PROJECT GUIDE

HiMSEN H32/40
FOR STATIONARY

HYUNDAI HEAVY INDUSTRIES | ENGINE & MACHINERY

HiMSEN

DISCLAIMER

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

General

This project guide provides necessary information and recommendations for the application of HYUNDAI's HiMSEN H32/40 generating sets(gen-set).

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

HiMSEN H32/40 generating sets are delivered as complete packages, an engine and a generator are mounted on a common base frame together with related auxiliary equipments.

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

Each sheet is identified by the engine type and own 'Sheet Number'. Therefore, please use engine type 'H32/40' and 'Sheet No.' for easier communications.

ENGINE MODEL DESIGNATION

6 H 32 / 40 (M/S)

- No. of Cylinders (6, 7, 8, 9)
- HYUNDAI's HiMSEN
- Cylinder Bore in cm
- Piston Stroke in cm
- Marine or Stationary Application

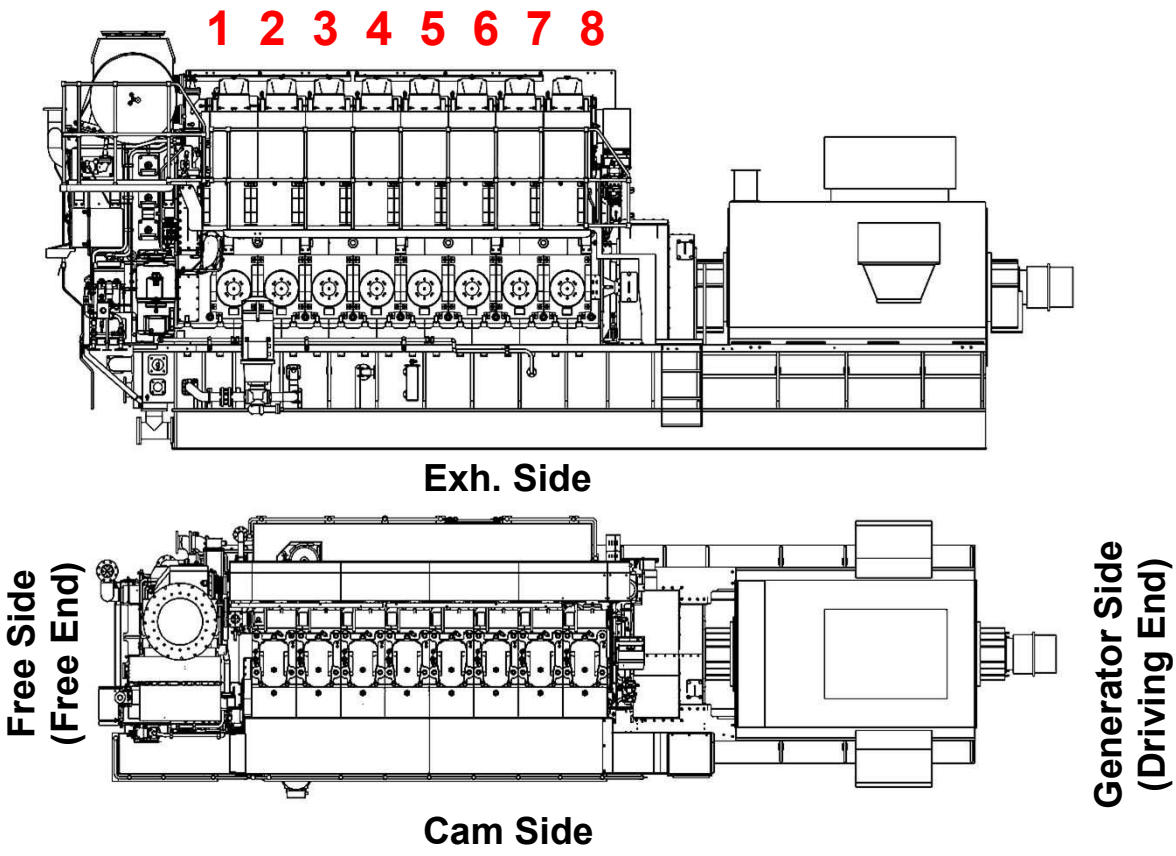
SHEET NUMBER

P . XX . XXX

- Project Guide Book
- Section number
- Sub Section with Serial number

Nov. 2023

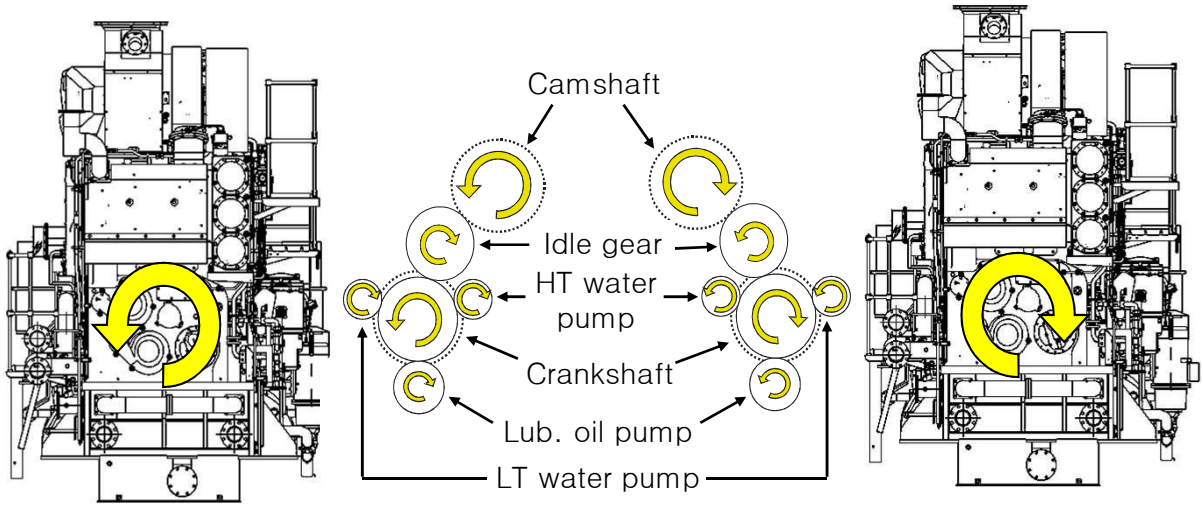
Cylinder Numbering



Direction of Engine Rotation

Clockwise Engine : Clockwise viewed from Driving end
CounterClockwise viewed from Free End
Counterclockwise Engine : Counterclockwise viewed from Driving end
Clockwise viewed from Free End

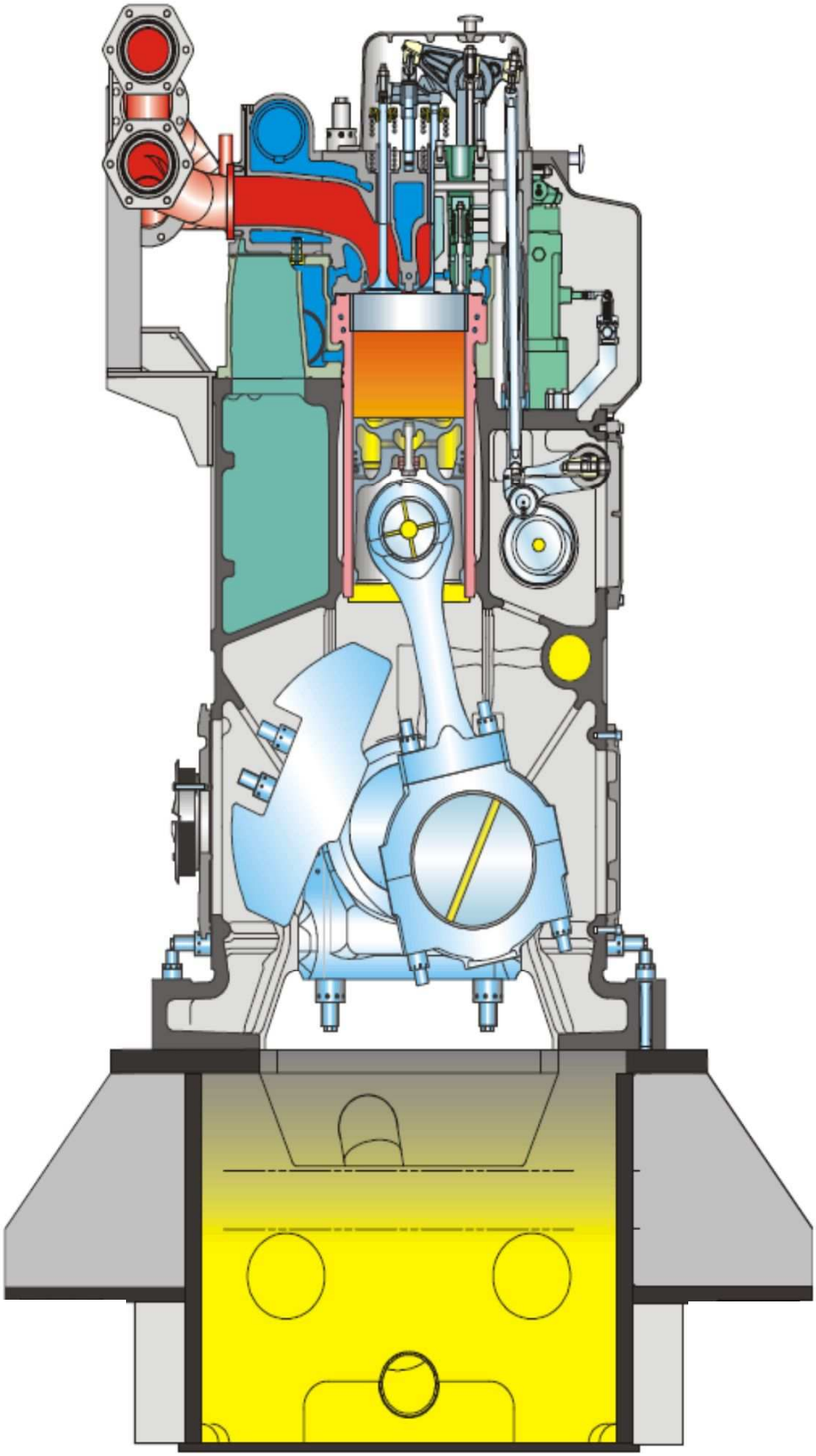
Clockwise Engine
(Viewed from Free End)



Counterclockwise Engine
(Viewed from Free End)

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**	**720**	**750**
Power per Cylinder	**kW**	**500**	**500**
Cylinder Bore	**mm**	**320**	
Piston Stroke	**mm**	**400**	
Swept Volume per Cylinder	**dm³**	**32.2**	
Mean Piston Speed	**m/s**	**9.6**	**10.0**
Mean Effective Pressure	**bar**	**25.9**	**24.9**
Compression Ratio		**15 : 1**	
Direction of Engine Rotation		**Clockwise viewed from Generator Side (Non-Reversible)**	

Cylinder Firing Order	**6H32/40M**	**1 - 4 - 2 - 6 - 3 - 5**
	7H32/40M	**1 - 2 - 4 - 6 - 7 - 5 - 3**
	8H32/40M	**1 - 3 - 5 - 7 - 8 - 6 - 4 - 2**
	9H32/40M	**1 - 3 - 5 - 7 - 9 - 8 - 6 - 4 - 2**



1. General

Hyundai engine 'HiMSEN H32/40' family have simple and smart design suitable for marine application with high reliability and performance. The key features are summarized as below :

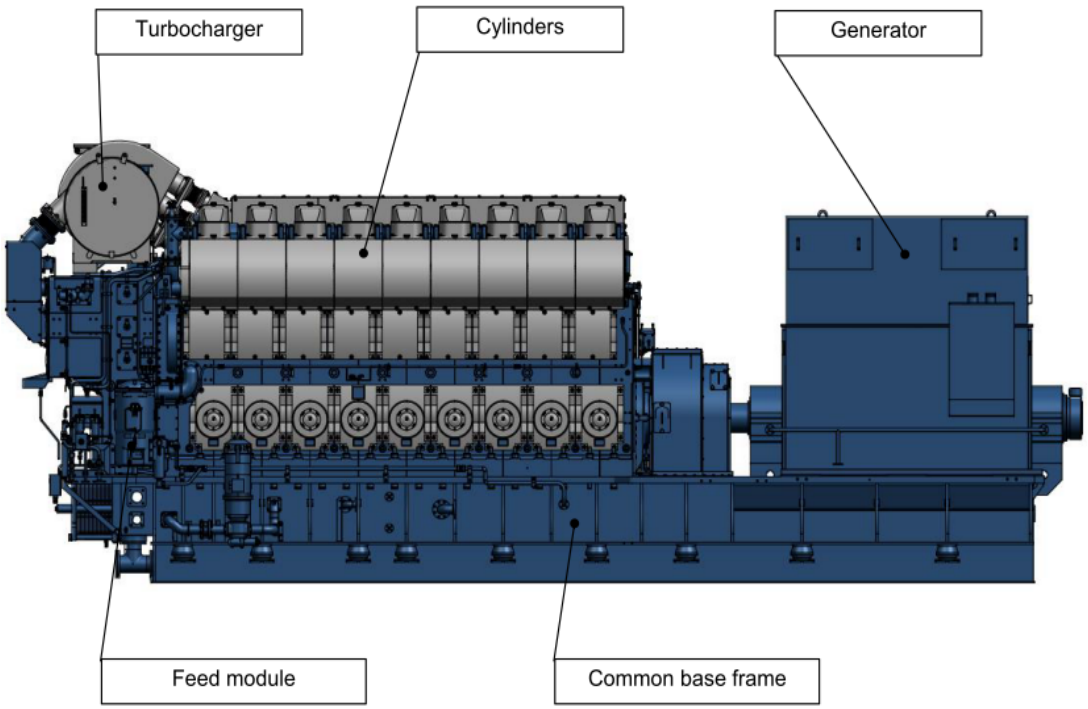
1. **Heavy fuel engine** can be run with same fuel of main engine (Uni-fuel concept).

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

- High stroke to bore ratio
- High compression ratio
- Optimized supercharging with miller cycle
- High fuel injection pressure

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

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



2. Design of Main Components

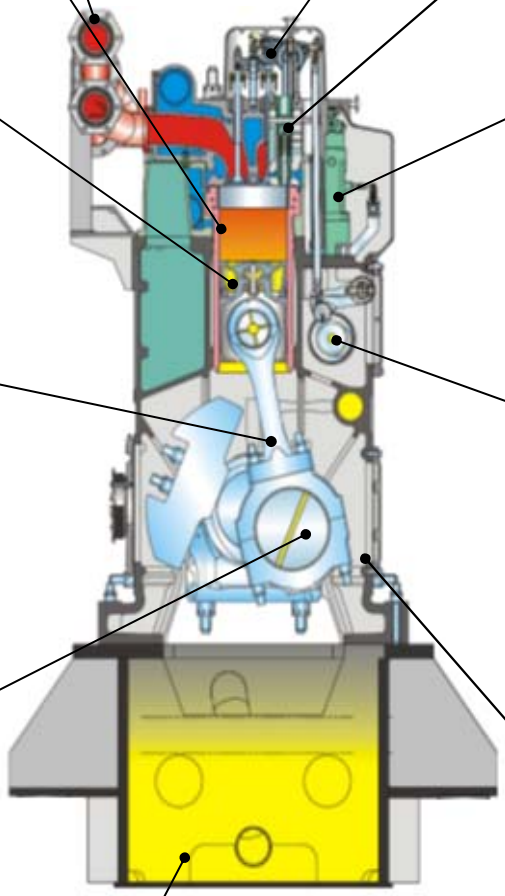
Exhaust System
- Pulse Type

Cylinder Liner
- Special alloy cast iron,
- Flame ring of alloy steel.

Piston
- 2-piece composite type,
- Special forged alloy steel crown,
- 2 compression rings,
- 1 oil scraper ring.

Connecting Rod
- 3-piece marine head type,
- Special die-forged steel,
- All hydraulic fasteners,
- Aluminum bi-metal bearings.

Crankshaft
- Continuous grain flow die-forged, alloy steel,
- Hydraulically fastened counter weight,
- Aluminum bi-metal bearings.



Exhaust and Intake Valves
- Special heat resistant alloy steel,
- Hardfacing welded seats.

Cylinder Head
- Spherical graphite cast iron,
- Replaceable valve seats.

Fuel Injection Equipments
- High injection pressure,
- Die forged steel block.

Camshaft
- Large diameter for high injection pressure,
- Die forged alloy steel,
- Cam profile optimized by hermite spline curve.

Engine Block
- Grey cast iron mono block,
- Water free, corrosion free,
- Large air chamber,
- Built in L.O. passage,
- Large crankcase door for easier maintenance.

Common Bed
- Steel plate welded,
- Robust structure,
- Large oil capacity,
- Resilient mounting.

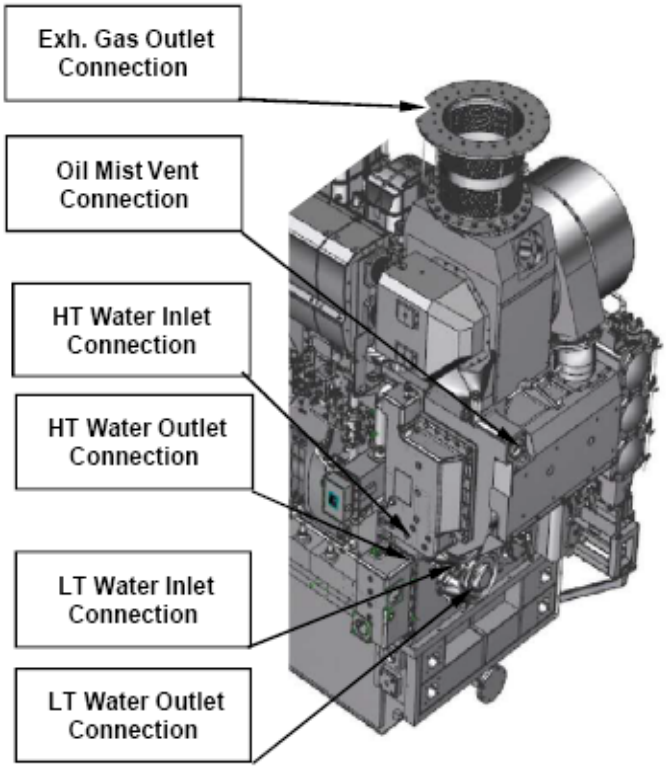
3. Description of Feed Module

HiMSEN has a unique design of Feed Module for better reliability and easier maintenance, that is, the feed system of the engine, such as cooling water and lubricating oil system, are fully modularized into the Feed Module with the following key features;

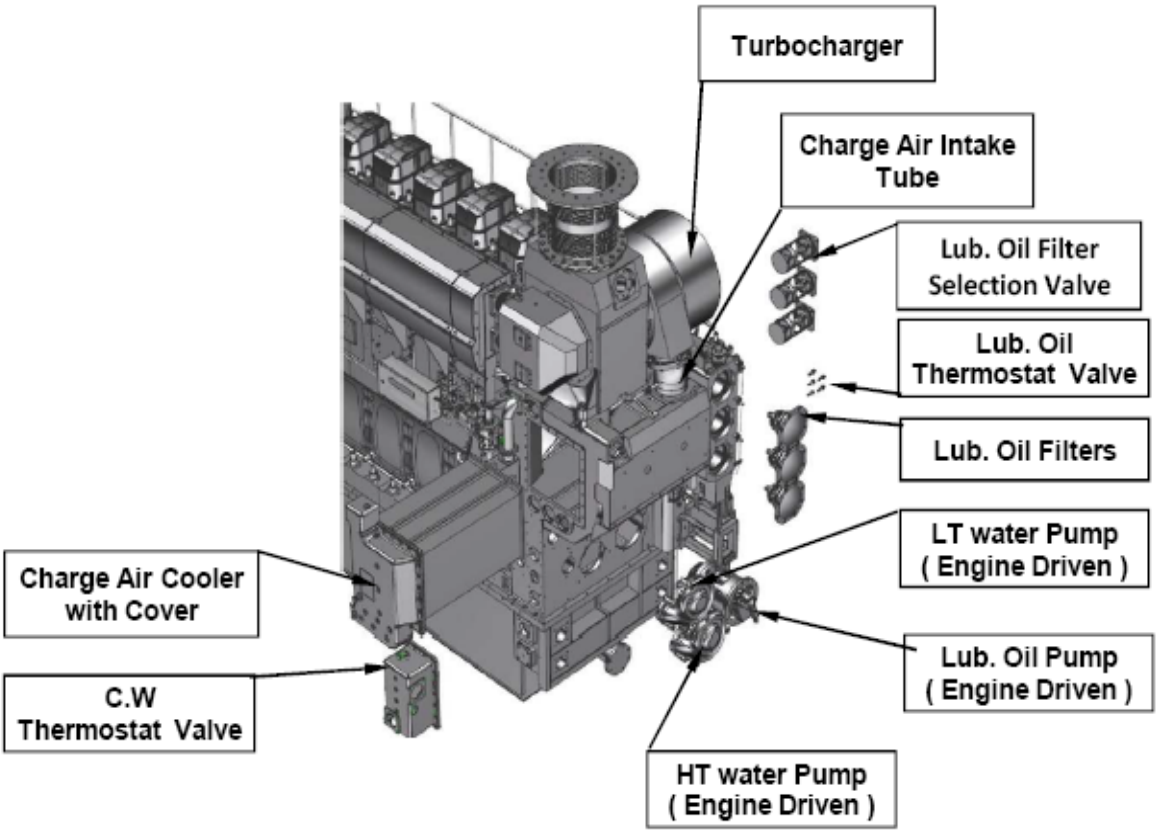
1. All the components of the system, for example, pumps, valves, filters and coolers, are mounted on Feed Block without any pipe connection, which provides direct accessibility with fewer parts for easier maintenance as shown below.

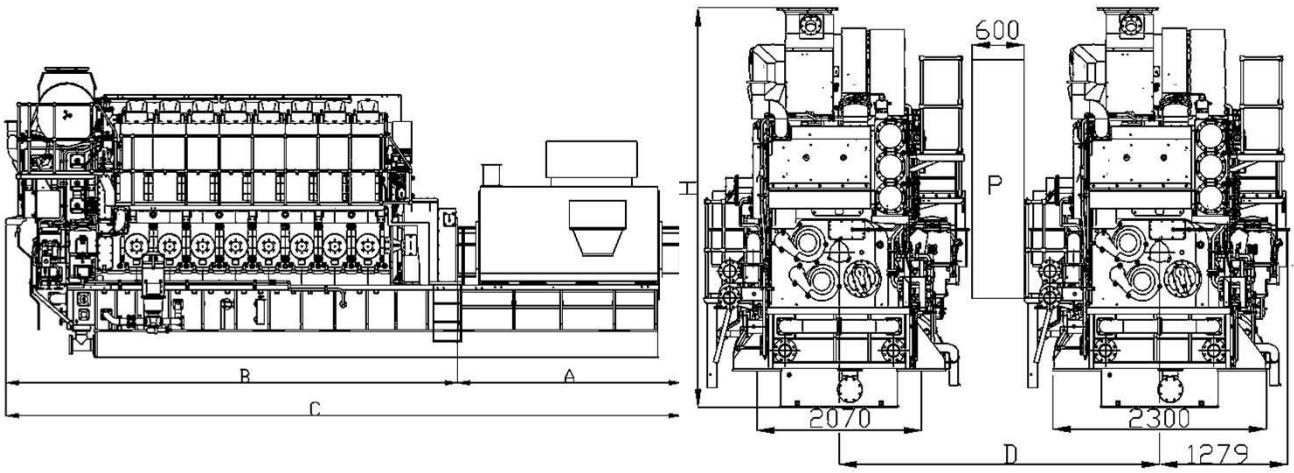
2. Feed Block has cast-in flow channels for Cooling Water and Lub Oil circuits, which are arranged to secure water-tight to oil space and simplified in combination with pumps and valve housings for better flow characteristics to avoid any risk of corrosion due to cavitation.

Outline of Feed Module



Components of Feed Module





Genset for 720 rpm (500 kW/cyl.)

Engine type	Dimension (mm)					Dry Weight (ton) 2)	
	A	B 1)	C 1)	D	H 5)	Engine 3)	Genset 4)
6H32/40	5,055	3,490	8,545	3,037	3,759	33.7	65.2
7H32/40	5,545	3,490	9,035	3,037	3,882	38.6	72.6
8H32/40	6,035	3,785	9,820	3,037	4,132	41.5	78.6
9H32/40	6,525	3,685	10,210	3,037	4,132	44.6	82.7

Genset for 750 rpm (500 kW/cyl.)

Engine type	Dimension (mm)					Dry Weight (ton) 2)	
	A	B 1)	C 1)	D	H 5)	Engine 3)	Genset 4)
6H32/40	5,055	3,490	8,545	3,037	3,759	33.7	65.2
7H32/40	5,545	3,490	9,035	3,037	3,882	38.6	72.6
8H32/40	6,035	3,785	9,820	3,037	4,132	41.5	78.6
9H32/40	6,525	3,685	10,210	3,037	4,132	44.6	82.7

1) : Depending on alternator.
2) : Weight included a standard alternator (Maker : HHI-EES)
3) : Without Common base frame
4) : With Common base frame & Generator
5) : No T/C spec is decided yet. Confirmation from HHI to be needed when applying
D : Min distance between engines - 3,037mm (with gallery)
P : Free passage between the engines, width 600mm and height 2,000mm
Note) All dimensions and weight are approximate value and subject to change without prior notice

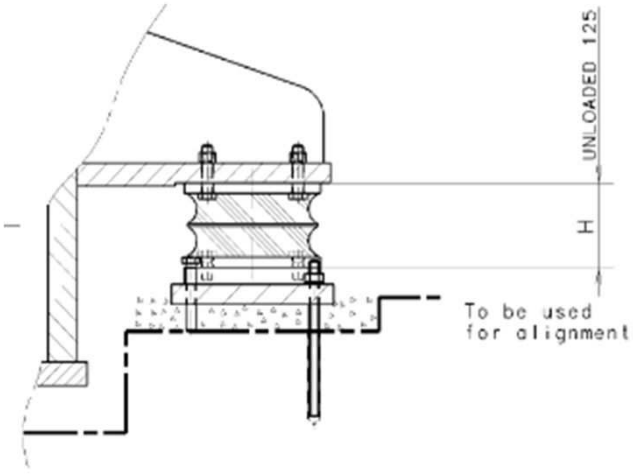
General

A HiMSEN Generating-set consists of Diesel engine and Generator mounted on Common Base Frame. The Common Base Frame is installed on resilient mounts on the steel structure of the concrete foundation.

Design of Resilient Mounting

A resilient mounting of the generating-set is made with a number of rubber elements to isolate vibrations between generator set and hull structure. These rubber elements are bolted to brackets of the Common Bed as shown on right figure.

The number and position of the rubber elements depend on the dynamic characteristics of the plant. Therefore, the final specification of the rubber elements shall be decided based on the information from the plant contractor case by case.



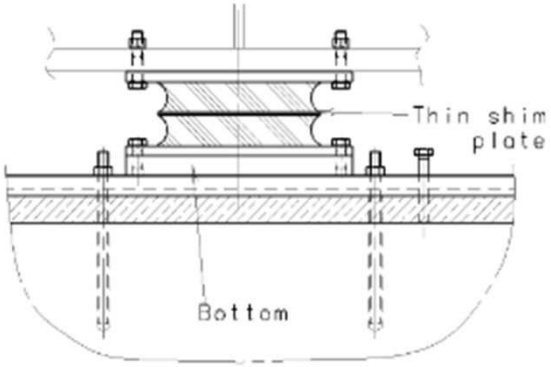
< Resilient mounting >

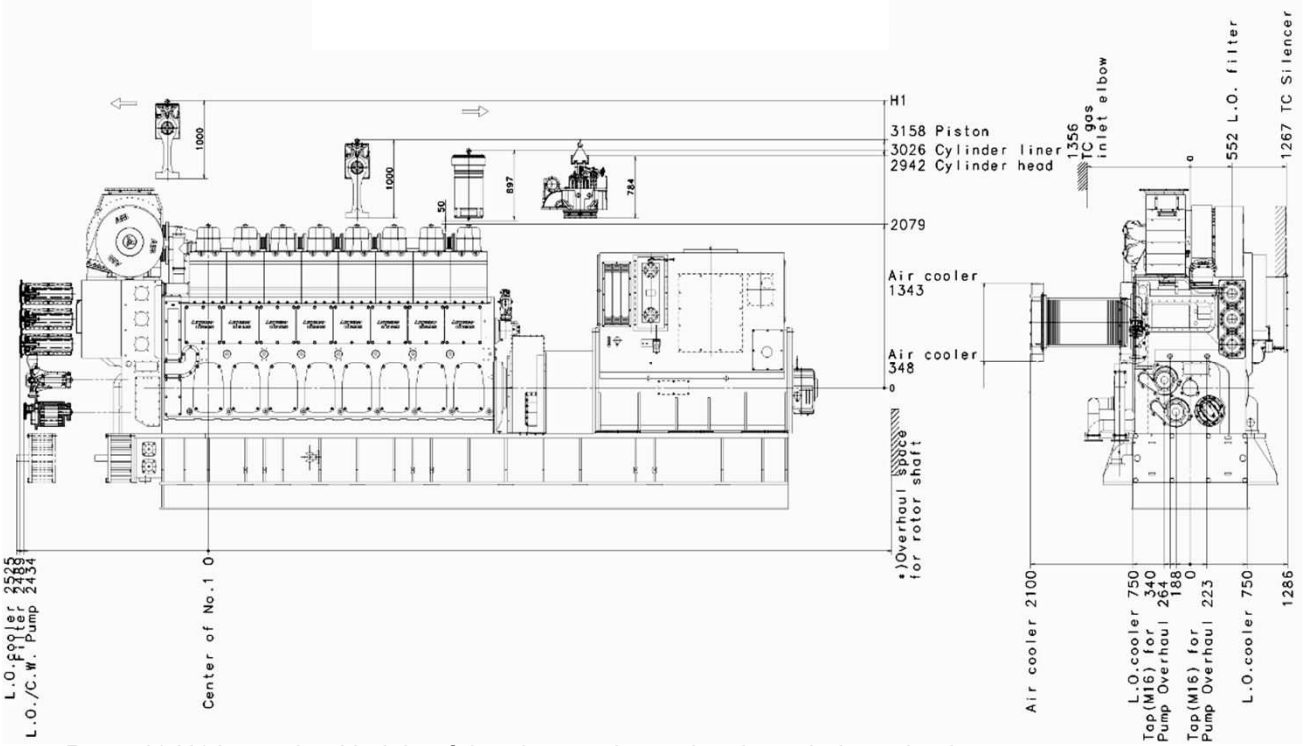
Connections to the Generating-set (for resilient mounting)

Generating-set mounted on the resilient mounts usually has some relative motions to the foundation structure(of concrete block). Any rigid fixing between generator set and foundation structure cause damages of generator set. Therefore, all connections, for example, pipes, gratings, ladders, electric wires, etc., should be flexible enough to absorb the relative movements.

