electric motor)	:	500 cSt (SAE 40)

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

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

The specifications of the cooler should be as follows:

Required heat dissipation	:	See P.02.200 "Engine Capacity Data". (It should include the margin of 15% for a fouling.)
Temperature of the lubricating oil after the cooler	:	Max. 70°C
Flow rate of the lubricating oil	:	Lubricating oil flow in the engine(s) at MCR, See P.02.200 "Engine Capacity Data".
Pressure drop on the lubricating oil side	:	Max. 0.5 bar

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

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

Set temperature	:	65°C

- **Pressure regulating valve (PV-601)**

In order to control the pressure of the lubricating oil before the engine(s), it is advisable to provide the pressure regulating valve on the external system downstream of thermostatic valve (TV-601) as close as possible to the engine inlet. The surplus oil from pressure regulating valve should be led back to system oil tank.

Set pressure	:	4…6 bar

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, vent pipes for the crankcase 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

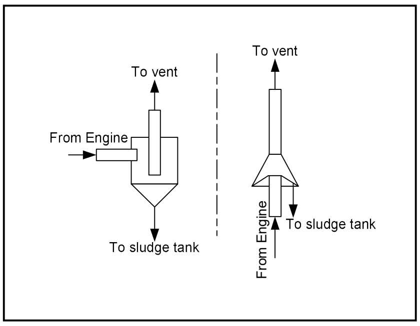


Figure 6-2-2: an example of condensation trap

- 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.
- The connection between the engine and vent pipe of the external system should be flexible.
- 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.

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

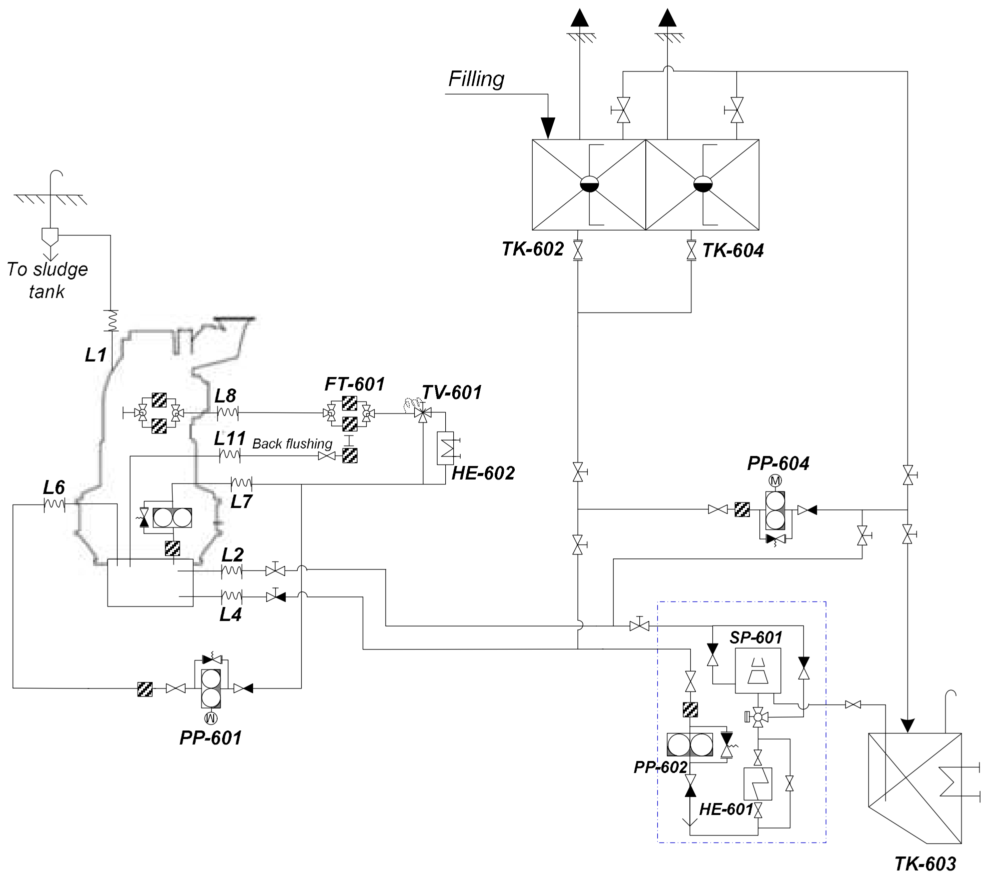


Figure 6-2-3: External lubricating oil system (Wet Sump) for a single engine installation

System components		Pipe connections	
Code	Description	Code	Description
TK-602	Storage tank	PP-601	Stand-by pump
TK-603	Sludge tank	PP-602	Feed pump for the separator
TK-604	Separated oil tank	PP-604	Transfer pump
SP-601	Separator	FT-601	Automatic filter
TV-601	Thermostatic valve		
HE-601	Pre-heater for the separator		
HE-602	Lubricating oil cooler		
Pipe connections			
Code	Description	Code	Description
L1	Oil vapor discharge	L6	Lubricating oil to stand by pump
L2	Lubricating oil from separator/filling	L7	Lubricating oil to cooler
L4	Lubricating oil to separator	L8	Lubricating oil from cooler

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

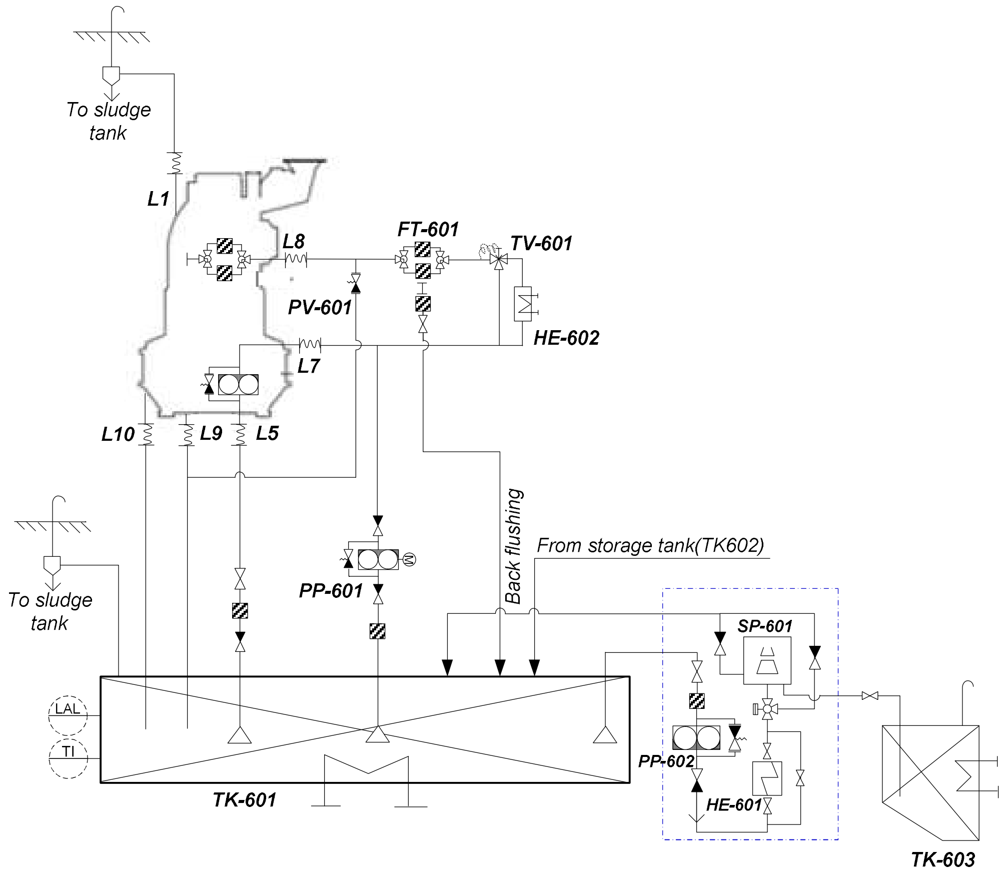


Figure 6-2-4: External Lubricating oil system (Dry Sump) for a single engine installation

System components		Pipe connections	
Code	Description	Code	Description
TK-601	System oil tank	HE-602	Lubricating oil cooler
TK-602	Storage tank	PP-601	Stand-by pump
TK-603	Sludge tank	PP-602	Feed pump for the separator
SP-601	Separator	FT-601	Automatic filter
TV-601	Thermostatic valve		
PV-601	Pressure regulating valve		
HE-601	Pre-heater for the separator		
Pipe connections			
Code	Description	Code	Description
L1	Oil vapor discharge	L8	Lubricating oil from cooler
L5	Lubricating oil to engine driven pump	L9	Lubricating oil to bottom tank, Flywheel end(Propeller) side
L7	Lubricating oil to cooler	L10	Lubricating oil to bottom 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.

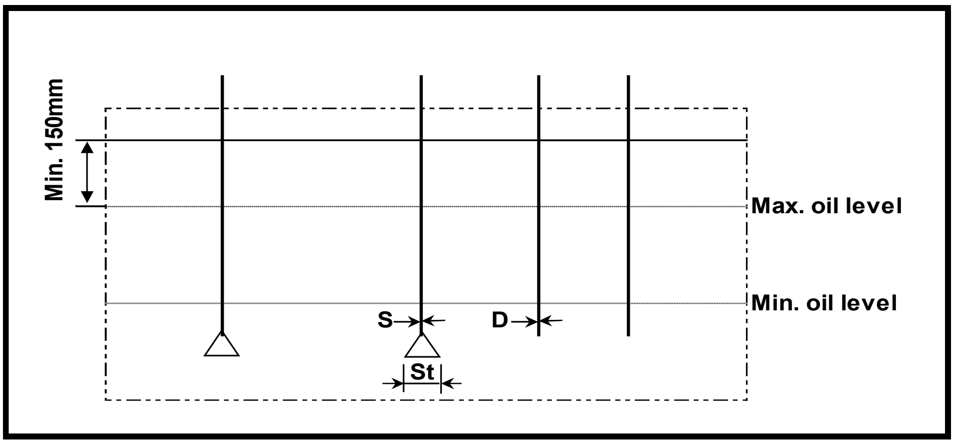


Figure 6-2-1: Example of System oil tank design

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.

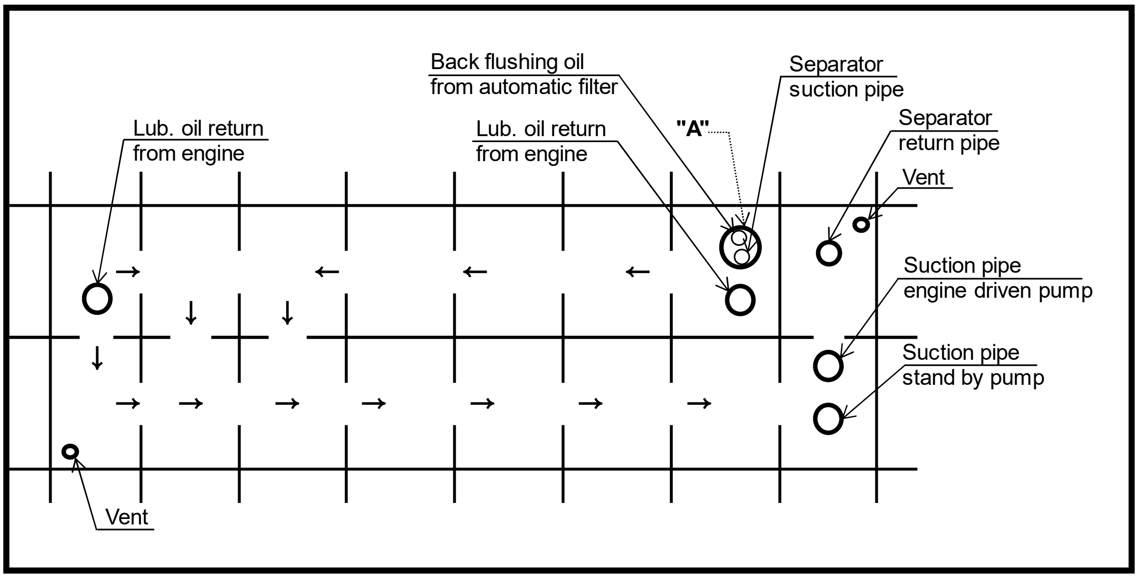


Figure 6-2-1-1: Example of System oil tank design

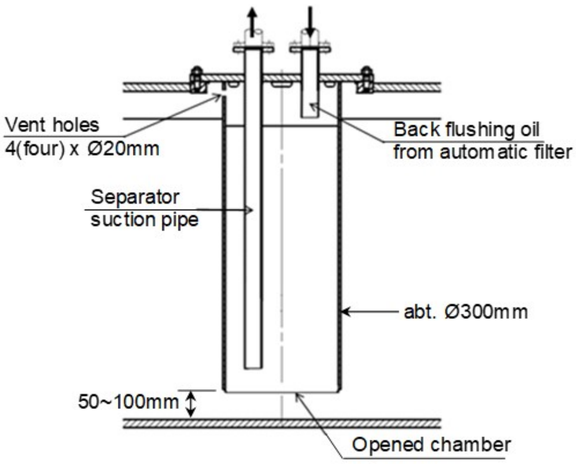


Figure 6-2-1-2: Example of “back-flushing drain tank, Detail “A”

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”.

Especially, please note that some of HiMSEN engine models such as H46/60(V)P is fitted with electric governor. Electric governor consists of electric controller and actuator.

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

The BN which is typically recommended depending on the fuel sulfur contents and the specific lubricating oil consumptions is as shown below:

Lubricating oil selection

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

When the MDO/MGO is to be used only for temporary engine operation, higher BN lubricating oil used for residual fuel (HFO) would not present any problems. The acceptable period of temporary operation is less than 200 hours.

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

Residual fuel

Sulfur contents (%)	BN
3.5 ~	40 ~ 55
0.5 ~ 3.5	30 ~ 40
0.1 ~ 0.5	20 ~ 30
~ 0.1	20

Distillate fuel (MGO/MDO) : BN 10~20

* Refer to the Sheet No. P.05.300 for specification of residual and distillate fuel.