Recommendations for Seating Design and Adjustment (for resilient mounting)

The foundation for Common Base Frame mounting should be rigid enough to support the load from Generator Set. The thin shim plate can be used between bottom of mounting and Top of filling piece are required to adjust leveling of each mount.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 generator set.





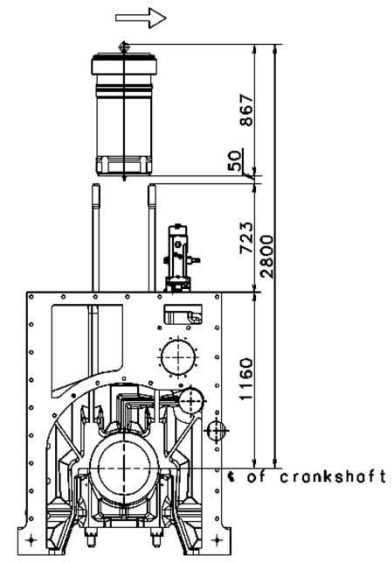
Remark) H1 is overhaul height of the piston unit passing through the turbocharger.

H1=3,410mm, for 6H32/40

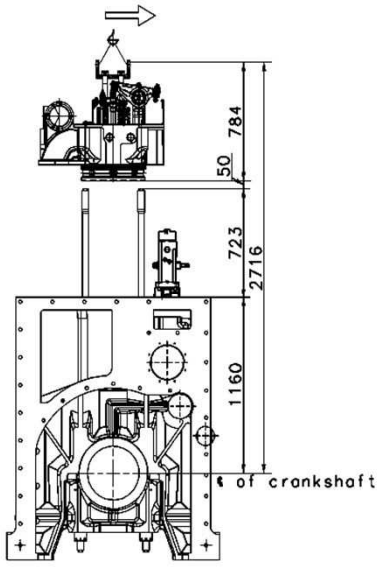
H1=3,600mm, for 7H32/40

H1=3,600mm, for 8H32/40

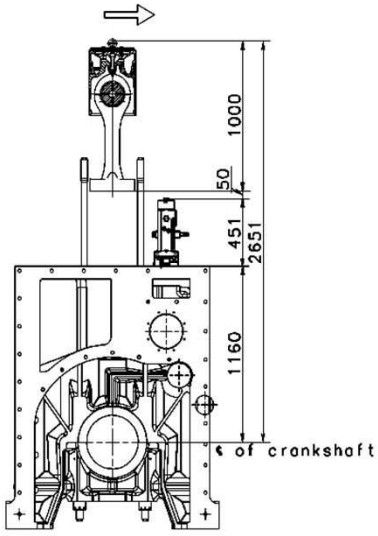
H1=3,600mm, for 9H32/40



Cylinder liner



Cylinder head



Piston

Engine Type	Rated Output at			
	720 rpm/60Hz		750 rpm/50Hz	
	Engine (kW_m)	Generator (kW_e)	Engine (kW_m)	Generator (kW_e)
6H32/40S	3,000	2,880	3,000	2,880
7H32/40S	3,500	3,360	3,500	3,360
8H32/40S	4,000	3,840	4,000	3,840
9H32/40S	4,500	4,320	4,500	4,320

Remark : 1) According to ISO 3046-1:2002, overload > 100%, it is allowed to use overload > 100% for governing purpose only such as transient load conditions and suddenly applied load. The overload engine power shall not be used for the supply of electrical consumers.
2) The alternator outputs are calculated by an efficiency of 96% and a power factor of 0.8 lagging.

Reference Condition

General definition of diesel engine rating is specified in accordance with ISO 3046/1.
However the engine outputs are available within tropical condition without derating.

ISO Conditions
Turbocharger air inlet pressure : 1,000 mbar
Turbocharger air inlet temperature : 298 K (25 ℃)
Charge air coolant temperature : 298 K (25 ℃)

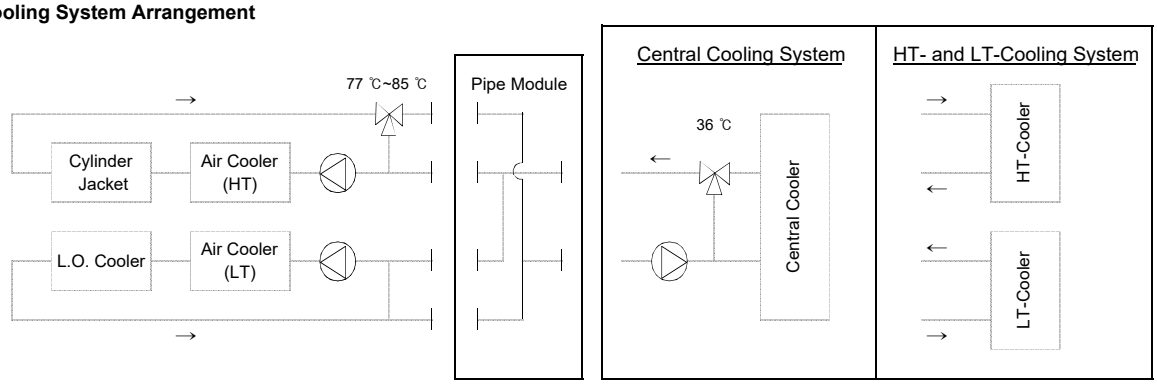
Tropical Conditions
Turbocharger air inlet pressure : 1,000 mbar
Turbocharger air inlet temperature : 318 K (45 ℃)
Charge air coolant temperature : 309 K (36 ℃)*
* Valid for central cooling system up to 36 ℃ normally, 38 ℃ specially.

720 rpm/60 Hz (500 kW/cyl.)

Engine MCR		Cyl.	6	7	8	9
		kW	3000	3500	4000	4500
COOLING CAPACITIES						
Charge Air						
HT-Heat dissipation1)		kW	851	1000	1139	1288
LT-Heat dissipation1)		kW	251	286	331	366
Cooling water flow (H.T & L.T)		㎥/h	70	70	85	85
LT-cooling water temperature, cooler	in / out	℃	36 / 39	36 / 40	36 / 39	36 / 40
Lubricating Oil						
Heat dissipation1),3)		kW	494	576	658	741
LT-cooling water flow		㎥/h	70	70	85	85
LT-cooling water temperature, cooler	in / out	℃	39 / 45	40 / 47	39 / 46	40 / 47
Cylinder Jacket						
Heat dissipation1)		kW	461	538	614	691
HT-cooling water flow		㎥/h	70	70	85	85
HT-cooling water temperature, engine	in / out	℃	75 / 82	75 / 82	75 / 82	75 / 82
GAS DATA2)						
Combustion air consumption		kg/h	21600	25200	28800	32400
Exhaust gas flow		kg/h	22149	25841	29532	33224
Exhaust gas temperature		℃	335	335	335	335
Allowable exhaust gas back pressure	max.	mbar	30	30	30	30
HEAT RADIATION						
Engine radiation1)		kW	99	115	132	148
Alternator radiation		kW	(See separate data from alternator maker)			
STARTING AIR						
Air consumption per start (with jet air)		N㎥	4.40	4.60	4.80	5.00
Air consumption per start (without jet air)		N㎥	1.90	2.10	2.30	2.50
Jet air consumption at starting		N㎥	2.50	2.50	2.50	2.50
Jet air consumption at sudden load up		N㎥	(To be adjusted depending on the loading condtion)			
Starting air pressure at engine during start	(Max./Min.)	bar	30 / 15	30 / 15	30 /15	30 / 15
PUMP CAPACITIES						
Engine Driven Pumps5)						
Lubricating oil pump	(6 bar)	㎥/h	120	120	140	140
HT-cooling water pump	(1~2.5 bar)	㎥/h	70	70	85	85
LT-cooling water pump	(1~2.5 bar)	㎥/h	70	70	85	85
External Pumps 4)						
MDO pump(head)	(8 bar)	㎥/h	2.22	2.59	2.96	3.33
HFO supply pump(head)	(4 bar)	㎥/h	1.11	1.29	1.48	1.66
HFO booster pump	(8 bar at Engine inlet, F1)6)	㎥/h	2.22	2.59	2.96	3.33

Remark :
1) under tropical condition with tolerance 10%
2) under ISO reference condition with flow tolerance +/-5% and exhaust gas temperature +/-25 ℃
3) including additional heat for purification (30 kJ/kWh)
4) to be added flushing oil quantity of automatic filter
5) the flow capacity to be within a tolerance of 0% to +10%.
6) HFO booster pump head to be designed by external system designer considering pressure loss of external system.
7) Engine performance data depends on LCV (Low Calorific Value) of used fuel oil respectively, which influences fuel rack index of fuel injection pump.

Cooling System Arrangement



750 rpm/50 Hz (500 kW/cyl.)

Engine MCR			Cyl.	6	7	8	9
			kW	3000	3500	4000	4500
COOLING CAPACITIES							
Charge Air							
HT-Heat dissipation1)			kW	851	1000	1139	1288
LT-Heat dissipation1)			kW	251	286	331	366
Cooling water flow (H.T & L.T)			m³/h	70	70	85	85
LT-cooling water temperature, cooler		in / out	℃	36 / 39	36 / 40	36 / 39	36 / 40
Lubricating Oil							
Heat dissipation1),3)			kW	499	582	665	749
LT-cooling water flow			m³/h	70	70	85	85
LT-cooling water temperature, cooler		in / out	℃	39 / 45	40 / 47	39 / 46	40 / 47
Cylinder Jacket							
Heat dissipation1)			kW	466	543	621	699
HT-cooling water flow			m³/h	70	70	85	85
HT-cooling water temperature, engine		in / out	℃	75 / 82	75 / 82	75 / 82	75 / 82
GAS DATA2)							
Combustion air consumption			kg/h	21600	25200	28800	32400
Exhaust gas flow			kg/h	22155	25548	29540	33233
Exhaust gas temperature			℃	335	335	335	335
Allowable exhaust gas back pressure		max.	mbar	30	30	30	30
HEAT RADIATION							
Engine radiation1)			kW	100	116	133	150
Alternator radiation			kW	(See separate data from alternator maker)			
STARTING AIR							
Air consumption per start (with jet air)			Nm³	4.40	4.60	4.80	5.00
Air consumption per start (without jet air)			Nm³	1.90	2.10	2.30	2.50
Jet air consumption at starting			Nm³	2.50	2.50	2.50	2.50
Jet air consumption at sudden load up			Nm³	(To be adjusted depending on the loading condtion)			
Starting air pressure at engine during start		(Max./Min.)	bar	30 / 15	30 / 15	30 /15	30 / 15
PUMP CAPACITIES							
Engine Driven Pumps5)							
Lubricating oil pump		(6 bar)	m³/h	125	125	145	145
HT-cooling water pump		(1~2.5 bar)	m³/h	70	70	85	85
LT-cooling water pump		(1~2.5 bar)	m³/h	70	70	85	85
External Pumps 4)							
MDO pump(head)		(8 bar)	m³/h	2.24	2.62	2.99	3.36
HFO supply pump(head)		(4 bar)	m³/h	1.12	1.31	1.49	1.68
HFO booster pump	(8 bar at Engine inlet, F1)6)		m³/h	2.24	2.62	2.99	3.36

Remark :
1) under tropical condition with tolerance 10%
2) under ISO reference condition with flow tolerance +/-5% and exhaust gas temperature +/-25 ℃
3) including additional heat for purification (30 kJ/kWh)
4) to be added flushing oil quantity of automatic filter
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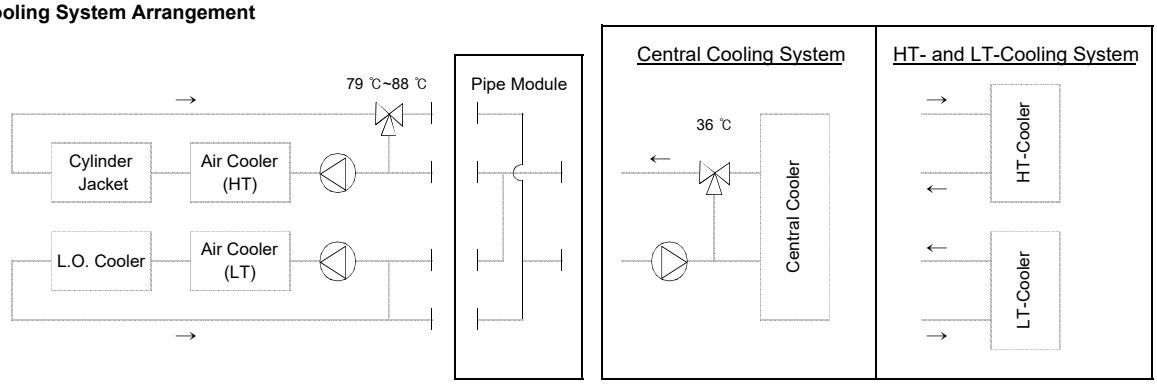
7) Engine performance data depends on LCV (Low Calorific Value) of used fuel oil respectively, which influences fuel rack index of fuel injection pump.

Cooling System Arrangement



1. Engine Performance Data

Rated Power : 500 kW/cyl. at 720 rpm

Performance Data		Engine Load (%)					
		110	**100**	90	75	50	25
CYLINDER DATA							
Cylinder Output	kW	550	**500**	450	375	250	125
Max. Combustion Pressure, MV	bar	200	**190**	178	154	107	71
Mean Effective Pressure	bar	28.5	**25.9**	23.3	19.4	13.0	6.5
Fuel Pump Index, MV	mm	50	**45**	40	30	20	10
COMBUSTION AIR DATA 1)							
Mass Flow	kg/kWh	7.1	**7.2**	7.3	7.6	8.1	10.2
Air Pressure (abs.)	bar	5.4	**5.0**	4.6	4.0	2.8	1.6
Air Temperature after Compressor	℃	240	**230**	220	200	155	85
Air Temperature after Cooler	℃	45	**45**	45	45	45	45
EXHAUST GAS DATA 1)							
Mass Flow	kg/kWh	7.3	**7.4**	7.5	7.8	8.3	10.4
Gas Temperature before Turbine	℃	540	**520**	500	475	460	410
Gas Temperature after Turbine	℃	355	**345**	340	330	365	355
HEAT BALANCE DATA 2)							
Charge Air, Stage 2(LT)	kJ/kWh	338	**340**	349	359	350	338
Charge Air, Stage 1(HT)	kJ/kWh	1251	**1150**	1093	977	660	123
Lubricating Oil	kJ/kWh	613	**592**	596	682	867	1228
Jacket Cooling Water	kJ/kWh	554	**553**	558	570	714	1316
Exhaust Gas	kJ/kWh	1542	**1546**	1624	1700	2134	2836
Radiation	kJ/kWh	128	**118**	123	140	173	380
FUEL OIL CONSUMPTION 3)							
Specific Fuel Oil Consumption	g/kWh	186	**183**	185	188	201	242

Remarks

1) Reference condition based on ISO 3046/1 (air press. 1 bar, air temp. 25℃, cooling water temp. 25 ℃)
Mass flow tolerance +/-5%, gas temperature tolerance -/+25℃
The exhaust gas temperatures stated above are only for guidance as these depend on the ambient condition and engine characteristics of pulse turbocharging system. (See the sheet No. P.04.800 for normal operating range at rated power.)

2) Reference condition based on tropical condition (air press. 1 bar, air temp. 45℃, cooling water temp. 36 ℃)
Heat dissipation tolerance 10%
Additional heat for lube oil purification included (30 kJ/kWh)

3) Reference condition based on ISO 3046/1 (air press. 1 bar, air temp. 25℃, cooling water temp. 25 ℃)
SFOC tolerance +5%
Engine driven pumps attached : Lube oil pump, HT-pump, LT-pump
Fuel oil based on MDO, LCV 42700 kJ/kg
Warranted at 100% load

1. Engine Performance Data

Rated Power : 500 kW/cyl. at 750 rpm

Performance Data		Engine Load (%)					
		110	**100**	90	75	50	25
CYLINDER DATA							
Cylinder Output	kW	550	**500**	450	375	250	125
Max. Combustion Pressure, MV	bar	200	**190**	178	154	107	71
Mean Effective Pressure	bar	27.4	**24.9**	22.4	18.7	12.4	6.2
Fuel Pump Index, MV	mm	50	**45**	40	30	20	10
COMBUSTION AIR DATA 1)							
Mass Flow	kg/kWh	7.1	**7.2**	7.3	7.6	8.1	10.2
Air Pressure (abs.)	bar	5.4	**5.0**	4.6	4.0	2.8	1.6
Air Temperature after Compressor	℃	240	**230**	220	200	155	85
Air Temperature after Cooler	℃	45	**45**	45	45	45	45
EXHAUST GAS DATA 1)							
Mass Flow	kg/kWh	7.3	**7.4**	7.5	7.8	8.3	10.4
Gas Temperature before Turbine	℃	540	**520**	500	475	460	410
Gas Temperature after Turbine	℃	355	**345**	340	330	365	355
HEAT BALANCE DATA 2)							
Charge Air, Stage 2(LT)	kJ/kWh	338	**339**	348	358	349	338
Charge Air, Stage 1(HT)	kJ/kWh	1252	**1151**	1093	978	660	123
Lubricating Oil	kJ/kWh	620	**599**	602	690	875	1238
Jacket Cooling Water	kJ/kWh	560	**559**	564	576	721	1327
Exhaust Gas	kJ/kWh	1614	**1618**	1695	1770	2202	2896
Radiation	kJ/kWh	130	**120**	124	141	175	383
FUEL OIL CONSUMPTION 3)							
Specific Fuel Oil Consumption	g/kWh	188	**185**	187	190	203	244

Remarks

1) Reference condition based on ISO 3046/1 (air press. 1 bar, air temp. 25℃, cooling water temp. 25 ℃)
Mass flow tolerance +/-5%, gas temperature tolerance -/+25℃
The exhaust gas temperatures stated above are only for guidance as these depend on the ambient condition and engine characteristics of pulse turbocharging system. (See the sheet No. P.04.800 for normal operating range at rated power.)

2) Reference condition based on tropical condition (air press. 1 bar, air temp. 45℃, cooling water temp. 36 ℃)
Heat dissipation tolerance 10%
Additional heat for lube oil purification included (30 kJ/kWh)

3) Reference condition based on ISO 3046/1 (air press. 1 bar, air temp. 25℃, cooling water temp. 25 ℃)
SFOC tolerance +5%
Engine driven pumps attached : Lube oil pump, HT-pump, LT-pump
Fuel oil based on MDO, LCV 42700 kJ/kg
Warranted at 100% load

Correction for ambient condition

Specific Fuel Oil Consumption(SFOC) is refered to the ISO 3046/1 reference condition normally.

However, for the condition other than ISO 3046-1:2002 reference condition,
the SFOC at MCR can be estimated according to the below mentioned formula.

$SFOCamb = SFOC_{ISO} * dSFOC$

$dSFOC = [100 + (Tintake-25)*0.05 - (Pamb-1000)*0.007 + (Tcw-25)*0.07] / 100 *(42700/LCV)$

SFOCamb : Specific Fuel Oil Consumption at actual operating condition [g/kWh]
$SFOC_{ISO}$: Specific Fuel Oil Consumption at ISO 3046/1 reference condition [g/kWh]
dSFOC : Deviation of the SFOC
Tintake : Intake air temperature at actual operating condition [℃]
Pamb : Ambient air pressure at actual operating condition [mbar]
Tcw : Cooling water temperature before Charge Air Cooler(CAC) at actual operating condition [℃]
LCV : Lower Calorific Value of the fuel oil [kJ/kg]

Example,
Intake air temperature(Tintake) : 30 [℃]
Pamb : 1000 [mbar]
Cooling water temperature(Tcw) : 30 [℃]
Lower Calorific Value(LCV) : 42700 [kJ/kg]
$SFOC_{ISO}$: 183 [g/kWh] at 720[rpm], MCR

then, dSFOC = 1.006 and the SFOC at site condtion will be increased to 184.1[g/kWh].

Clean leak fuel oil

Clean leak fuel oil (recycling fuel oil) during engine operation is subtracted from measured fuel oil consumpti
(Refer to P.05.100 Internal fuel oil system)

FOCamb = FOC - clean leak fuel oil *)

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

Correction of additional fuel consumption

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

Item	Additional SFOC [g/kWh]
Lub. Oil pump	+ 2
L.T Cooling water pump.	+ 1
H.T. Cooling water pump	+ 1
F.O. Feed pump	Please discuss with HHI-EMD
Charge air pressure control device	Please discuss with HHI-EMD
Operation with MGO	+ 2
500mmWC > Exhaust gas back pressure after turbine > 300 mmWC	+ 0.5 / 100 mmWC

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

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

Load	100 ~ 25%	Under 25%
x	1.15	1.28

1. General

Correction for ambient condition

Exhaust gas temperature after turbine is refered to ISO 3046/1 standard condition normally.

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

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

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

$T_{exh.ISO}$: Exhaust gas temperature after turbine at ISO 3046/1 standard condition [℃]

dT_{exh} : Deviation of the exhaust gas temperature after turbine [℃]

T_{intake} : Intake air temperature at actual operating condition [℃]

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

Example,

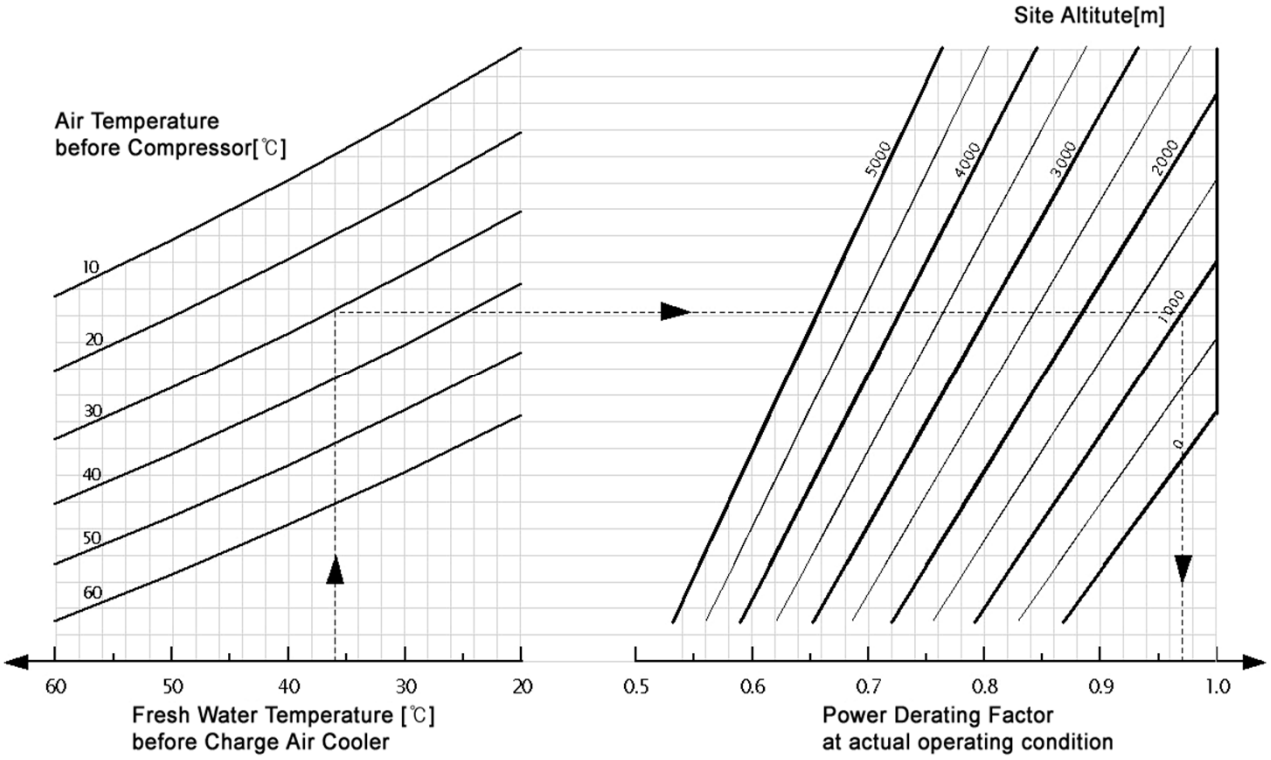
Intake air temperature(T_{intake}) : 35 [℃]

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

$T_{exh.ISO}$: 290 [℃] at 720 [rpm], MCR

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

Engine output power at MCR shall be reduced depending on the intake air temperature, cooling water temperature and site altitute.



Example

Cooling water temperature before charge air cooler : 36[℃]
Intake air temperature : 30[℃]
Site altitute : 1000[m]

From the power derating diagram, the power derating factor at actual operating condition is 0.97.
Therefore the engine output power at actual operating condition should be derated to the 97% of the standard engine power.

Engine Type	Speed	External Forces and Moments				Guide Force Moments		
		Order		Moment		Order		Moment
				Horizontal	Vertical			
	rpm	No.	Hz	kNm	kNm	No.	Hz	kNm
6H32/40	720	1	12.0	0.0	0.0	3	36.0	39.1
		2	24.0	0.0	0.0	6	72.0	17.2
	750	1	12.5	0.0	0.0	3	37.5	36.2
		2	25.0	0.0	0.0	6	75.0	17.2
7H32/40	720	1	12.0	0.3	24.7	3.5	42.0	72.6
		2	24.0	0.0	21.4	7	84.0	10.2
	750	1	12.5	0.4	26.8	3.5	43.8	72.6
		2	25.0	0.0	23.2	7	87.5	10.2
8H32/40	720	1	12.0	0.0	0.0	4	48.0	62.6
		2	24.0	0.0	0.0	8	96.0	5.4
	750	1	12.5	0.0	0.0	4	50.0	62.3
		2	25.0	0.0	0.0	8	100.0	5.4
9H32/40	720	1	12.0	0.2	17.9	4.5	54.0	57.0
		2	24.0	0.0	11.6	9	108.0	2.1
	750	1	12.5	0.2	19.4	4.5	56.3	57.0
		2	25.0	0.0	12.6	9	112.5	2.1

Engine Type	Speed	Rating	Moments of Inertia ; J 1)				
			Engine MOI	Flywheel MOI	Flywheel Mass	Alternator MOI 2)	Total MOI
	1/min	kW	kg m²	kg m²	kg	kg m²	kg m²
6H32/40	720	3000	400.4	60.0	276.0	508.9	969.3
	750	3000	400.4	60.0	276.0	508.9	969.3
7H32/40	720	3500	458.8	400.0	1633.0	563.0	1421.8
	750	3500	458.8	400.0	1633.0	563.0	1421.8
8H32/40	720	4000	517.1	190.0	809.0	704.0	1411.1
	750	4000	517.1	190.0	809.0	704.0	1411.1
9H32/40	720	4500	575.5	60.0	276.0	704.0	1339.5
	750	4500	575.5	60.0	276.0	704.0	1339.5

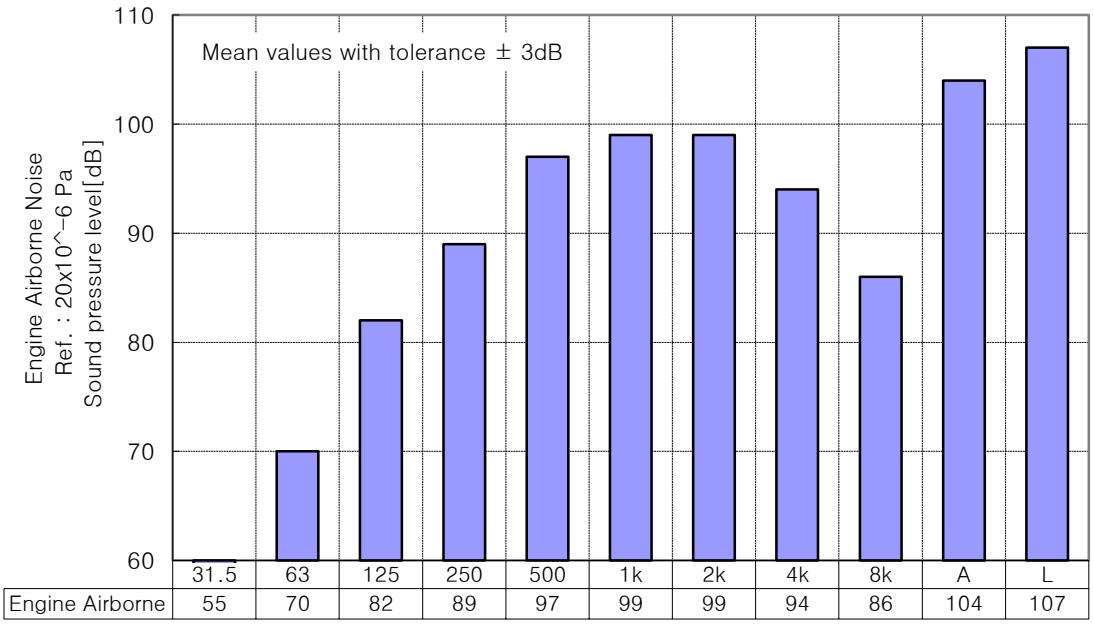
1) Moment of Inertia : $GD^2 = 4 \times J$ (kg m²)

2) Recommended values, in case of different MOI, should be confirmed by a torsional vibration analysis.