Approved lubricating oils

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

Oil brand / Oil company	Engine system lubricating oil: Brand name	SAE	BN*)	Governor oil
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	

List of Lubricants

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	
Petro-Canada	Sentinel 445	40	4.7	
Oil volume	See the separate data for sump volume as per each engine type.			UG-25+: 2.1 Liter

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

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

Remark:

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

Diagram for internal cooling water system

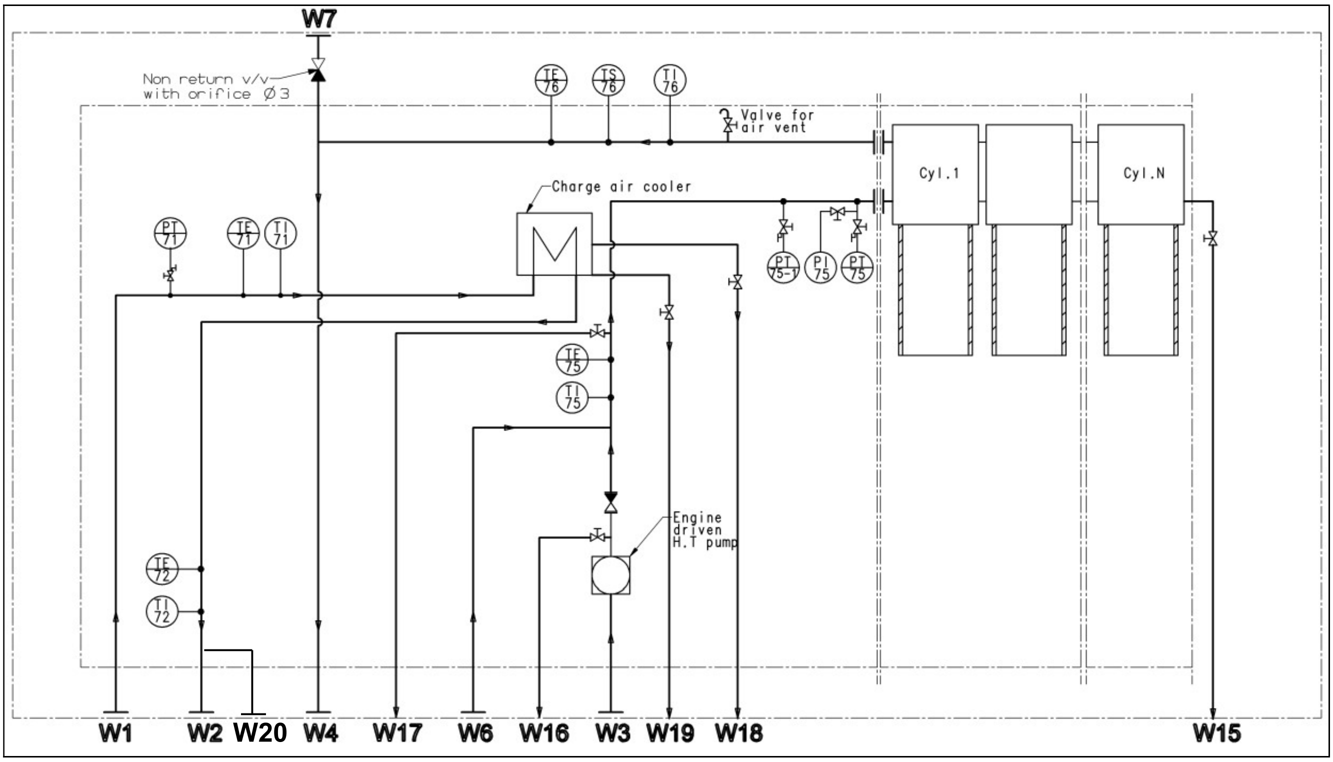


Figure 7-1-1: Internal cooling water system

Sizes of external pipe connections

Code	Description	Size	Standard
W1	L.T cooling water inlet	5K-100A	JIS B 2220
W2	L.T cooling water outlet	5K-100A	JIS B 2220
W3	H.T cooling water inlet	5K-100A	JIS B 2220
W4	H.T cooling water outlet	5K-100A	JIS B 2220
W6	H.T cooling water inlet from stand by pump	5K-100A	JIS B 2220
W7	Venting to expansion tank	5K-25A	JIS B 2220
W15	Jacket water drain	OD10	
W16	H.T cooling water drain	OD10	
W17	H.T cooling water drain	OD10	
W18	Charge air cooler air vent	OD10	
W19	Charge air cooler drain	OD10	
W20	L.T cooling water drain	OD10	

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 system internally and externally, which are low temperature (L.T) and high temperature (H.T) cooling water system.

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

- Charge air cooler
- Engine driven H.T cooling water pump

Pressure drops

The pressure drops over the engine are as follows:

H.T circuit: approx. 0.5 bar

L.T circuit: approx. 0.5 bar

Water volumes

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

Engine type	Volumes of the H.T and L.T cooling water [L]
6H25/33P	460
7H25/33P	480
8H25/33P	500
9H25/33P	520

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

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

  The Lube. Oil cooler is recommended to be of a plate type. The L.T cooling water after the engine is typically used as a cooling medium. If the sea water which is not treated is directly used as a cooling medium, it is required to add a fouling margin which is recommended by the cooler manufacture.

Required heat dissipation	:	See P.02.200 “Engine Capacity Data”. (It should include the margin of 15% for a fouling.)
Flow rate of the cooling water	:	L.T cooling water flow in the engine(s) at MCR, See P.02.200 “Engine Capacity Data”.
Pressure drop on the cooling water side	:	max. 0.2 bar

- **L.T Central cooler (HE-701)**

  The L.T central cooler can be of shell & tube or plate type. It can be in common with other engines. 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 capacity should be considered the other equipment such as lube oil cooler, fuel oil cooler and lube oil cooler of reduction gear, etc, if commonly used in one system.

The specifications of each cooler should be as follows:

Required heat dissipation	:	See P.02.200 “Engine Capacity Data”. (It should include the margin of 15% for a fouling.)
Temperature of the fresh water after the cooler	:	max. 36°C
Flow rate of the fresh water	:	required engine flow rate including the other equipment
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.)

- **H.T cooler (HE-702)**

The H.T cooler can be of shell & tube or plate type. It can be in common with other engines.

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 a fouling.)
Temperature of the fresh water after the cooler	:	max. 77°C
Flow rate of the fresh water	:	required engine flow rate including the other equipment
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.)

- **Thermostatic valve for L.T cooling water (TV-701)**

  In order to control the temperature of the fresh water before the engine(s), the L.T thermostatic valve should be provided after the L.T cooler. It is required to be as a mixing three-way valve and can be of a motor-operated type, an electric pneumatic, or a wax thermostat.

  Set temperature : 36°C

- **Thermostatic valve for H.T cooling water (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.

  Set temperature : 82°C at the engine jacket outlet

- **Pump for L.T cooling water circuit (PP-701)**

  The L.T and L.T stand-by pump are required for the L.T cooling water line for the 1 stage charge air cooler and the other coolers such as fuel oil cooler and reduction gear lube oil cooler etc.
  The pump capacity should be considered the other equipment including the required engine capacity.
  And it should be of a centrifugal type and electrically driven.

  Delivery capacity : See P.02.200 “Engine Capacity Data”.

  Delivery head : 3 bar

- **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.

  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

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

  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).

The water pipe from/to the de-aerating tank has to be discharged just below the lowest water level.

There may be air in the jacket water system before an alarm gives signals so that the water level is too low in the expansion tank, and the reason why the pipes end slightly up in the tank is to avoid sludge in the pipe.

Capacity of the tank	:	min. 10% of the total cooling water system (not less than 120 liters)

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.

- **Preheater 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 preheater. The heating source can be steam or electric power.

  The specification of the pre-heater should be as follows:

Heat capacity	:	min. 2.2 kW per cylinder
Temperature of the cooling water after the heater	:	min. 60°C
Flow rate of the cooling water	:	same as the delivery capacity of the circulation pump for the preheater
Pressure drop on the cooling water side	:	max. 0.5 bar

- **Circulation pump for preheating (PP-703)**

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

  The specification of the pump should be as follows:

Delivery capacity	:	min. 0.1 m^3/h per cylinder
Delivery head	:	1 bar

Diagram for the external cooling water system, a single engine installation

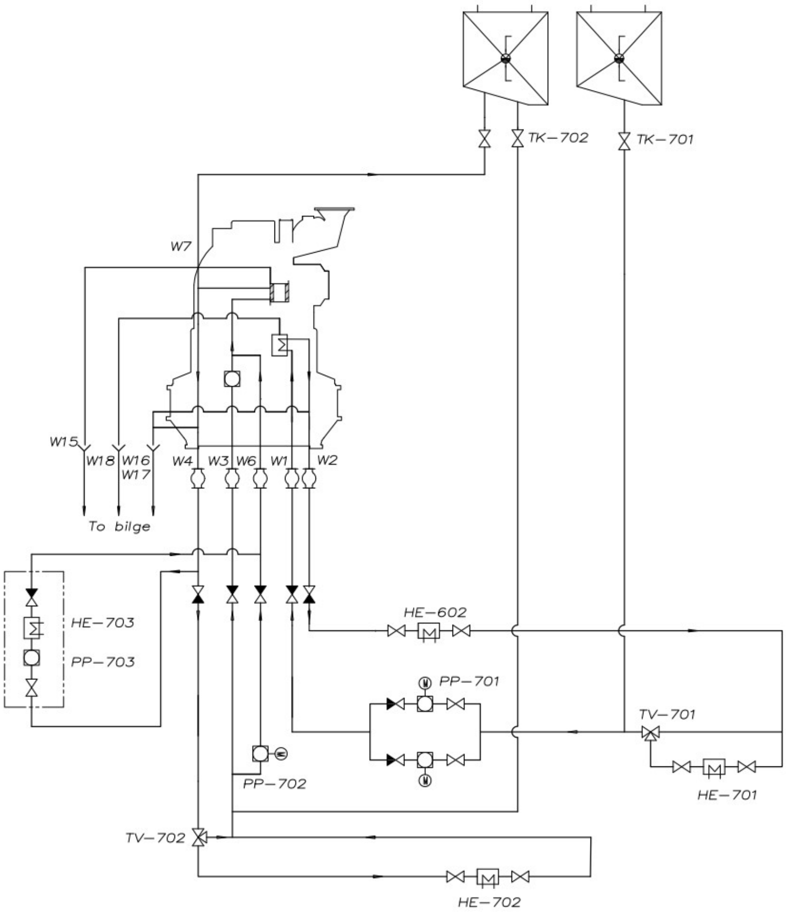


Figure 7-2-1: External cooling water system for a single engine installation

System components			
Code	Description	Code	Description
TK-701	L.T Expansion tank	TV-701	Thermostatic valve for L.T cooling
TK-702	H.T Expansion tank	TV-702	Thermostatic valve for H.T cooling
HE-602	Lubricating oil cooler	PP-701	L.T cooling water pump with stand-by
HE-701	L.T Central cooler	PP-702	Stand-by pump for H.T cooling water circuit
HE-702	H.T Central cooler	PP-703	Circulation pump for preheating
HE-703	Preheater for H.T cooling water		
Pipe connections			
Code	Description	Code	Description
W1	L.T cooling water inlet	W7	Venting to expansion tank
W2	L.T cooling water outlet	W15	Jacket water drain
W3	H.T cooling water inlet	W16	L.T cooling water drain
W4	H.T cooling water outlet	W17	H.T cooling water drain
W6	H.T cooling water inlet from stand by pump	W18	Charge air cooler air vent

Diagram for the external cooling water system, a multi-engine installation

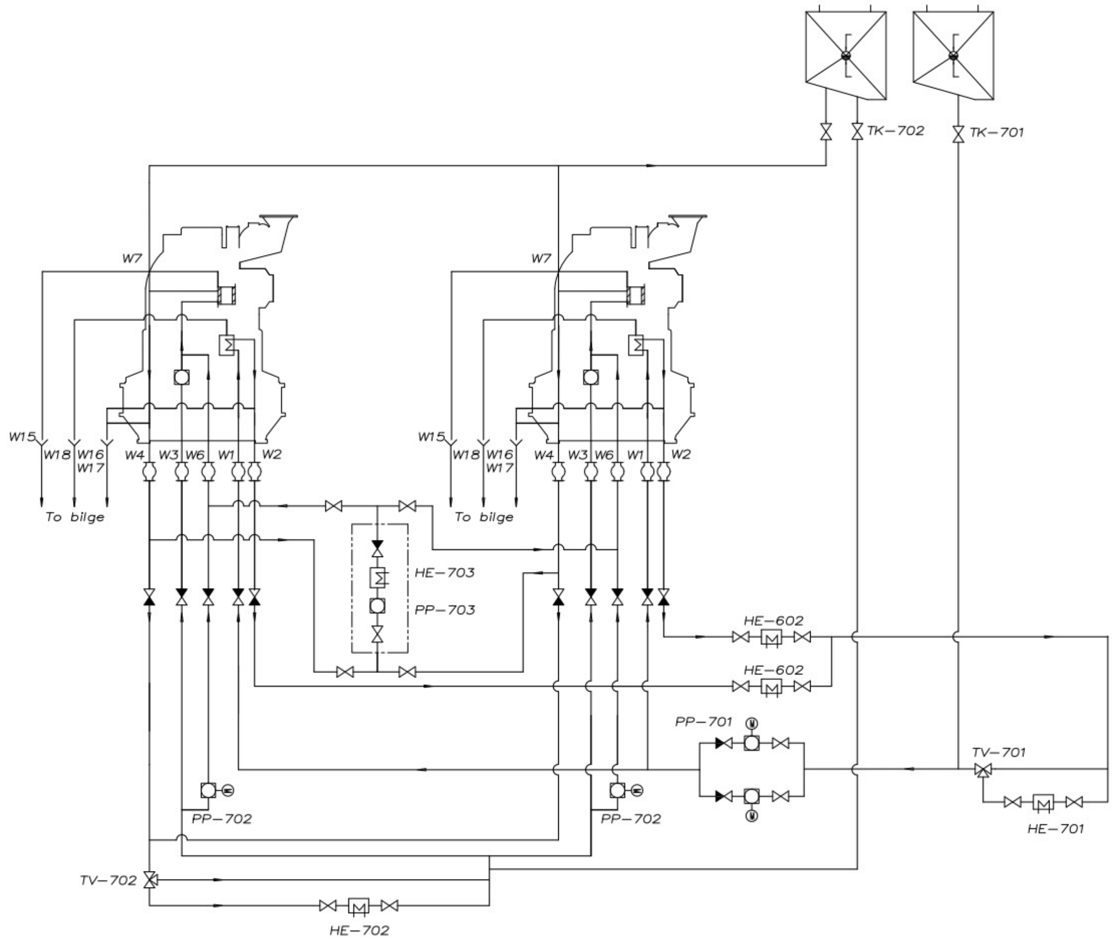


Figure 7-2-2: External cooling water system for a multi-engine installation

System components			
Code	Description	Code	Description
TK-701/2	Expansion tank	TV-701	Thermostatic valve for L.T cooling
HE-602	Lubricating oil cooler	TV-702	Thermostatic valve for H.T cooling
HE-701	L.T Central cooler	PP-701	L.T cooling water pump with stand-by
HE-702	H.T Central cooler	PP-702	Stand-by pump for H.T cooling water circuit
HE-703	Preheater for H.T cooling water	PP-703	Circulation pump for preheating
Pipe connections			
Code	Description	Code	Description
W1	L.T cooling water inlet	W7	Venting to expansion tank
W2	L.T cooling water outlet	W15	Jacket water drain
W3	H.T cooling water inlet	W16	L.T cooling water drain
W4	H.T cooling water outlet	W17	H.T cooling water drain
W6	H.T cooling water inlet from stand by pump	W18	Charge air cooler air vent