General

The airborne noise of the engine is defined as a sound pressure level according to ISO 6798 and ISO 8528-10, and measured at the distance 1 m 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.
The measured value for specific project, if required, could be a little differenct from the below.

720 rpm



	31.5	63	125	250	500	1k	2k	4k	8k	A	L
Engine Airborne	55	70	82	89	97	99	99	94	86	104	107

Octave band center frequency[Hz]

1. General

HiMSEN is a heavy fuel engine and it is not necessary to change over to diesel fuel at any operating condition, for example, engine start, stop, low load running, etc. However, there are some recommendations to maintain good performance and reliability consistently.

2. Starting Condition with Warm Engine

Lub. Oil
- Continuous prelubrication is required,
- Temperature : over 40 ℃ (Preheated)

Cylinder Cooling Water
- Start on MDO/MGO : over 40 ℃ (Preheated),
- Start on HFO : over 60 ℃ (Preheated).

Intake Air
- Air temperature : between 0 ℃ and 45 ℃.

Starting Air
- Refer to Sheet No. P.02.200.

Fuel Oil (MDO/MGO or HFO)
- Precirculation is required.
- Engine inlet viscosity :
  12 ~ 18 cSt (HFO).
  2 ~ 14 cSt (MDO/MGO).

3. Starting Condition with Cold Engine

- Fuel Oil : only MDO/MGO acceptable,
- Cylinder Cooling Water : minimum 15 ℃,
- Lube Oil : minimum 10 ℃, prelubricated, (approx.1,000 cSt based on SAE 40)
- Intake air temperature : minimum 0 ℃.

4. Engine Start

Engine start ready

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

Starter
- An air motor is installed in engine side and drives fly wheel through gears.
- The air motor is operated by compressed air and controlled by pneumatic solenoid valve.

(See 'P.08.100 Internal compressed air system')

Start block signals
- Turning gear engaged
- 'Blocking' switch 'on'
- Stop signal 'activated'
- Common shutdown
- Lubricating oil pressure at engine inlet low
- Tacho failure

5. Restrictions for Low Load Operation

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

Long Term Low Load operation

Marine diesel oil and marine gas oil operation

- Over 15 % load operation : no restriction
- Below 15 % load operation : load up over 70 % load at every limited time at corresponding load in "Low Load Operation Criteria"

Heavy fuel oil operation

- Over 20 % load operation : no restriction
- Below 20 % load operation : load up over 70 % load at every limited time at corresponding load in "Low Load Operation Criteria".

6. Engine Load-Up

HiMSEN generating sets fulfill all requirements regarding the load application of all major classification societies and IACS.

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

Continuous Load-Up

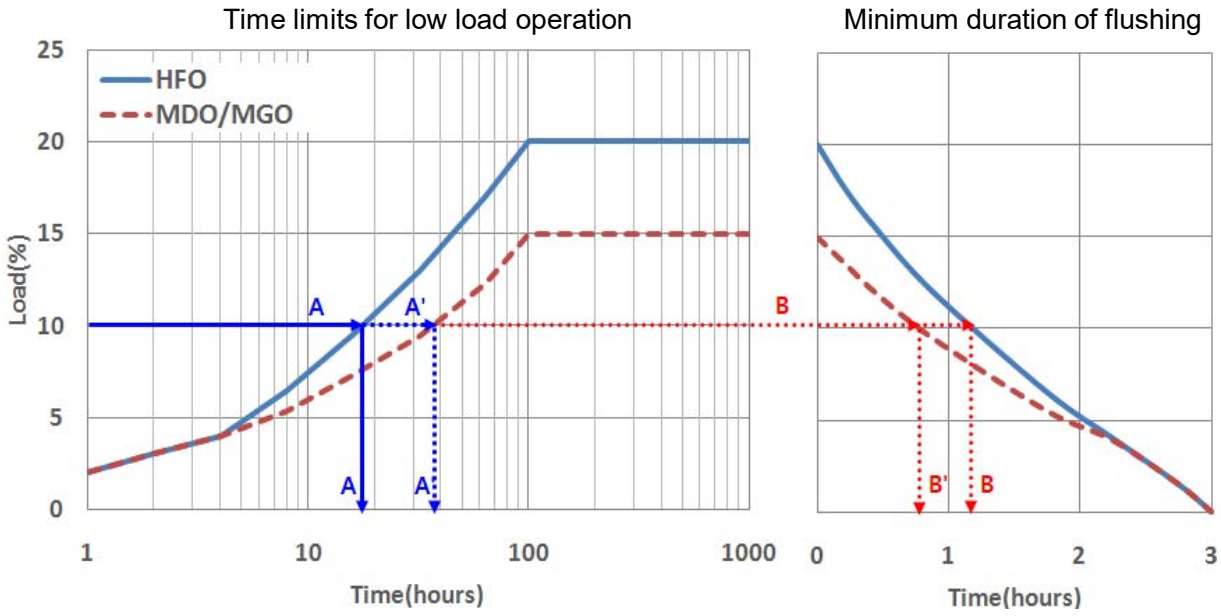
The continuous load up capacity in engine condition is referred in "Engine load up capacity in ramp"
At warm condition, the 100 % load can be achieved in 2 min. by continuous ramping up at normal condition. At emergency condition, the load can be more quickly increased to 100 % in 30 sec.

Step by Step Load-Up

Considering the time required for stabilizing the frequency deviation due to sudden load-up, it is recommended to load up from idle to full load by more than three steps under approval of classification society.

HiMSEN gen-sets fulfill the requirements of classification societies concerning the frequency deviation and recovery time when loading up by 3 steps from 0% to 100%.

<Low Load Operation Criteria>



A no-load operation is recommended for a minute, not exceed 5 minutes.

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

<Example>

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

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

Engine load-up

HiMSEN engines fulfill all requirements regarding the load application of all major classification societies and IACS.

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

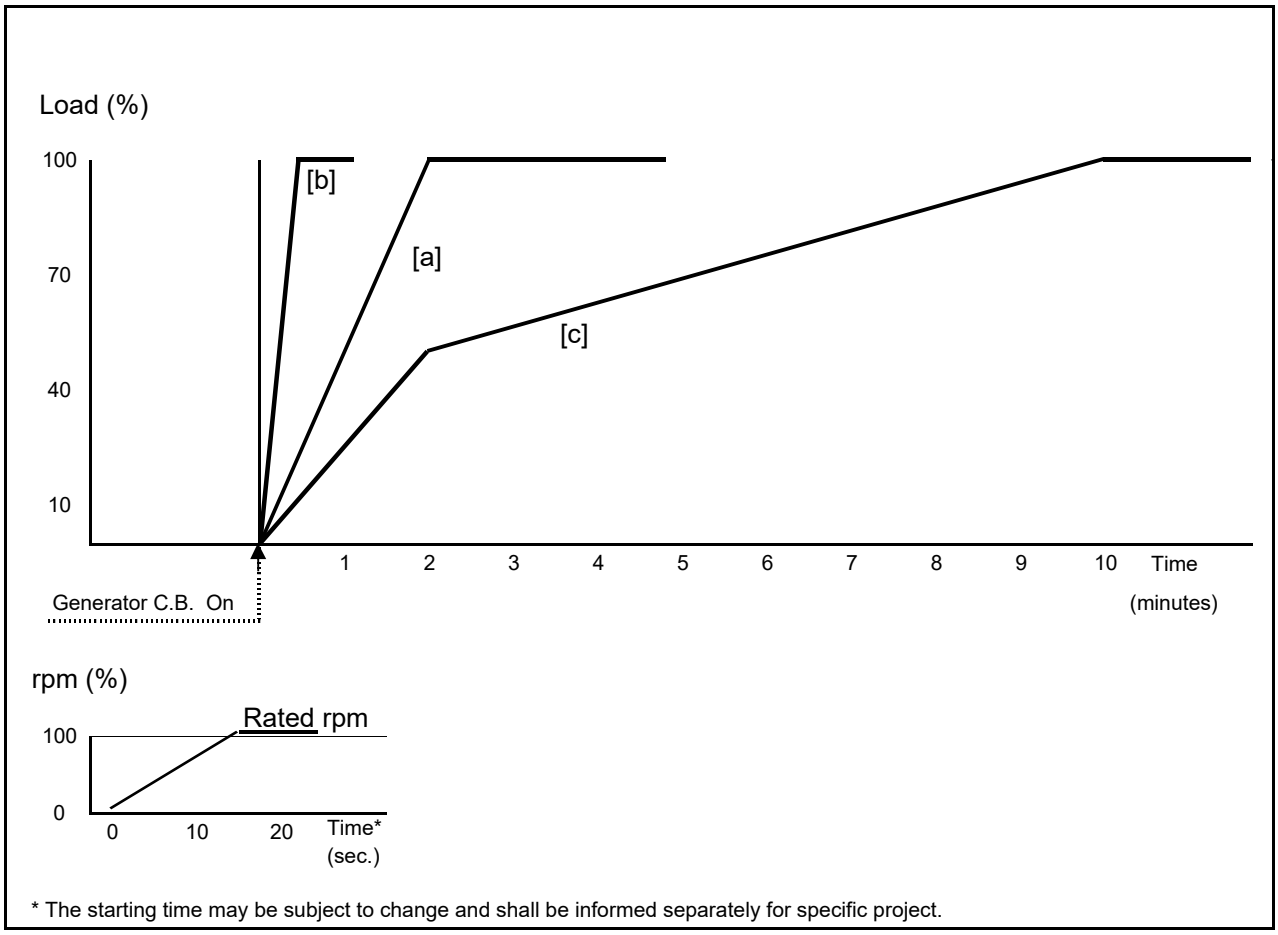
Continuous load-up

The continuous load up capacity in engine condition is referred in "Engine load up capacity in ramp".

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

Step by step load-up

Considering the time and safety required for stabilizing the frequency due to sudden load up, it is recommended to load up from idle to full load by more than three steps under approval of classification society. HiMSEN generating-sets fulfill the requirements of classification societies concerning the frequency deviation and recovery time when loading up 3 steps from 0 % to 100 %.



* The starting time may be subject to change and shall be informed separately for specific project.

Engine load up capacity in ramp

Curve [a] : Starting condition & load-up with warm(stand by) engine

. Continuous prelubrication is required
. Lubricating oil Temperature : over 40 ℃
. Jacket cooling water temperature : over 40 ℃ on MDO start.
. Jacket cooling water temperature : over 60 ℃ on HFO start.
. Intake air(Compressor air inlet) temperature : between 0 ℃ and 45 ℃
. Starting air pressure: Refer to Sheet No. P.02.200.
. Fuel oil : MDO or HFO
-Temperature controlled fuel oil should be circulated continuously before engine start.

Curve [b] : Max. capacity for quick starting & load-up with warm(stand by) engine

. Required same condition as [a].

Curve [c] : Starting condition & load-up with cold engine

. Continuous prelubrication is required
. Lubricating Oil Temperature : minimum 10 ℃
. Jacket cooling water temperature : minimum 15 ℃
. Intake air(Compressor air inlet) temperature : minimum 0 ℃
. Starting air pressure: Starting condition with warm engine + Min. 5 bar
. Fuel oil : only MDO acceptable

1. Engine stop

Two stop functions are applied to engine for safety reason.

2. Emergency stop

Emergency stop valve activates stop air cylinder at each fuel injection pump and governor stops the engine via fuel regulating shaft by stop solenoid valve simultaneously.

3. Normal stop

Governor stops the engine via fuel regulating shaft.

4. Stop signals

Both stoppers are activated by normal stop order by stop button or shut-down signals as below;

- Lubricating oil pressure switch 'Low'
- High temperature cooling water temperature switch 'High'
- Engine over speed rpm 'High'
- Emergency stop switch 'Operation'
- Bearing temperature switch 'High' (Option)
- Oil mist density 'High' (Option)
- Both engine speed sensors 'Fail'

5. Prelubrication system

Prelubricating oil pump

The pump unit is installed in engine side and supplies prelubricating oil to engine during either
the engine stops or the engine's rpm level is below run state during engine starting.

General

HiMSEN generating-sets provide automation system for engine safety, control and indicating based on programmable logic controller.

The system is independently installed in each engine and also can be connected to the remote system, for example main switch board of engine control room via hard wired communication cables.

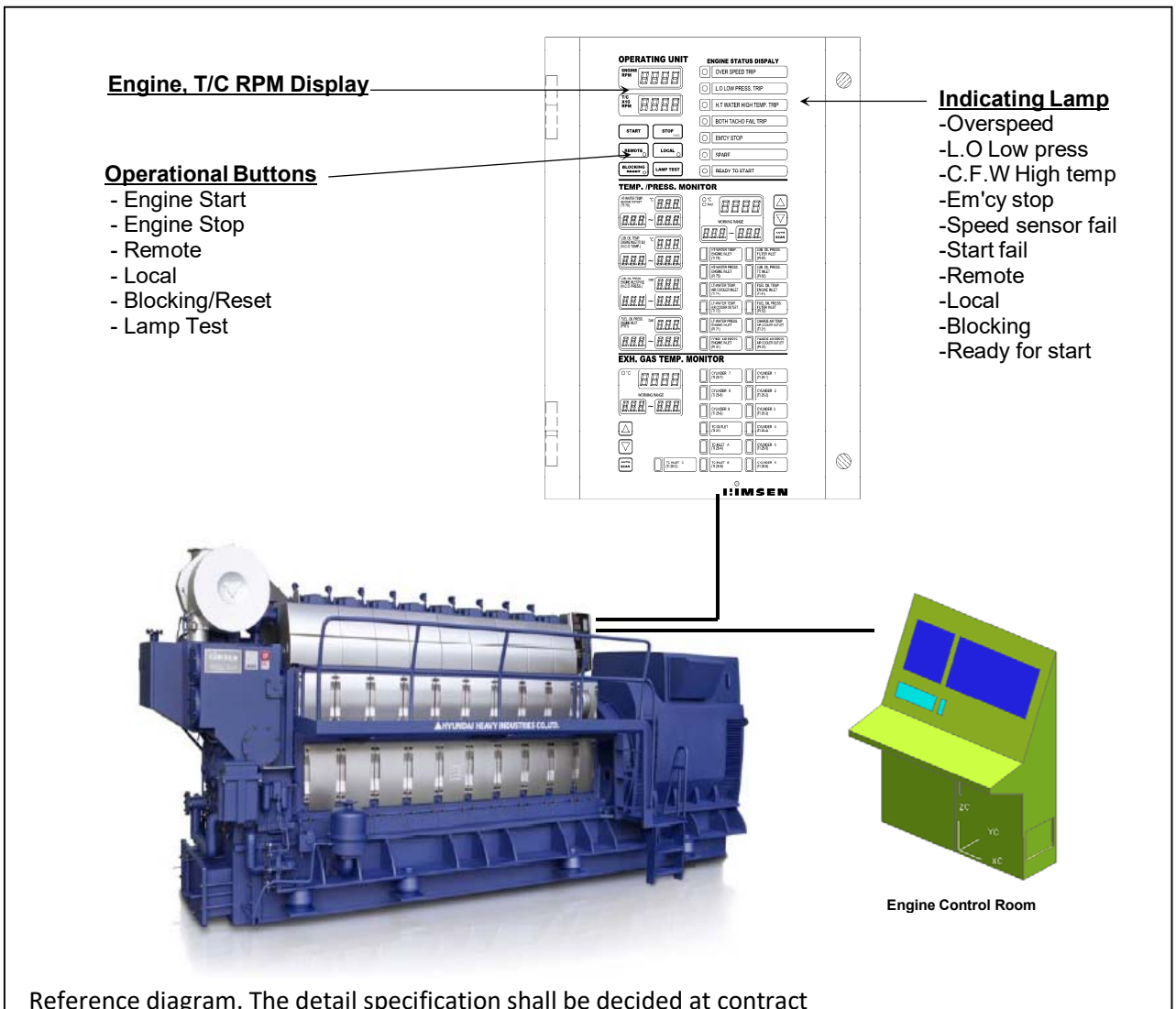
In addition to fulfilling the requirements of all classification societies and IACS, the system provides more friendly features to customers. For example,

- Compact size and easy installation,
- Digital display,(Engine & T/C rpm)
- Simple operation and no maintenance.

System Configuration

The system consists of the following sub systems.

- Control(Start/Stop) and Safety system,
- Digital Tachometer Unit(Engine & T/C rpm),
- Indicating & Switch Unit
- Electronic Instrumentation,
- Local gauges,
- Provision for external signal interface of Yard's requirement.



Reference diagram. The detail specification shall be decided at contract

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

System	Descriptions	Normal Operation Range at Rated power		Alarm & Sensor		Autostop of Engine	
Speed Control	Engine speed	SI47	720/750 rpm			SSH47	113% (1st) 115%(2nd)
	Turbochager rpm	SI42		SAH42			
Fuel Oil System	For continuous HFO operation						
	- Press. inlet engine (HFO)	PI51	8 $^{+2}_{-1}$ bar (A)	PAL51	6 bar		
	- Press. inlet engine (MDO)	PI51	4~6 bar	PAL51	1 bar		
	For continuous MDO operation						
	- Press. inlet engine (MDO)	PI51	7~8 bar	PAL51	6 bar		
	Temp. inlet engine (HFO)	TI51	110~150 ℃	TAH51	155 ℃		
	Temp. inlet engine (MDO)	TI51	30~45 ℃				
	Fuel leakage			LAH54	High level		
	F.O. safety filter diff. press. (G)			PDAH52-51	1.5 bar		
Lub. Oil System	Press. drop across filter (F)		0.1~1.0 bar	PDAH61-62	1.5 bar		2.0 bar★)
	Press. before filter	PI61	4.2~6 bar				
	Press. inlet engine	PI62	4~5 bar	PAL62	3.5 bar	PSL62	3 bar
	Press. priming L.O.			PAL65	0.1 bar		
	Temp. inlet engine, SAE40	TI62	60~70 ℃	TAH62	80 ℃		
	Press. inlet T/C	PI63	(C)	PAL63	(C)		
	Lub. oil level in base frame			LAL/H68	Low/High level		
	Temp. main bearing★)	TI69		TAH69	95 ℃	TSH69	100 ℃
	Oil mist detector			LAH92	High level	LSH92	High level
Cooling Water System	LT water press. inlet engine	PI71	1.0~4.5 bar	PAL71	0.4+(B) bar		
	LT water temp. inlet engine	TI71	30~40 ℃	TAH71	45 ℃		
	LT water temp. A/C outlet	TI72	35~50 ℃				
	HT water press. inlet engine	PI75	2.0~4.5 bar	PAL75	0.4+(B) bar		
	HT water temp. inlet engine	TI75	70~80 ℃				
	HT water temp. each cyl. out★)	TI77	75~85 ℃				
	HT water temp. outlet engine	TI76	75~85 ℃	TAH76	90 ℃	TSH76	95 ℃
Combustion Gas/Air System	Cylinder pressure (D)		Max.210 bar				
	Cylinder pressure deviation from average of cylinders		Max. ±5 bar				
	Charge air press. after cooler	PI21(E)	3.5~4.5 bar				
	Charge air temp. after cooler	TI21	35~55 ℃				
	Exh. Gas temperature deviation from average of cylinders	TI25	±50 ℃	TDAH25	±70 ℃		
	Exh. gas temp. inlet T/C	TI26	450~580 ℃	TAH26	620 ℃		
	Exh. gas temp. outlet T/C	TI27	250~410 ℃	TAH27	450 ℃		
Compressed Air system	Compressed air inlet press.	PI41	30 bar	PAL41	15 bar		

* Temperature deviation between thermometer and thermocouple can be max.60℃ caused by different measuring point.
* Engine performance data depends on the LCV (Low Calorific Value) of used fuel oil respectively, which influences fuel rack index of fuel injection pump.

Remark : (A) F.O pressure not to be maintained below 6 bar at any case to avoid gasification of hot fuel.
(B) Depending on the height of expansion tank(static pressure).
(C) Depending on cylinder No. and T/C maker →

Cyl.	Maker	Normal range	Alarm
6	ABB	2~4bar	1.5ba
7,8,9	ABB	1.3~2.5bar	1.1~1.3
	Napier	2.2~3.3bar	2.2ba

(D) Measured at indicator cock
(E) in case of a power-derated engine, the actual value could be different. Please refer to the shop test result.
(F) Based on standard cartridge type filter. To be different depending on actual model in case of auto backwashing type (generally 1.2 bar for alarm with same normal range)
(G) Based on maker standard type. To be different in case of special type and be shown in the filter's manual.
★) Can be applied as option.

1. Introduction

Hyundai intelligent equipment management Solution

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

2. Benefits

2.1. On Ship

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

2.2. On Shore

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

3. Main features

3.1. On Ship

Real-time status monitoring of the HiMSEN engine

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

Analysis tools for engine data

- Performance, deviation, correlation analysis and Statistics.

Maintenance and guidance based on the instruction guide

- Alarm manager, maintenance manager, wearing parts manager.

3.2. On Shore

Status monitoring of the fleet of HiMSEN engines

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

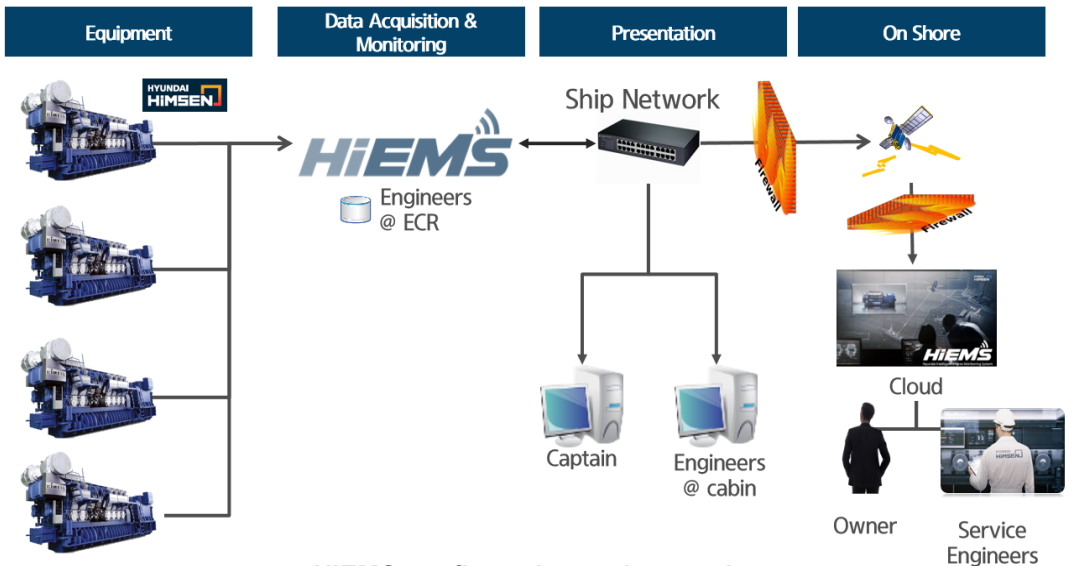
4. License policy

4.1. Standard Version

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

4.2 Reporting service version

- Including “Standard version” features, regular reporting service is available through Hyundai Global Service (HGS).
- Contact Hyundai Global Service (HGS) for reporting service.



HiEMS configuration and network

5. Key Functions

5.1 Monitoring

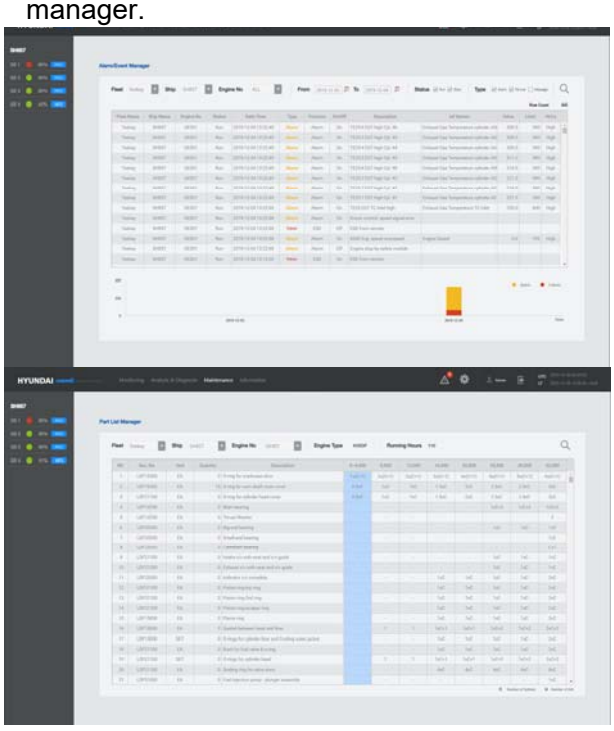
Real-time status monitoring of the HiMSEN engine

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

5.2 Maintenance

Maintenance and guidance based on the Instruction guide

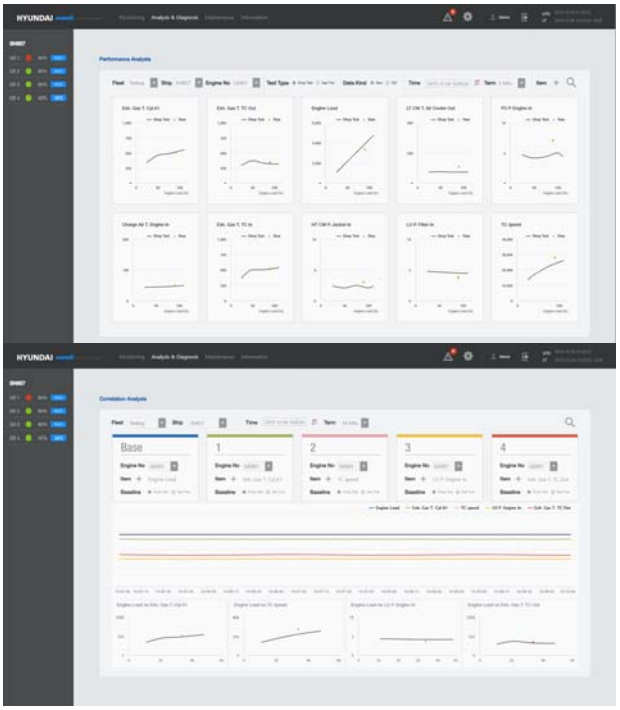
- Alarm/Event, maintenance, wearing parts manager.