Quality of cooling water

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

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

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

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

Remark:

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

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

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

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

Treatment of cooling water

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

Manufacturer	Brand name	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

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

Remark:

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

Diagram for internal compressed air system

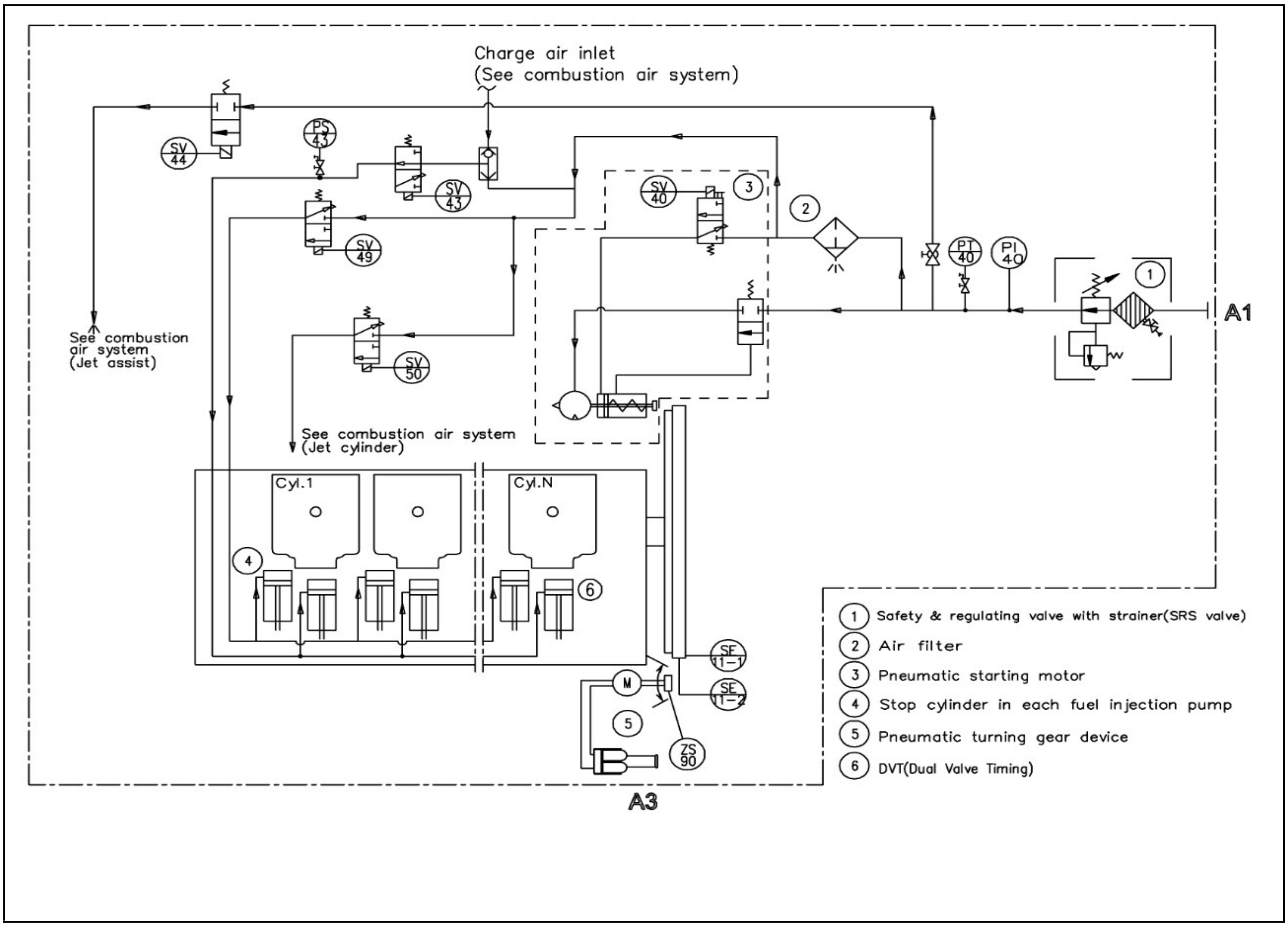


Figure 8-1-1: Internal compressed air system

Sizes of external pipe connections

Code	Description	Size	Standard
A1	Compressed air inlet	30K-40A	JIS B 2220
A3	Pneumatic turning gear air inlet	OD10	

Remark:

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

General

Compressed air is used to start engine and to provide actuating energy for safety and control devices.

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

- Safety & regulating valve with strainer(SRS valve)
- Air filter
- Pneumatic starting motor
- Stop cylinder in each fuel oil injection pump
- Pneumatic turning gear device

Engine start

The engine is started with a pneumatic starting motor. The starting motor drives a pinion that turns the gear mounted on the flywheel. The pinion is drawn back before fuel injection.

Emergency stop

Pneumatic stop cylinders are applied to each fuel oil injection pump. When solenoid valve (SV49) is activated and admits air to the stop cylinders, stop cylinders push the fuel oil injection pump to zero-delivery position.

Jet assist

The jet assist system is used to improve the acceleration response of the engine. When the jet assist function is activated, compressed air through a solenoid valve is injected via nozzle into the downstream right after the turbocharger compressor. It leads the acceleration of turbochargers and consequently the engine response.

General

The external compressed air system should be properly designed for nominal pressure of 30 bar and also be satisfied with the requirement of the corresponding classification societies. The system can be in common with other engines or an independent. In case of common system, it should be able to ensure the sufficient air supply to each engine with the required flow and pressure. In general, classification society requires that total capacity divide 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. The total capacity of air vessels should be sufficient to provide not less than the required number of consecutive starts without recharging the air vessels. The required numbers of consecutive starts can be variable depending on the classification societies and propulsion / auxiliary system arrangement such as the number of engines, the number of screws, and reduction gear, etc.

  The approximate volume for air vessels is as shown in the table below.

Engine Type	Volume [L] based on 1,000mbar, 0℃ 3)	
	Single engine 1)	Twin engines 2)
6H25/33P	2 x 650	2 x 1,100
7H25/33P	2 x 700	2 x 1,150
8H25/33P	2 x 750	2 x 1,250
9H25/33P	2 x 800	2 x 1,350

1) *For a single propulsion ship where one engine is coupled to a shaft through reduction gear.*
- *The number of starting: 6 starts and 1 margin (safety) start without jet assist air*

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 and 1 margin (safety) start without jet assist air*

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.

Table 8-2-1: Volume for air vessels

Remark:

1. The volume above is based on the condition, the gearbox and propeller shaft is disengaged.
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 (typically 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

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

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

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

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

  At least two air compressors are required in the external compressed air system and should be arranged to be able to charge each air vessel. At least one of the air compressors shall be driven independently 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. If the engine is started while being engaged with a propeller shaft or jet air assist is applied on the engine, the capacity is required to be increased.

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

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

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

V_c [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 each capacity of air vessels should be increased accordingly to supply enough air to jet assist system. Otherwise an additional air vessel may be required. At that time, a total capacity of compressors shall be increased and classification society approves the design. Otherwise, an additional compressor may be required. Please contact to HHI for this case.

- **Oil and water separator (WS-801)**
  The oil and water separator should be installed in the line between the compressors and the starting air vessels in order to ensure the drainage of the oil and water from the compressors.

- **Filter with water trap (FT-801)**
  It is recommended to install the filter with water trap as closed as possible to the engine air inlet pipe.

Diagram for the external compressed air system, a single engine installation

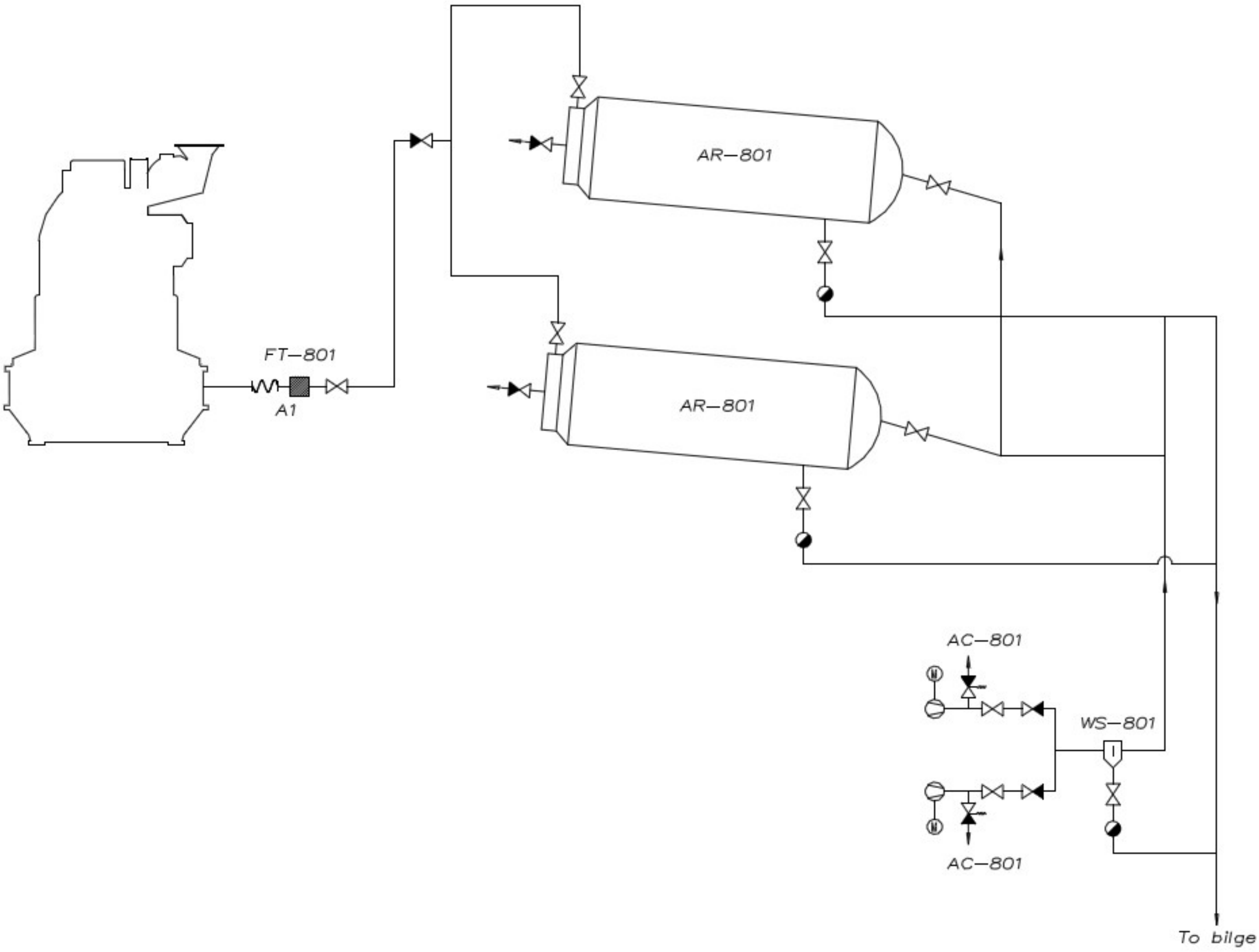


Figure 8-2-1: External compressed air system for a single engine installation

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, a multi- engine installation

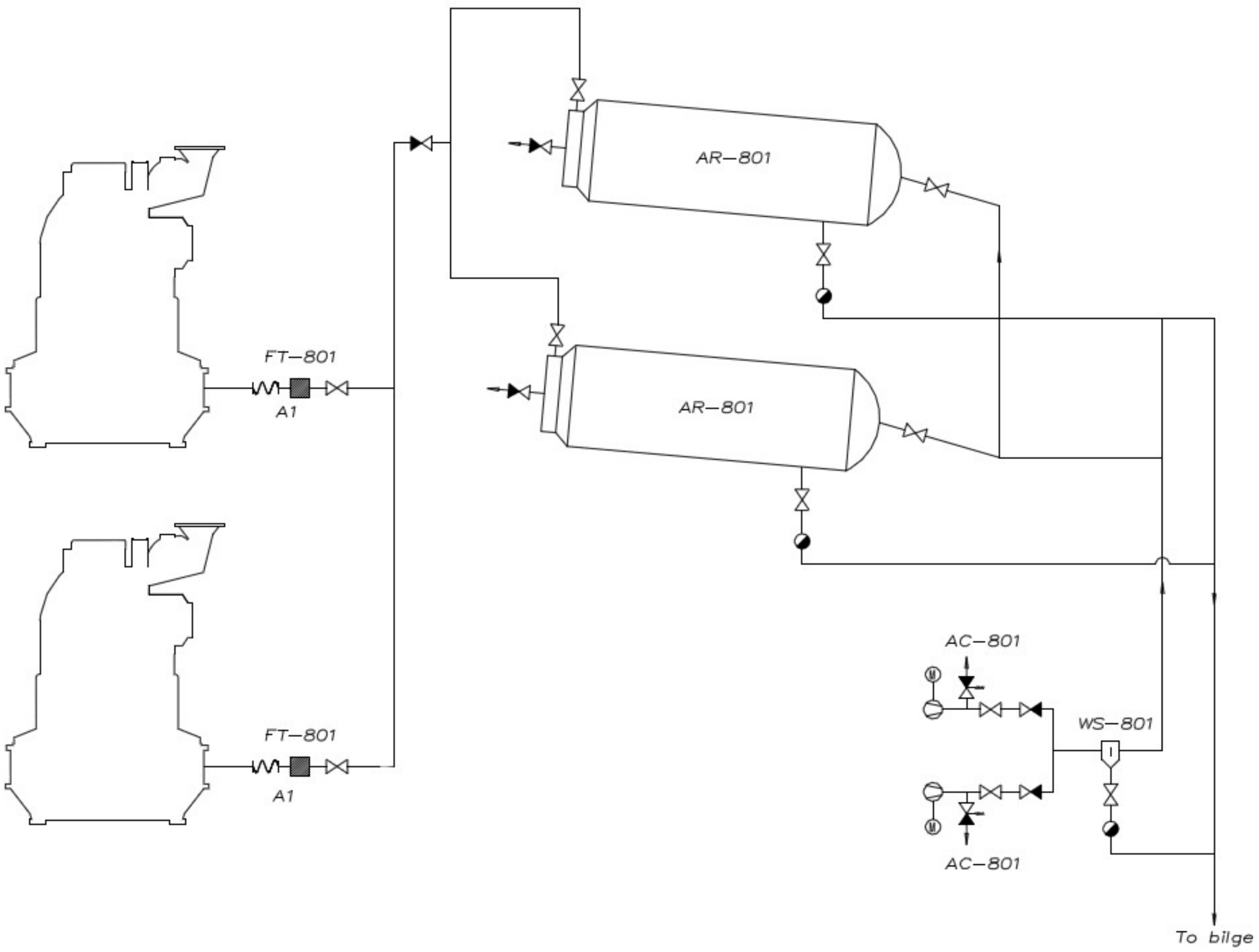


Figure 8-2-2: External compressed air system for a multi-engine installation

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 internal combustion air & exhaust gas system

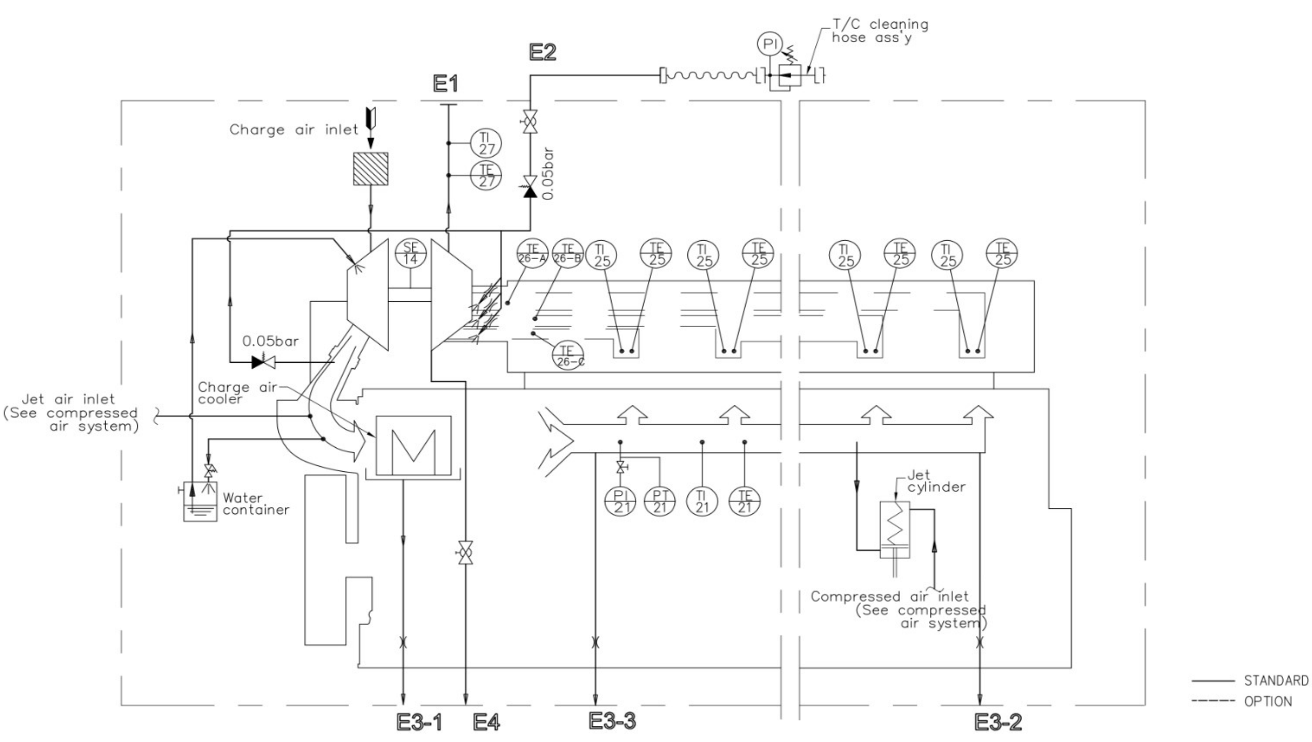


Figure 8-3-1: Internal combustion air and exhaust gas system

Sizes of External Pipe Connections

Code	Description	Pipe size	Standard
E1	Exhaust gas outlet	*)	JIS F 7805
E2	Cleaning water to turbine	OD13 nipple for high coupler	
E3-1	Condensate from water mist catcher	OD20 (Φ3 orifice)	
E3-2	Condensate from air chamber (No. 1 cylinder position)	OD10 (Φ3 orifice)	
E3-3	Condensate from air chamber (last cylinder position)	OD10 (Φ3 orifice)	
E4	Cleaning water from turbine	OD20	

*) See the P.08.510 “Exhaust Gas Pipe Connection

Remark:

1. 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 the engine room through filters fitted on the turbochargers. The combustion air should be free from sea water, dust and fumes, etc.

The engine is equipped with turbochargers which are of a radial type with a high efficiency. The turbochargers 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 is built on the engine and of a one-stage cooled type by low temperature fresh water. The charge air cooler of sea water cooled type is not recommended because of the corrosions of the engine parts.

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

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

- Turbocharger
- Charge air cooler
- Water mist catcher
- Air chamber
- Exhaust pipe system

General

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

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

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

Combustion air

- **Arrangement of air intake pipes**

  The arrangement of air intake pipes should be made to supply fresh air for the reliable engine combustion, which should be free from any risk of water spray, exhaust gas, dust, oil mist and electric equipment, etc. The piping system of intake air should be considered to allow thermal expansion and harmful vibration to avoid stress of pipe. The end of deep slope position of intake pipe, cleanable waste trap and water drain should be prepared.

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

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

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

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

- **Air velocity**

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

- **Air consumption volume**

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

- **Air filtration**

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

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

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

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

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

Ventilation of the engine room

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

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

Q [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

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

General

The external exhaust gas system must be designed so that the exhaust gas of an engine can flow out smoothly from a turbocharger to the atmosphere.

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

- Where two or more engines are installed, the independent exhaust gas system must be provided for each engine even in the case of the common boiler system with other engines.
- Back pressure of the exhaust system in total is recommended to be less than 300mmWC at MCR. The maximum back pressure should not exceed 500mmWC at MCR. Please see the P.02.610 for the fuel consumption correction in case of exceeding 300mmWC at MCR. The measuring position is approx. 1~2m after the turbocharger gas outlet casing not turbocharger gas outlet casing.
- The velocity of the exhaust gas should be less approx. 40 m/sec in the exhaust pipes.
- The insulation of the whole exhaust system is required for the safety and to reduce thermal loss and noise. It should comply with the requirements of classification societies and other related authorities.

The external exhaust gas system typically is comprised of an expansion joint, an exhaust gas boiler and a silencer, etc. The general requirements are described as follows and more detailed information can be provided for specific projects if needed.

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

External exhaust gas system

- **Expansion joint**

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

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

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

  The general requirements are as follows:

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

- The rigid support must be provided for the expansion joints on the turbocharger. It should be positioned directly above the expansion joints in order to prevent the transmission of forces due to the weight of the joints and the pipes, thermal expansion and lateral displacement of the exhaust piping to the turbocharger.
- The exhaust pipes should be with a slope towards the gas outlet on the engine. It is recommended to have drain facilities in order to remove condensate or rainwater.

- **Burner**

  In order to have appropriate exhaust gas temperature (approx. 290°C) for operating Selective Catalytic Reactor (SCR), the burner should be installed before SCR unit.

  Operating condition of SCR depends on the SCR provider.

  For the exhaust gas data to design the burner, see P.02.200 "Engine Capacity Data".

- **Exhaust gas boiler**

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

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

  For the exhaust gas data to design the boiler, see P.02.200 "'Engine Capacity Data".

- **Silencer**

  The silencer with or without 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).

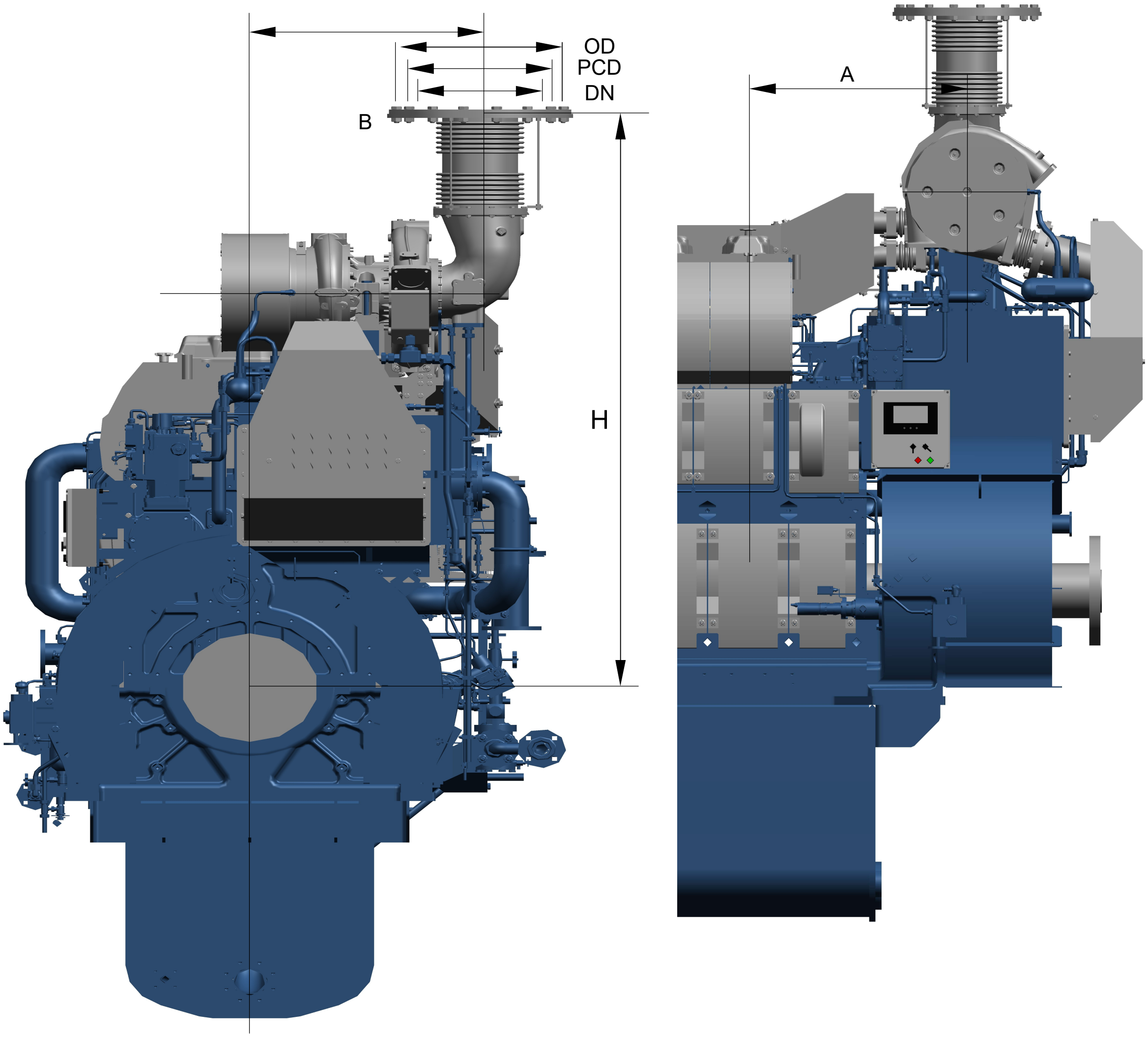
  For more information, see P.08.600 "Silencer with Spark Arrestor", and P.08.610 "Silencer without Spark Arrestor".

Piping design for the exhaust gas system

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

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

Exh. Gas Pipe Connection



Main engine for 900 rpm (290 kW / cyl.)