5.3 Analysis & Diagnosis

Analysis tools for engine data

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



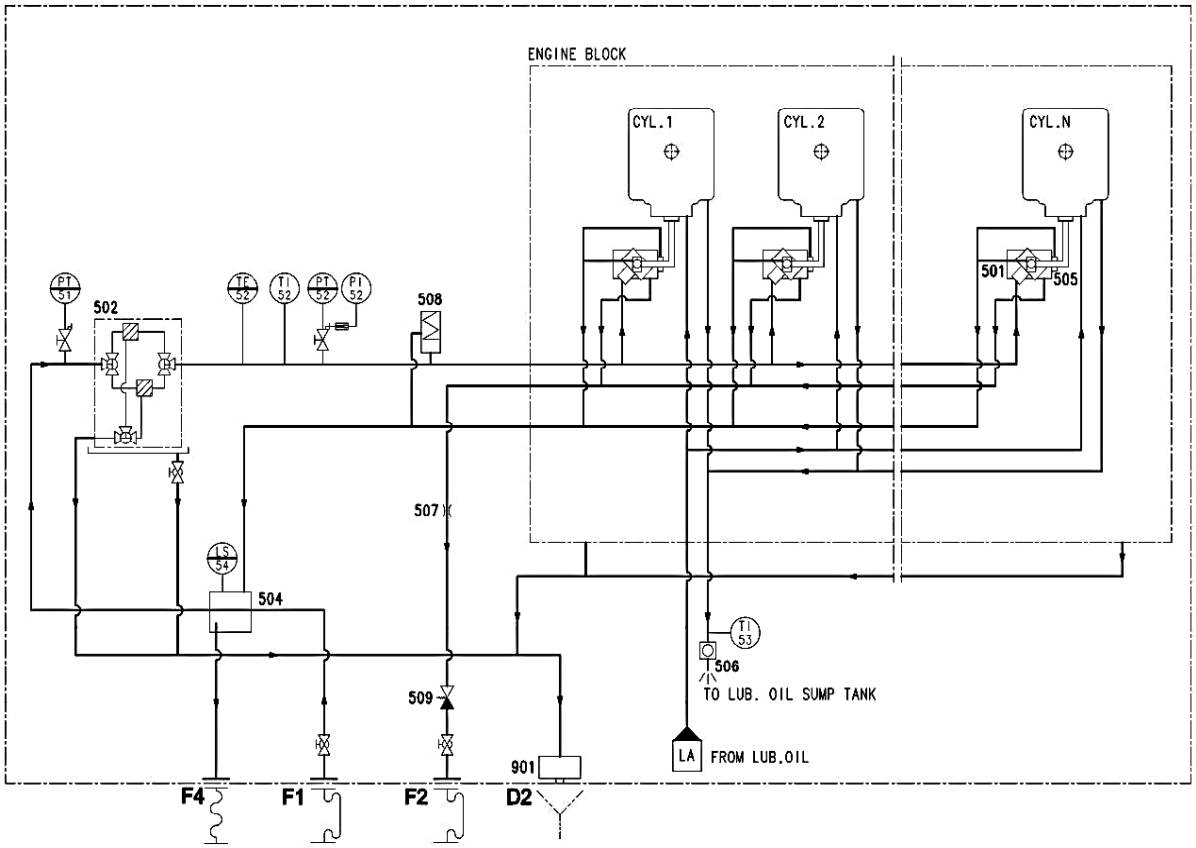
5.4 Fleet Management(Option)

On shore, status monitoring of the fleet of HiMSEN engines

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

Digital innovation center

Diagram for Internal Fuel Oil System



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

General Description

Fuel system for the diesel engine is designed for a reliable combustion of heavy fuel oil as well as diesel fuel oil. Therefore, it is not recommended to change over the fuels except for the cold starting, flushing of the system, maintenance or long term stand still.

Fuel Injection Equipment comprises an injection pump, connection block, injection pipe and injection valve, which are installed on each cylinder in line. The system is designed for operating high fuel injection pressure for better combustion.

The amount of fuel injection is controlled by governor via the common regulating shaft and spring loaded linkage, which maintains the engine speed at the preset-value by continuous positioning of the fuel pump rack.

The clean leak oil from each injection pump, high pressure connection block, etc. is drained and collected to the recycling fuel oil leakage alarm tank. It can be recycled without additional separation process. Recycling fuel oil leakage alarm tank is a modularized box for the external connections, which provides :

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

The dirty leak oil is collected to the common drain pipe led to the sludge tank.
The total leak rate of fuel oil is 0.30 x C_f[1)] liter / cylinder hour (Tolerance ± 50 %).
The recycling fuel oil can be led to external tank to be reused.
1) Cf : Heavy fuel oil = 0.5,
Marine diesel oil = 1.0, Marine gas oil = 2.0

Option
Fuel oil safety filter can be mounted on request as an option.

Size of External Pipe Connections

Code	Description	Size
F1	Fuel Oil Inlet	25A
F2	Fuel Oil Outlet	25A
F4	Leaked Fuel Oil Drain (clean oil)	15A
D2	Waste Oil Drain (dirty oil)	Φ25

Connection size is according to
JIS B 2220.

1. General Requirements

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

Well Cleaned Fuel
Solid particles and water in the fuel cause overwear and frequent maintenance for the engine itself as well as external fuel system. Therefore, qualified separation equipment should be included in the external fuel oil system not only for HFO but also for distillate fuel.

Proper Viscosity, Temperature and Pressure
are necessary for proper operation of the system. Therefore, Preheating, Insulation with heat tracing, and Pressurizing equipment should be included in the external fuel oil system.
Especially if it is at low viscosity, fuel temperature shall be controlled to meet the required viscosity by fuel cooling device such as cooler unit.
In order to prevent excessive pressure losses and also to minimize possible pressure pulses in the piping system, the fuel oil velocity should not exceed:

MDO Suction Pipe	
MDO Pressure Pipe	: 0.5 ~ 1.0 m/s
HFO Suction Pipe	: 1.5 ~ 2.0 m/s
HFO Pressure Pipe	: 0.3 ~ 0.8 m/s
	: 0.5 ~ 1.2 m/s

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

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

2. Fuel Oil Treatment System

The fuel treatment system should be designed for proper cleaning of heavy fuel oil considering total fuel consumption of the plant.

Centrifugal Separators should be an automatic type with the same additional stand-by unit.
The separator should be capable of purifying the worst grade of fuel oil.
Normally, fuel oil grade of H380 to H700 require the capability of up to 1010 kg/㎥.
For distillate fuel, an independent purifier system is required.

It is necessary to ensure a proper cleaning of the HFO as follows:
- Selection and operation of the fuel oil centrifuges according to suppliers recommendation
- Correct HFO temperature at inlet to the centrifuges
  (The centrifuges should be always be operated with an inlet temperature of 98 ℃ for HFO)
- Correct throughput of fuel through the centrifuges

$Q = P \times b \times 24(h) / p \times t$

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

- Proper density of HFO in conformance with the centrifuge specification
- Proper maintenance of the centrifuges

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

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

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

3. Fuel Feed System

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

Day Tank for Heavy Fuel
The heavy fuel day tank is filled with cleaned fuel by continuous fuel separation.
- Tank Capacity : min. 24 operating hours feed for full load operation.
- Tank Heating : approx. 75 ℃, as stable as possible.
- Sludge/Water space and drain provided.

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

Supply Pump
. Capacity : min. 1.5 x total fuel consumption at MCR + back flushing quantity
. Pump head : 4 bar
. Operating temperature : 100 ℃
. Viscosity (for el-motor) : 1000 cSt

Mixing Tank
The major purpose of the Mixing tank is to ensure venting of gas from the hot fuel oil and a gradual temperature balance by mixing the hot returned oil from the engine with oil from the daily tank.
The tank is to be dimensioned to ensure fuel supply for 10~15 minutes at full load operation, but not less than 50 liters in any case.

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

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

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

Booster Pump
As the heated heavy fuel has to be continuously re-circulated, the fuel booster pump should ensure fuel circulation with the required pressure in the system.

. Capacity : min. 3.0 x total fuel consumption at MCR + back flushing quantity
. Pump head : 8 bar at F.O inlet, F1
. Operating temperature : 150 ℃
. Viscosity (for el-motor) : 500 cSt

Heater and Viscosity Controller
In order to ensure correct injection viscosity at 12-18 cSt, the dual heaters are controlled by a viscosity controller.
Each heater should have sufficient capacity for heating the fuel oil for all engines at full load, and one heater can therefore be overhauled while the other one is in service.

Auto Back Flushing Filter

In the circulating , Absolute 10 μm automatic back-flushing filter must be installed before the branch pipe to each engine to ensure the cleanness of the fuel oil. If the cleaning cycles of the automatic back-flushing filter are increased, the fuel oil treatment system must be optimized in order to protect the engine.

Safety Filter

Fuel oil safety filter, duplex type of absolute 50 μm, to be built in the fuel oil supply line of each engine.

Waste Oil Tank

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

4. MDO Feed System

Even for the heavy fuel oil engine, an independent MDO feed system is required for the cases as below;

- long time low load operation or stop,
- maintenance of HFO system,
- emergency situation such as a black-out.

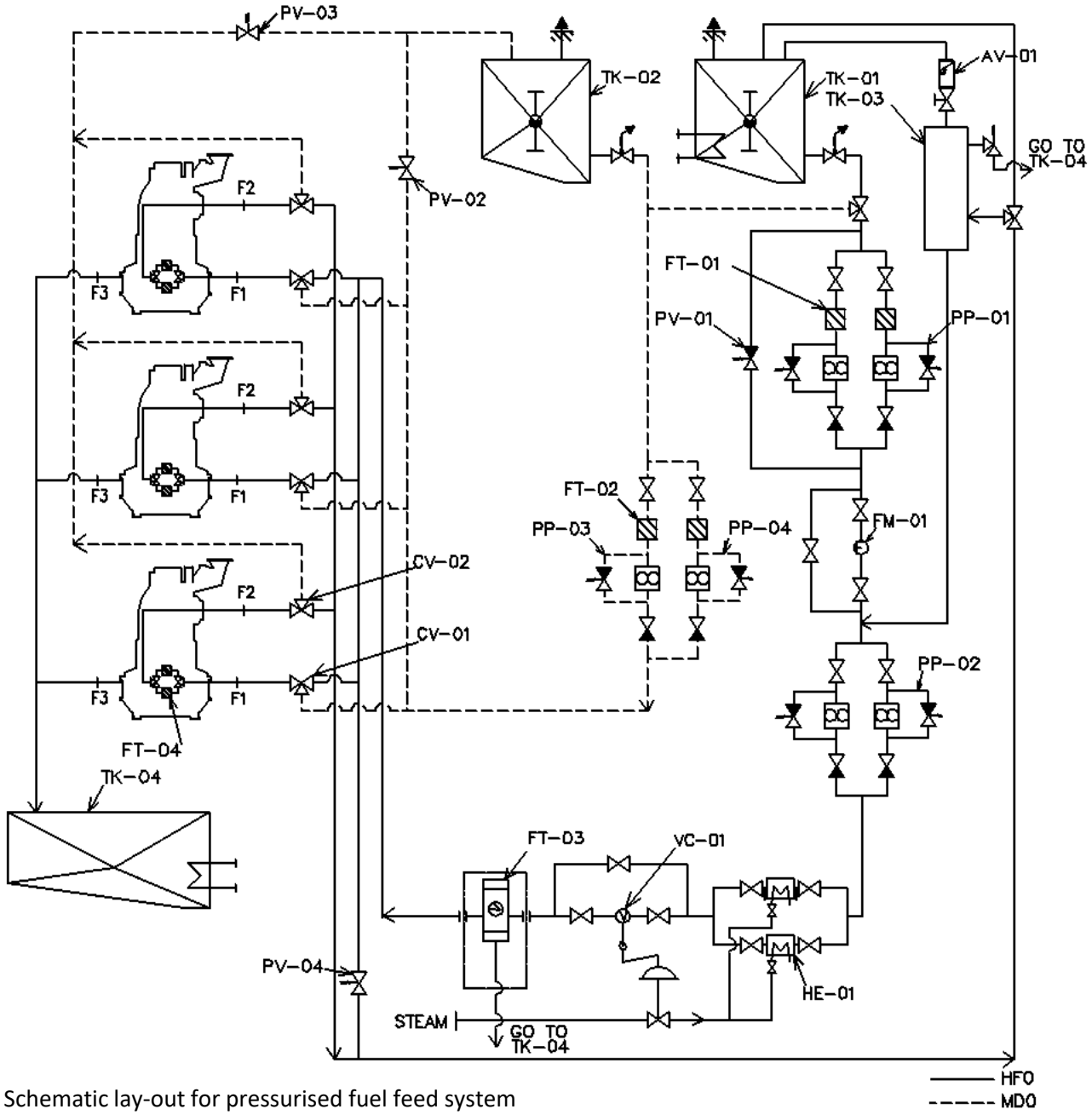
Emergency Start

MDO must be supplied to start up the stand-by engines with a sufficient fuel oil pressure, which can be supplied by emergency booster pump or a gravity tank which is minimum 8 m above the engine.

HFO/MDO Change-over Valves

The HFO/MDO change-over valve should be installed for each engine, which can be a manual type or an electro-pneumatic remote control type for a flexible selection of MDO and HFO-operating at any load condition.

Diagram for Heavy Fuel Oil System (Reference for HFO normal operation)



Schematic lay-out for pressurised fuel feed system

System components

TK-01 DAY TANK, HFO	FM-01 FLOWMETER	PV-01 HFO PRESSURE CONTROL VALVE
TK-02 DAY TANK, MDO	HE-01 HEATER	PV-02 MDO INLET PRESSURE CONTROL VALVE(6 bar)
TK-03 MIXING TANK	VC-01 VISCOSITY CONTROLLER	PV-03 MDO OUTLET PRESSURE CONTROL VALVE(2 bar)
TK-04 DRAIN TANK	AV-01 AUTO DEAERATING VALVE	PV-04 HFO INLET PRESSURE CONTROL VALVE(9 bar)
FT-01 SUCTION STRAINER, HFO	FT-04 SAFETY FILTER(50μm)	PP-01 HFO SUPPLY PUMP(4 bar)
FT-02 SUCTION STRAINER, MDO	PP-03 MDO PUMP(8 bar)	PP-02 HFO BOOSTER PUMP(8 bar at F.O. inlet,F1)
FT-03 AUTOMATIC FILTER(10μm)	PP-04 EM'CY MDO PUMP(6 bar)	

CV-01/CV-02 HFO/MDO CHANGE OVER VALVE (LOCAL OR REMOTE CONTROL)

*) In case of continuous MDO operation, contact to HHI-EMD.
(Note: Additional day tanks for low sulfur HFO and/or MDO may be required due to IMO MARPOL Annex VI, a special notation of classification societies, a local regulation, or other reasons.)

General

The fuel specifications are based on ISO 8217:2017. The fuels are largely classified into two categories as distillate fuels and residual fuels. Distillate fuels are divided into DMX, DMA, DFA, DMZ, DFZ, DMB, and DFB. 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,DFA,DMZ,DFZ)
MDO (Marine Diesel Oil)		S ≤ 1.5	2	11	Distillate marine fuels (DMB,DFB) 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		mm^2/s [a]	max.	5.5	6.0		6.0		11.0		ISO 3104
			min.	1.4	2.0		3.0		2.0		
Density at 15°C		kg/m^3	max.	-	890.0		890.0		900.0		ISO 3675 or ISO 12185
Cetane index		-	min.	45	40		40		35		ISO 4264
Sulfur [b]		mass %	max.	1.0	1.0		1.0		1.5		ISO 8754 ISO 14596 ASTM D4294
Flash point		°C	min.	43.0	60.0		60.0		60.0		ISO 2719
Hydrogen sulfide		mg/kg	max.	2.0	2.0		2.0		2.0		IP 570
Acid number		mg KOH/g	max.	0.5	0.5		0.5		0.5		ASTM D664
Total sediment by hot filtration		mass %	max.	-	-		-		0.10 [c]		ISO 10307-1
Oxidation stability		g/m^3	max.	25	25		25		25 [d]		ISO 12205
Fatty acid methyl ester(FAME)[e]		volume %	max	-	-	7.0	-	7.0	-	7.0	ASTM D7963 or IP579
Carbon residue: micro method on the 10% volume distillation residue		mass %	max.	0.3	0.30		0.30		-		ISO 10370
Carbon residue: micro method		mass %	max.	-	-		-		0.30		ISO 10370
Cloud point [f]	Winter	°C	max.	-16	report		report		-		ISO 3015
	summer	°C	min	-16	-		-		-		
Cold filter plugging point [f]	Winter	°C	max.	-	report		report		-		IP 309 OR IP 612
	summer	°C	min	-	-		-		-		
Pour point (upper) [f]	Winter	°C	max.	-	-6		-6		0		ISO 3016
	summer	°C	max.	-	0		0		6		
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 mm^2/s = 1 cSt*

[b] *Notwithstanding the limits given, a purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Introduction of ISO 8217:2017.*

[c] *If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required. See 6.8 and 6.12 of ISO 8217:2017.*

[d] *If the sample is not clear and bright, the test cannot be undertaken and therefore, compliance with this limit cannot be shown.*

e) *See 5.1 and Annex A ISO 8217:2017.*

f) *Pour point cannot guarantee operability for all ships in all climates. The purchaser should confirm that the cold flow characteristics (pour point, 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.*

h) *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
	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 for the ship's intended area of operation.*

*) *International statutory requirements*

This document specifies allowable minimum flash point limits following the provisions given in the SOLAS convention. MARPOL Annex VI, which controls air pollution from ships, includes a requirement that either the fuel shall not exceed a specified maximum sulfur content or an approved equivalent alternative means be used. During the lifetime of this document, regional and/or national bodies may introduce their own local emission requirements, which can impact the allowable sulfur content, for example, the EU Sulfur Directive. It is the purchaser's and the user's responsibility to establish which statutory requirements are to be met and specify on that basis the corresponding maximum fuel sulfur content to the supplier.

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 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 Specifications of biodiesel(FAME)

Characteristics b)	Unit	Min. limit	Max. limit	Test method reference
FAME content	% (m/m)	96.5	-	EN 14103
Density at 15°C	kg/m³	860	900	EN ISO 3675 / EN ISO 12185
Viscosity at 40°C	mm²/s	3.5	5.0	EN ISO 3104 / EN 14105
Cold filter plugging point(CFPP)	°C	-	a)	EN 116
Flash point	°C	101	-	EN ISO 2719 / EN ISO 3679
Sulfur content	mg/kg	-	10	EN ISO 20846 / EN ISO 20884
Cetane number	-	51.0	-	EN ISO 5165
Sulfated ash content	% (m/m)	-	0.02	ISO 3987
Water content	mg/kg	-	500	EN ISO 12937
Total contamination	mg/kg	-	24	EN 12662
Copper strip corrosion (3 hours at 50 °C)	rating	**1b(Class1)**	1a	EN ISO 2160
Oxidation stability, 110°C	hours	8	-	EN 14112
Total Acid Number (TAN)	mg KOH/g	-	0.5	EN 14104
Iodine value	-	-	120	EN 14111
Linolenic Acid Methylester	% (m/m)	-	12	EN 14103
Polyunsaturated (>= 4 Double bonds) Methylester	% (m/m)	-	1	EN 14103
Methanol content	% (m/m)	-	0.2	EN 14110
Monoglyceride content	% (m/m)	-	0.7	EN 14105
Diglyceride content	% (m/m)	-	0.2	EN 14105
Triglyceride content	% (m/m)	-	0.2	EN 14105
Free Glycerine	% (m/m)	-	0.02	EN 14105 / EN 14106
Total Glycerine	% (m/m)	-	0.25	EN 14105
Group I metals (Na+K)	mg/kg	-	5	EN 14108 / EN 14109 / EN 14538
Group II metals (Ca+Mg)	mg/kg	-	5	EN 14538
Phosphorus content	mg/kg	-	4	EN14107

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

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

Hydrotreated Vegetable Oil (HVO)

The EN 15940:2016 + A1:2018 + AC:2019 standard covers hydrotreated paraffinic renewable diesel fuel and synthetic Fischer-Tropsch products GTL, BTL and Coal-to-Liquid (CTL).
Since HVO consists of paraffinic hydrocarbons, it cannot meet the requirements set by EN 14214:2013+ A2:2019, which is a standard developed and valid only for methyl ester chemistry type biodiesel, namely FAME. As a matter of fact, HVO meets EN 590, except the requirement for minimum density.
International standards EN 15940 are commonly used to specify the quality of HVO. (See the Table 5-3-5)

Table 5-3-5 Specifications of HVO(EN15940)

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

a) The temperatures related to filterability have to be at least 10~15℃ above the minimum fuel oil tempera
(maximum temperature among cloud point, pour point, CFPP, and LTFT) in the whole fuel treatment proc
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 bio-blends(B##) except for biodiesel-blends(BD##) are referred to the Table 5-3-6.

General biofuels

The quality standards of general liquid biofuels except biodiesel(FAME) are as shown below Table 5-3-6.(General biofuels include a wide range of specifications. In order to reduce confusion when applying biofuel standards, HiMSEN set the integrated standard with the Table 5-3-6.)
Only biofuels that meet EN14214 or EN15940 can be applied to Micro-Pilot (MP) injector.
The information of storage and deterioration of biofuels should be discussed/checked by fuel oil supplier before the biofuel is applied to engine.

Table 5-3-6 Specifications of general biofuel, bio-blends.

Characteristics b)	Unit	Min. limit	Max. limit	Test method reference
Viscosity before injection pumps	cSt	2	18	ISO 3104
Kinematic viscosity at 50℃	mm²/s	-	700	
Density at 15℃	kg/m³	-	1010	ISO 3675 / ISO 12185
Sulfur	mass %	Statutory requirements		ISO 8754 / ISO 14596 / ASTM D4294
Flash point	℃	60	-	ISO 2719
Cloud point	℃	-	a)	ISO 3015
Cold filter plugging point (CFPP)	℃	-	a)	IP 309
Pour point	℃	-	a)	ISO 3016
Total sediment by hot filtration	mass %	-	0.1	ISO 10307-1
Total sediment aged	mass %	-	0.1	ISO 10307-2
Ash	mass %	-	0.15	ISO 6245
Carbon residue (a) : micro method on the 10% volume distillation residue	mass %	-	0.3	ISO 10370
Carbon residue (b) : micro method	mass %	-	20	ISO 10370
Asphaltenes	mass %	-	8	-
Water	vol %	-	0.5	ISO 3733
Total Acid number (TAN)	mg KOH/g	-	2.5 b)	ASTM D664
Strong acid number	mg KOH/g	-	0	ASTM D664
Oxidation stability	g/m³	-	25	ISO 12205
Hydrogen sulfide	mg/kg	-	2	IP 570
Copper strip corrosion (3h at 50℃)	Rating	1b	1a	ASTM D130

Characteristics b)	Unit	Min. limit	Max. limit	Test method reference
Lubricity, corrected wear scar diameter	µm	-	520	ISO 12156-1
Vanadium	mg/kg	-	450	IP 501 / IP 470 / ISO 14597
Sodium	mg/kg	-	100	IP 501 / IP 470
Aluminium + Silicon	mg/kg	-	60 c)	IP 501 / IP 470 / ISO 10478
Used lubricating oils (ULO):	-	-	-	IP 501 / IP 470 / IP 500
- Calcium (Ca)	mg/kg	30	-	
- Zinc (Zn)	mg/kg	15	-	
- Phosphorus (P)	mg/kg	15 d)	-	
Cetane number	-	51	-	ISO 4264
Alkali content (Na+K)	mg/kg	-	100	EN 14108 / EN 14109 / 14538
Alkali content (Ca+Mg)	mg/kg	-	30	EN 14538
Lead (Pb) content	mg/kg	-	10	ASTM D 5059
Steel corrosion (24/72h at 20, 60, 120degC)	rating	No signs of corrosion		LP 2902
Lodine 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

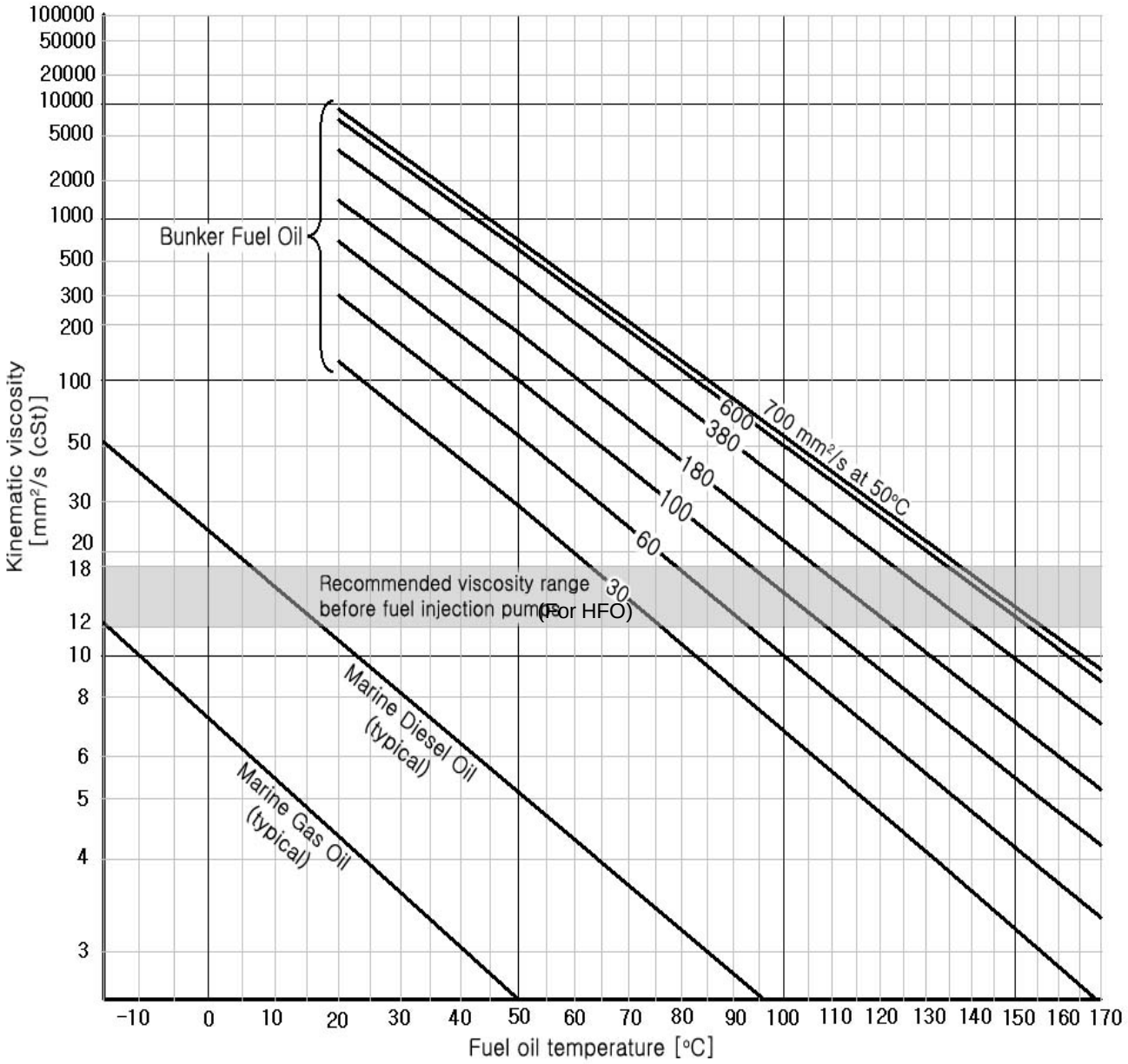
a) The temperatures related to filterability have to be at least 10~15℃ above the minimum fuel oil temperature (maximum temperature among cloud point, pour point, CFPP, and LTFT) in the whole fuel treatment process, even during engine stop unless flushing using pure diesel oil were performed before engine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

The viscosity of HFO to the engine should be kept within the value of 12-18 cSt.
However, the viscosity varies depending on the properties and the temperature of the fuel oil. Maximum preheating temperature of HFO is limited up to 155 ℃ to avoid vaporing in fuel system.
A typical fuel oil viscosity diagram regarding temperature is as follows :



Note : The viscosity of MDO/MGO to the engine should be kept within the value of 2 ~ 14 cSt in order to avoid possible sticking of fuel injection pump due to low lubricity of MDO/MGO.

1. Fuel Characteristics

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

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

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

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

Vanadium and Sodium
Vanadium is oil – soluble and comes from crude oil mostly. However sodium is water-soluble and comes from crude oil as well as contaminated fuel by salt water.

As vanadium and sodium become corrosive ash after combustion, these should be removed as possible. A sodium compound contributes to lower the melting point of vanadium ash, which is very corrosive and harmful to exhaust valves and turbocharger. Therefore, compounds should be less than 1/3 of vanadium contents in weight.

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

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

Water
The water content can be measured by a standardized distillation test. The water causes corrosion and cavitations of the fuel injection pump and fouling of the exhaust system and turbochargers. The water content should be reduced to maximum 0.2% by centrifuging.

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

2. Ignition Quality

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

Calculated Carbon Aromaticity Index

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

D = Density (kg/㎥ at 15 ℃)
Vk = Viscosity (cSt at 50 ℃)

Note
If the value of CCAI is increased, the ignition quality has decreased value. The Fuel oil with high CCAI value may be happened a combustion problem.

To prevent any troubles about poor ignition quality, engine should be preheated sufficiently before start and has proper functions of cooling system and injection system.
From light distillates to residual fuels, net & gross specific energy can be tested or calculated according to various international standards. Basically, the specific energy value provided by fuel supplier is adapted for the determination of the heat of combustion. If it is not supplied from fuel supplier, it can be calculated by the specification of other properties as the equations given below.