Engine Type	Exh. Outlet Position(mm)			Exh. Outlet Connection Flange(mm)				
	A	B	H	DN	OD	T	PCD	N-d
6H25/33P	986	807	2691	450A	605	18	555	16-25
7H25/33P	986	807	2691	500A	655	18	605	16-23
8H25/33P	986	807	2691	550A	660	18	620	16-23
9H25/33P	955	837	2801	550A	660	18	620	16-23

※ Turbocharger located on driving-end
※ Dimensions can be changed according to project specification and turbocharger type

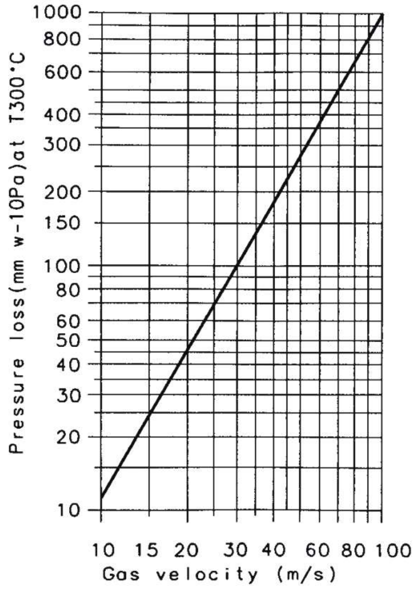
Silencer with Spark Arrestor

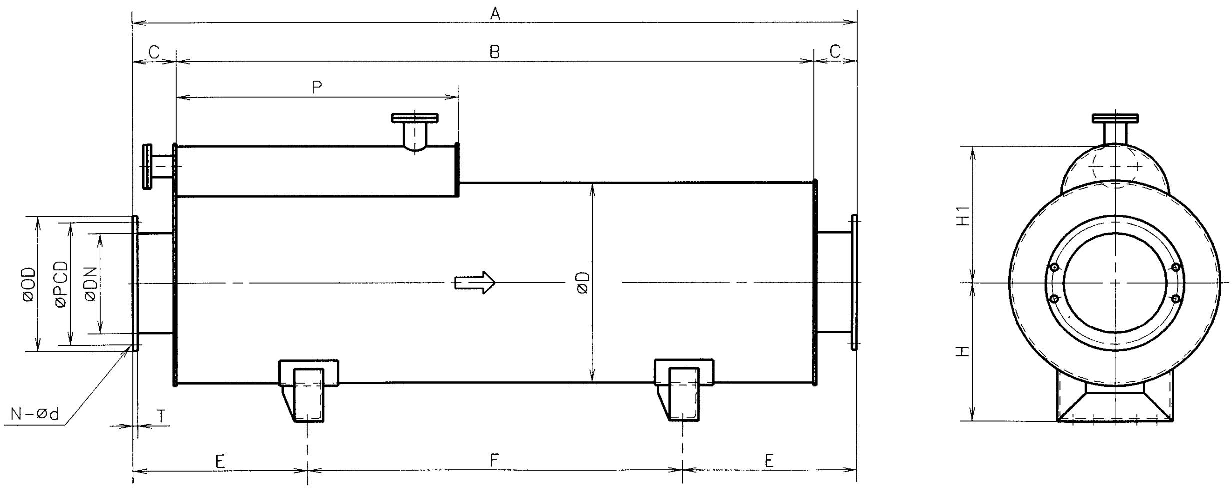
General

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

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

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





25dB Type Silencer

Unit : mm, kg

Eng type	DN	A	B	C	D	E	F	H	H1	P	PCD	OD	T	N-d	Weight
6H25/33P	450	3400	3100	150	810	800	1800	550	554	1100	555	605	16	16-Φ23	810
7H25/33P	500	3700	3400	150	860	850	2000	600	582	1180	605	655	16	20-Φ23	920
8,9H25/33P	550	3800	3500	150	910	900	2000	630	610	1240	620	660	16	16-Φ23	1000

35dB Type Silencer

Unit : mm, kg

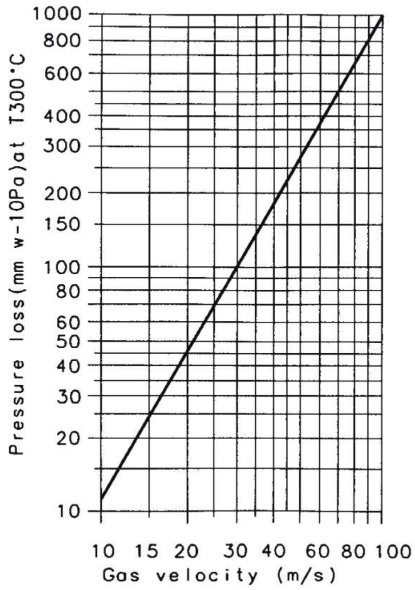
Eng type	DN	A	B	C	D	E	F	H	H1	P	PCD	OD	T	N-d	Weight
6H25/33P	450	4900	4600	150	810	1250	2400	550	554	1100	555	605	16	16-Φ23	900
7H25/33P	500	5400	5100	150	860	1350	2700	600	582	1180	605	655	16	20-Φ23	1070
8,9H25/33P	550	5900	5600	150	910	1500	2900	630	610	1240	620	660	16	16-Φ23	1215

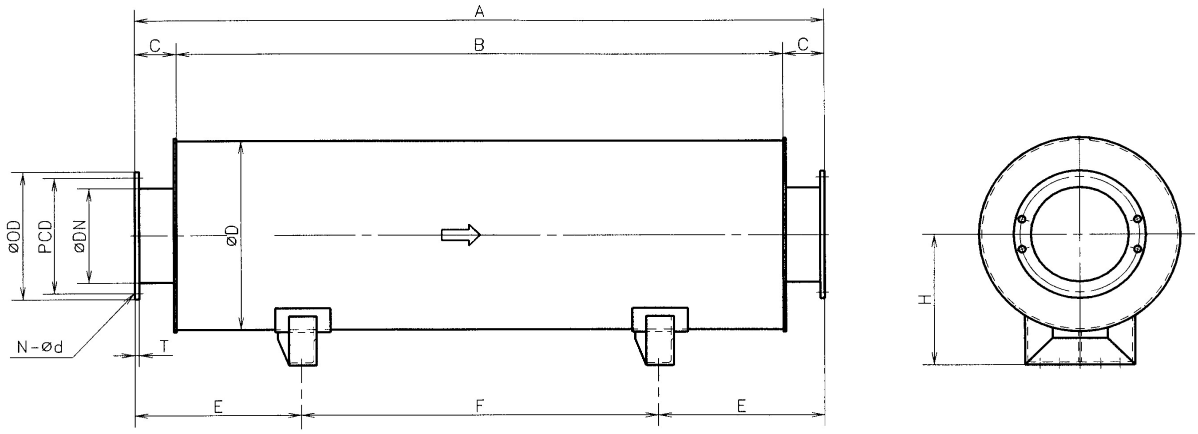
General

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

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

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





25dB Type Silencer

Unit : mm, kg

Eng type	DN	A	B	C	D	E	F	H	PCD	OD	T	N-d	Weight
6H25/33P	450	3200	2900	150	810	800	1600	550	555	605	16	16-Φ23	710
7H25/33P	500	3500	3200	150	860	850	1800	600	605	655	16	20-Φ23	830
8,9H25/33P	550	3600	3300	150	910	900	1800	630	620	660	16	16-Φ23	940

35dB Type Silencer

Unit : mm, kg

Eng type	DN	A	B	C	D	E	F	H	PCD	OD	T	N-d	Weight
6H25/33P	450	4400	4100	150	810	1100	2200	550	555	605	16	16-Φ23	865
7H25/33P	500	4900	4600	150	860	1200	2500	600	605	655	16	20-Φ23	1035
8,9H25/33P	550	5300	5000	150	910	1350	2600	630	620	660	16	16-Φ23	1165

Major Overhaul Guidance

Section No.		Description	Others	500 *)	1,500	3,000	6,000	9,000	12,000	15,000	18,000	21,000	24,000	Remark
		Major Fasteners - Confirmation												
M11100	C11100	Bolt for Base Frame and Resilient Mount		▲			◆							
G11100	-	Nut for Resilient Mount and Foundation		▲			◆							
-	C13000	Bolt for Engine Block and Base Frame		◆			◆							
M13250	C13000	Hyd. Nut for Main Bearing Cap		◆			◆							
M21100	C13000	Hyd. Nut for Cylinder Head		◆			◆							
M25000	C25000	Bolt and Nut for Camshaft		▲			◆							
M31000	C32000	Hyd. Nut for Con-Rod (Shaft)		◆			◆							
M31000	C32000	Hyd. Nut for Con-Rod (Big-end)		◆			◆							
M33200	C33100	Hyd. Nut for Counter Weight		◆			◆							
M35300	C35000	Bolt and Nut for Timing Gear		▲			◆							
-	C81000	Bolt and Nut for Turbocharger Mounting		▲			◆							
		Major Bearing												
M13250	C13250	Main Bearing					√				▣			
M13250	C13250	Thrust Washer : Axial Clearance					◎						▣	
M25000/M25300	C25300	Camshaft Bearing : Clearance					√		◎				▣	
M32120	C32000	Con-Rod Bearing (Big-end)					√		■		▣			
M32130	C32000	Con-Rod Bearing (Small-end)					√		■				▣	
M35300	C35000	Bearing Bush for Idle Gear : Clearance											▣	
		Resilient Mount												
M11100	C11100	Resilient Mount	●				●							**)
		Cylinder Unit and Con. Rod												
M15100	C15000	Cylinder Liner					√		■					
M15100	C15000	Flame Ring					√		▣					
M21100	C15000/C21100	Cylinder Head & Water Jacket Cooling Water Space					√		■					
M21120/M21130 /M21200	C21100/C21200	Intake/Exhaust v/v Spindle, Seat Ring and v/v Guide: Overhaul and Reconditioning					√		■		▣			
M21210	C21200	Intake/Exhaust v/v : Clearance		●	●									**)
M21210	C21200	Rocker Arm Shaft and Bush					√		■					
M21220	C21200	Rotocap			○				■					
-	C22000	Indicator Valve							▣					
M31100	C31100	Piston Rings					√		▣					
M31100	C31100	Piston and Piston Pin					√		■					
M31100/M31101	C32000	Con-Rod Bore (Big-end)					√		■					
M31100/M32130	C32000	Piston Pin & Con-Rod (Small-end) : Clearance					√		■					
-	C32000	Shim Plate for Con-Rod					√		▣					
-	C32000	Stud for Con-Rod Shaft											▣	

▣ 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

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	
		Crankshaft and Gears												
M33100	C33100	Crankshaft : Deflection					◎							
-	C33300/C42300	Gear Teeth on Flywheel & Turning Gear					▲							
-	C33400	Torsional Vibration Damper : Fluid sampling (Only for Viscous Damper)							◎					(See Manual for T/V Damper)
-	C33500	Flexible Coupling (If applied)	▲											(See Manual for Flex.Coupling)
M35300	C35000	Timing Gear and Pump Driving Gear : Clearance and Backlash							◎					
		Valve Operating Mechanism												
M23000	C23000	Swing Arm Roller Shaft and Bush							■				▣	
M25000	C23000/C25000	Contact Faces of Cam and Swing Arm Roller Camshaft Bearing		▲			▲							
		Control System												
G40000	C41000	Fuel Control Linkage : Movement Check	○											Weekly
G40001	-	Safety Device : Function Check	○											Monthly
-	C41000	Governor Oil Level (Only for Mechanical Hydraulic Governor)	▲											Daily (See Manual for Governor)
M45200	C45200	Engine RPM Pick-up Sensor : Clearance					●							
M45200	C45200	Temperature / Pressure Sensor	○											In case of necessity
		Fuel System												
G05100	-	Analyze Fuel Oil Properties : Sampling	◎											Every Bunkering
M51100	C51000	Fuel Injection Pump												
		- Deflector : Erossion			◎	▣								
		- Plunger Assembly					■						▣	
		- Delivery Valve Assembly (except case)					■		▣					
		- Delivery Valve Case					■						▣	
		- Roller Bush for Tappet							■				▣	
M52000/M52002 /M52003	C52000	Fuel Injection Valve : Opening Pressure		●	●		▣							****) ▣ : Atomizer life time
M98380	C98380	Fuel Oil Shock Absorber (If applied)				■								
M56000	C56000	Fuel Oil Filter	■											If pressure drop reaches limit (See G01400)
		Lubricating Oil System												
G06200	-	Analyze Lub. Oil Properties : Sampling	◎											Every 3 month
M61000	C61000	Lubricating Oil Pump							■					
M63000	C63000	Lubricating Oil Filter	■											If pressure drop reaches limit (See G01400)
M63000	C63000	Lubricating Oil Filter (Cartridge Type)	■		▣									If pressure drop reaches limit (See G01400)

▣ 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

Section No.		Description	Others	500 *)	1,500	3,000	6,000	9,000	12,000	15,000	18,000	21,000	24,000	Remark
		Cooling Water System												
G07100	-	Analyze Cooling Water Properties : Sampling	◎											Weekly : Test Kit Every 3 month : Lab. Test
M71000	C71000	Cooling Water Pump							■					
-	C74000	Thermostatic Valve : Clean & Check Elements							■					(See Manual for Thermo. v/v)
M75000	C75000	Water Drain Line : Cleaning	●											Weekly (Depend on condition)
		Compressed Air System												
O02300	-	Air Running	○											Monthly
G40000	-	Check Starting & Stop Syatem	○											Weekly (Over a Week Stand-still)
-	C42100	Starting Air Motor	■											(See Manual for Starting Air Motor)
		Supercharging System												
M80000	C83000	Turbocharger	■											(See Manual for Turbocharger)
		- Clean Air Filter (Only for Filter Silencer type)	■		▣									Every 500hrs running
		- Turbine : Water-w ashing	●											Every 200hrs running
		- Compressor : Water-w ashing	●											Every 24~50hrs running
M84000	C84000	Charge Air Cooler							■					

▣ Expected life time
■ Overhaul inspection
● Check & adjustment
○ Function test

√ 1 Cylinder overhaul. If not good, check all cylinders.
◆ Confirm tightening: Tighten with specified torque or hyd.pressure. Do not loosen!
◎ Measuring or sampling without dismantling
▲ Visual Inspection

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

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

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

List of Consumable Parts for one engine
(C=Number of cylinder / U=Number of unit)

Section No.	Parts Description	Quantity for the operating hours								
		set/ea	0-3000	0-6000	0-9000	0-12000	0-15000	0-18000	0-21000	0-24000
	Covers for Engine Block									
C17000 C19300	Gaskets for gear case cover	set	-	1	1	2	2	3	3	4
C19300	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
C19300	O-ring for camshaft cover	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
C21100	O-rings for cylinder head cover	ea	0.5 x C	1 x C	1.5 x C	2 x C	2.5 x C	3 x C	3.5 x C	4 x C
	Bearings									
C13250	Main bearing (upper & lower)	set	-	-	-	-	-	1xC+2	1xC+2	1xC+2
C13250	Thrust washer	ea	-	-	-	-	-	-	-	4
C25300	Camshaft bearing	ea	-	-	-	-	-	-	-	1xC+1
C32000	Big-end bearing (upper & lower)	set	-	-	-	-	-	1 x C	1 x C	1 x C
C32000	Small-end bearing	ea	-	-	-	-	-	-	-	1 x C
C35000	Bearing bush for idle gear	ea	-	-	-	-	-	-	-	1
	Cylinder Unit and Con-Rod									
C15000	Flame ring	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
C15000	O-rings & gasket for cylinder liner / cooling water jacket	set	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
C21100	O-ring for cylinder head	ea	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
C21100	Bush & O-ring for fuel valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
C21100	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
C21100 C21200	Intake v/v spindle, seat ring and v/v guide	set	-	-	-	-	-	1 x C	1 x C	1 x C
C21100 C21200	Exhaust v/v spindle, seat ring and v/v guide	set	-	-	-	-	-	1 x C	1 x C	1 x C
C22000	Indicator v/v complete	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
C23000	Roller bush for swing arm	ea	-	-	-	-	-	-	-	1 x C
C31100	Piston top ring / 2nd ring / scraper ring	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
C32000	Shim plate for con-rod	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
C32000	Stud for con-rod shaft	ea	-	-	-	-	-	-	-	4 x C
	Fuel System									
C51000	Plunger assembly for fuel pump	ea	-	-	-	-	-	-	-	1 x C
C51000	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
C51000	Gskets & seal ring for fuel pump	set	-	-	-	-	-	-	-	1 x C
C51000	Deflector & gasket for fuel pump	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
C51000	Delivery valve assembly (except case)	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
C51000	Delivery valve case	ea	-	-	-	-	-	-	-	1 x C
C51000	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
C51000	O-ring for fuel pump drive	ea	-	-	-	-	-	-	-	1 x C
C52000	Fuel injection nozzle with dowel pin	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
C52000	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
C52300	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
C53000	O-rings for fuel feed pipe connection	set	-	1	1	2	2	3	3	4

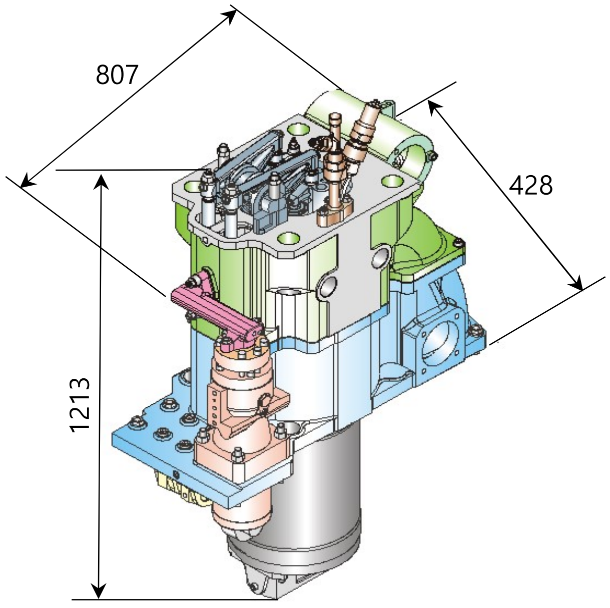
Section No.	Parts Description	Quantity for the operating hours								
		set/ea	0-3000	0-6000	0-9000	0-12000	0-15000	0-18000	0-21000	0-24000
	Lubricating Oil System									
C61000	Bushes for lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
C61000	O-rings for lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
C62000	O-ring for lub. oil cooler connection (Installation on engine side)	set	-	-	-	10	10	10	10	20
	Cooling Water System									
C71000	Oil seal, mechanical seal & O-ring for HT pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
C77000	O-ring for cooling water connection	set	-	1	1	2	2	3	3	4
C78000	O-ring for cyl.head cooling water connection	ea	-	8	8	4xC+6	4xC+6	4xC)14	4xC+14	8xC+12
	Supercharging System									
C81000	Gaskets and O-ring for compressor out	set	-	-	-	1	1	1	1	2
C82000	Gasket for connection flange	ea	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
C83000	O-rings and gaskets for T/C connection	set	-	-	-	1	1	1	1	2
	Charge Air Cooler									
C84000	O-rings and gaskets for air cooler	set	-	-	-	1	1	1	1	2
	Turbocharger									
	Spare parts for turbocharger (See manual for turbocharger)	set	-	-	-	-	-	-	-	-
	Air filter mat (Engine room air suction)	ea	2	4	6	8	10	12	14	16

List of standard spare parts for each vessel

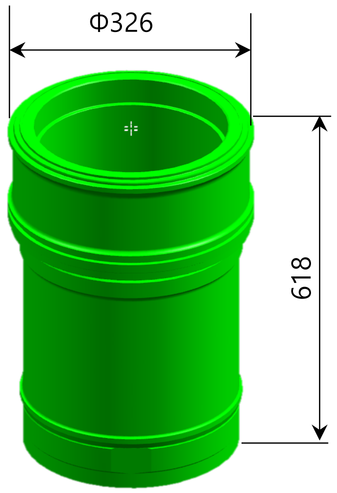
Description	Section No.	Item No.	Quantity
Engine Block and Cover			
Main bearing, upper	C13250	251	1
Main bearing, lower	C13250	251	1
Thrust washer	C13250	252	4
Main bearing stud M45	C13000	231	2
Nut for main bearing stud M45	C13000	232	2
O-ring for crankcase door	C19300	384	1
Cylinder Liner			
Cylinder liner	C15000	111	1
Flame ring	C15000	122	1
Metal gasket for cylinder liner	C15000	191	1
O-ring(No.56) for cylinder liner D296	C15000	192	1
O-ring(No.57) for cylinder liner D304.1	C15000	193	1
Cylinder Head			
Cylinder head complete with valve & rocker arm	C21100	100	1
O-ring(No.59) for cylinder head D327	C21100	903	2
O-ring for cylinder head cover D323	C21100	805	1
O-ring for cooling water connection D29.75	C15000	922	1
O-ring for cooling water connection D32.92	C15000	923	1
O-ring for cooling water connection D17.04	C15000	932	2
O-ring for cooling water connection P102	C78000	712	4
O-ring for cooling water jacket G170	C15000	901	1
O-ring for cooling water jacket P180	C15000	902	1
O-ring for cooling water jacket P50A	C15000	903	2
O-ring for exh. valve seat ring	C21100	118	4
O-ring for valve guide	C21100	291	6
Cylinder head stud M45	C13000	311	4
Cylinder head nut M45	C13000	312	4
Safety valve	C22000	600	1
Intake Valve			
Intake valve spindle	C21200	201	2
Intake valve seat rings	C21100	111	2
Spring	C21200	203	2
Roto cap	C21200	204	2
Conical piece	C21200	206	2

Description	Section No.	Item No.	Quantity
Exhaust Valve			
Exhaust valve spindle	C21200	202	4
Exh. valve seat rings	C21100	112	4
Spring	C21200	203	4
Roto cap	C21200	204	4
Conical piece	C21200	206	4
Connecting Rod			1
Connection rod complete	C32000	100	1
Including Pin bush	C32000	130	1
Stud M36	C32000	191	2
Stud M22	C32000	194	4
Nut M36	C32000	192	2
Nut M22	C32000	195	4
Pin	C32000	193	4
Big end bearing, upper & lower	C32000	120	1
Piston			
Piston complete (without pin, rings, retaining ring)	C31100	110	1
Piston pin	C31100	120	1
Retaining ring	C31100	130	2
Piston rings – Top, 2nd, scraper ring	C31100	151/2/3	2/each
Fuel Injection Equipment			
Fuel injection pump	C51000	100	1
Fuel injection valve	C52000	100	One engine
Fuel injection block assembly	C52300	100	1
Flexible Pipe (Only Resilient mounting type)			
Each flexible connecting pipe	C98370	-	1
Spare for Air Cooler			
Gasket for air cooler	C84000	103	1

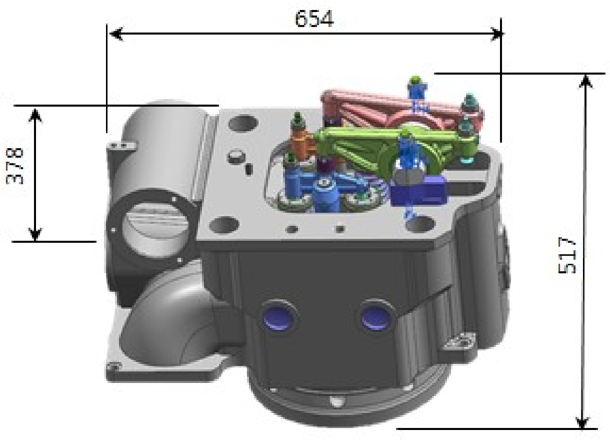
* The list of standard spare parts stated above is only for reference as it depends on the actual project and engine design.



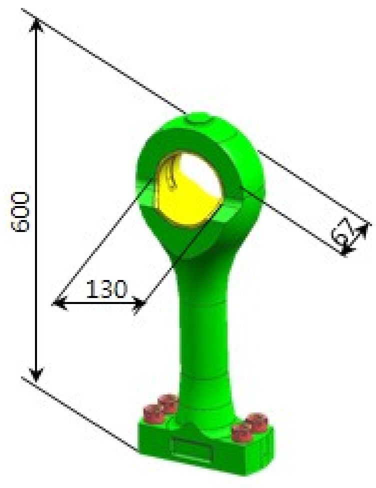
Cylinder unit
Approx. 570 kg



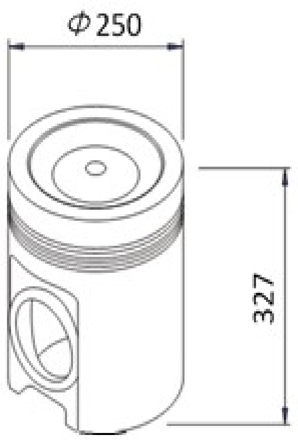
Cylinder liner
Approx. 98 kg



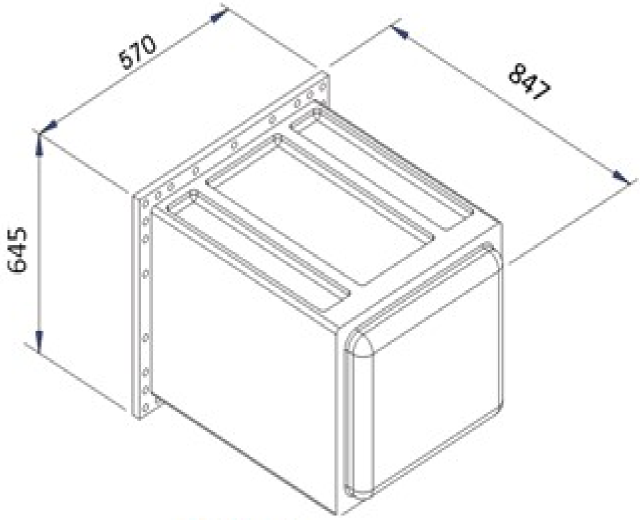
Cylinder head and rocker arms assembly
Approx. 250 kg



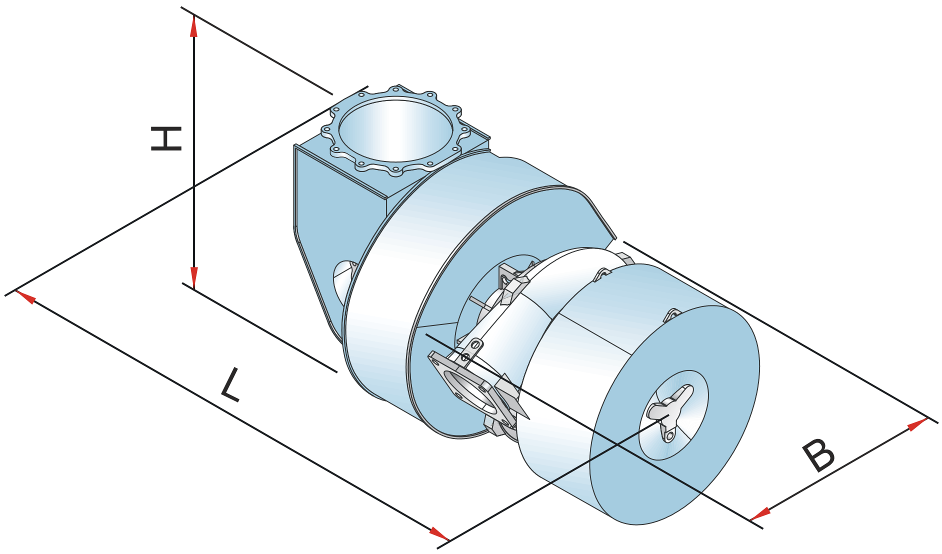
Connecting rod shaft
Approx. 37 kg



Piston
Approx. 40 kg



Air Cooler
Approx. 298 kg



Turbocharger type	Dimensions [mm]			Weight [kg]
	B	H	L	
ST5	600	705	1320	385
ST6	750	855	1575	580
A140	630	720	1310	460
A145	745	855	1565	750