For residual fuels,

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

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

For marine distillate fuels,

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

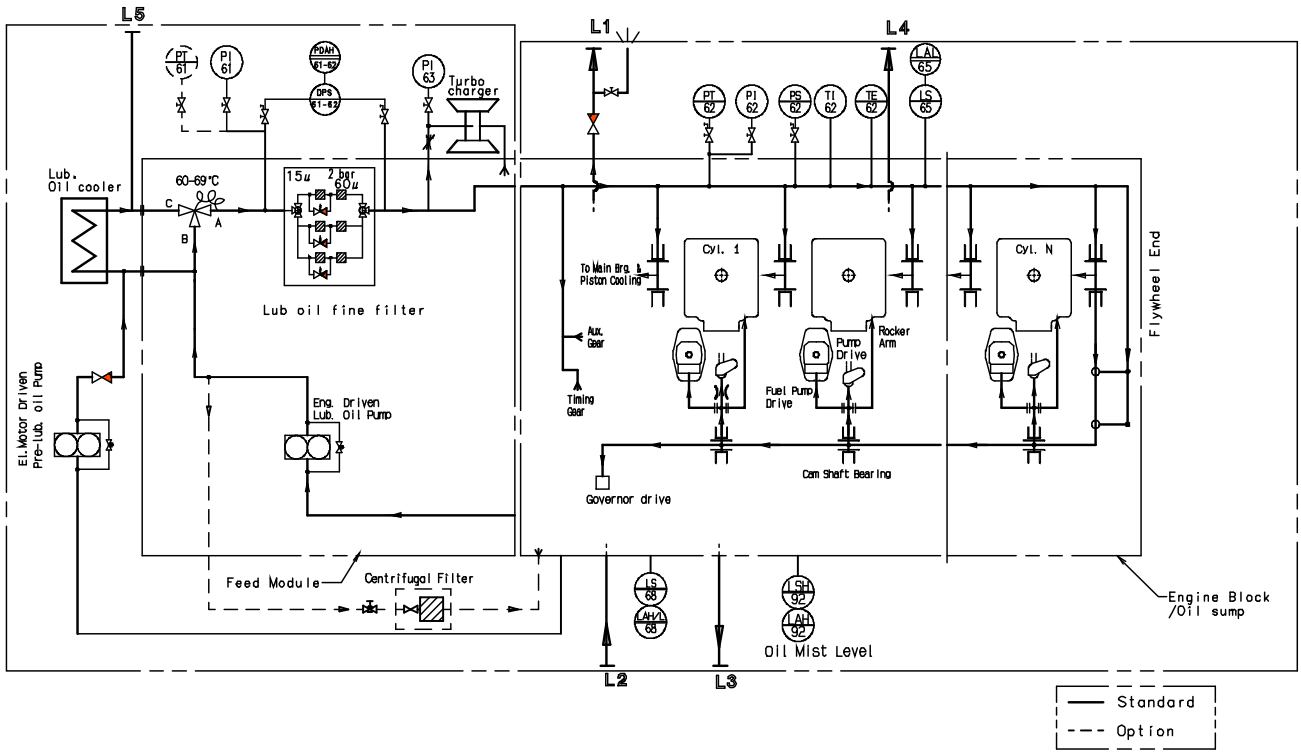
$$G = (51.916 - 8.792\rho^2 10^{-6}) \times [1 - 0.01(w + a + s)] + 0.0942s$$

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

Ref. ISO 8217:2017(E)

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

Diagram for Internal Lubricating Oil System



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

1. General Description

The engine has its own Internal Lubricating Oil system with wet type 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 and the equipments of the system are mounted directly on Feed Module without pipe connections.

The system comprises following equipments;

1. Lubricating oil cooler
2. Engine driven Lubricating oil pump (with pressure regulating valve)
3. El. motor driven prelubricating pump
4. Lubricating oil thermostatic valve
5. Lubricating oil filter
6. Wet sump tank
7. Centrifugal oil filter
8. Oil mist detector

2. Sizes of External Pipe Connections

Code	Description	Pipe size
L1	Oil vapor discharge	125A
L2	Lub. Oil from separator	50A
L3	Lub. Oil overflow	80A
L4	Lub. Oil to separator	50A
L5	C.W.auto shut-off valve	PF1/4

Size of Connections are standard according to JIS B 2220.

3. Quantity of Lubricating Oil

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

Engine type	Oil quantities in liter	
	720/750 rpm	
	min.	max.
6H32/40	2180	2730
7H32/40	2410	3020
8H32/40	2810	3520
9H32/40	3130	3910

4. Specific Lubricating Oil Consumption

SLOC : 0.5 g/kWh
- Tolerance : +25% depending on the operating conditions
- Only MCR should be used to evaluate the lubricating oil consumption.

5. Engine Driven Lubricating Oil Pump

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

6. Prelubricating Oil Pump

The prelubricating pump is of the electric motor driven gear type, which is operated automatically when engine is stopped.

Prelubrication is recommended during engine stop period if fuel oil is circulating.

In case that the automatic prelubrication has been switched off, the engine must be prelubricated sufficiently before starting-up.

7. Lubricating Oil Cooler

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

8. Thermostatic Valve

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

9. Lubricating Oil Filter

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

- Paper cartridge fineness : 15 ㎛,
- Safety cartridge fineness : 60 ㎛.

10. Pressure Regulating Valve

The pressure regulating valve adjusts inlet pressure lub. oil filter at 4~5 bar and is mounted on engine driven lubricating oil pump.

11. Centrifugal Oil Filter

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

12. Lubricating Oil Sump Drain

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

1. General

The external lubricating oil system is required not only for cleaning but also for heating the oil to start the engine quickly. The system may be used commonly for all auxiliary engines.

Though filtering equipments built on engine may be sufficient for the engine operating only on MDO, centrifugal purification is commonly required for the engine operating on MDO and HFO.

2. Lubricating Oil Separator

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

Separator Capacity

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

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

F = required flow (l/h),
p = total engine output (kW),
n = number of oil circulation per day,
(4 for MDO/MGO, 6 for HFO)
t = actual separation time per day,
(Normally 23 hour)

As simple estimation, above formula can be expressed as follows:

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

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

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

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

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

3. Separator installation

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

With multi-engine plants the best installation would be to have one separator per engine. (Fig. 1) The cleaning systems of auxiliary engines are often designed such that the separator intermittently serves on engine at a time. If only one separator is in operation, the following lay-outs can be used. (Fig. 2)

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

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

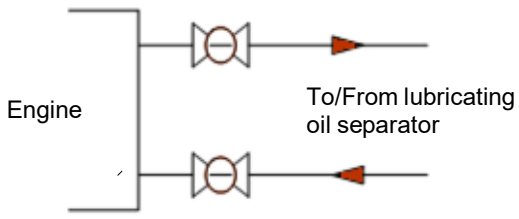


Fig. 1 Principle lay-out for direct separating on a single plant

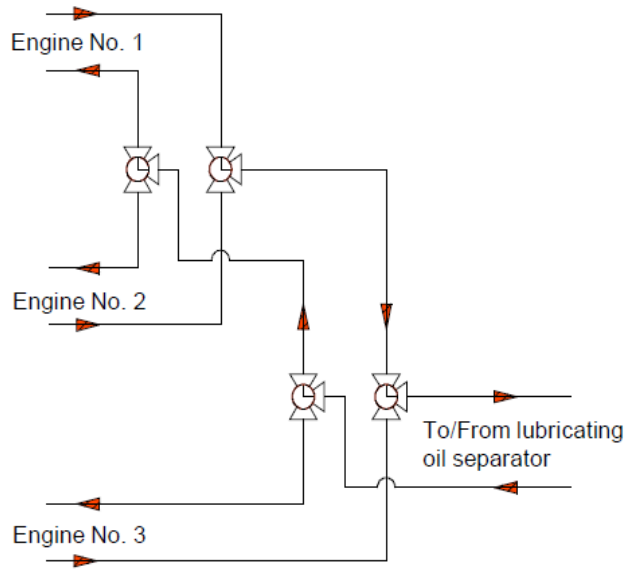


Fig. 2 Principle lay-out for direct separating on a multi plant

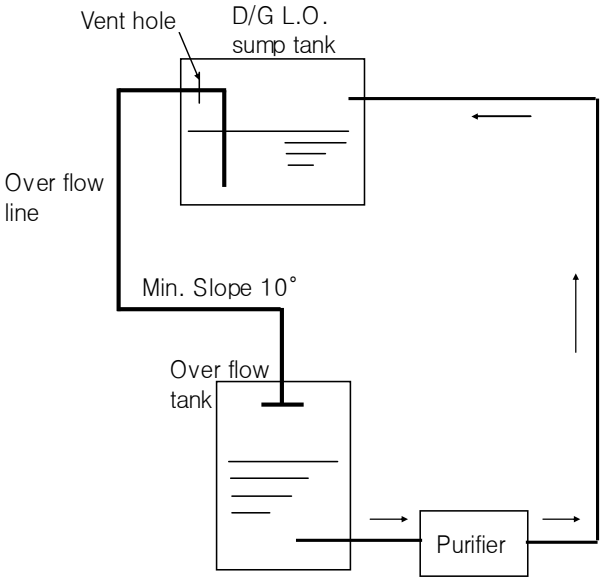


Fig. 3 Principle lay-out for overflow system

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

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

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

4. Overflow system

In some cases, overflow system can be applied as an alternative for continuous purification (Fig. 3).
In order to have a better siphon effect, the overflow pipe from sump to overflow tank should have a continuous downward gradient of minimum 10 degrees without high and low point.

5. Suction Strainer

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

6. Pump for separator

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

7. Heater for separator

The lubricating oil in wet sump tank and in the system is to be warm-up to 40 ℃ from the separator heater prior to engine starting. Sump tank is to be heated-up to approx 65 ℃ in engine service.

Heater for separator should be designed to heat the lubricating oil from 65 ℃ up to 95 ~ 98℃ according to separator maker's recommendation.

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

8. Velocities and Pressure Losses

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

Suction Pipe : 0.5 ~ 1.5 m/s
Pressure Pipe : 1.0 ~ 2.5 m/s

9. Crank Case Ventilation

Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication 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 to any other branch such as a tank vent, etc

- The outlet of vent pipe is to be fitted with corrosion resistant flame screen separately for each engine.

- The vent pipe should have a continuous upward gradient of minimum 10 degrees without high point or low point.

- The vent pipe should be equipped with a condensate trap and drain near the engine.

- The connection between the engine and yard vent pipe is to be flexible, if resilient mounting is applied.

- The dimension of the flexible connection is 125A, and the vent pipe size after the flexible connection must be min. 125A.

- The oil mist should not be flowed into suction air from outside intake duct (for outdoor type) or engine room (for indoor type)

If manifold arrangement is used, in order to avoid high back pressure in the system its arrangement is to be as follows:

- Generator engine's vent pipes could only be connected to the manifold for D/G engines. The vent pipes for main engine and any other piping system must not be connected to the manifold for D/G engines.

- The vent pipe from each engine is to run independent to the manifold.

- The vent pipe from each engine is fitted with corrosion resistant flame screen within the manifold.

- The manifold is to be located as high as practicable so as to allow substantial length of piping separating the crankcase.

- The manifold is to be vented to the top of funnel, such that the vent outlet is fitted with corrosion resistant flame screen.

- The clear open area of the vent outlet is not less than the aggregate area of the individual crankcase vent pipes entering the manifold.

- The manifold is to be provided with drainage arrangement.

Criteria for high back pressure of crankcase ventilation is that the maximum crankcase inner-pressure should not exceed 35 mmWC at MCR.

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

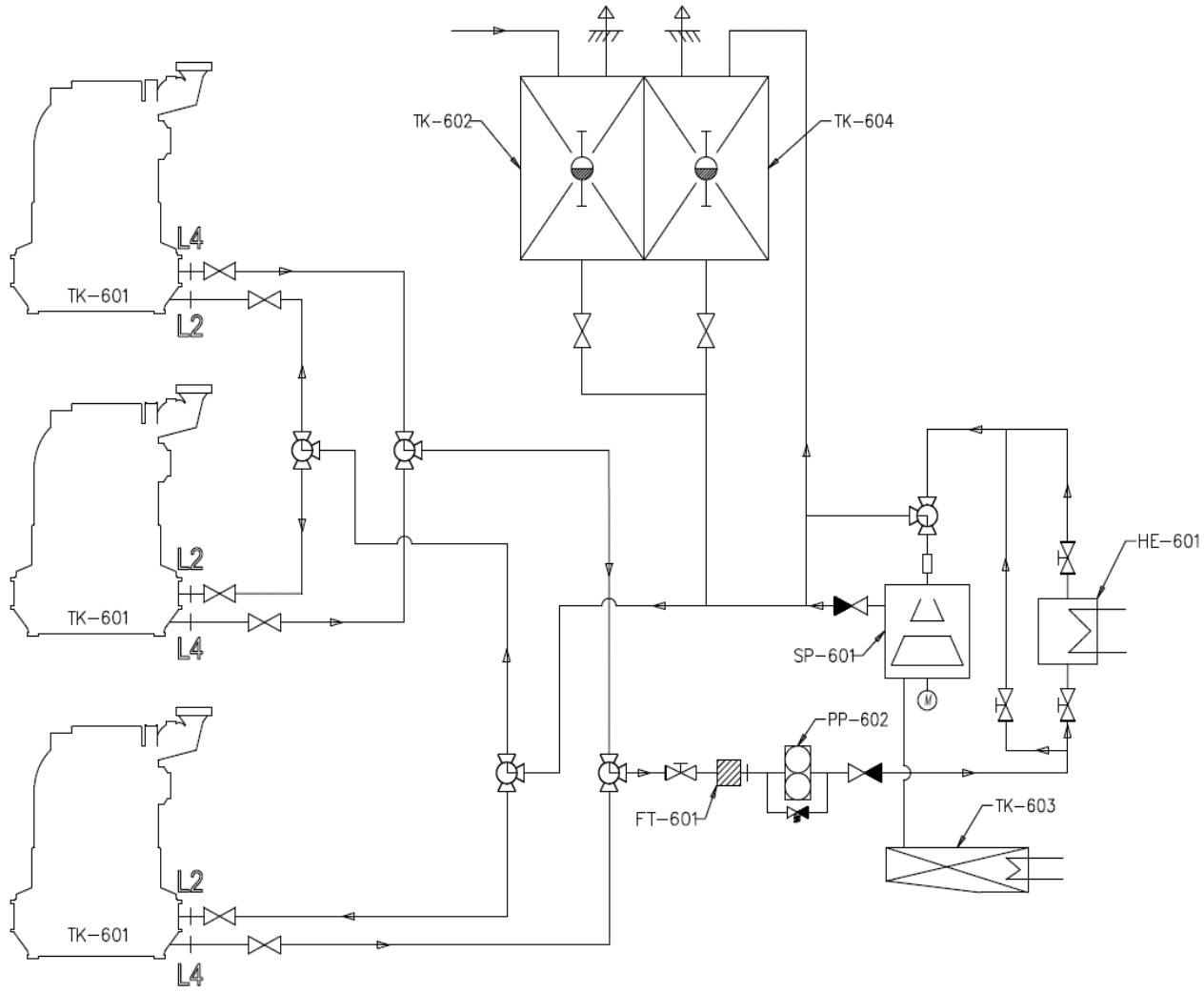


Fig. 4 External lubricating oil system (Wet Sump) for multi-engine installation (B91-314112-7.1)

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

1. Oil Grade

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

Please refer to the table 'List of Lubricants'.

2. Oil Viscosity

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

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

3. Governor Oil Grade

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

BN - Value

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

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

- High sulfur fuel + Low BN lube oil
  → Excessive corrosive wear

- Low sulfur fuel + High BN lube oil
  → Excessive top land deposit formation
  → Lacquering formation on cylinder liner surface

4. Lubricating oil selection

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

When the marine diesel oil / marine gas oil is to be used only for temporary engine operation, higher BN lubricating oil used for residual fuel (heavy fuel oil) 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

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

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

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

Oil brand	Engine system lubricating oil			Governor oil
Oil company	Brand name	SAE	BN*)	
Gulf Oil Marine	GulfSea Power MDO 4012, SeaLub Power MDO 4012	40	12	1) Same as Engine system 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
	GulfSea Power MDO 4015, SeaLub Power MDO 4015		15	
	GulfSea Power MDO 4020, SeaLub Power MDO 4020		20	
	GulfSea Power 4030, SeaLub Power 4030		30	
	GulfSea Power 4040, SeaLub Power 4040		40	
	GulfSea Power 4055, SeaLub Power 4055		55	
ENI S.p.A.	AGIP CLADIUM 120	40	12	
	AGIP CLADIUM 300		30	
	AGIP CLADIUM 400		40	
	AGIP CLADIUM 500S		50	
Petronas	PETRONAS Disrol 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		50	
	ALFAMAR 455		55	
SINOPEC TPEO	SINOPEC TPEO 4012	40	12	
	SINOPEC TPEO 4015		15	
	SINOPEC TPEO 4020		20	
	SINOPEC TPEO 4030		30	
	SINOPEC TPEO 4040		40	
	SINOPEC TPEO 4050		50	
Hyundai Oilbank	Hyundai XTeer HGSL 40	40	4.5	
	Hyundai XTeer TPEO 4012		12	
	Hyundai XTeer TPEO 4015		15	
	Hyundai XTeer TPEO 4020		20	
	Hyundai XTeer TPEO 4030		30	
	Hyundai XTeer TPEO 4040		40	
	Hyundai XTeer TPEO 4050		50	
Gazpromneft Lubricants	Gazpromneft Ocen TPL 1240	40	12	
	Gazpromneft Ocen TPL 1540		15	
	Gazpromneft Ocen TPL 2040		20	
	Gazpromneft Ocen TPL 3040		30	
Petro-Canada	Sentinel 445	40	4.7	
Oil volume	See the separate data for sump volume as per each engine type.			UG-25+: 2.1 Liter Europa : 1.5 Liter

This list is given as guidance only.

) Refer to Sheet No. P.06.300 when selecting BN value.

1. General

The engine has two cooling water circuits internally, which are low temperature(LT) and high temperature(HT) water circuits.
Most of the element of the circuits are modularized and directly mounted on the feed block (See Sheet No. P.01.300 'Engine Design Outline').

Low temperature w ater circuit comprises;
- Engine driven pump(option)
- Charge air cooler
- Lubricating oil cooler

High temperature water circuit comprises;
- Engine driven pump
- Charge air cooler
- Engine water jackets and Cylinder Heads
- Wax type thermostat valve (dividing type) (Temp. range 79 - 88℃ fixed)

2. External Connections

Two kinds of external connections are provided for the engine room conditions as follows (Refer to system diagrams.);

System-1 : Combined connection for only L.T water supply and return.
System-2 : Separated system for L.T and H.T water system.

3. Cooling Water

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

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

4. Preheating

In order to ensure an engine starting and quick load-up, preheating facility must be provided on internal cooling circuit or external cooling circuit and preheating for all engines are recommended.

Preheating temperature for :
- MDO operation : Min. 40℃
- HFO operation : Min. 60℃

Heating capacity : approx. 3.5 kW per cyl.

Electric Preheating Element (Option)
The mount on the cooling water preheating arrangement consists of a thermostat-controlled electric-heating element which is built in H.T cooling water circuit located on the engine's Feed Module. The pre-heater is activated by thermostat at 60℃ which provides water(60℃) to jacket water outlet.

The recommended capacity of preheater

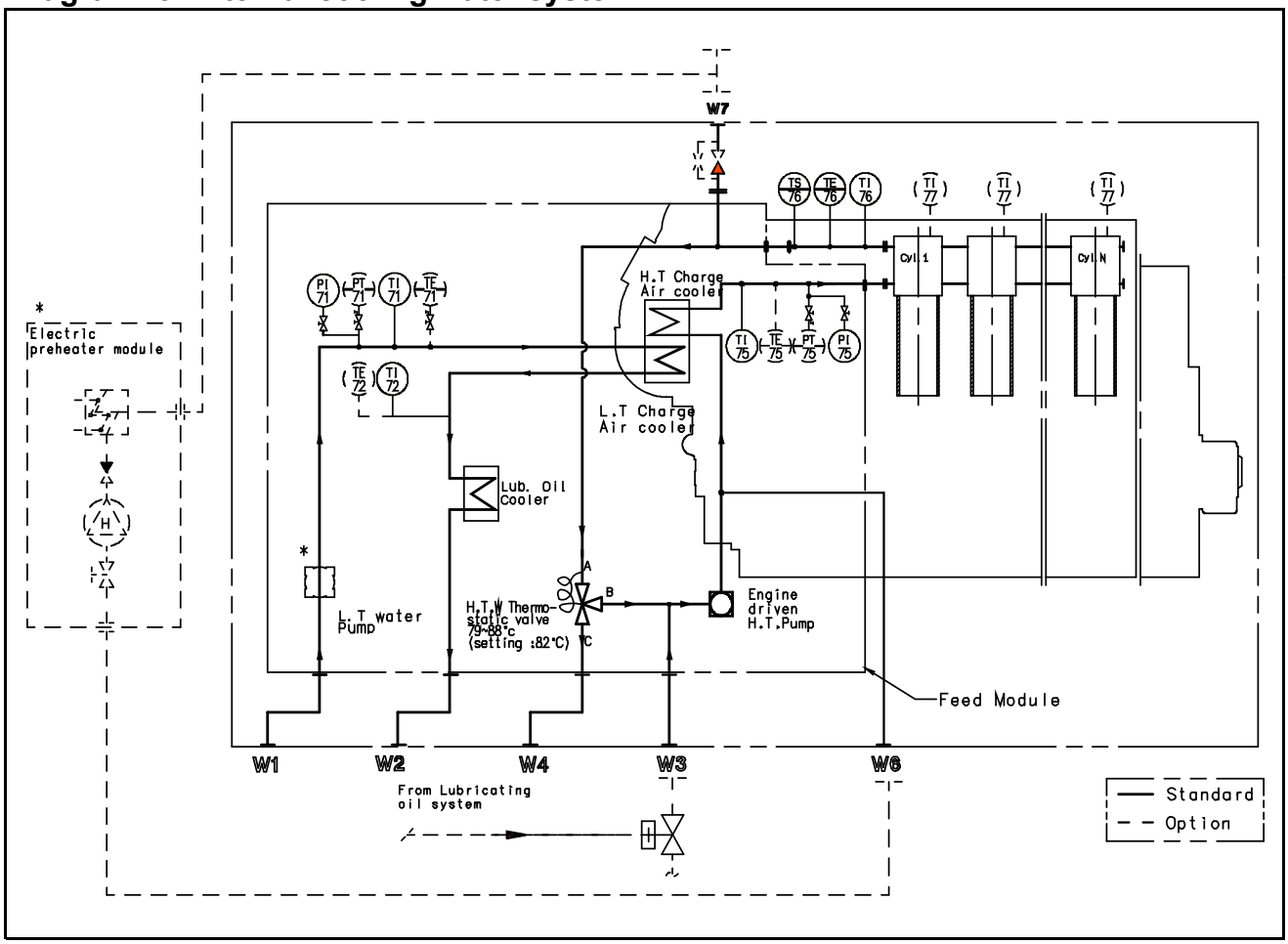
Cyl.	Elec. Preheater (kW)
6	32
7	32
8	32
9	32

*)The biggist capacity is applied for all cylinder for better heating effect

Operation
Engines initial starting on HFO/MDO, the engine jacket must be pre-heated by pre-heater. It is recommended that the pre-heater is arranged for automatic operation, so that the pre-heater is disconnected when the engine is running and connected when the engine is stand-by condition.

Note
When the engine is in standstill, an external valve must be shut off the cooling water inlet.

Diagram for internal cooling water system



1. General Description

The 'Internal cooling water system' has external circulation of L.T. water and H.T. water system, which are separated each other internally and externally.

2. Size of External Pipe Connections

Code	Description	Pipe size
W1	L.T. Water Engine Inlet	125A
W2	L.T. Water Engine Outlet	125A
W3	H.T. Water Engine Inlet	125A
W4	H.T. Water Engine Outlet	125A
W6	H.T Pre-heating Outlet	25A
W7	Venting to Expansion Tank	25A

Size of Connections is standard according to JIS B 2220.

3. Scope of Supply

The internal cooling system consists of the following built-in equipments.
Marked(*) equipments can be supplied as option on request.

* 1. Engine driven L.T. pump
2. Engine driven H.T. pump
3. Two stage charge air cooler
4. H.T.W. control thermostatic valve
* 5. Electric Preheater unit
or Electric Preheater element on engine

Note

L.T.W.control thermostatic valve, if required, to be installed on external piping.

1. General

The engine has two cooling circuits of LT and HT internally. However, the external connections can be provided for one (System1) or two string (System2) cooling circuits.

2. Design Data for External Cooling Water System

Pressure drop

Engine HT system : approx. 0.5 bar
Lub Oil Cooler : approx. 0.2 bar
Thermostatic Valve : approx. 0.5 bar
Charge Air Cooler(HT & LT) : approx. 0.5 bar(each)
(These values may be different depending on the actual design of each plant.)

Fresh Water Velocity

Max. 2.5 m/s

Sea Water Velocity

Suction Pipe : 1.0 - 1.5 m/s
Delivery Pipe : 1.5 - 2.5 m/s

Expansion tank(TK-101)

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

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

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

Engine type	HT & LT Water Volume
6H32/40	582 liter
7H32/40	617 liter
8H32/40	651 liter
9H32/40	686 liter

Central Cooling

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

Fresh Water Side

Flow Quantity and Heat Dissipation : Please refer to 'Engine Capacity Data'.
Pressure drop : Max. 0.5 bar.
Pump : centrifugal type(El. motor driven)
Water Temp. before Engine : Nor. 36 ℃

Sea Water Side

Flow Quantity : typically 1.5 times of Fresh Water flow.
Pressure drop : typically 1.0-1.5 bar.

Engine Inlet Cooling Water Pressure

Engine inlet cooling water pressure should be kept under 2.5bar.

Preheating

In order to ensure an engine starting and quick load-up, preheating must be provided on the external cooling circuit and preheating for all engines is recommended. Pre-heating unit can be supplied as option comprising :

- Electric or steam heater
- Circulating water pump
- Control panel & circulating pump starter
- Switch on-off of heating media

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

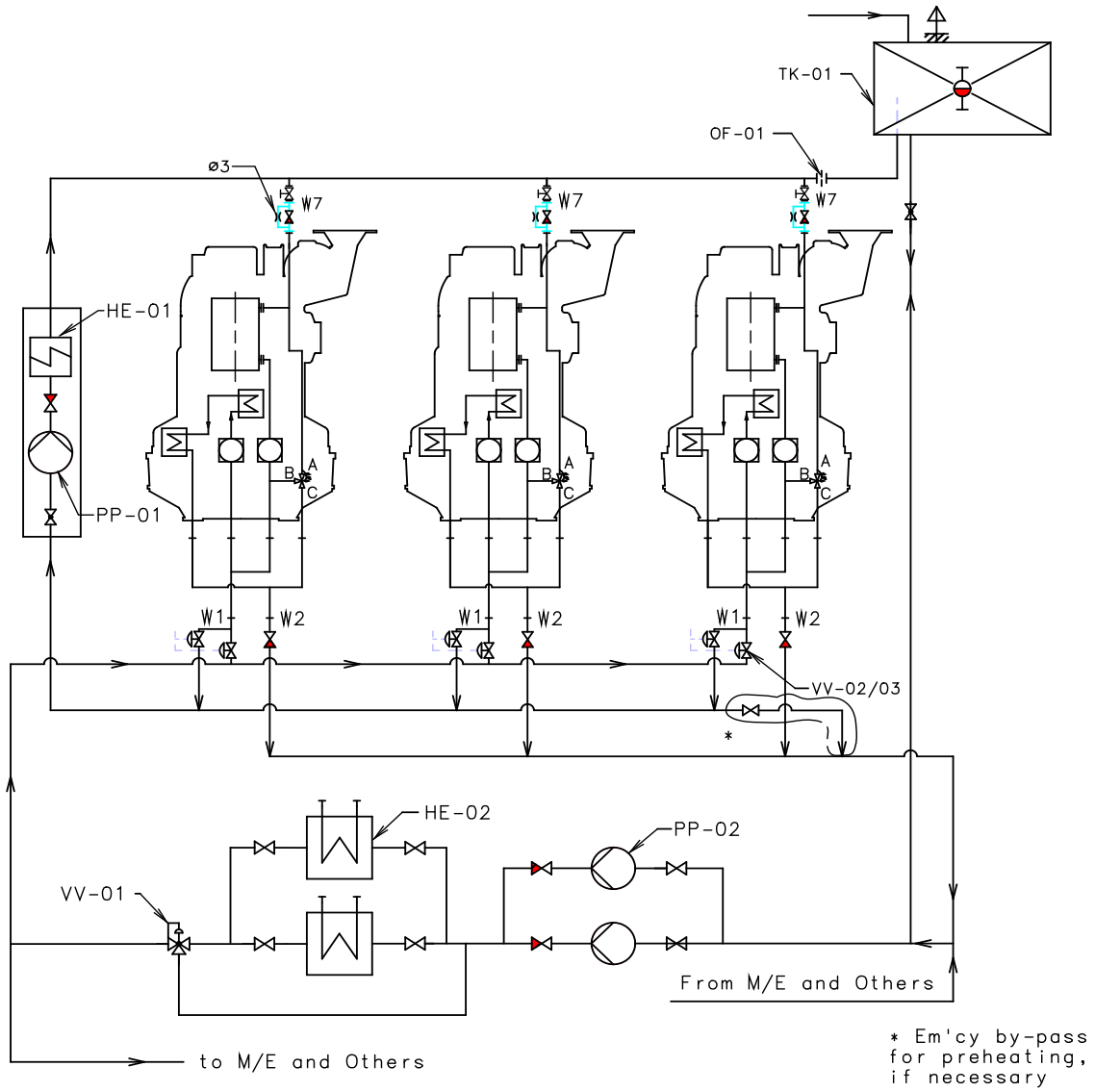
Auto shut off valve must be installed on the external cooling water system to ensure preheating, which prevents cooling water from flowing into the engine during preheating.

Preheating of stand-by engine

When only a part of the D/G sets are in service and others in stand-by, cold cooling water should not be passed into stand-by engine's cooling jacket which will cause cold corrosion in cooling system.

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

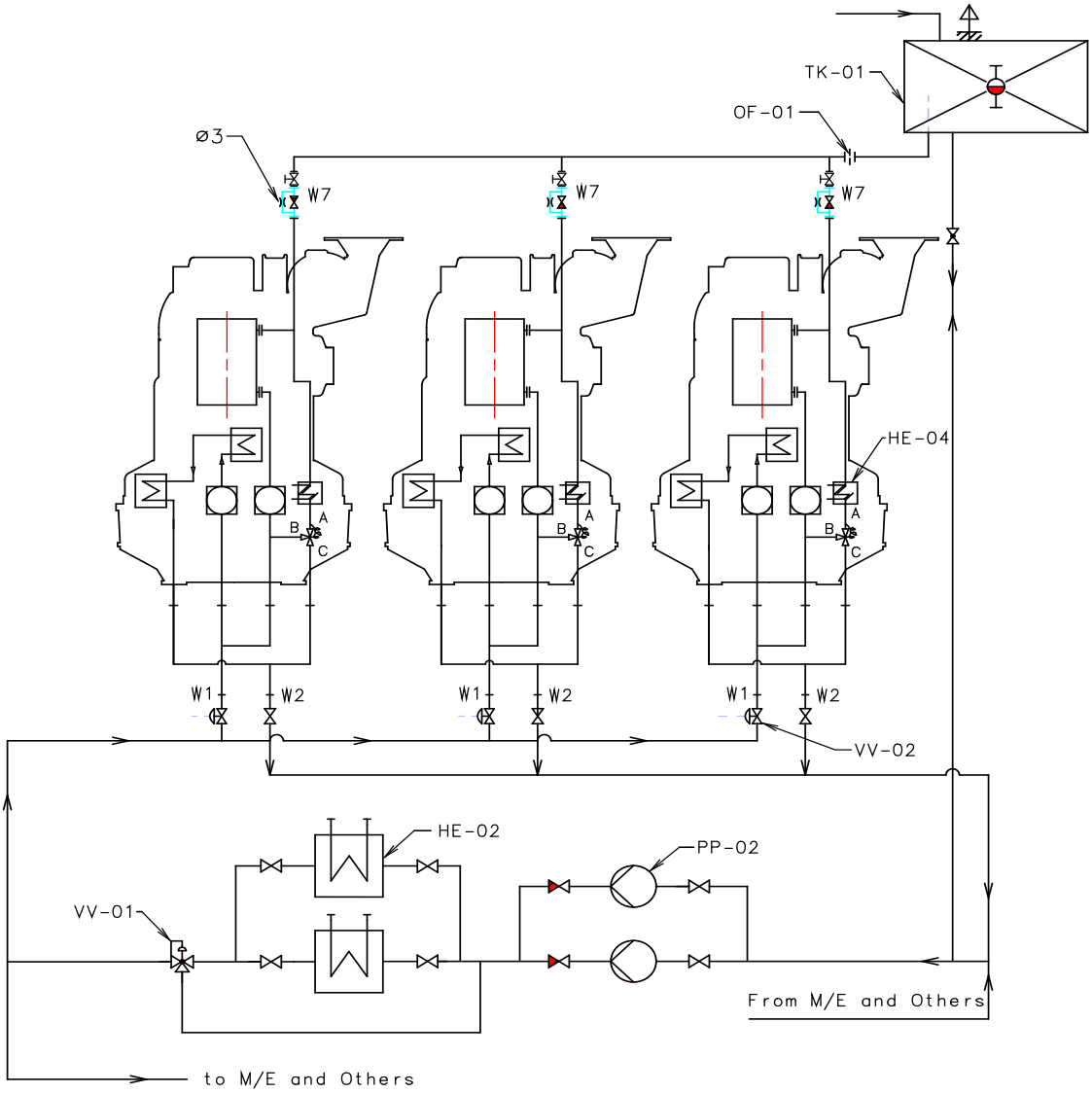
External Cooling Water System-1 with jacket preheating unit (for reference)



System components

TK - 01	Expansion tank	PP - 02	Central cooling water pump
HE - 01	Preheater	VV - 02/03	Auto shut-off v/v
PP - 01	Preheating pump	OF - 01	Orifice (ø3)
HE - 02	Central cooler	VV - 01	Thermostatic v/v

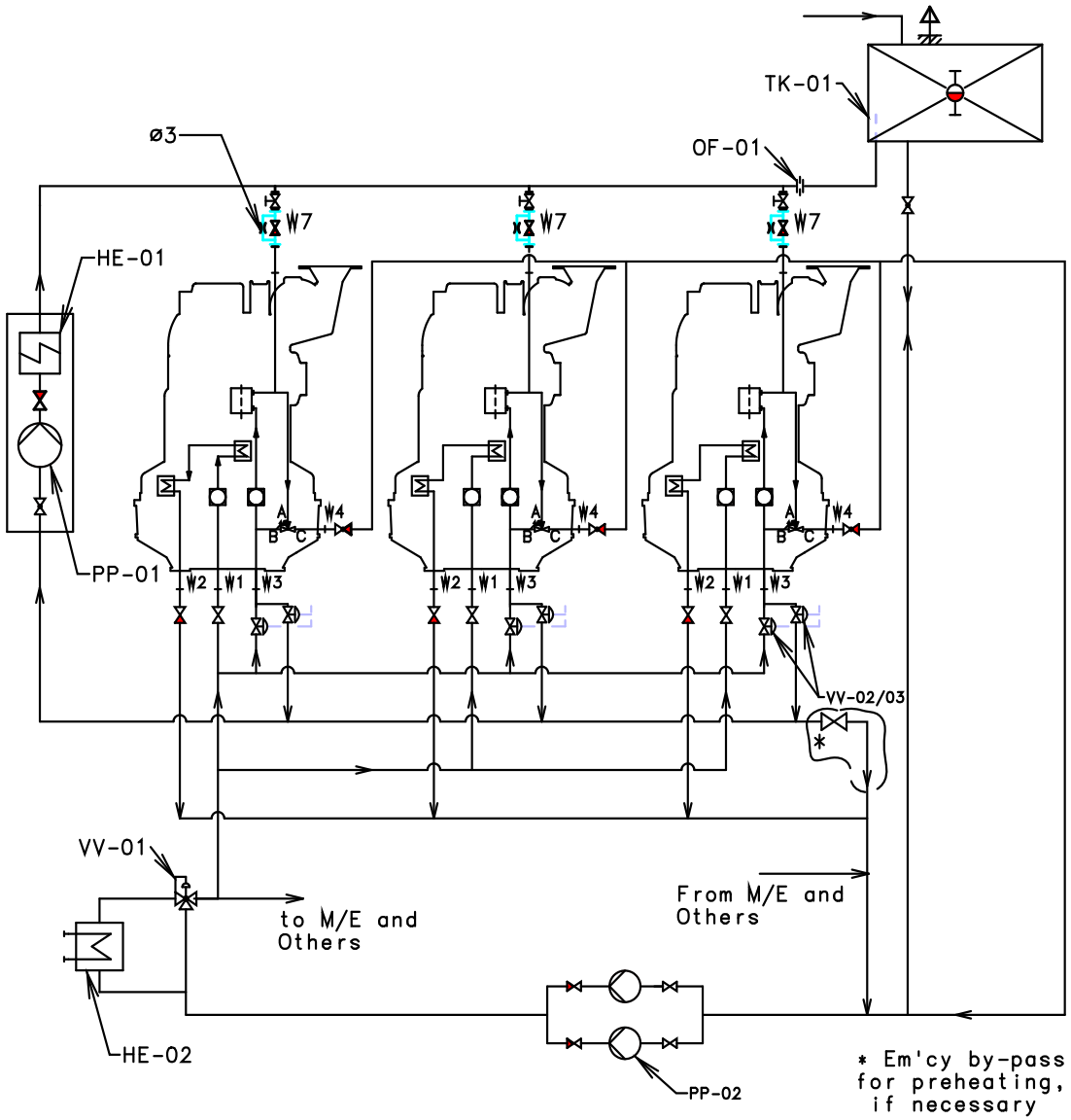
External Cooling Water System-1 with jacket preheating element (for reference)



System components

TK - 01	Expansion tank	PP - 02	Central cooling water pump
HE - 04	Electric preheating element	VV - 02	Auto shut-off v/v
HE - 02	Central cooler	OF - 01	Orifice (ø3)
VV - 01	Thermostatic v/v		

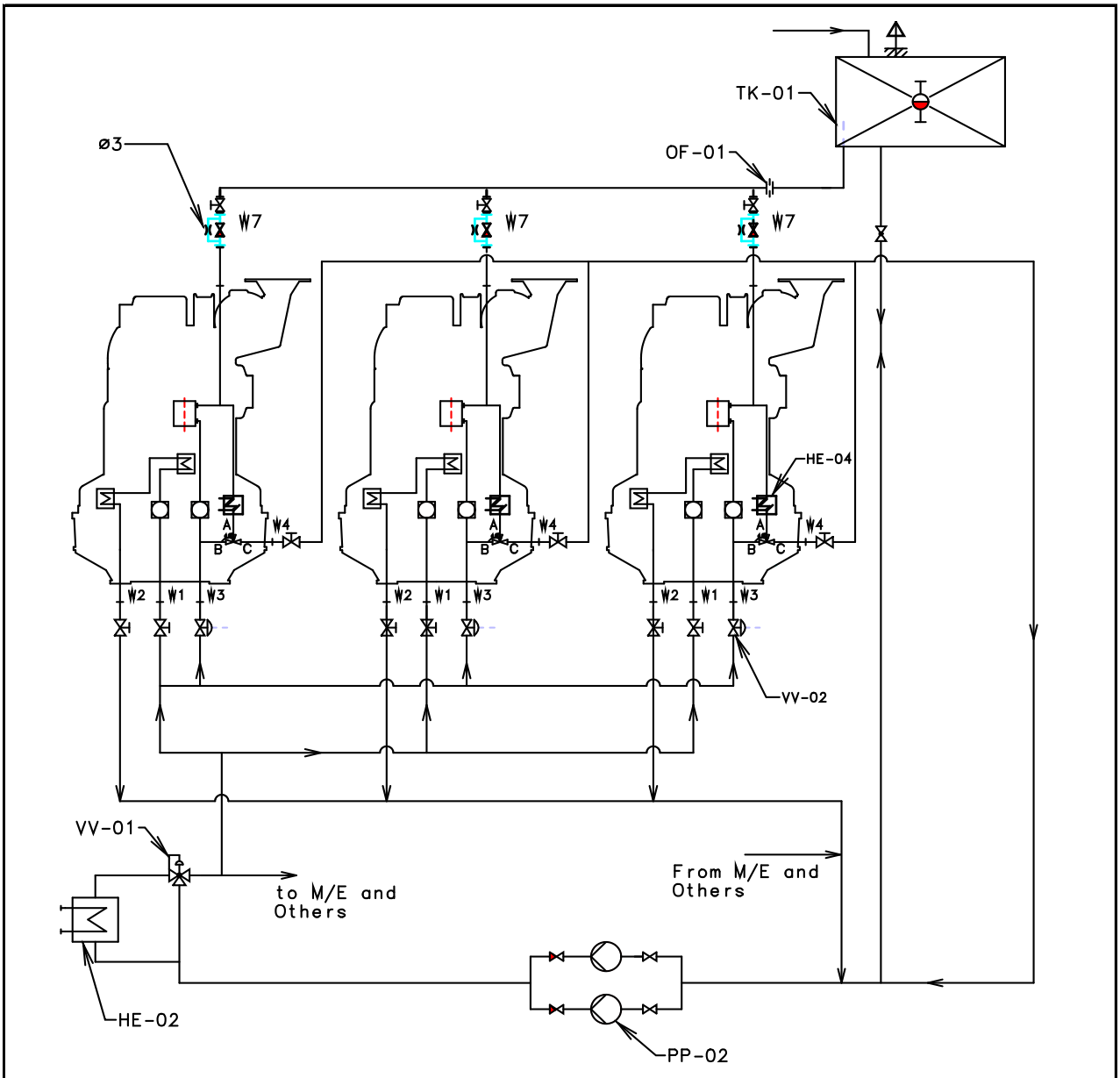
External Cooling Water System-2 with jacket preheating unit (for reference)



System components

TK - 01	Expansion tank	PP - 02	Central cooling water pump
HE - 01	Preheater	VV - 02/03	Auto shut-off v/v
PP - 01	Preheating pump	OF - 01	Orifice (ø3)
HE - 02	Central cooler	VV - 01	Thermostatic v/v

External Cooling Water System-2 with jacket preheating element (for reference)



System components

TK - 01	Expansion tank	PP - 02	Central cooling water pump
HE - 04	Electric preheating element	VV - 02	Auto shut-off v/v
HE - 02	Central cooler	OF - 01	Orifice (ø3)
VV - 01	Thermostatic v/v		

1. Quality of Cooling Water

The cooling of the engine should be only distilled (demineralized) or fresh water, which should be checked and treated to satisfy following requirements below table before adding corrosion inhibitor. It is necessary for keeping effective cooling and preventing corrosion of the system. Though the distilled water fully satisfy to the requirements for cooling water, it is necessary to add corrosion inhibitor before applying cooling water to engine cooling water system because untreated cooling water absorbs carbon dioxide from the air and then becomes corrosive.

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

Sea water or fresh water contaminated by sea water even in small amount is not allowed to be used as cooling water of the engine due to high risk of severe corrosion and deposits formation in the system.
Rainwater is heavily contaminated and highly corrosive in general, which is also not recommended as cooling water.
Tap water (drinking water) is not recommended as cooling water due to risk of chalk deposit formation inside the cooling system. However, if the distilled water, for example from fresh water generator, is not available, tap water may be used as cooling water after softening and some other treatments according to the ingredients.

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

2. Treatment of Cooling Water

Cooling water should be treated properly and corrosion inhibitor should be added.
The analysis and treatment of cooling water are recommended to be carried out by experts. Otherwise, comply the treatment procedures strictly according to the instructions from the supplier.
The recommended products are listed in following table.

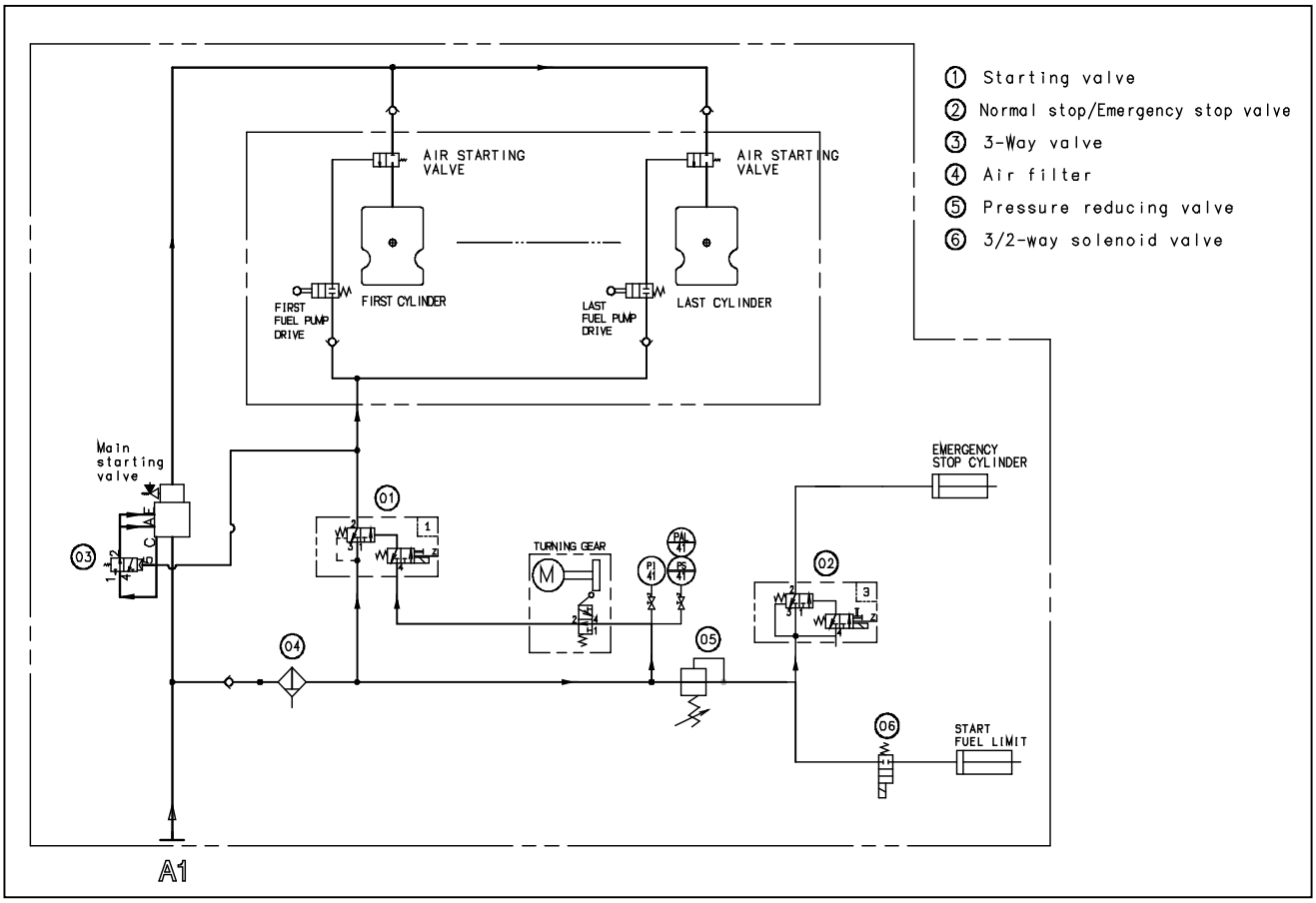
Manufacturer	Brand Name	Constituent	Delivery Form	Recommended Dosage
Chevron (FAMM)	DELO XLI(Havoline XLI)	Carboxylates	Liquid	75 liter / 1,000 liter
VECOM	Cooltreat NCLT	Nitrite	Liquid	48 liter / 1,000 liter
Wilhelmsen Chemicals	Rocor NB	Nitrite, Borate	Liquid	63 liter / 1,000 liter
NALCO	NALCOOL2000	Nitrite, Borate	Liquid	128 liter / 1,000 liter
	TRAC100	Molybdate, silicate	Liquid	17.5 liter / 1,000 liter
	TRAC115, TRAC108	Nitrite, Borate	Liquid	28 liter / 1,000 liter
GE Water & Process Technologies	CorrShield NT4200	Nitrite	Liquid	30 liter / 1,000 liter
Shell	Shipcare Cooling Water Treat	Nitrite, Borate	Liquid	128 liter / 1,000 liter
Drew marine	LIQUIDEWT	Nitrite	Liquid	24 liter / 1,000 liter
	MAXIGARD	Nitrite	Liquid	64 liter / 1,000 liter

Note
Follow the guidelines of corrosion inhibitor manufacturer for cooling water treatment.

Note
Oily inhibitors adhere to cooling surface and influence cooling efficiency, which are not recommended for cooling water. Only nitrite-borate based inhibitors are recommended.

Note
Some inhibitors may be toxic and hazardous. Strict control is required when handling inhibitors.

Diagram for Internal Compressed Air System



1. General Description

Compressed air is supplied for engine start, emergency stop and safety system as for the control air. The detail information of engine operation is explained in the chapter 'Operation and control system'.

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

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

Fuel Limiter Unit is provided for Governor, which limits the amount of fuel during engine starting.

2. Size of External Pipe Connection

Code	Description	Pipe size
A1	Compressed air inlet	50A

Size of Connection is standard according to JIS B 2220.

3. Scope of Supply

The compressed air system consists of the following built-in equipments.

1. Main Starting Valve
2. Stop Sol. Valve and Stop Cylinders
3. Fuel Limiter Unit for Governor

1. General Requirements

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

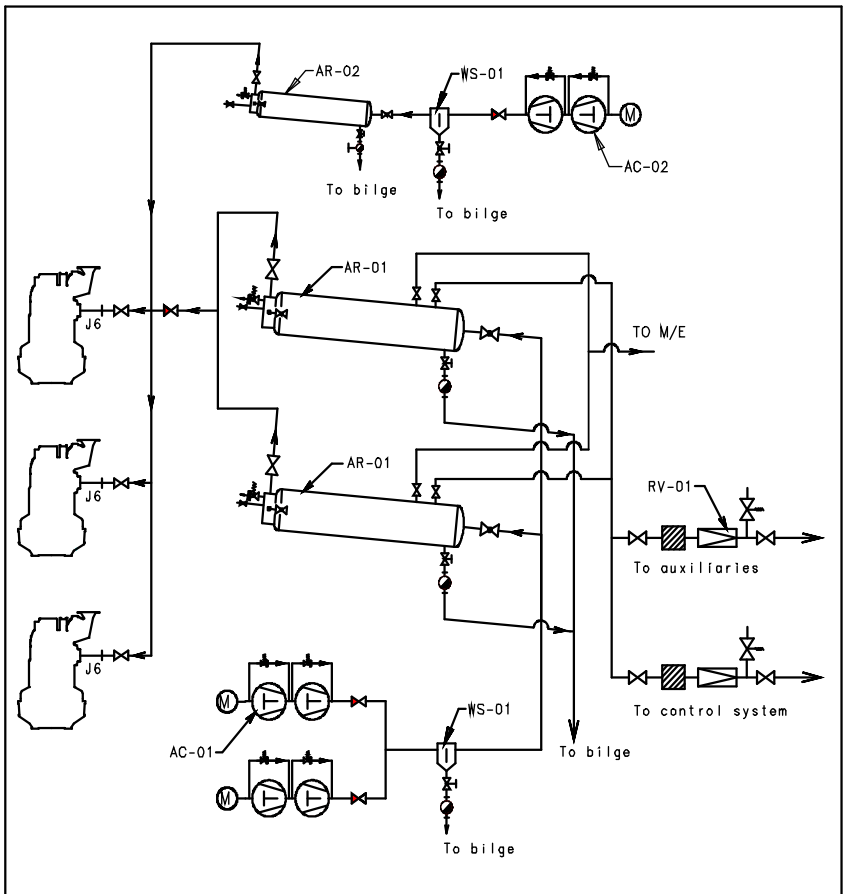
Dry and Clean Air is essential for the reliable function of the engine starting and control system. Therefore, the compressed air supply system should include Oil and Water Separating equipments. The air supply pipe to engine should also be arranged with slope and the water trap is to be positioned at the lowest points.

2. Starting Air Vessels

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

Engine Type	Volume (liter)
6H32/40	880
7H32/40	920
8H32/40	960
9H32/40	1,000

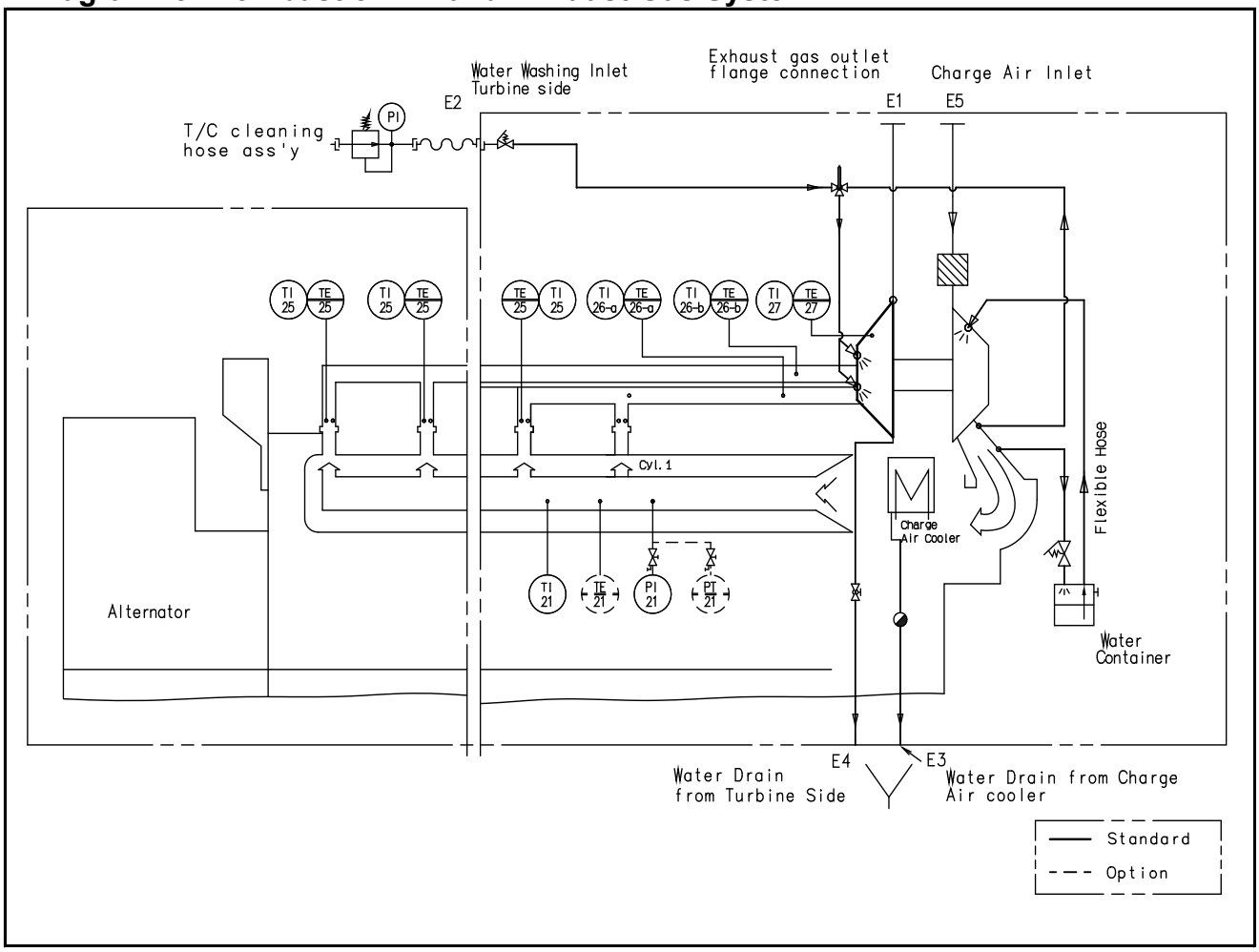
A typical Diagram for External Compressed Air System



System components

AR-01	Main air receiver	WS-01	Oil & Water separator
AR-02	Aux. air receiver	RV-01	Reduction station
AC-01	Main air compressor	AC-02	Em'cy air compressor

Diagram for Combustion Air and Exhaust Gas System



General Description

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

Turbocharger is a axial uncooled type with high efficiency and mounted on the Feed Block of the engine, The water washing systems for the Compressor and Turbine are supplied as standard.

Charge Air Cooler is a 2-stage H.T & L.T fresh water cooled type. A sea water cooled type charge air cooler is not recommended in general.

Water Mist Catcher is installed between Charge Air Cooler and Air Chamber of Engine Block.

Air Chamber is incorporated into the Engine Block with large volume for even distribution of induced air to each cylinder.

Exhaust Pipe System is a Pulse type, which has better performance at low load with good acceleration. In this case, a Jet Air system may be required to improve acceleration.

Water Drain Pipes are installed for the Air Chamber, and Water Mist Catcher.

1. General

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

2. Combustion Air

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

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

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

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

Air consumption volume should be designed in accordance with " Engine Capacity Data " (P.02.200).

Air filteration should be prevented from the outdoor's sand,cement, dust, and other particles, all particles size are not to be entered Max. 5 μm and above.
Oil bath type filter are generally used for the industrial area,cement plants, and sand winded area. Recommendable pressure loss of oil bath intake filter is 50~70 mm WC and even of fouled condition, must be kept within 110 mm WC.

Environmental Condition of Max.particle size of dust is typically applied depending on site.

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

3. Ventilation of Engine Room

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

[Total amount of ventilation of auxiliary engine]

$= Qc + Qr + Qv \ (m^3/h)$

where,

Qc (m^3/h) : Air required for engine combustion,

Qr (m^3/h) : Air required for engine radiation,

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

Qv (m^3/h) : Air required for other heat sources such as alternator and exhaust gas pipe , etc.

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

1. General Requirements

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

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

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

Recommended velocity external exhaust gas piping is recommended to be designed that velocity of exhaust gas through pipes should not exceed approximately 40 m/sec at maximum continuous rating.

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

2. Piping Design for Exhaust Gas System

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

- Pipe should be as short and straight as possible. Pipe bendings are minimized and the bending radius should be as large as possible.

- A water separating pocket and drain should be provided on the pipe.

- Rigid (fixed) supports and movable supports must be provided considering the thermal expansion and vibration of pipes.

- The exhaust gas outlet of Turbocharger can be turned on request.
For more information, please refer to the sheet 'External Exh. Gas Pipe Connection (P.08.510)'.

3. Expansion Bellows

The expansion bellows has to be mounted between the turbocharger outlet and external exhaust gas pipe in order to compensate thermal expansion and mechanical vibration.

The expansion bellows are supplied separately as standard. However, an additional expansion bellows may be required depending on the actual length of exhaust pipe in total.

Note

1. The external exhaust pipe must not exert any force against the gas outlet on the engine.

2. The external exhaust pipe just on expansion bellows should be fixed rigidly so that turbocharger can be free from any forces from the external exhaust pipe.

3. The sturdy fixed-point support must be provided for the expansion bellows on the turbocharger. It should be positioned, immediately above the expansion bellows in order to prevent the transmission of forces, resulting from the weight, thermal expansion or lateral displacement of the exhaust piping, to the turbocharger.

4. The exhaust piping should be mounted with a slope towards the gas outlet on the engine. It is recommended to have drain facilities in order to be able to remove condensate or rainwater.

4. Installation Procedure for Exp. Bellows

1) The generating set (or engine) should be installed in its final position before any external pipes are connected.

2) Remove the counter flange from the engine connection, if fitted.

3) Fasten the counter flange temporarily to the outlet side of the bellows.
For the correct orientation of the bellows (flow direction), see the dimensional drawing.

4) Fasten the bellows to the engine temporarily.

5) Align the external pipe to the counter flange.
No axial, lateral or angular deflection of the bellows is allowed.
Anchor the external pipe to the steel structure within 1 m from flange.
Observe that the pipe clamping with bracket must be very rigid in order to prevent vibration and movement of the exhaust gas pipe.
Most problems with bursting and vibration originate from poor clamping and support.
Especially the support in the axial direction must be rigid.

6) Put some temporary protection cover between the flanges in order to prevent debris from falling into the turbocharger.

7) Tack weld the counter flange to the external pipe.

8) Remove the bellows and weld the flange finally to the external pipe.

9) Remove the protection cover.
Place the bellows with gaskets between the flanges.

10) Lubricate the threads of the connection screw with heat resistant grease and tighten first until finger tight. Finally tighten the screw in a diagonal sequence.

11) Remove the guide bar between the flanges of the bellows.

5. Exhaust Gas Boiler

Thermal energy of exhaust gas can be utilized by boiler. Please refer to the sheets 'Engine Capacity Data (P.02.200)' for the exhaust gas data.

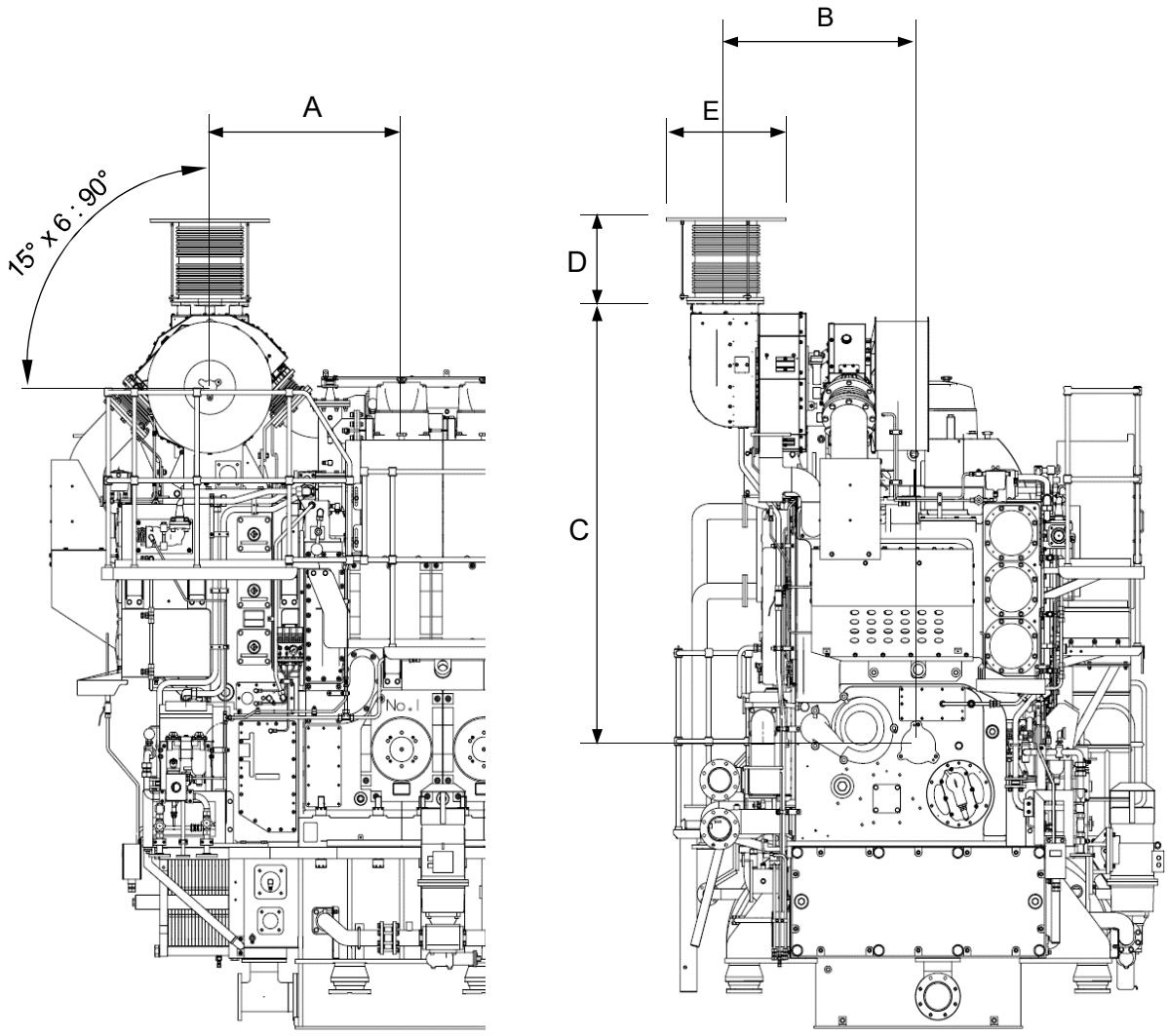
A boiler may be a separate unit for each engine or a common unit with other engines.

In any cases, however, the exhaust gas line for each engine should be separated from other engine's exhaust gas lines.

The back-pressure through boiler should be minimized to be within limited level for total exhaust gas system.

6. Exhaust Gas Silencer

Exhaust Gas Silencer can be supplied as option on request. The noise attenuation of silencer shall be either 25 dB(A) or 35 dB(A). For more information, please refer to the sheets for 'Exh. Gas Silencer (P.08.610/620)'.



Genset for 720 / 750 rpm (500 kW / cyl.) - KBB

Engine Type	Exh. Outlet Position(mm)				E	
	A	B	C	D	Size	Standard
6H32/40	1,035	1,084	2,359	470	600A	JIS F 7805
7H32/40	1,201	1,208	2,711	489	650A	JIS F 7805
8H32/40	1,032	1,168	2,528	542	700A	JIS F 7805
9H32/40	1,201	1,208	2,711	489	750A	JIS F 7805

Note) All dimensions and weight are approximate value and subject to change without prior notice

Genset for 720 / 750 rpm (500 kW / cyl.) - ABB

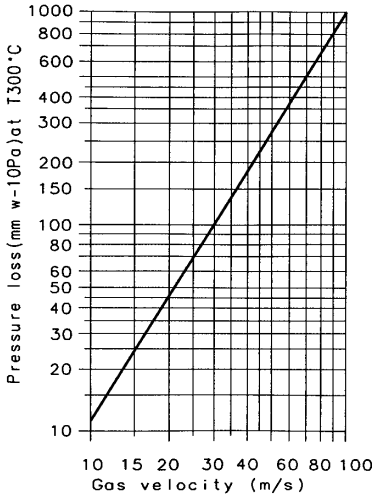
Engine Type	Exh. Outlet Position(mm)				E	
	A	B	C	D	Size	Standard
6H32/40	1,143	1,143	2,520	470	600A	JIS F 7805
7H32/40	1,136	1,262	2,612	540	650A	JIS F 7805
8H32/40	1,136	1,262	2,612	540	700A	JIS F 7805
9H32/40	1,229	1,352	2,735	542	750A	JIS F 7805

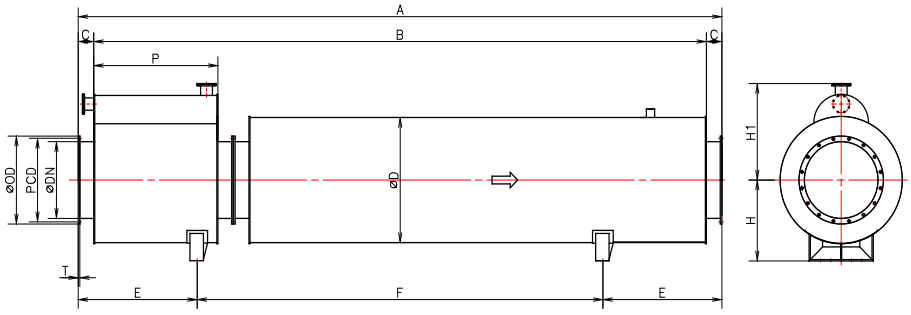
Note) All dimensions and weight are approximate value and subject to change without prior notice

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

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

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





25dB Type Silencer Unit : mm

Cylinder type	DN	A	B	C	D	E	F	H	H1	P	PCD	OD	T	N-d	Weight (kg)
6 (720rpm)	600	4980	4680	150	1060	990	3000	700	792	1000	670	710	16	16-Ø23	1873
7 (720rpm)	650	5680	5380	150	1110	1090	3500	730	819	1100	720	760	16	16-Ø23	2080
8 (720rpm)	700	6220	5920	150	1160	1150	3920	750	885	1200	775	815	16	16-Ø23	2385
9 (720rpm)	750	6660	6360	150	1210	1170	4320	780	910	1200	825	865	20	20-Ø23	2660

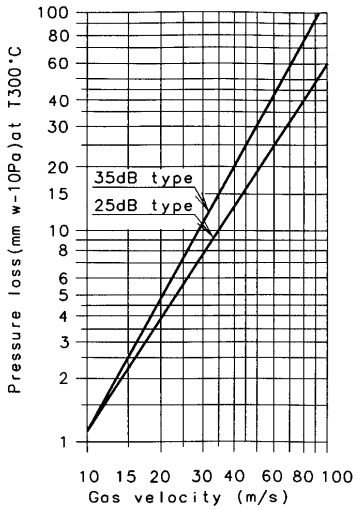
35dB Type Silencer Unit : mm

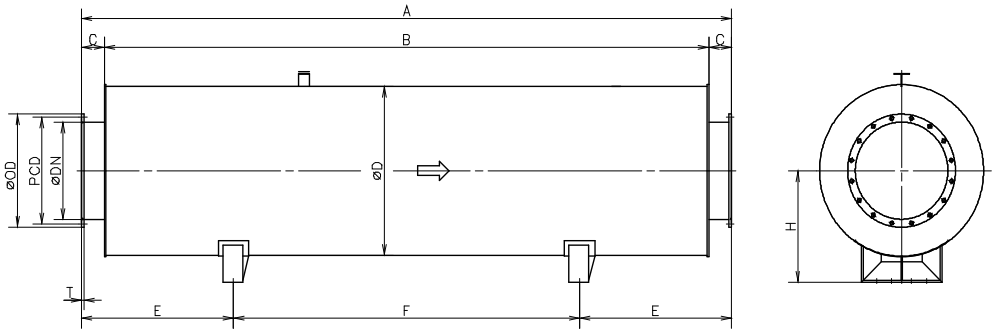
Cylinder type	DN	A	B	C	D	E	F	H	H1	P	PCD	OD	T	N-d	Weight (kg)
6 (720rpm)	600	6230	5930	150	1060	990	4250	700	792	1000	670	710	16	16-Ø23	2065
7 (720rpm)	650	6980	6680	150	1110	1090	4800	730	819	1100	720	760	16	16-Ø23	2295
8 (720rpm)	700	7570	7270	150	1160	1150	5270	750	885	1200	775	815	16	16-Ø23	2615
9 (720rpm)	750	8060	7760	150	1210	1170	5720	780	910	1200	825	865	20	20-Ø23	2910

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

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

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



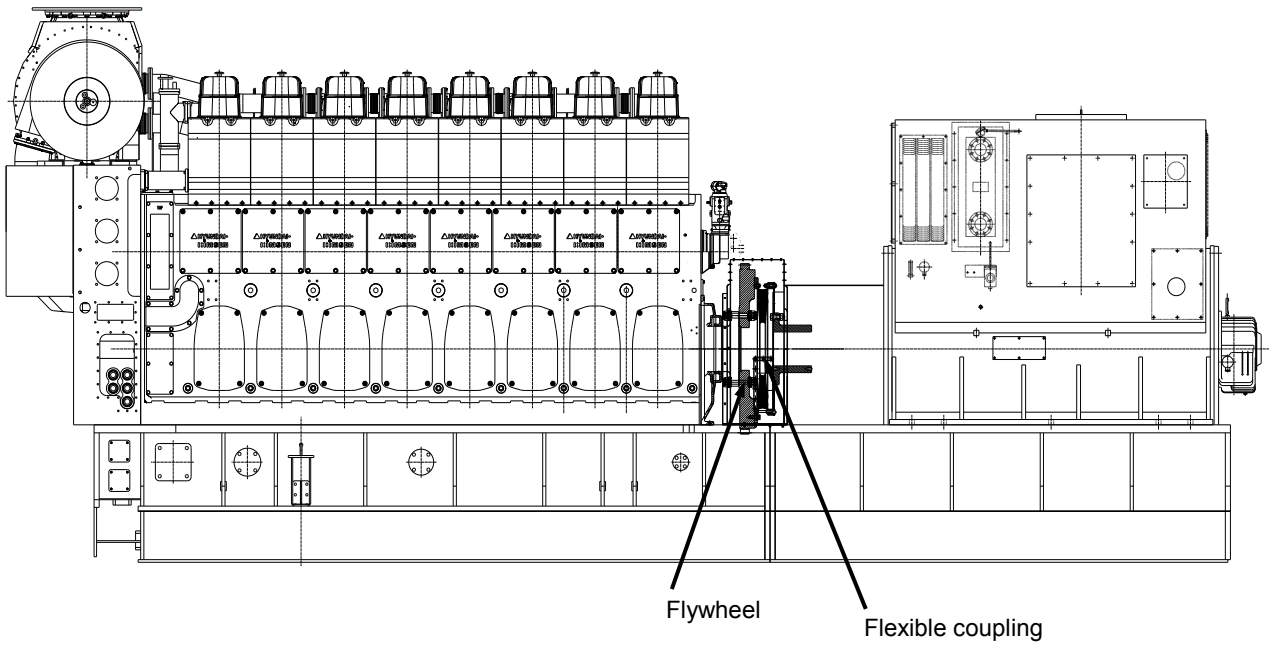


25dB Type Silencer Unit : mm

Cylinder type	DN	A	B	C	D	E	F	H	PCD	OD	T	N-d	Weight (kg)
6 (720rpm)	600	4280	3980	150	1060	1000	2280	700	670	710	16	16-Ø23	1500
7 (720rpm)	650	4880	4580	150	1110	1140	2600	730	720	760	16	16-Ø23	1804
8 (720rpm)	700	5320	5020	150	1160	1150	3020	750	775	815	16	16-Ø23	2070
9 (720rpm)	750	5760	5460	150	1210	1170	3420	780	825	865	20	20-Ø23	2345

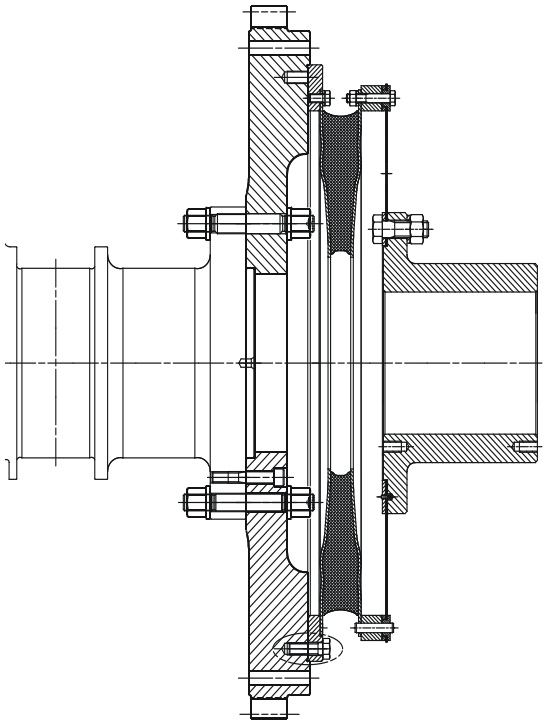
35dB Type Silencer Unit : mm

Cylinder type	DN	A	B	C	D	E	F	H	PCD	OD	T	N-d	Weight (kg)
6 (720rpm)	600	4930	4630	150	1060	990	2950	700	670	710	16	16-Ø23	1605
7 (720rpm)	650	5580	5280	150	1110	1090	3400	730	720	760	16	16-Ø23	1920
8 (720rpm)	700	6070	5770	150	1160	1150	3770	750	775	815	16	16-Ø23	2200
9 (720rpm)	750	6560	6260	150	1210	1170	4220	780	825	865	20	20-Ø23	2480



Mounting of Generator

As a standard design of H32/40 engine, the engine and generator are coupled with flexible coupling and rigidly mounted on common base frame.



Generator Bearing

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

for Stationary Gen-Set

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	
		Major Fasteners - Confirmation												
M11100	L11100	Bolt for Base Frame and Resilient Mount		▲			◆							
G11100	-	Nut for Resilient Mount and Foundation		▲			◆							
M13250	L13000	Hyd. Nut for Main Bearing Cap		◆			◆							
M21100	L13000	Hyd. Nut for Cylinder Head		◆			◆							
M25000	L25000	Bolt and Nut for Camshaft		▲			◆							
M31000	L32000	Hyd. Nut for Con-Rod (Shaft)		◆			◆							
M31000	L32000	Hyd. Nut for Con-Rod (Big-end)		◆			◆							
M33200	L33100	Hyd. Nut for Counter Weight		◆			◆							
M35300	L35000	Bolt and Nut for Timing Gear		▲			◆							
M35300	L35000	Hyd. Nut for Idle Gear (Only for Vee-type engine)		◆			◆							
-	L81000	Bolt and Nut for Turbocharger Mounting		▲			◆							
		Major Bearing												
M13250	L13250	Main Bearing					√				▣			
M13250	L13250	Thrust Washer : Axial Clearance					◎						▣	
M25000/M25300	L25300	Camshaft Bearing - 6, 7H32/40 and 12, 14H32/40V												
		- All Position : Clearance					√		◎				▣	
		Camshaft Bearing - 8, 9H32/40 and 16, 18, 20H32/40V												
		- #1(in-line) / #A0,A1,B0,B1(Vee) : Clearance					√		▣					Replacement based on visual inspection
		- Rest Positions : Clearance					√		◎				▣	
M32120	L32000	Con-Rod Bearing (Big-end)					√		■		▣			
M32130	L32000	Con-Rod Bearing (Small-end)					√		■				▣	
M35300	L35000	Bearing Bush for Idle Gear : Clearance							◎				▣	
		Resilient Mount												
M11100	L11100	Resilient Mount		●			●							
		Cylinder Unit and Con. Rod												
M15100	L15000	Cylinder Liner					√		■					
M15100	L15000	Flame Ring					√		▣					
M21100	L15000/L21100	Cylinder Head & Water Jacket Cooling Water Space					√		■					
M21120/M21130 /M21200	L21100/L21200	Intake/Exhaust v/v Spindle, Seat Ring and v/v Guide: Overhaul and Reconditioning					√		■		▣			
M21210	L21200	Intake/Exhaust v/v : Clearance		●	●									
M21210	L21200	Rocker Arm Shaft and Bush					√		■					
M21220	L21200	Rotocap			○				■					
M21400	L21400	Starting Valve					√		■					
-	L22000	Indicator Valve							▣					
M31100	L31100	Piston Rings					√		▣					
M31100	L31100	Piston and Piston Pin					√		■					
M31100/M31101	L32000	Con-Rod Bore (Big-end)					√		■					
M31100/M32130	L32000	Piston Pin & Con-Rod (Small-end) : Clearance					√		■					
-	L32000	Shim Plate for Con-Rod					√		▣					
-	L32000	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.

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.

for Stationary Gen-Set

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	L33100	Crankshaft : Deflection					◎							
-	L33300/L42300	Gear Teeth on Flywheel & Turning Gear					▲							
-	L33400	Torsional Vibration Damper : Fluid sampling (Only for Viscous Damper)							◎					(See Manual for T/V Damper)
-	L33500	Flexible Coupling	▲											(See Manual for Flex.Coupling)
M35300	L35000	Timing Gear and Pump Driving Gear : Clearance and Backlash							◎					
		Valve Operating Mechanism												
M23000	L23000	Swing Arm Roller Shaft and Bush							■				▣	
M25000	L23000/L25000	Contact Faces of Cam and Swing Arm Roller Camshaft Bearing		▲			▲							
		Control System												
G40000	L41000	Fuel Control Linkage : Movement Check	○											Weekly
G40001	-	Safety Device : Function Check	○											Monthly
-	L41000	Governor Oil Level (Only for Mechanical Hydraulic Governor)	▲											Daily (See Manual for Governor)
M45200	L45200	Engine RPM Pick-up Sensor : Clearance					●							
M45200	L45200	Temperature / Pressure Sensor	○											In case of necessity
		Fuel System												
G05100	-	Analyze Fuel Oil Properties : Sampling	◎											Every Bunkering
M51100	L51000	Fuel Injection Pump												
		- Deflector : Erosion				◎	▣							
		- Plunger Assembly					■				▣			
		- Delivery Valve Assembly (except case)					■		▣					
		- Delivery Valve Case					■						▣	
		- Roller Bush for Tappet							■				▣	
M52000/M52002 /M52003	L52000	Fuel Injection Valve : Opening Pressure		●	●	▣								Atomizer life time
M53000	L53000	O-rings for Feed Block					▣							
M53010	L53010	Fuel Oil Shock Absorber				■								
M56000	L56000	Fuel Oil Filter (In-Line engine)	■											If pressure drop reaches limit (See G01400)
-	L56000	Fuel Oil Filter (Vee-type engine) - See Manual for FO Filter	■											If pressure drop reaches limit (See G01400)
		Lubricating Oil System												
G06200	-	Analyze Lub. Oil Properties : Sampling	◎											Every 3 month
M61000	L61000	Lubricating Oil Pump							■					
M62000	L62000	Lubricating Oil Cooler							■					(See Manual for LO Cooler)
M63000	L63000	Lubricating Oil Filter (Cartridge Type)	■		▣									If pressure drop reaches limit (See G01400)
-	L63000	Auto Backwashing Filter (If Applied)	■											(See Manual for Auto Filter)
-	L64000	Thermostatic Valve : Clean & Check the Elements							■					(See Manual for Thermo.v/v)
M67000	L67000	Lubricating Oil Centrifugal Filter	■											(See Manual for Centrifugal Filter)

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

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

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.

for Stationary Gen-Set

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	
		Cooling Water System												
G07100	-	Analyze Cooling Water Properties : Sampling	◎											Weekly : Test Kit Every 3 month : Lab. Test
M71000	L71000	Cooling Water Pump							■					
-	L74000	Thermostatic Valve : Clean & Check the Elements							■					(See Manual for Thermo.V/v)
		Compressed Air System												
O02300	-	Air Running	○											Monthly
G40000	-	Check Starting & Stop Syatem	○											Weekly (Over a Week Stand-still Condition)
M42100	L42100	Safety Stop System (Acc. to each application)	■											
		Supercharging System												
M80000	L83000	Turbocharger	■											(See Manual for Turbocharger)
		- Clean Air Filter (Only for Filter Silencer type)	■		▣									Every 500hrs running
		- Turbine : Water-washing	●											Every 200hrs running
		- Compressor : Water-washing	●											Every 24~50hrs running
M81000	L81000	Charge Air Shut-off Valve (If Applied)	○											Weekly (See Manual for C/A shut off valve)
M84000	L84000	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.

for Stationary Gen-Set

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									
L13000	Gaskets for gear case cover	set	-	1	1	2	2	3	3	4
L19300	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
L19300	O-ring for camshaft cover	ea	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
L21100	O-rings for cylinder head cover	set	0.5 x C	1 x C	1.5 x C	2 x C	2.5 x C	3 x C	3.5 x C	4 x C
	Bearings									
L13250	Main bearing (upper & lower)	set	-	-	-	-	-	1xC+1	1xC+1	1xC+1
L13250	Thrust washer	ea	-	-	-	-	-	-	-	2
L25300	Camshaft bearings	ea	-	-	-	-	-	-	-	1xC+1
L32000	Big-end bearing (upper & lower)	set	-	-	-	-	-	1 x C	1 x C	1 x C
L32000	Small-end bearing	ea	-	-	-	-	-	-	-	1 x C
L35000	Bearing bush for idle gear	ea	-	-	-	-	-	-	-	1
	Cylinder Unit and Con-Rod									
L15000	Flame ring	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
L15000	O-rings & gasket for cylinder liner / cooling water jacket	set	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
L21100	O-ring for cylinder head	ea	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
L21100	Bush & O-ring for fuel valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
L21100	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
L21100 L21200	Intake v/v spindle, seat ring and v/v guide	set	-	-	-	-	-	1 x C	1 x C	1 x C
L21100 L21200	Exhaust v/v spindle, seat ring and v/v guide	set	-	-	-	-	-	1 x C	1 x C	1 x C
L21400	O-rings for starting valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
L22000	Indicator v/v complete	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
L23000	O-rings for push rod cover	set	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
L23000	Roller bush for swing arm	ea	-	-	-	-	-	-	-	1 x C
L31100	Piston ring-top ring / 2nd ring / scraper ring	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
L32000	Shim plate for con-rod	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
L32000	Stud for con-rod shaft	ea	-	-	-	-	-	-	-	4 x C
	Fuel System									
L51000	Plunger assembly for fuel pump	ea	-	-	-	-	-	1 x C	1 x C	1 x C
L51000	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
L51000	Gaskets & seal ring for fuel pump	set	-	-	-	-	-	1 x C	1 x C	1 x C
L51000	Deflector & gasket for fuel pump	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
L51000	Delivery valve assembly (except case)	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
L51000	Delivery valve case	ea	-	-	-	-	-	-	-	1 x C
L51201	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
L51201	Roller bush for tappet	ea	-	-	-	-	-	-	-	1 x C
L51201	O-ring for fuel pump drive	ea	-	-	-	-	-	-	-	1 x C
L52000	Fuel injection nozzle with dowel pin	set	1 x C	2 x C	3 x C	4 x C	5 x C	6 x C	7 x C	8 x C
L52000	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
L52300	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
L53000	O-rings for fuel feed pipe connection	set	-	1	1	2	2	3	3	4
L53000	Wearing ring & sealing ring for F.O shock absorber	set	1 x U	2 x U	3 x U	4 x U	5 x U	6 x U	7 x U	8 x U

for Stationary Gen-Set

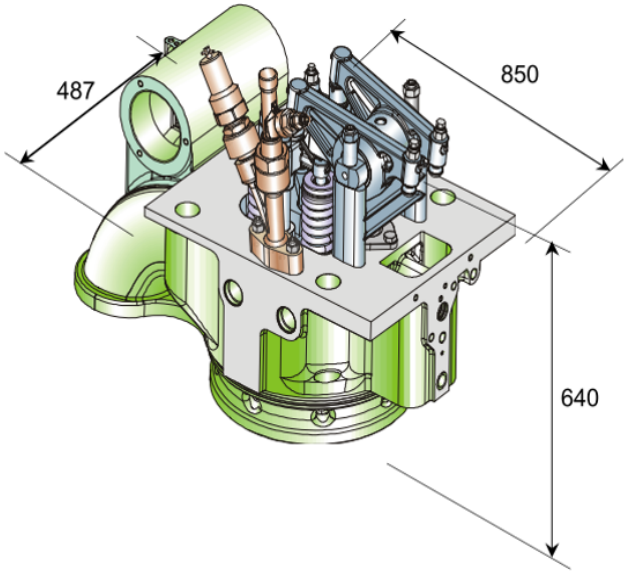
Section No.	Parts Description	Quantity for the operating hours								
		set/ea	0-3000	0-6000	0-9000	0-12000	0-15000	0-18000	0-21000	0-24000
	Lubricating Oil System									
L61000	Bushes for lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
L61000	O-rings for lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
L62000	O-ring for lub. oil cooler connection (Installation on engine side)	ea	-	-	-	4	4	4	4	8
L63000	Lub. oil filter cartridge (Paper cartridge type)	ea	2 x U	4 x U	6 x U	8 x U	10 x U	12 x U	14 x U	16 x U
L63000	O-rings for lub. oil filter assembly (Paper cartridge type)	set	1 x U	2 x U	3 x U	4 x U	5 x U	6 x U	7 x U	8 x U
L63000	Spare parts for auto backwashing filter (See manual for auto backwashing filter)	set	-	-	-	-	-	-	-	-
L63000	Packing for auto backwashing filter	ea	-	-	-	1	1	1	1	2
L64000	O-ring for lub. oil thermostat valve	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
L64000	Gasket for thermostatic valve cover (No installation of auto backwashing filter)	ea	-	-	-	1	1	1	1	2
L67000	Spare parts for centrifugal filter (See manual for centrifugal filter)	set	-	-	-	-	-	-	-	-
	Cooling Water System									
L71000	Oil seal, mechanical seal & O-ring for HT and LT-pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
L74000	O-ring for C.W thermostat valve (Wax type installed on engine)	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
L74000	Gasket for thermostatic valve cover (Wax type installed on engine)	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
L77000	O-ring for cooling water connection	ea	-	2	2	4	4	6	6	8
L78000	O-ring for cyl.head cooling water connection	ea	-	8	8	(4xC)+6	(4xC)+6	(4xC)+14	(4xC)+14	(8xC)+12
	Supercharging System									
L81000	Gaskets and O-ring for compressor out	set	-	-	-	1	1	1	1	2
L82000	Gasket for connection flange	ea	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
L83000	O-rings and gaskets for T/C connection	set	-	-	-	1	1	1	1	2
	Charge Air Cooler									
L84000	O-rings and gaskets for air cooler	set	-	-	-	1	1	1	1	2
	Turbocharger									
	Turbine nozzle ring (See manual for turbocharger)	ea	-	-	-	1	1	1	1	2
	Spare parts for turbocharger (See manual for turbocharger)	set	-	-	-	-	-	-	-	-
	Air filter mat (Engine room air suction)	ea	2	4	6	8	10	12	14	16

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

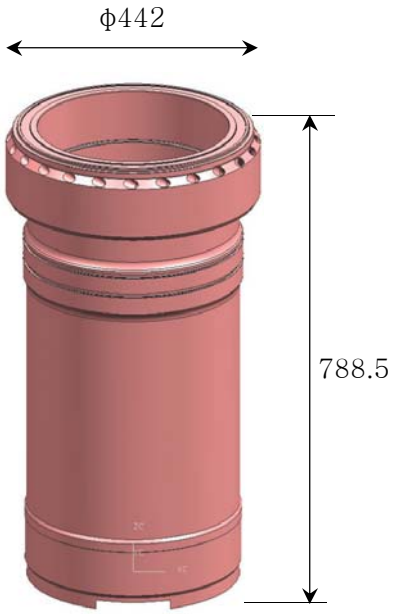
List of minimum Spare Parts for each plant

Parts Description	Q'ty	Sec. No.	Item No.	Remark
Engine block and covers				
Main bearing, upper	1	L13250	251	
Main bearing, lower	1	L13250	251	
Thrust washer	2	L13250	252	
Main bearing stud (M48)	2	L13000	231	
Nut for main bearing stud (M48)	2	L13000	232	
Oil sealing for crankcase door	1	L19300	380	
Cylinder head and cylinder liner				
Valve spindle, intake	2	L21200	201	
Valve spindle, exhaust	4	L21200	202	
Conical piece	6	L21200	206	
Valve spring, outer	6	L21200	207	
Valve spring, inner	6	L21200	208	
Valve seat, inlet	2	L21100	111	
Valve seat, exhaust	4	L21100	112	
Valve guide	6	L21100	113	
Valve roto cap	6	L21200	204	
Air start valve	1	L21400	400	
O-ring for starting valve D54	1	L21400	409	
O-ring for starting valve D52.87	1	L21400	410	
O-ring for starting valve D56.83	1	L21400	411	
O-ring for starting valve D63.76	1	L21400	412	
O-ring for starting valve D65.74	1	L21400	413	
O-ring for starting valve D67.72	1	L21400	414	
O-ring for starting valve D69.70	1	L21400	415	
O-ring for starting valve D71.68	1	L21400	416	
O-ring for starting valve D73.66	1	L21400	417	
O-ring for exhaust valve seat ring	4	L21100	118	
O-ring for valve guide	6	L21100	291	
O-ring for cylinder head	2	L21100	901	
O-ring for cylinder head cover, lower	1	L21100	805	
O-ring for cylinder head cover, upper	1	L21100	806	
O-ring for cooling water jacket, D193	1	L15000	901	
O-ring for cooling water jacket, P225	1	L15000	902	
O-ring for cooling water jacket, D402	1	L15000	192	
O-ring for cylinder liner, D370	2	L15000	193	
O-ring for cooling water connection, P125	4	L78000	460	
Sealing ring for cylinder liner	1	L15000	191	
O-ring for cooling water jacket, G55	1	L15000	922	
O-ring for cooling water jacket, P31	1	L15000	923	
O-ring, D66.27	4	L23000	405	Only for non-DVT
O-ring for DVT, G65	C	L24100	340	Only for DVT C = Number of Cylinde
O-ring, D66.27	2 x C	L24100	420	Only for DVT C = Number of Cylinde

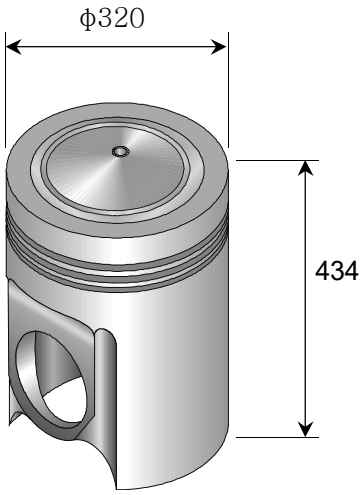
Parts Description	Q'ty	Sec. No.	Item No.	Remark
Piston and connecting rod				
Piston pin	1	L31100	120	
Piston ring, top	1	L31100	151	
Piston ring, 2nd	1	L31100	152	
Piston ring, scraper	1	L31100	153	
Connecting rod bearing	1	L32000	113	
Small-end bush for connecting rod	1	L32000	114	
Connecting rod big end stud, M33	4	L32000	191	
Connecting rod shaft stud, M33	4	L32000	194	
Nut for connecting rod, M33	8	L32000	192	
Cylindrical pin	4	L32000	193	
Shim plate	2	L32000	195	
Gasket for fuel injection valve	15 x C	L52000	196	C = Number of Cylinde
Fuel injection equipment				
Fuel injection pump	1	L51000	100	
Fuel injection valve	N	L52000	100	N : half of maximum. cylinder No.
Fuel high pressure block	1	L52300	100	
Piping system				
Flexible connecting pipe, each type	1 set	L98370	-	
Lube oil Filter, 1st filter, If applied	1 set	L63000	702	Only for LO filter
Centrifugal filter				
Paper insert for centrifugal filter, If applied	1 set	L67000	701	
Air cooler				
Gasket for air cooler cover	1	L84000	111	
Gasket for air cooler cover	1	L84000	131	
Air cooler spare kit	1 set			Maker supply
Turning gear				
Turning gear spare kit	1 set			Maker supply



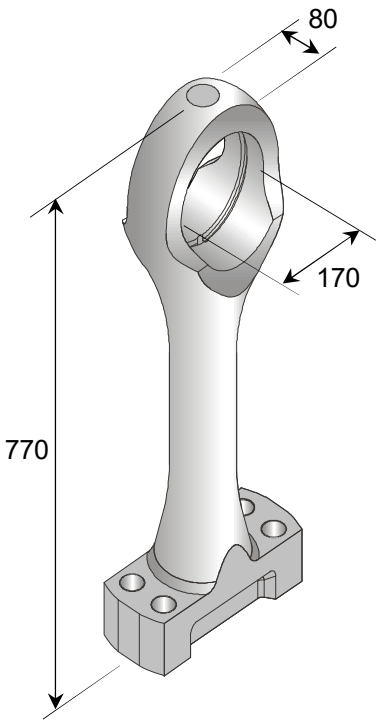
Cylinder head and rocker arms assembly
Approx. 474 kg



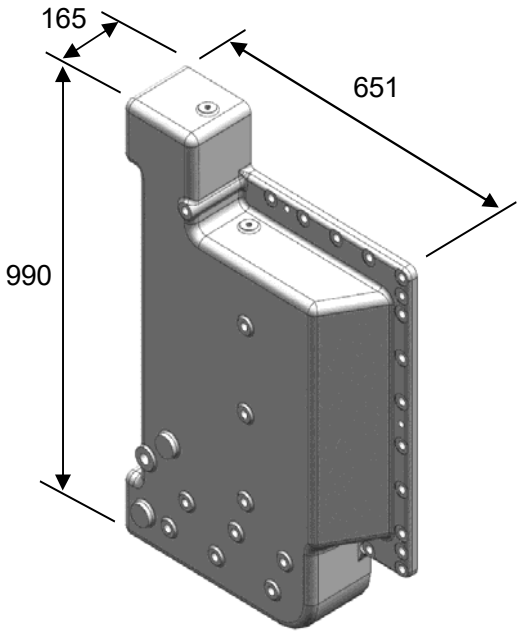
Cylinder liner
Approx. 189 kg



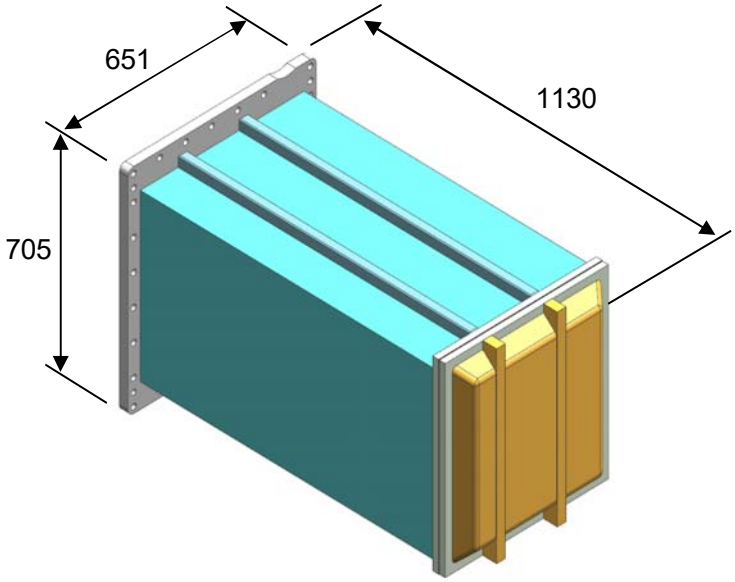
Piston assembly
Approx. 79 kg



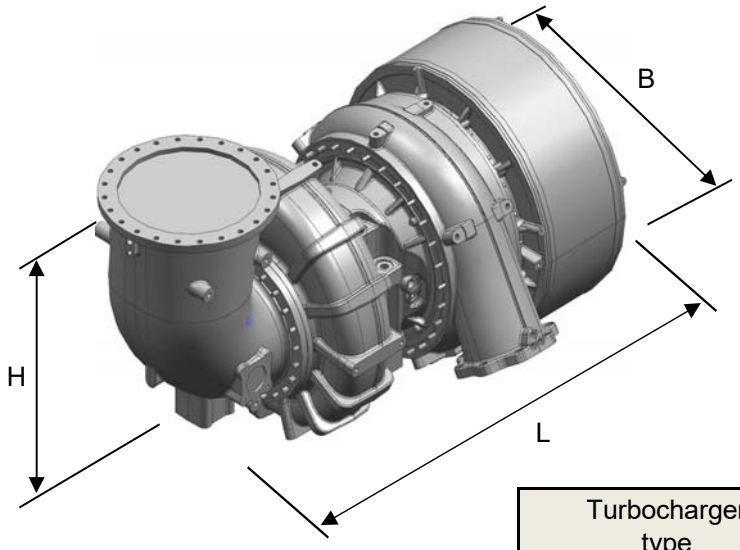
Connecting rod shaft
Approx. 74 kg



Air Cooler Cover
Approx. 154 kg



Air Cooler
Approx. 535 kg



Turbocharger

Turbocharger type	B (mm)	H (mm)	L (mm)	Weight (kg)
ST6	734	827	1,574	582
ST7	870	1,530	1,960	1,270
A145	736	1,227	1,436	750
A150	807	1,310	1,747	970
A155	940	1,559	2,052	1,650

for Stationary Gen-Set

List of minimum Spare Parts for each plant

Parts Description	Q'ty	Sec. No.	Item No.	Remark
Cylinder Head				
Intake valve seat ring	2	L21100	111	
Exhaust valve seat ring	2	L21100	112	
Valve spindle, intake	2	L21200	201	
Valve spindle, exhaust	2	L21200	202	
Fuel Injection Equipment				
Fuel injection pump complete	1	L51000	100	
Fuel injection valve complete	1	L52000	100	
Atomizer for Fuel injection valve	2	L52000	111	
Dowel pin for fuel injection nozzle	4	L52000	102	
Fuel high pressure block ass'y	2	L52300	100	
Sealing & O-ring				
Metal gasket for cylinder liner	1	L15000	191	
O-ring for cooling water jacket	1	L15000	192	
O-ring for cooling water jacket	2	L15000	193	
O-ring for cooling water jacket	1	L15000	901	
O-ring for cooling water jacket	1	L15000	902	
O-ring for cooling water jacket	1	L15000	922	
O-ring for cooling water jacket	1	L15000	923	
Sealing ring for crankcase cover	1	L19300	380	
Sealing ring for camshaft cover	2	L19300	390	
O-ring for exhaust valve seat ring	2	L21100	118	
O-ring for fuel valve bush	2	L21100	119	
O-ring for cylinder head cover, lower	1	L21100	805	
O-ring for cylinder head cover, upper	1	L21100	806	
O-ring for cylinder head	1	L21100	901	
O-ring for cylinder head	4	L21100	291	
O-ring, D66.27	4	L23000	405	Only for non-DVT
O-ring for DVT, G65	C	L24100	340	Only for DVT C = Number of Cylinder.
O-ring for DVT, P66.2	2xC	L24100	420	Only for DVT C = Number of Cylinder.
Thrust washer	CxE	L51000	–	C = Number of Cylinder.
O-ring for fuel injection valve	2	L52000	108	
O-ring for fuel injection valve	2	L52000	109	
Gasket for fuel injection valve	3xC	L52000	196	C = Number of Cylinder.
O-ring for high pressure block	1	L52300	116	
O-ring for high pressure block	1	L52300	117	
O-ring for FO block, D23.16	2xC	L53000	467	C = Number of Cylinder.
O-ring for FO block, D50.17	(4xC)+2	L53000	468	C = Number of Cylinder.
O-ring for FO block, D43.82	4xC	L53000	469	C = Number of Cylinder.
Mechanical seal for C.W pump	1	L71000	209	
O-ring for cooling water connection	4	L78000	460	
Bellows				
Axial compensator for T/C inlet	1	L82000	202	
Gasket for exhaust pipe	1	L82000	401	

for Stationary Gen-Set

List of minimum Spare Parts for each plant

Parts Description	Q'ty	Sec. No.	Item No.	Remark
Sensors & Solenoid valves				
F.O leakage level switch	1	L45220	540	
Level switch with L.O sump tank	1	L45215	680	
Temp. switch (70~120'C)	1	L45230	-	
Press. switch (1~10bar)	1	L45260	-	
Engine rpm pick-up sensor	1	L45210	-	
Press. transmitter (0~6bar)	1	L45260	-	
Press. transmitter (0~10bar)	1	L45260	-	
Press. transmitter (0~16bar)	1	L45260	-	
Press. transmitter (0~40bar)	1	L45260	-	
Temp. transmitter (PT100, L:40)	1	L45230	-	
Temp. transmitter (PT100, L:80)	2	L45230	-	
Temp. transmitter exhaust gas cylinder outlet	1	L45235	-	
Temp. transmitter for T/C inlet	1	L45236	-	
Temp. transmitter for T/C outlet	1	L45237	-	
Temp. transmitter for main bearing	1	L45240	-	
Oil mist detector	1	L45225	-	Option
Amplifer	1	L46002	-	Option

* The list of minimum spare parts stated above is only for guidance as depends on contracts.

List of minimum Tool Parts for each plant

Tool Description	Q'ty	Tool No.	Remark
Cylinder Head and Liner			
Tool for dual valve timing assembly	1	91.063	Only for DVT
Lifting tool for cylinder head	1	91.110	
Fit/Removal device for valve conical clamping piece	1	91.120	
Grinding tool for cylinder head/liner/block	1	91.140	
Extract/Suspension device for cylinder liner	1	91.150	
Cylinder bore gauge	1	91.260	
Removal device for flame ring	1	91.270	
Feeler gauge for in/exh valve	1	91.280	
Lapping device for in/exh valve seat	1	91.360	
Removal device for cooling water connection	1	91.380	
Removal device for exh valve seat	1	91.580	
Air gun	1	91.620	
Plier for locking ring	1	91.940	
Piston and Connecting Rod			
Guide bush for piston	1	91.160	
Lifting tool for piston	1	91.170	
Holding piece for crank pin bearing	2	91.180	
Guide support for con-rod	1	91.200	
Turning bracket for con-rod	1	91.210	
Clamping support for con-rod	2	91.220	
Plier 125 for piston pin locking ring	1	91.240	
Plier for piston ring opener	1	91.250	
Crankshaft and Main Bearing			
Lifting device(Eye bolt M12) for main bearing cap	4	91.290	
Fitting device for main bearing	1	91.300	
Deflection gauge for crankshaft	1	91.310	
Fuel Injection Valve			
Removal device for fuel injection valve	1	91.130	
Test tool for fuel valve nozzle	1	91.340	
Lapping device for injection valve bush	1	91.350	
Cleaning tool for fuel injection valve nozzle	1	91.370	
Removal tool for atomizer nut	1	91.390	
Long socket for nozzle nut	1	91.630	
Removal device for fuel valve bush	1	91.720	

List of minimum Tool Parts for each plant

Tool Description	Q'ty	Tool No.	Remark
Hydraulic Tools			
Hydraulic Jack (M48x3) for cylinder head main bearing cap	4	91.400	
Hydraulic Jack (M39x3) for side stud/counter weight	2	91.410	
Hydraulic Jack (M33x2) for Con-rod shaft/big end	2	91.420	
Angle piece	2	91.421	
Set of spare parts for hyd. jack M48	1	91.430	
Set of spare parts for hyd. jack M39	1	91.440	
Set of spare parts for hyd. jack M33	1	91.450	
Support (hyd. Jack M48) for main bearing cap	2	91.460	
Support (hyd. Jack M39) for side stud/counter weight	2	91.470	
Support (hyd. Jack M48) for cylinder head	4	91.480	
Support (hyd. Jack M33) for Con-rod shaft/big end	2	91.490	
Extension screw (hyd. Jack M48) for cylinder head	4	91.500	
Insert screw (hyd. Jack M33) for Con-rod shaft/big end	2	91.511	
Distributing piece (2-port)	1	91.541	
Distributing piece (4-port)	1	91.542	
High pressure hose (L=800)	4	91.551	
High pressure hose (L=4000)	2	91.552	
Adapter	1	91.552	
Turning pin (Φ10)	2	91.600	
Turning pin (Φ8)	2	91.610	
Pneumatic hydraulic pump	1	91.850	
General Tools			
Max pressure indicator	1	91.100	
Spanner for fuel high pressure block	1	91.330	
Flexible air hose for pneumatic hydraulic pump	1	91.851	
Air cooler jig tool	1	91.920	Only for bolows. - ABB: A150, 155 - KBB: ST7 - MET: 30SCR, 37SR(
Turbocharger cleaning hose valve	1/Eng	91.934	
Tool for air starting valve	1	91.950	
Lapping device for starting valve	1	91.960	
Turbocharger cleaning hose	1	98.100	
Standard Tool Box			
Spare & Tool box	5	91.640	
Supercharging System			
Air cooler tool	1 set	-	Maker supply
Turning Equipment			
Turing gear tool	1 set	-	Maker supply

List of general tools for each plant

Tool Description	Q'ty	Tool No.	Remark
TORQUE WRENCH(20-120NM)	1	91.820	
TORQUE WRENCH(140-760NM)	1	91.830	
TORQUE WRENCH(750-2000NM)	1	91.840	
REDUCER(FROM 3/4" TO 1/2")	1	99.150	
REDUCER(FROM 1" TO 3/4")	1	99.160	
TEE HANDLE 12.5	1	99.170	
EXTENSION BAR 60	1	99.240	
EXTENSION BAR 24-LONG	1	99.460	
SPANNER 8x9	1	99.701	
SPANNER 10x11	1	99.702	
SPANNER 12x14	1	99.703	
SPANNER 13x17	1	99.704	
SPANNER 19x22	1	99.705	
SPANNER 24x27	1	99.706	
SPANNER 30x32	1	99.707	
SPANNER 36x41	1	99.708	
SPANNER 13	1	99.709	
SPANNER 46	1	99.710	
SPANNER 50	1	99.711	
SPANNER 55	1	99.712	
SPANNER 60	1	99.713	
SPANNER 65	1	99.714	
RING SPANNER 24x27	1	99.715	
RING SPANNER 30x32	1	99.716	
RING SPANNER 13x17	1	99.717	
RING SPANNER 19x22	1	99.718	
RING SPANNER 24x27	1	99.719	
RING SPANNER 30x32	1	99.720	
SCREW DRIVER 0.8x5.5	1	99.721	
SCREW DRIVER 1.2x8	1	99.722	
SCREW DRIVER 2x13	1	99.723	
TOMMY BAR 8	1	99.724	
TOMMY BAR 10	1	99.725	
TOMMY BAR 12	1	99.726	
TOMMY BAR 13	1	99.727	
HEXAGON HEAD SPANNER 3	1	99.728	

List of general tools for each plant

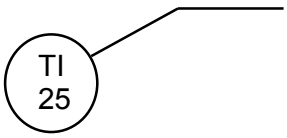
Tool Description	Q'ty	Tool No.	Remark
HEXAGON HEAD SPANNER 4	1	99.729	
HEXAGON HEAD SPANNER 5	1	99.730	
HEXAGON HEAD SPANNER 6	1	99.731	
HEXAGON HEAD SPANNER 8	1	99.732	
HEXAGON HEAD SPANNER 10	1	99.733	
HEXAGON HEAD SPANNER 12	1	99.734	
HEXAGON HEAD SPANNER 14	1	99.735	
HEXAGON HEAD SPANNER 17	1	99.736	
HEXAGON HEAD SPANNER 19	1	99.737	
CROWBAR S550A-15	1	99.738	
EXTENSION BAR 11x1/2"	1	99.739	
EXTENSION BAR 13x1/2"	1	99.740	
EXTENSION BAR 14x1/2"	1	99.741	
EXTENSION BAR 17x1/2"	1	99.742	
EXTENSION BAR 19x1/2"	1	99.743	
EXTENSION BAR 22x1/2"	1	99.744	
EXTENSION BAR 24x1/2"	1	99.745	
EXTENSION BAR 27x1/2"	1	99.746	
EXTENSION BAR 30x1/2"	1	99.747	
EXTENSION BAR 32x1/2"	1	99.748	
EXTENSION BAR 36x1/2"	1	99.749	
EXTENSION BAR 41x1/2"	1	99.750	
EXTENSION BAR 1/2"x125	1	99.751	
EXTENSION BAR 1/2"x250	1	99.752	
UNIVERSAL JOINT 1/2"	1	99.753	
SPANNER 1/2" (12.5)	1	99.755	
PLIERS A10-25	1	99.756	
PLIERS A19-60	1	99.757	
PLIERS C19-60	1	99.758	
PLIERS C32-100	1	99.759	
TOOL BOX	1	99.760	
SOCKET SPANNER 14	1	99.763	

NO.	SYMBOL	SYMBOL DESIGNATION	NO.	SYMBOL	SYMBOL DESIGNATION
1. GENERAL CONVENTIONAL SYMBOLS					
1.1		PIPE	1.6		HIGH PRESSURED PIPE
1.2		PIPE WITH INDICATION OF DIRECTION OF FLOW	1.7		TRACING
1.3		VALVES, GATE VALVES, COCKS AND FLAPS	1.8		ENCLOSURE FOR SEVERAL COMPONENTS ASSEMBLED IN ONE UNIT
1.4		APPLIANCES			
1.5		INDICATING AND MEASURING INSTRUMENTS			
2. PIPES AND PIPE JOINT					
2.1		CROSSING PIPES, NOT CONNECTED	2.13		BLANK FLANGE
2.2		CROSSING PIPES, CONNECTED	2.14		SPECTACLE FLANGE
2.3		TEE PIPE	2.15		BULKHEAD FITTING WATER TIGHT, FLANGED
2.4		FLEXIBLE PIPE	2.16		BULKHEAD CROSSING, NON-WATERTIGHT
2.5		EXPANSION PIPE (CORRUGATED) GENERAL	2.17		TEST PIECE WITH PLUG
2.6		JOINT, SCREWED	2.18		ORIFICE
2.7		JOINT, FLANGED	2.19		REDUCER
2.8		JOINT, SLEEVE	2.20		OPEN DRAIN & AIR VENT
2.9		JOINT, HOSE COUPLING	2.21		ORIFICE
2.10		EXPANSION JOINT WITH GLAND	2.22		LOOP EXPANSION JOINT
2.11		EXPANSION PIPE	2.23		SNAP-COUPLING
2.12		CAP NUT			
3. VALVES, GATE VALVES, COCKS AND FLAPS					
3.1		VALVE, STRAIGHT THROUGH	3.10		FLAP, ANGLE
3.2		VALVE, ANGLE	3.11		REDUCING VALVE
3.3		STOP VALVE (SCREW ENDED)	3.12		SAFETY VALVE
3.4		VALVE, THREE-WAY	3.13		ANGLE SAFETY VALVE
3.5		NON-RETURN VALVE(FLAP) STRAIGHT	3.14		SELF-CLOSING VALVE
3.6		NON-RETURN VALVE(FLAP) ANGLE	3.15		QUICK-OPENING VALVE
3.7		NON-RETURN VALVE(FLAP) STRAIGHT, SCREW DOWN	3.16		QUICK-CLOSING VALVE
3.8		NON-RETURN VALVE(FLAP) ANGLE, SCREW DOWN	3.17		REGULATING VALVE
3.9		FLAP, STRAIGHT THROUGH	3.18		ANGLE VALVE

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

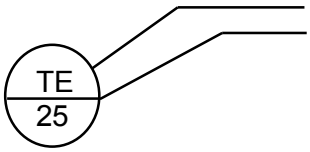
NO.	SYMBOL	SYMBOL DESIGNATION	NO.	SYMBOL	SYMBOL DESIGNATION
5.5		SEPARATOR	5.16		AIR FILTER WITH MANUAL CONTROL
5.6		STEAM TRAP	5.17		AIR FILTER WITH AUTOMATIC DRAIN
5.7		CENTRIFUGAL PUMP	5.18		WATER TRAP WITH MANUAL CONTROL
5.8		GEAR-OR SCREW PUMP	5.19		AIR LUBRICATOR
5.9		HAND PUMP(BUCKET)	5.20		SILENCER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

Symbol explanation



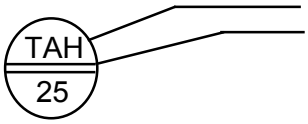
Measuring device Locally reading

Temperature Indicator No. 25*



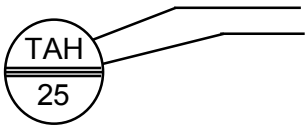
Measuring device
Sensor mounted on engine/unit
Reading/identification mounted in a panel on the engine/unit

Temperature element No. 25*



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

Temperature Alarm High No. 25*



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

Temperature Alarm High No. 25*

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

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

General

Standard text for instruments

Diesel engine / generator

1. Combustion gas system

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

2. Compressed air system

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

3. Fuel oil system

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

4. Lub. oil system

61 Lub. oil at filter inlet
62 Lub. oil at engine inlet
63 Lub. oil at TC inlet
65 Prelubricating
68 Level in base frame
92 Oil mist detector

5. Cooling water system

71 L.T. water at air cooler inlet
72 L.T. water at air cooler outlet
75 H.T. water at engine inlet
76 H.T. water at engine outlet
77 H.T. water each cyl. outlet

NOTES

Global Leader

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