Description	Quantity
For Cylinder Head and Liner	
Max. pressure indicator	1
Lifting tool for cylinder head	1
Fitting/Removal device for valve cone/spring	1
Removal device for fuel injection valve	1
Lapping device for fuel injection valve bush	1
Pliers for valve lock ring	1
Removal device for fuel injection valve bush	1
Grinding tool for cylinder head/liner	1
Removal device for CW connection	1
For Piston, Connecting rod, Cylinder Liner	
Extraction/Suspension device for cylinder liner	1
Guide for piston	1
Lifting tool for piston	2
Holding piece for crank pin bearing	2
Suspension device for crankpin bearing	2
Guide support for connecting rod	1
Turning bracket for connecting rod	1
Clamping support for connecting rod	2
Suspension device for connecting rod & piston	2
Pliers for piston pin lock ring	1
Piston ring expander	1
Cylinder bore gauge	1
Removing device for flame ring	1
For Inlet & Exhaust Valve	
Feeler gauge	1
Lapping device for in/exhaust valve seat	1
Removal device for exhaust valve seat	1
For Crankshaft and Main Bearing	
Lifting device for main bearing cap	4
Fitting device for main bearing	1
Crankshaft deflection gauge	1
For Fuel Injection Equipment	
Test tool for fuel injection valve nozzle	1
Cleaning tool for fuel injection nozzles	1
Long socket for nozzle nut	1
Removal tool for nozzle nut	1

*

<u>Hydraulic Tools</u>	
Hydraulic tightening device M39	4
Hydraulic tightening device M36	2
Hydraulic tightening device M22	2
Set of spare parts for hydraulic tools M39	2
Set of spare parts for hydraulic tools M36	1
Set of spare parts for hydraulic tools M22	1
Support for main bearing cap M39	2
Support for connecting rod big end M36	2
Support for counterweight side bolt & flywheel M36	2
Support for cylinder head M39	4
Support for connecting rod shaft M22	2
Extension screw for cylinder head M39	4
Extension screw for counterweight M36	2
Extension screw for connecting rod shaft M22	1
Angle piece	2
Distribution piece 2-port	1
Distribution piece 4-port	1
High pressure hose L=550	4
High pressure hose L=3000	2
Pneumatic / hydraulic pump, spare kit	1
Adapter for hydraulic pump	1
Handle	2
<u>General Tools</u>	
Plier 250	1
Converter 1/2”-3/4”	1
Reducer 3/4”-1/2”, 1”-3/4”	1
Tee handle 12.5	1
Extension bar set	1
Eye bolt M16, M20	4
Spanner set	1
Box and key set	1
Torque wrench 20-120 Nm	1
Torque wrench 50-300 Nm	1
Torque wrench 140-760 Nm	1
Torque wrench 750-2000 Nm	1
Air gun for engine cleaner	1
Wrench set	1
Spare & Tool box	5

The list of standard tool parts stated above is only for reference as it depends on the actual project and engine design.

Operation range for fixed pitch propeller (FPP)

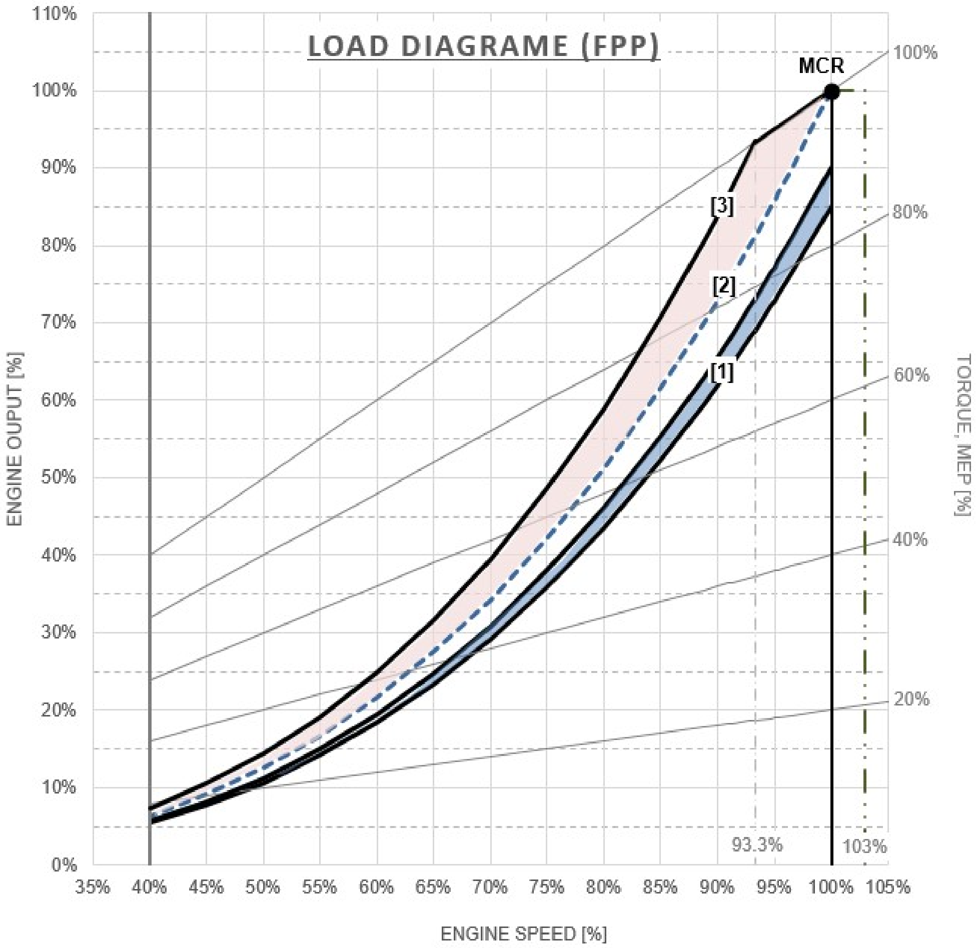


Figure 10-1-1: Load diagram for fixed pitch propeller

- **Line [1] : Design area of propeller**

  Propeller curve under clean hull and calm weather-light running, used for propeller layout and design. This curve is typically determined range from N=0.85P to N=0.9P depends on vessel's specification. If the extension of propeller design margin is required, this curve is designed below N=0.85P upon consideration between ship owner and ship designer.

- **Line [2] : Theoretical propeller curve ($P=N^3$) in propeller law**

  Propeller curve under fouled hull and heavy weather-heavy running. This curve must not to be exceeded, operation during maneuvering and acceleration.

- **Line [3] : Torque(load) limit (1.15P)**

  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.

- **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 LT(Low Temperature) 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 fixed pitch propeller is recommended as follows:

  N = 0.4…0.6 x MCR speed

Engine power recommendation

When determining the engine power for the fixed pitch propeller, the following should be considered:

- 15% of a sea margin considering the hull's resistance and sea conditions, etc.
- Mechanical efficiency of the shaft generator and gear box, etc.
- Mechanical losses of the stern bearing
- Propeller cavitation
- Rotating moment of the shaft and propeller

IMO NOx certification for FPP

Propulsion engine connected to Fixed Pitch Propeller having a propeller law operation is tested and issued to E3 (Variable speed) test cycle in accordance with regulation of IMO NOx Technical code.

Operation range for controllable pitch propeller (CPP)

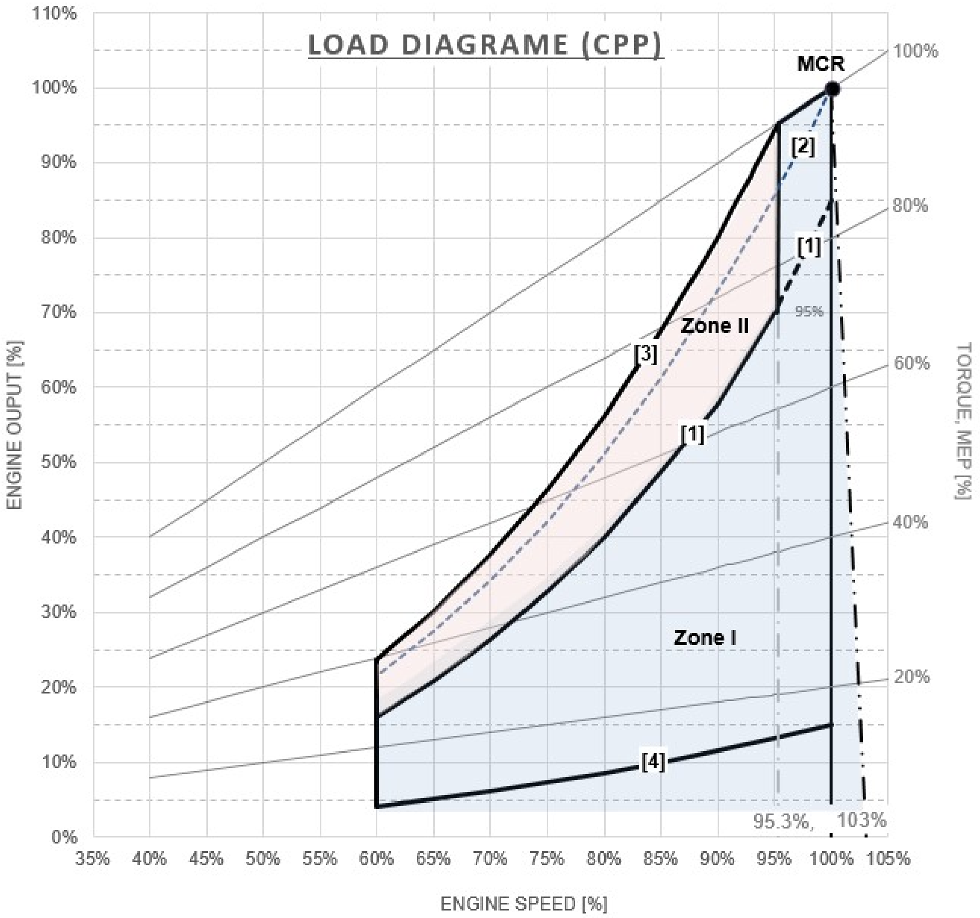


Figure 10-1-2: Load diagram for controllable pitch propeller

- **Line [1] : Combined operation curve**

  Propeller design based on the combination between pitch angle and engine speed. The combination curve 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**

  Theoretical propeller curve of fixed pitch propeller is described for reference.

- **Line [3] : Torque(load) limit (1.1P)**

  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 LT(Low Temperature) 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.

Operation range for mechanical pump drive

There are several operation demands of engine for mechanical pump drive. It means that the stricter limitations always need to be applied is valid for all operation applications as below;

- **Operation ranges per application for mechanical pump drive**

Propulsion	Pump drive	Applicable torque limitation
NO	Dredger pump	Load diagram for Dredger pump
Fixed Pitch Propeller	Dredger pump	Load diagram for Fixed Pitch Propeller
Controllable Pitch Propeller	Dredger pump	Load diagram for Dredger pump
Controllable Pitch Propeller with Power Take Off	Dredger pump	Load diagram for Dredger pump

- **Load diagram for dredger pump**

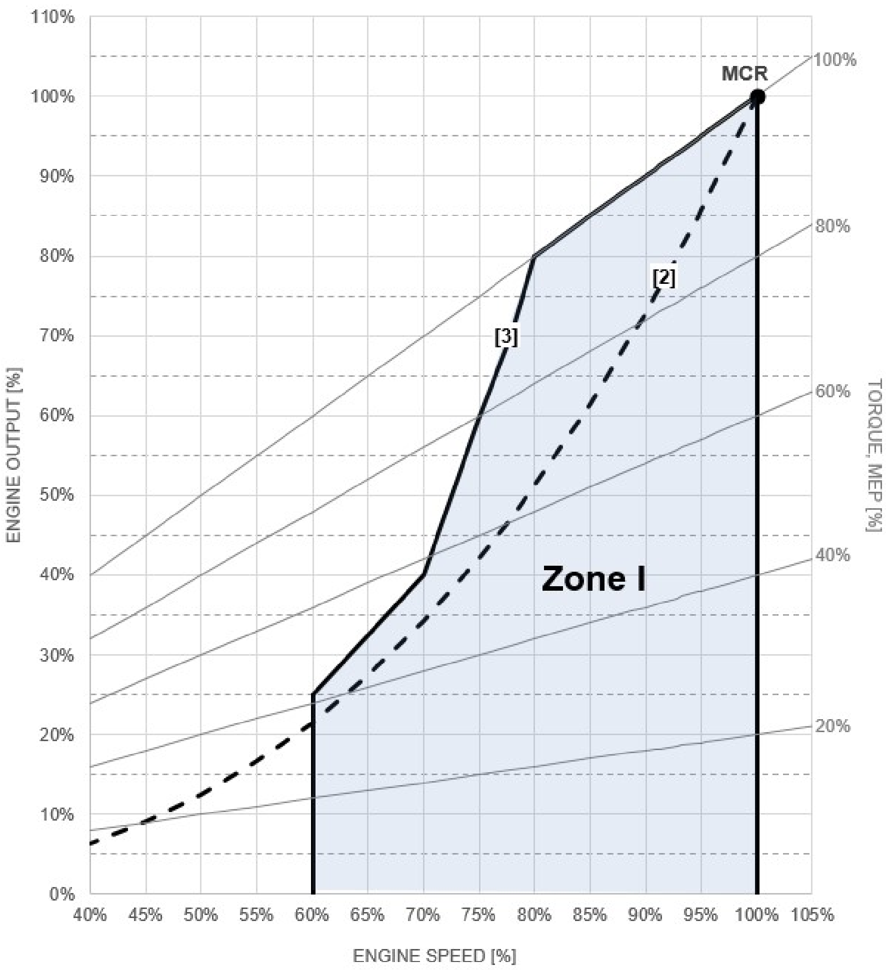


Figure 10-1-3: Load diagram for dredger pump

- **Zone I : Operation range for continuous operation**

  The dredger application on direct driven mechanical pump by engine need to be applied the full constant torque operation between 80% and 100% of rated engine speed. This specific operation range results a reduced engine output in accordance with below table.

- **Available maximum continuous rating (MCR)**

Engine model	Load diagram	Output (kW) per cylinder
H21/32P	Mechanical(FPP & CPP) propulsion	200
	Mechanical pump drive	180
H25/33P	Mechanical(FPP & CPP) propulsion	290
	Mechanical pump drive	261
H32/40(V)P	Fixed Pitch Propeller	480
	Controllable Pitch Propeller	500
	Mechanical pump drive	450
H32CVP	Mechanical(FPP & CPP) propulsion	600
	Mechanical pump drive	540
H46/60(V)P	Controllable Pitch Propeller	1,250
	Mechanical pump drive	1,125

- **Line [2] : Theoretical propeller curve ($P=N^3$) in propeller law**

  Theoretical propeller curve of fixed pitch propeller is described for reference.

- **Line [3] : Torque(load) limit**

  This curve related to maximum permitted overload. The engine load must not exceed this curve at any conditions.

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.

IMO NOx certification for mechanical pump drive

Engine connected to mechanical pump operation only is tested and issued to C1 (variable speed, variable load auxiliary engine) test cycle. When the engine shall be connected to dredger pump and propulsion either fixed pitch propeller or controllable pitch propeller, the test cycle is complied with E3 or E2 test cycle in accordance with regulation of IMO NOx Technical code.

General

The FPP control system is designed for remote control of the HiMSEN main engine from the telegraph and maneuvering lever in wheelhouse and engine control room. By controlling the panel and lever, the system will start, reverse, stop and speed-set the HiMSEN main engine and reduction gear. The engine can also be controlled by using engine stating box located in the local side.

The main function of FPP control system are:

- Remote control system
- Engine telegraph system
- Engine safety system
- Interface with AMS(Alarm Monitoring System)

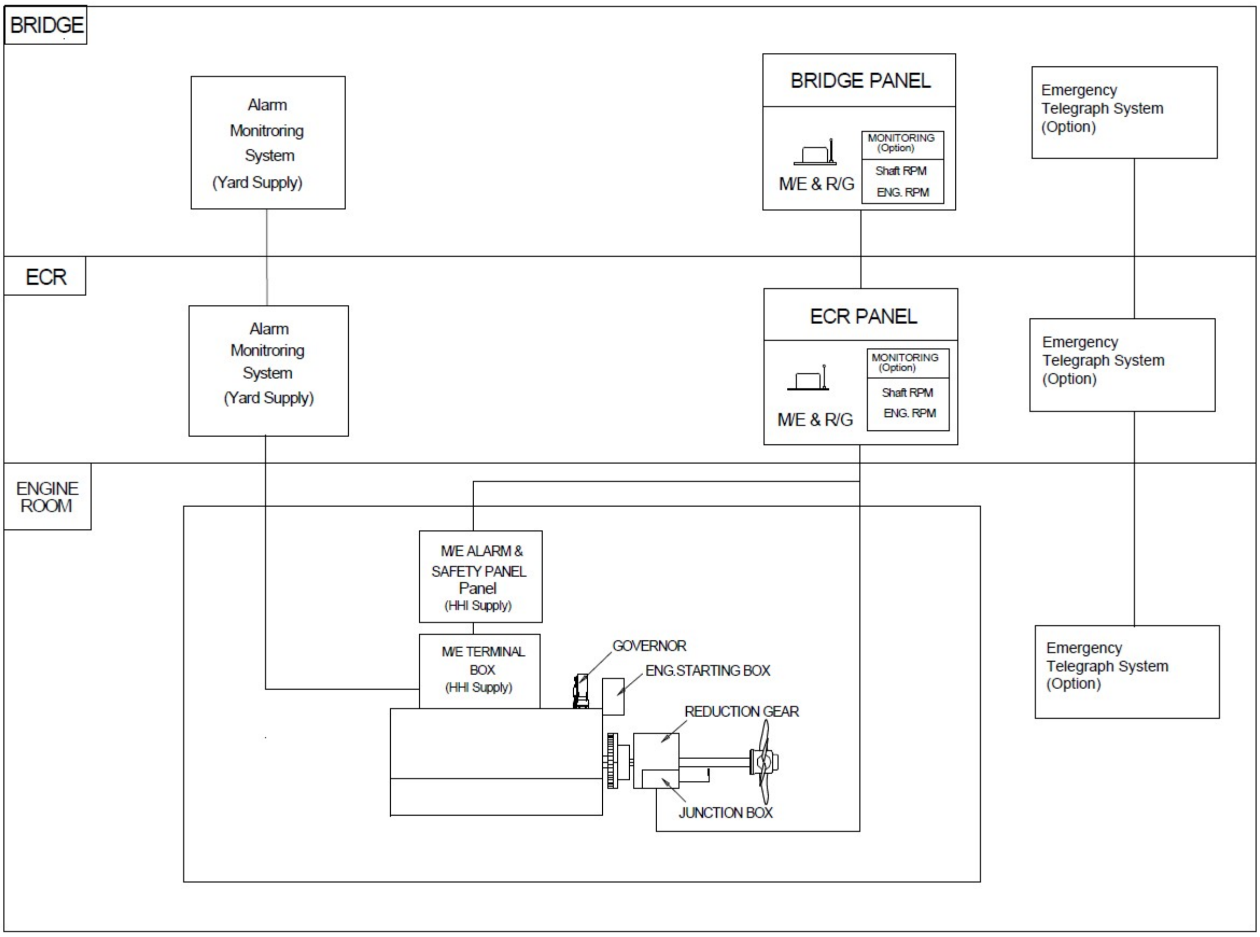


Figure 11-1-1: Diagram of the control system for the FPP

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

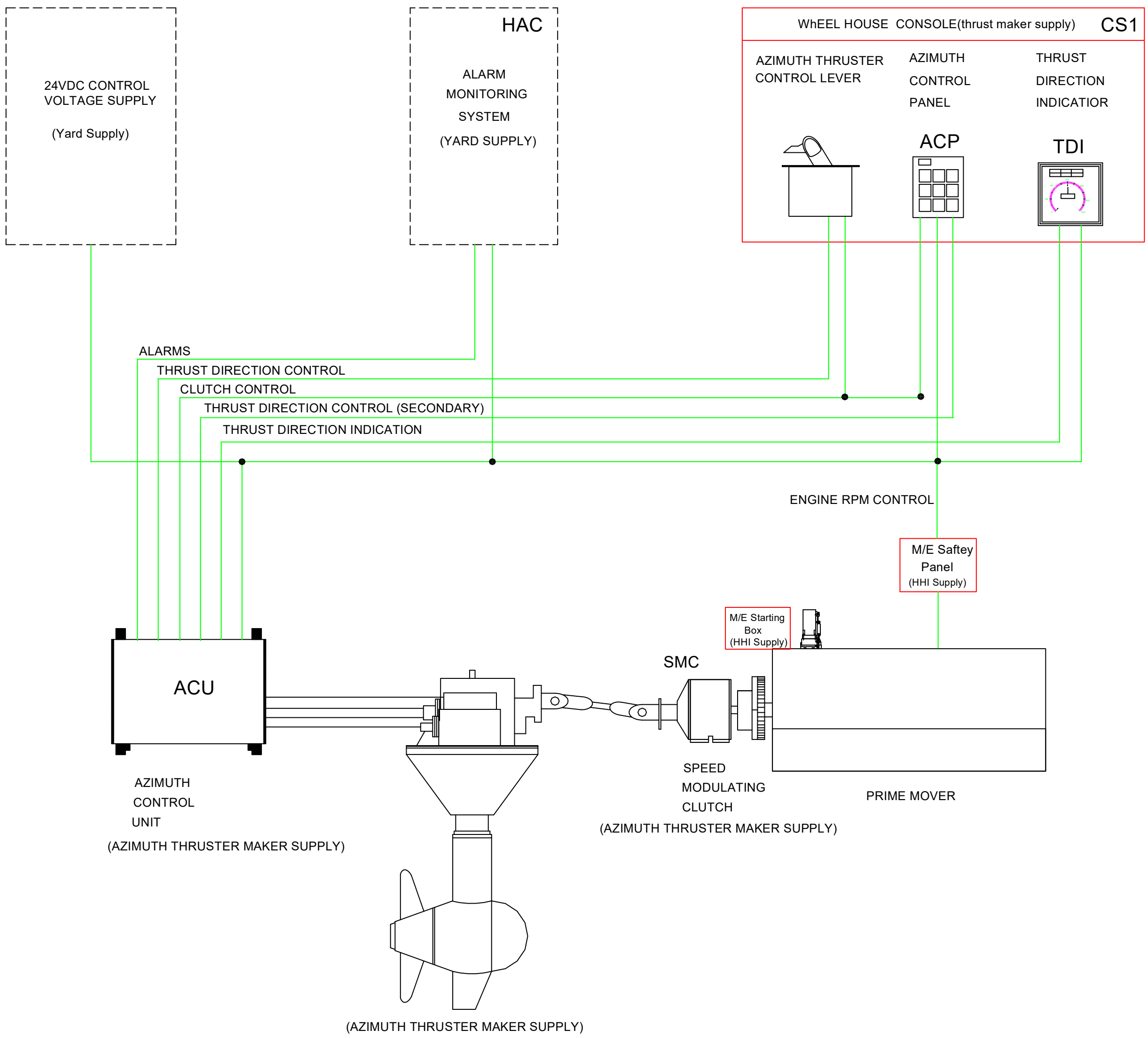


Figure 11-2-1: Diagram of the control system for the azimuth thruster

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.

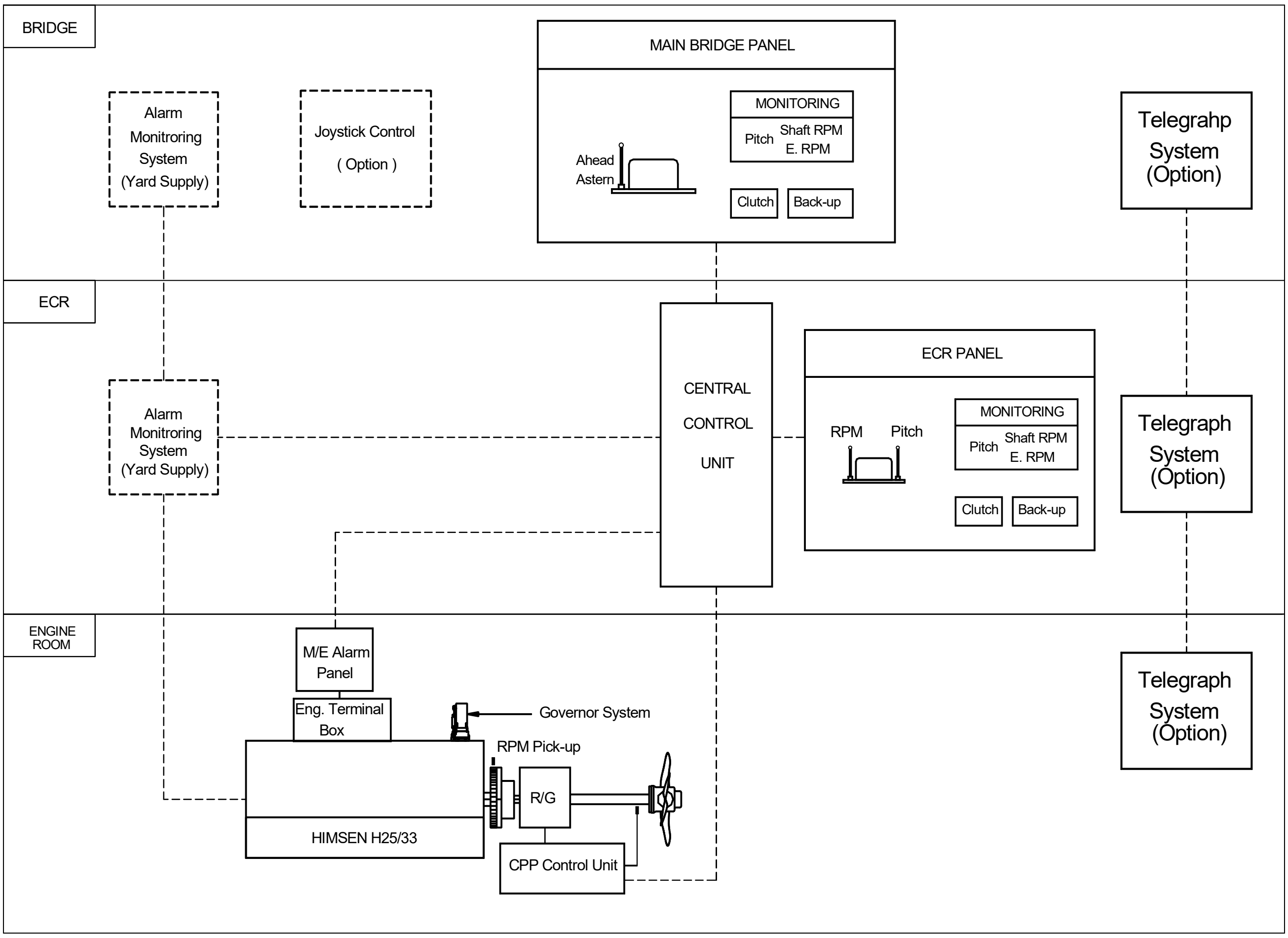


Figure 11-3-1: Diagram of the control system for the CPP

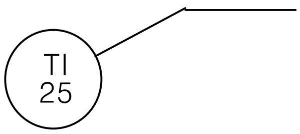
Appendix

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

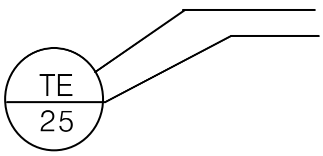


Measuring device

Locally reading

Temperature Indicator

No. 25*



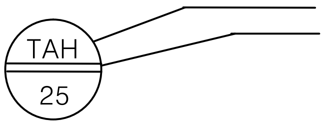
Measuring device

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 cooler inlet	21	Charge 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 injection 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

Global Leader
www.hhi.co.kr

HYUNDAI HiMSEN

HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY