PROJECT GUIDE

HiMSEN H35/40GV
FOR STATIONARY

HYUNDAI HEAVY INDUSTRIES
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 H35/40GV gas generating sets(gen-set).

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

The HiMSEN H35/40GV 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 'H35/40GV', and 'Sheet No.' for easier communications.

ENGINE MODEL DESIGNATION

12 H 35 / 40 G V

- 12 — No. of Cylinders
- H — HYUNDAI's HiMSEN
- 35 — Cylinder Bore in cm
- 40 — Piston Stroke in cm
- G — Gas Engine
- V — Vee-type Configuration

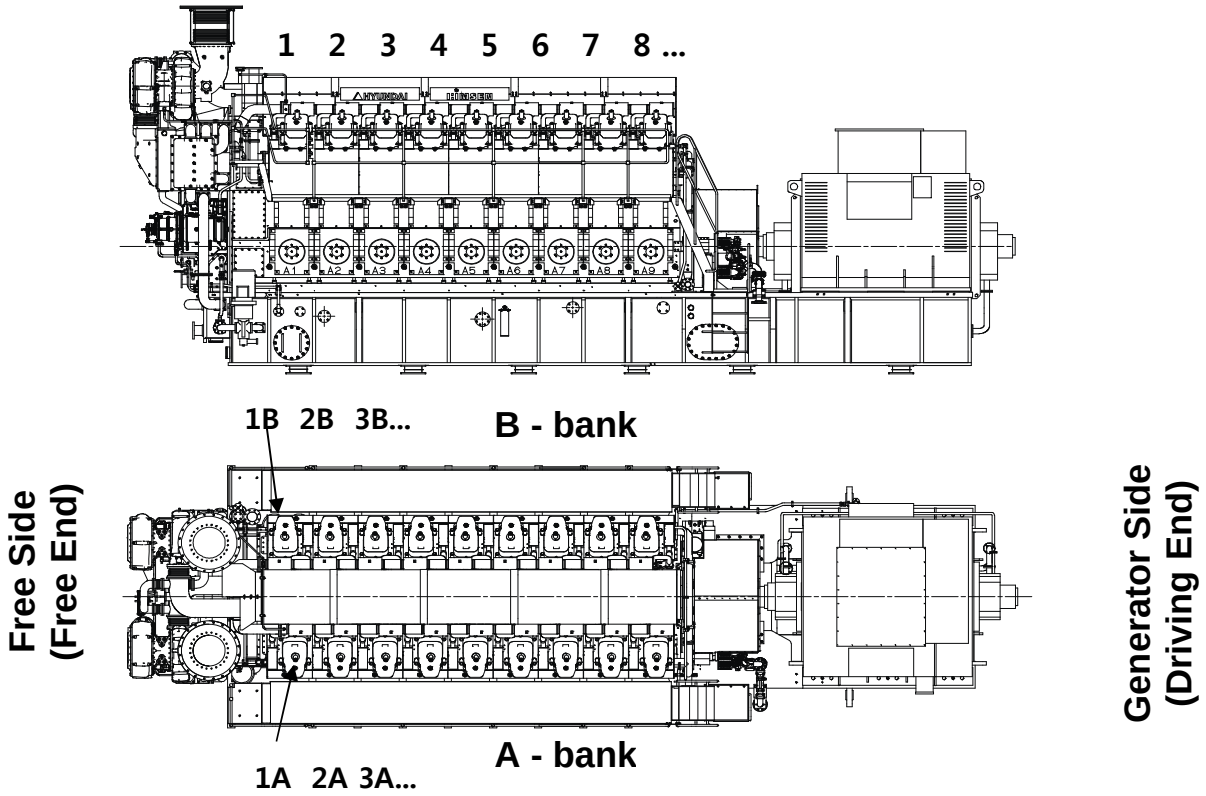
SHEET NUMBER

P . XX . XXX

- P — Project Guide Book
- XX — Section number
- XXX — Sub Section with Serial number

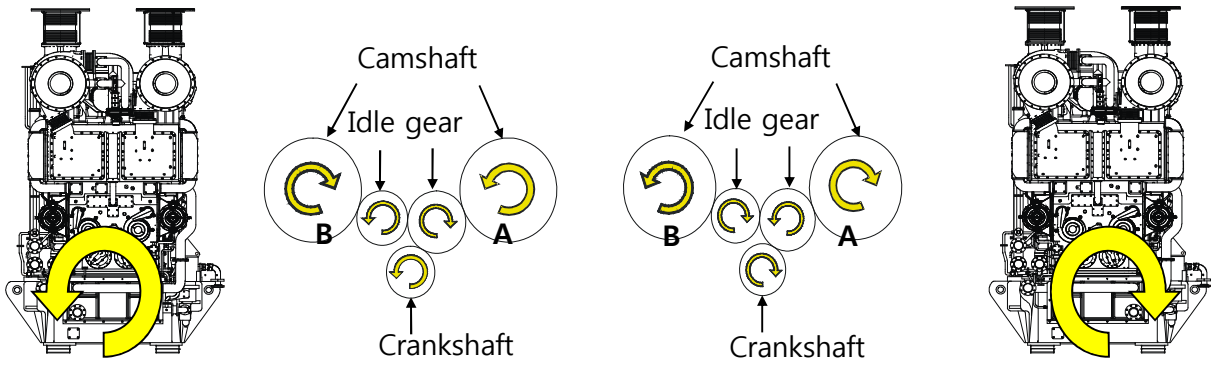
Mar. 2023

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)

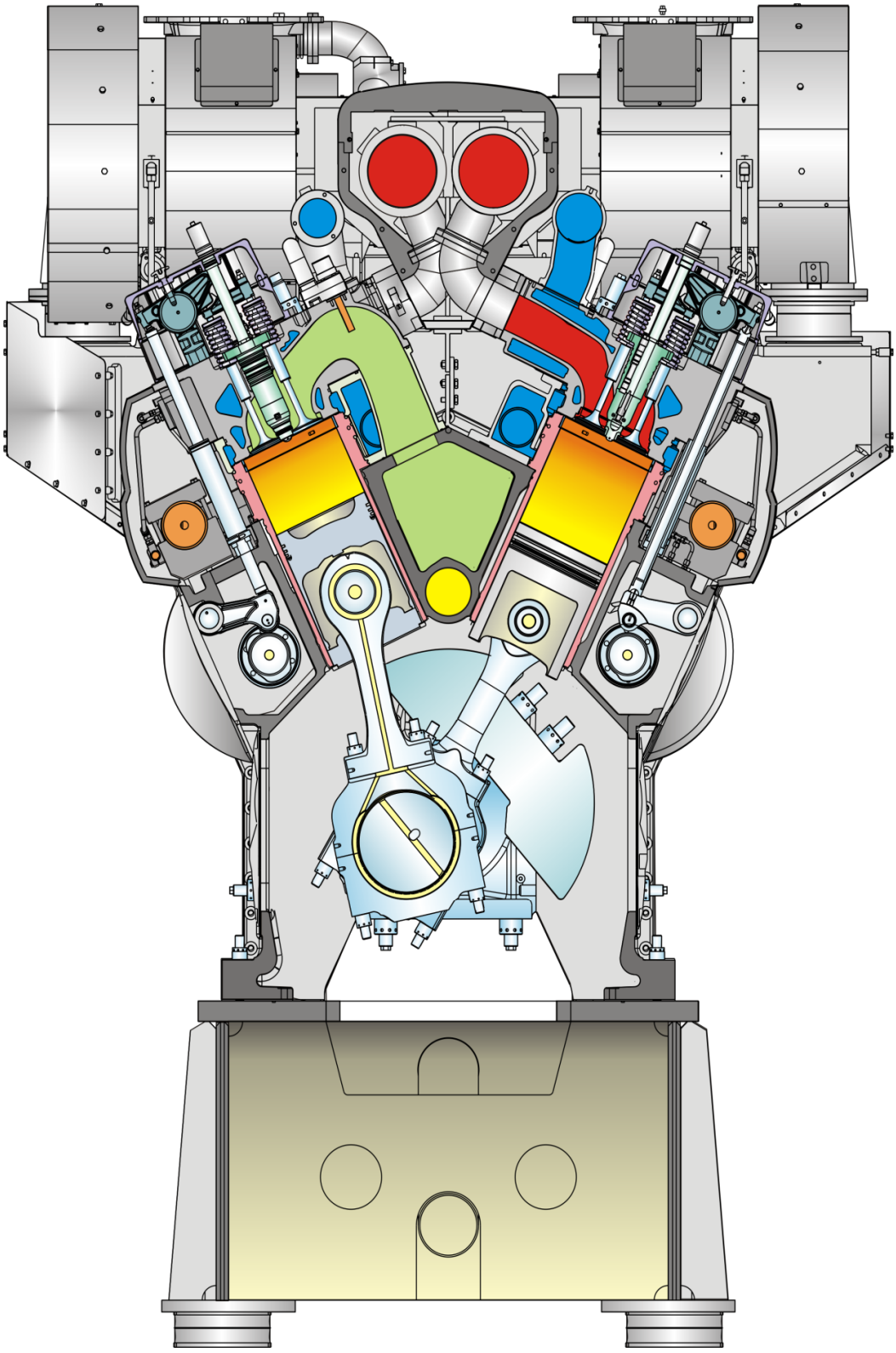
(CW)

(CCW)

Counterclockwise Engine
(Viewed from Free End)

Type of Engine		**4-stroke, Turbocharged and inter-cooled, Prechamber ignited lean-burn gas engine**
Cylinder Configuration		**Vee**
Number of Cylinder		**12 - 14 - 16 - 18 - 20**
Rated Speed	**rpm**	**720 750**
Max. Power per Cylinder	**kW**	**480 500**
Cylinder Bore	**mm**	**350**
Piston Stroke	**mm**	**400**
Swept Volume per Cylinder	**dm³**	**38.5**
Mean Piston Speed	**m/s**	**9.6 10.0**
Mean Effective Pressure	**bar**	**20.8**
Compression Ratio		**13.0 : 1 ***
Direction of Engine Rotation		**Clockwise viewed from Generator Side (Non-Reversible)**
Cylinder Firing Order	**12H35GV**	**1 - 4 - 2 - 6 - 3 - 5**
	14H35GV	**1 - 2 - 4 - 6 - 7 - 5 - 3**
	16H35GV	**1 - 3 - 5 - 7 - 8 - 6 - 4 - 2**
	18H35GV	**1 - 3 - 5 - 7 - 9 - 8 - 6 - 4 - 2**
	20H35GV	**1 - 5 - 9 - 4 - 3 - 10 - 6 - 2 - 7 - 8**

*) Compression ratio can be lowered depending on site conditions and fuel gas.



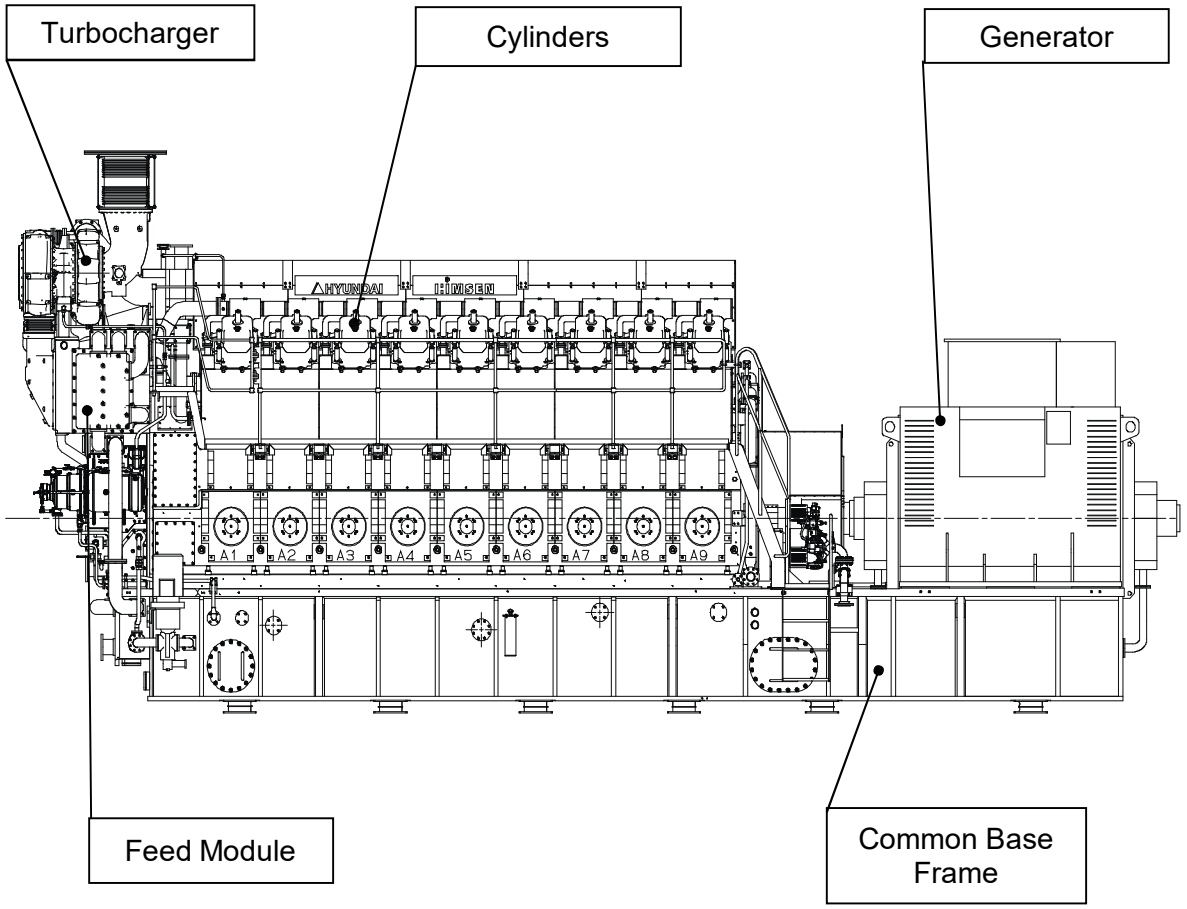
1. General

Hyundai's Stationary Genset 'HiMSEN H35/40GV' Family have simple and smart design suitable for stationary application with high reliability and performance. The key features are summarized as below ;

1. **Lean-burn gas engine** with pre-chamber spark ignition and individual feeding concept operated with natural gas.

2. **Economical and Ecological Engine** with the lowest fuel consumption and NOx emission which are based on the following specific designs ;
   - High air fuel ratio
   - Optimized combustion parameters, i.e. spark plug with pre-chamber, piston bowl, and intake air parts, etc.

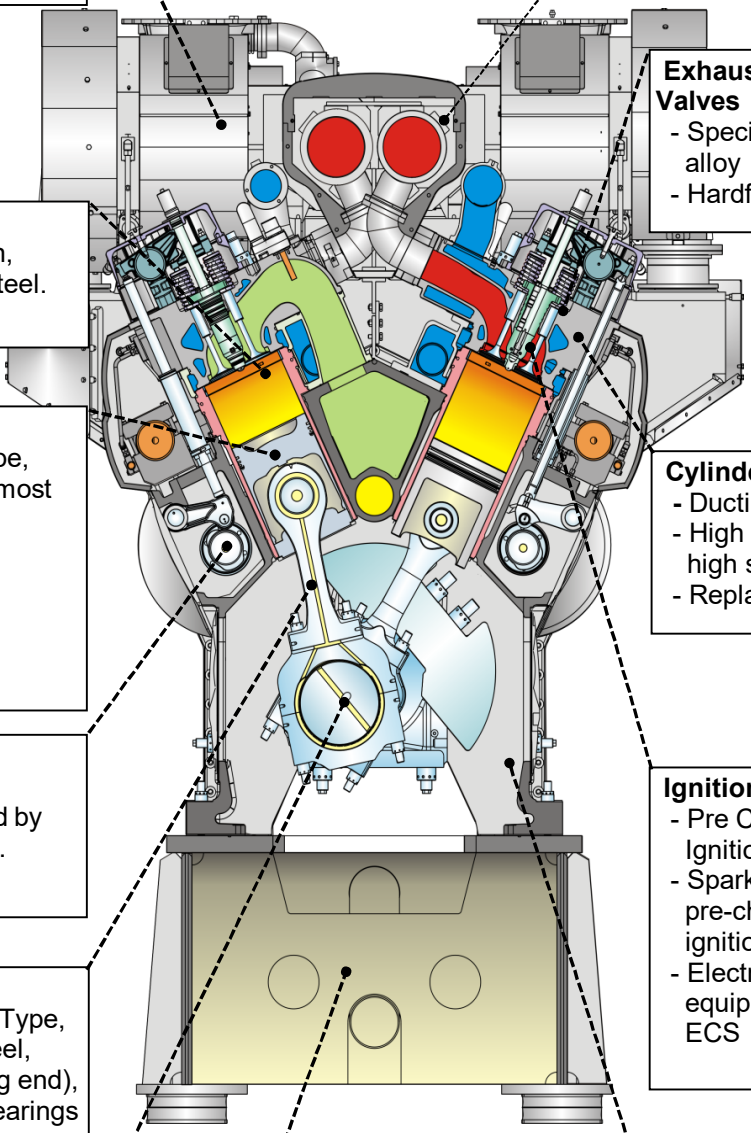
3. **Reliable and Practical Engine** with simple, smart and robust structure.
   - A number of engine components are minimized with pipe-free design
   - Most of the components are directly accessible for easy maintenance
   - Maintenance concept for each parts is to be provided
   - Feed system is fully modularized with direct accessibility
   - Highly integrated control system
   - Raven components are applied
   - Free from gas leakage
   - Up-to-date technology is adopted



2. Design of Main Components

Air & Exhaust gas system
- High efficiency turbocharger
- Exhaust gas wastegate valve system

Exhaust System
- MPC type



Exhaust and Intake Valves
- Special heat resistant alloy Steel,
- Hardfacing welded Seats

Cylinder liner
- Special alloy cast iron,
- Flame Ring of alloy steel.

Piston
- 2-piece composite type,
- High turbulence and most effective bowl shape
- Special forged alloy steel crown
- 2 Compression rings,
- 1 Oil Scraper ring.

Cylinder Head
- Ductile Cast Iron,
- High swirl intake ports for high swirl
- Replaceable Valve Seats.

Camshaft
- Die forged alloy steel
- Cam Profile optimized by Hermite Spline Curve.

Ignition system
- Pre Chamber Spark Ignition,
- Spark plug with pre-chamber amplifying ignition energy
- Electronic ignition equipment controlled by ECS

Connecting Rod
- 3 piece Marine Head Type,
- Special die-forged steel,
- Hydraulic fastners (big end),
- Aluminum bi-metal Bearings with large bearing area.

Crankshaft
- Continuous grain Flow die forged alloy steel,
- Aluminum bi-metal bearings with large bearing areas.

Engine Block
- Grey cast iron mono block,
- No water, no corrosion,
- Optimized Air Chamber,
- Large Crankcase Door for easier Maintenance.

Common Base Frame
- Steel Plated welded,
- Robust Structure,
- Large Oil Capacity,
- Resilient Mounting.

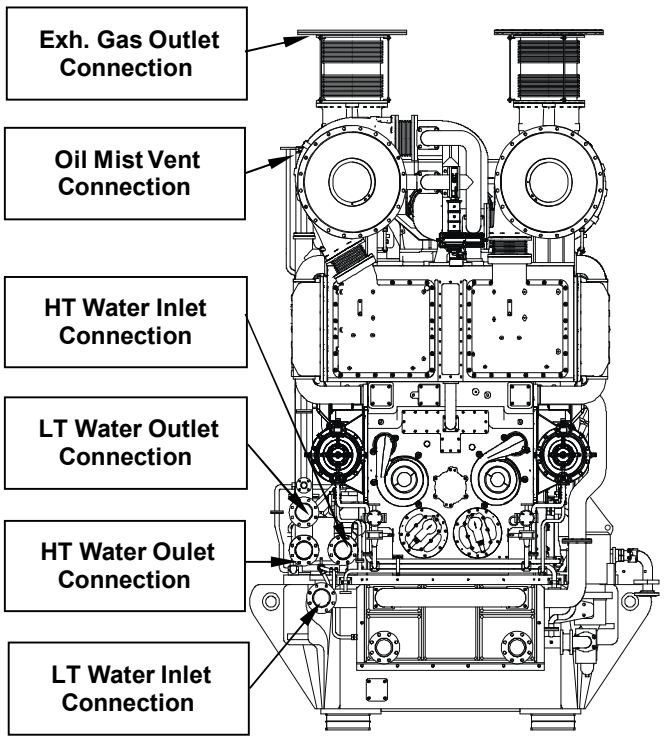
3. Description of Feed Module

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;

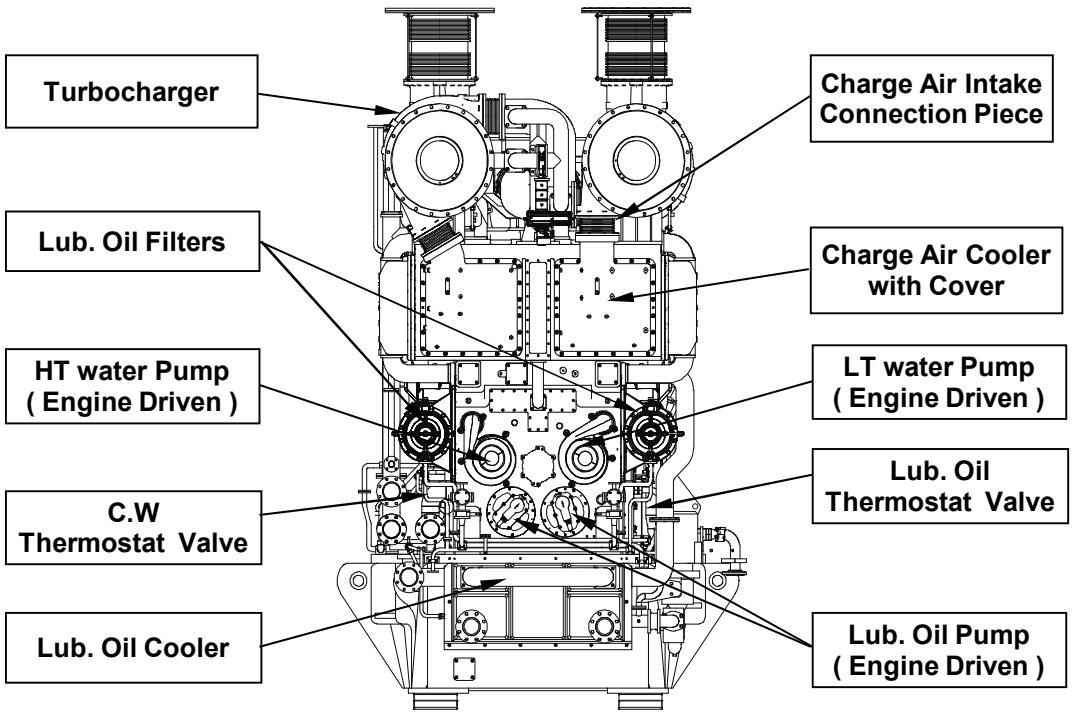
- All the components of the system, for example, pumps, valves, filters and coolers, are mounted on Feed Block without any pipe connection, which provides direct accessibility with fewer parts for easier maintenance as shown below.

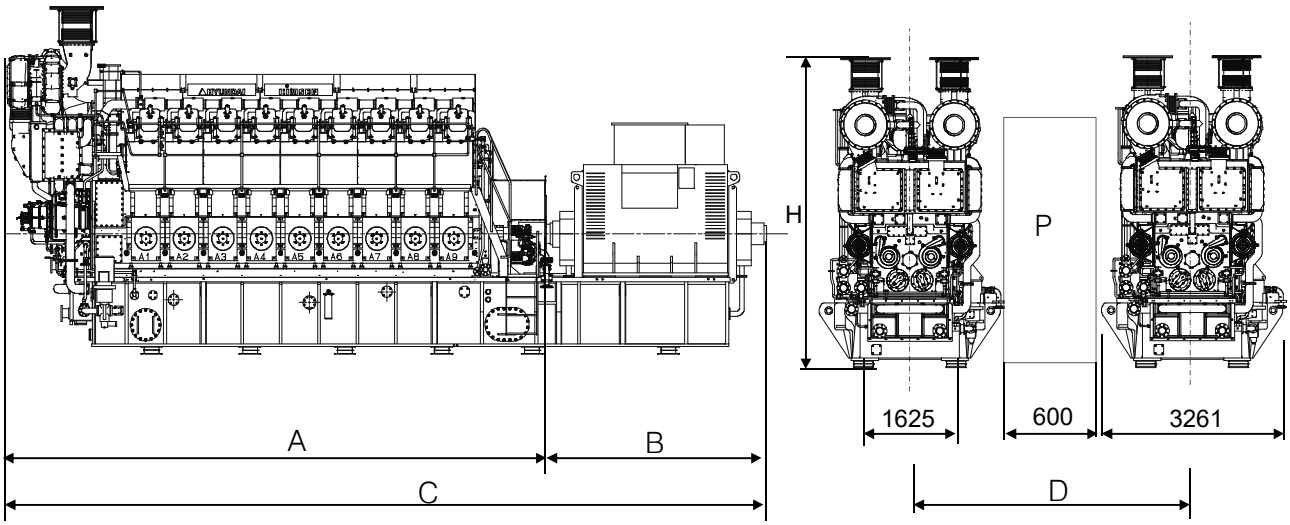
- Feed Block has cast-in flow channels for Cooling Water and Lub Oil circuits, which are arranged to secure water-tight to oil space and simplified in combination with pumps and valve housings for better flow characteristics to avoid any risk of corrosion due to cavitation.

Outline of Feed Module



Disassembly of Feed Module





Genset for 720 / 750rpm (480 kW/cyl.)

Engine type	Dimension (mm)					Dry Weight (ton) 2)	
	A	B 1)	C 1)	D	H 5)	Engine 3)	Genset 1),4)
12H35/40GV	6,624	3,760	10,384	4,405	4,723	56.0	108.8
14H35/40GV	7,295	3,860	11,155	4,405	4,723	63.3	121.3
16H35/40GV	7,914	3,479	11,393	4,405	4,723	69.1	130.9
18H35/40GV	8,585	3,859	12,444	4,405	4,794	76.3	141.2
20H35/40GV	9,344	3,659	13,003	4,405	4,794	84.0	153.9

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 (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

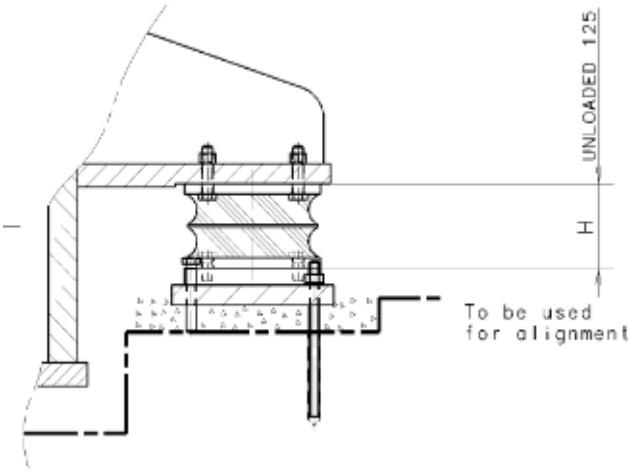
General

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



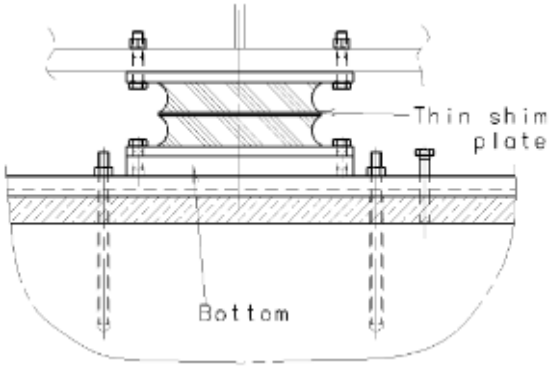
< Resilient mounting >

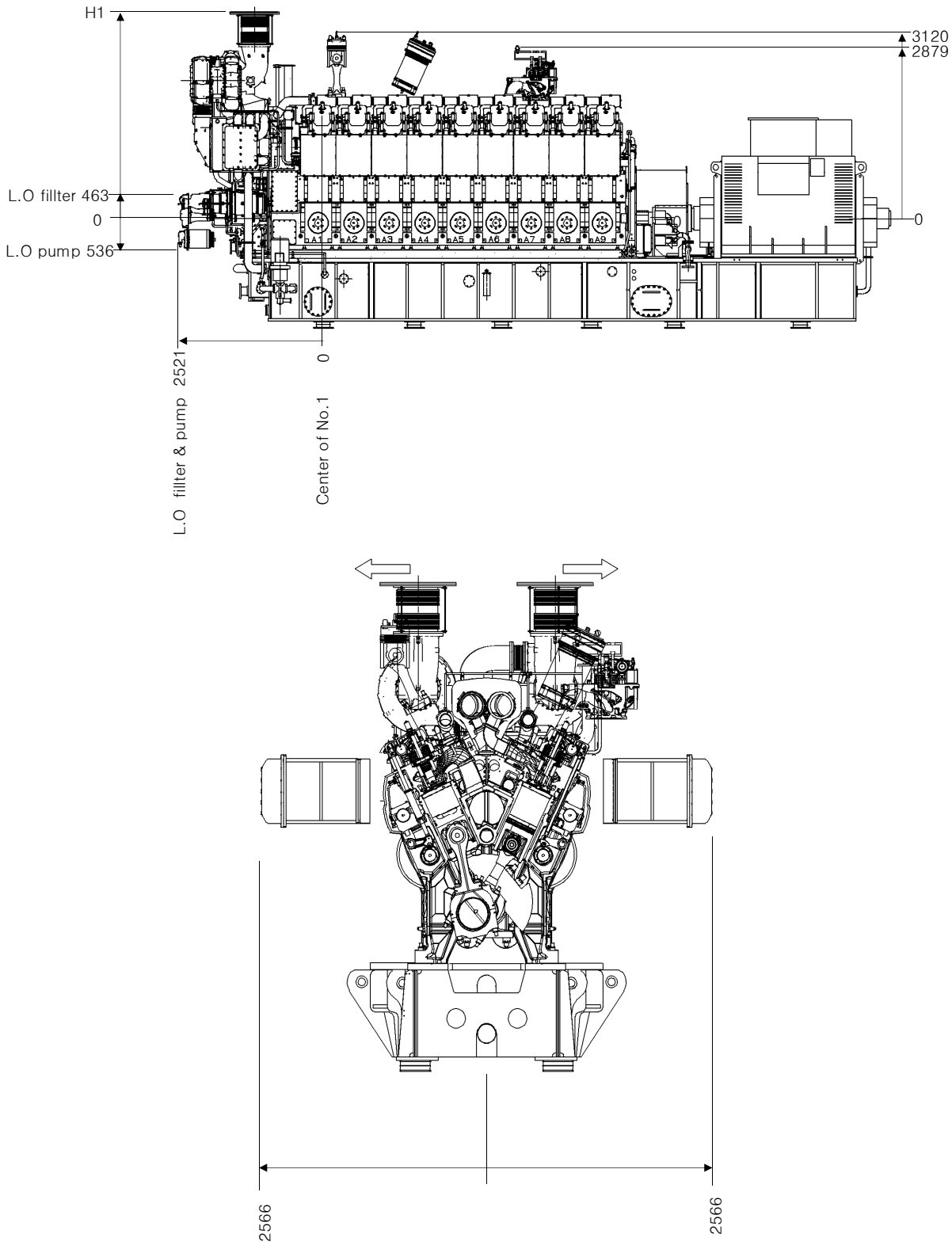
Connections to the Generating-set (for resilient mounting)

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= 2903 mm, for 12H35/40GV
H1= 2903 mm, for 14H35/40GV
H1= 3474 mm, for 16H35/40GV
H1= 3474 mm, for 18H35/40GV
H1= 3474 mm, for 20H35/40GV

Engine Type	Rated Output at			
	720 rpm / 60Hz		750 rpm / 50Hz	
	Engine (kW_m)	Generator (kW_e)	Engine (kW_m)	Generator (kW_e)
12H35GV	5,760	5,558	6,000	5,790
14H35GV	6,720	6,518	7,000	6,790
16H35GV	7,680	7,449	8,000	7,760
18H35GV	8,640	8,380	9,000	8,730
20H35GV	9,600	9,312	10,000	9,700

Remark : 1) The alternator outputs are calculated for an efficiency of 96~96.5%(Inline), 96.5~97%(V-type) and a power factor of 0.8 lagging.
2) Power adjusting within -5% derating is generally accepted, other power adjusting must be consulted to engine builder.
3) No overload operation is permissible caused by higher risk of gas knocking.

Reference Condition

General definition of gas engine rating is specified in accordance with ISO 3046-1.
The engine outputs are available within HHI condition without derating (refer to the P.02.630)

ISO Conditions

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

720 rpm/60 Hz (480 kW/cyl.)

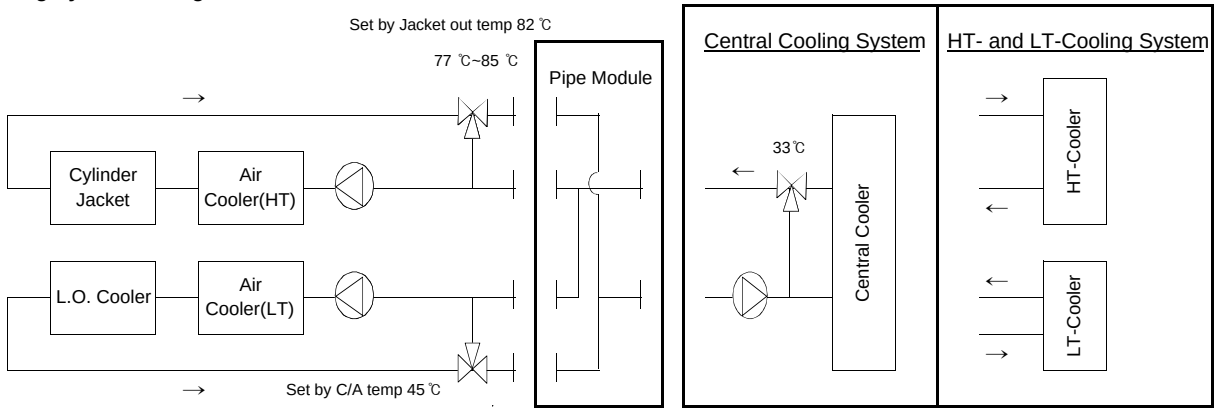
Engine MCR		Cyl. / kW	12 / 5760	14 / 6720	16 / 7680	18 / 8640	20 / 9600
COOLING CAPACITIES							
Charge Air							
HT- Heat dissipation 1)		kW	1305	1522	1740	1957	2175
LT- Heat dissipation 1)		kW	477	557	636	716	796
Cooling water flow (HT & LT)		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	33 / 36	33 / 36	33 / 36	33 / 36	33 / 36
Lubricating Oil							
Heat dissipation 1)		kW	802	936	1070	1198	1337
LT-cooling water flow		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	36 / 41	36 / 42	36 / 42	37 / 43	36 / 42
Cylinder Jacket							
Heat dissipation 1)		kW	853	995	1137	1274	1422
HT-cooling water flow		m³/h	140	140	170	170	200
HT-cooling water temperature, engine	in / out	℃	69 / 82	67 / 82	67 / 82	66 / 82	67 / 82
GAS DATA 2)							
Air flow		kg/h	32800	38270	43740	49210	54670
Exhaust gas flow		kg/h	33790	39420	45060	50690	56320
Exhaust gas temperature		℃	335	335	335	335	335
Allowable exhaust gas back pressure	max.	mbar	30	30	30	30	30
HEAT RADIATION							
Engine radiation 1)		kW	255	297	340	380	424
Alternator radiation		kW					
STARTING AIR							
Air consumption per start		Nm³	7.33	8.56	9.78	11.00	14.20
Starting air source, pressure (20℃)	max. / min.	bar	30 / 20	30 / 20	30 / 20	30 / 20	30 / 20
PUMP CAPACITIES							
Engine Driven Pumps 3)							
Lubricating oil pump	(6 bar)	m³/h	95 x 2	95 x 2	110 x 2	110 x 2	120 x 2
HT-cooling water pump	(1~2.5 bar)	m³/h	140	140	170	170	200
LT-cooling water pump	(1~2.5 bar)	m³/h	140	140	170	170	200

Remark : 1) Under HHI Condition with flow tolerance +/-5%

2) Under ISO Condition with flow tolerance +/-5% and exhaust gas temperature tolerance -/+25 ℃
Heat dissipation of charge air is based on HT cooling water system (Air cooler HT → cylinder jacket)

3) Flow capcity tolerance +10%

Cooling System Arrangement



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

Engine MCR		Cyl. / kW	12 / 6000	14 / 7000	16 / 8000	18 / 9000	20 / 10000
COOLING CAPACITIES							
Charge Air							
HT- Heat dissipation 1)		kW	1305	1522	1740	1957	2175
LT- Heat dissipation 1)		kW	477	557	636	716	796
Cooling water flow (HT & LT)		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	33 / 36	33 / 36	33 / 36	33 / 37	33 / 36
Lubricating Oil							
Heat dissipation 1)		kW	836	975	1114	1253	1393
LT-cooling water flow		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	36 / 41	36 / 42	36 / 42	37 / 43	36 / 42
Cylinder Jacket							
Heat dissipation 1)		kW	889	1037	1185	1333	1481
HT-cooling water flow		m³/h	140	140	170	170	200
HT-cooling water temperature, engine	in / out	℃	69 / 82	66 / 82	67 / 82	65 / 82	66 / 82
GAS DATA 2)							
Air flow		kg/h	32800	38270	43740	49210	54670
Exhaust gas flow		kg/h	33840	39480	45120	50760	56400
Exhaust gas temperature		℃	335	335	335	335	335
Allowable exhaust gas back pressure	max.	mbar	30	30	30	30	30
HEAT RADIATION							
Engine radiation 1)		kW	265	309	354	398	442
Alternator radiation		kW					
STARTING AIR							
Air consumption per start		Nm³	7.33	8.56	9.78	11.00	14.20
Starting air source, pressure (20℃)	max. / min.	bar	30 / 20	30 / 20	30 / 20	30 / 20	30 / 20
PUMP CAPACITIES							
Engine Driven Pumps 3)							
Lubricating oil pump	(6 bar)	m³/h	99 x 2	99 x 2	115 x 2	115 x 2	125 x 2
HT-cooling water pump	(1~2.5 bar)	m³/h	140	140	170	170	200
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3) Flow capcity tolerance +10%

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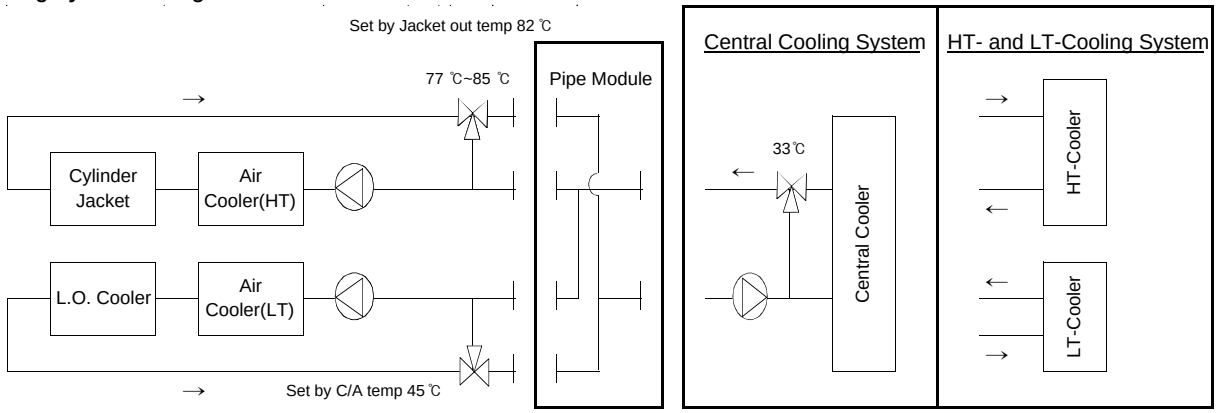

720 rpm/60 Hz (480 kW/cyl.)

Engine MCR - new HT system		Cyl. / kW	12 / 5760	14 / 6720	16 / 7680	18 / 8640	20 / 9600
COOLING CAPACITIES							
Charge Air							
HT- Heat dissipation 1)		kW	1201	1401	1601	1801	2001
LT- Heat dissipation 1)		kW	581	678	775	872	969
Cooling water flow (HT & LT)		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	33 / 37	33 / 37	33 / 37	33 / 37	33 / 37
Lubricating Oil							
Heat dissipation 1)		kW	802	936	1070	1203	1337
LT-cooling water flow		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	37 / 42	37 / 43	37 / 42	37 / 44	37 / 43
Cylinder Jacket							
Heat dissipation 1)		kW	853	995	1137	1280	1422
HT-cooling water flow		m³/h	140	140	170	170	200
HT-cooling water temperature, engine	in / out	℃	77 / 89	76 / 91	76 / 90	76 / 91	76 / 91
GAS DATA 2)							
Air flow		kg/h	32800	38270	43740	49210	54670
Exhaust gas flow		kg/h	33790	39420	45060	50690	56320
Exhaust gas temperature		℃	335	335	335	335	335
Allowable exhaust gas back pressure	max.	mbar	30	30	30	30	30
HEAT RADIATION							
Engine radiation 1)		kW	255	297	340	382	424
Alternator radiation		kW					
STARTING AIR							
Air consumption per start		Nm³	7.33	8.56	9.78	11.00	14.20
Starting air source, pressure (20℃)	max. / min.	bar	30 / 20	30 / 20	30 / 20	30 / 20	30 / 20
PUMP CAPACITIES							
Engine Driven Pumps 3)							
Lubricating oil pump	(6 bar)	m³/h	95 x 2	95 x 2	110 x 2	110 x 2	120 x 2
HT-cooling water pump	(1~2.5 bar)	m³/h	140	140	170	170	200
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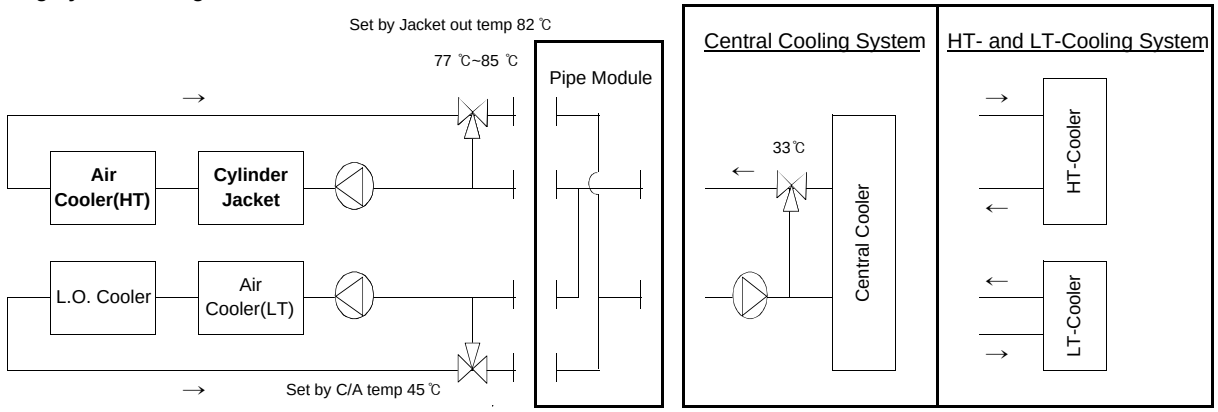
Heat dissipation of charge air is based on HT cooling water system (Cylinder jacket → Air cooler HT)

3) Flow capcity tolerance +10%

Cooling System Arrangement



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

Engine MCR- new HT system		Cyl. / kW	12 / 6000	14 / 7000	16 / 8000	18 / 9000	20 / 10000
COOLING CAPACITIES							
Charge Air							
HT- Heat dissipation 1)		kW	1201	1401	1601	1801	2001
LT- Heat dissipation 1)		kW	581	678	775	872	969
Cooling water flow (HT & LT)		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	33 / 37	33 / 37	33 / 37	33 / 37	33 / 37
Lubricating Oil							
Heat dissipation 1)		kW	836	975	1114	1253	1393
LT-cooling water flow		m³/h	140	140	170	170	200
LT-cooling water temperature, cooler	in / out	℃	37 / 42	37 / 43	37 / 43	37 / 44	37 / 43
Cylinder Jacket							
Heat dissipation 1)		kW	889	1037	1185	1333	1481
HT-cooling water flow		m³/h	140	140	170	170	200
HT-cooling water temperature, engine	in / out	℃	77 / 89	76 / 91	76 / 90	75 / 91	76 / 91
GAS DATA 2)							
Air flow		kg/h	32800	38270	43740	49210	54670
Exhaust gas flow		kg/h	33840	39480	45120	50760	56400
Exhaust gas temperature		℃	335	335	335	335	335
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Alternator radiation		kW					
STARTING AIR							
Air consumption per start		Nm³	7.33	8.56	9.78	11.00	14.20
Starting air source, pressure (20℃)	max. / min.	bar	30 / 20	30 / 20	30 / 20	30 / 20	30 / 20
PUMP CAPACITIES							
Engine Driven Pumps 3)							
Lubricating oil pump	(6 bar)	m³/h	99 x 2	99 x 2	115 x 2	115 x 2	125 x 2
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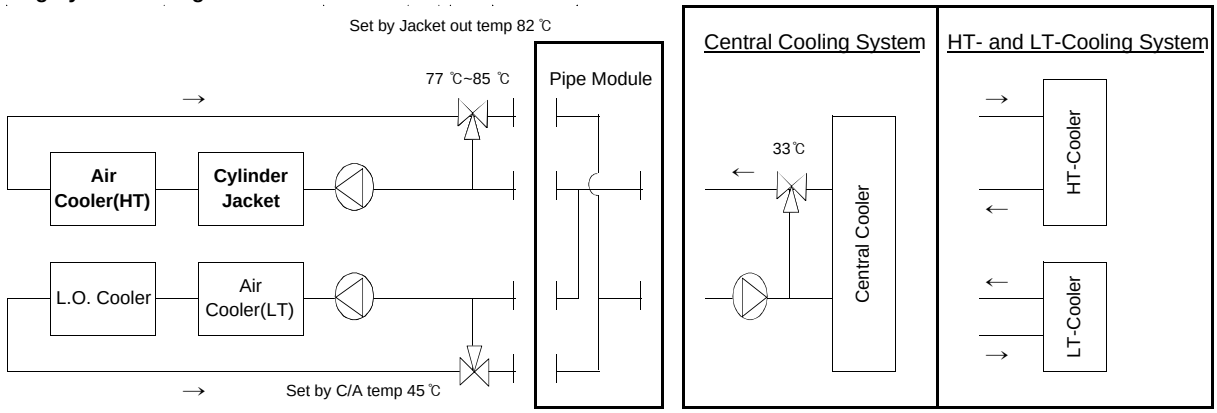
Cooling System Arrangement



1. Engine Performance Data

Rated Power : 480 kW/cyl. at 720 rpm

Performance Data - 720 rpm		Engine Load (%)			
		100	90	75	50
CYLINDER DATA					
Cylinder Output	kW	**480**	432	360	240
Mean Effective Pressure	bar	**20.8**	18.7	15.6	10.4
GAS MIXTURE DATA 1)					
Air Consumption	kg/kWh	**5.70**	5.80	5.86	5.97
Heat Rate 2)	kJ/kWh	**7547**	7613	7797	8406
Pressure after Compressor (abs.)	bar	**4.5**	4.1	3.4	2.3
Temperature after Compressor	°C	**225**	215	195	140
Temperature after Cooler	°C	**45**	45	45	45
EXHAUST GAS DATA 1)					
Mass Flow	kg/kWh	**5.87**	5.97	6.03	6.16
Gas Temperature after Cylinder, MV	°C	**485**	475	470	475
Gas Temperature before Turbine	°C	**520**	510	505	515
Gas Temperature after Turbine	°C	**335**	340	360	420
HEAT BALANCE DATA 3)					
Charge Air, Stage 1(HT)	kJ/kWh	**815**	770	610	240
Charge Air, Stage 2(LT)	kJ/kWh	**300**	320	340	370
Lubricating Oil	kJ/kWh	**500**	530	575	800
Jacket Cooling Water	kJ/kWh	**535**	530	525	425
Exhaust Gas	kJ/kWh	**1895**	2070	2370	3100
Radiation	kJ/kWh	**160**	160	165	175

Remarks

1) Reference condition based on ISO 3046/1 (air press. 1 bar, intake air temp. 25 °C, cooling water temp. 25 °C)
Mass flow tolerance +/-5%, gas temperature tolerance -/+25 °C
Heat Rate tolerance +5% at 100% load based on TA Luft
Engine driven pumps attached : Lube oil pump, HT-pump, LT-pump
Fuel gas based on LNG, LCV 36 MJ/Nm³ (≒50MJ/kg), MN 80
Warranted at 100% load

2) If there is no engine driven pump, the Heat Rate at MCR can be reduced approximately as follows:

Pump Type	Heat Rate [kJ/kWh]
Lub. Oil pump	88
L.T Cooling water pump	44
H.T. Cooling water pump	44

3) Heat dissipation tolerance ±10% for cooler, ±15% for heat recovery.
Heat dissipation of charge air is based on HT cooling water system " HT CW (Air cooler -> Cylinder jacket)"

1. Engine Performance Data

Rated Power : 480 kW/cyl. at 720 rpm

Performance Data - 720 rpm		Engine Load (%)			
		100	90	75	50
CYLINDER DATA					
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Mean Effective Pressure	bar	**20.8**	18.7	15.6	10.4
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Temperature after Compressor	°C	**225**	215	195	140
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Gas Temperature after Cylinder, MV	°C	**485**	475	470	475
Gas Temperature before Turbine	°C	**520**	510	505	515
Gas Temperature after Turbine	°C	**335**	340	360	420
HEAT BALANCE DATA 3)					
Charge Air, Stage 1(HT)	kJ/kWh	**750**	735	640	375
Charge Air, Stage 2(LT)	kJ/kWh	**365**	355	310	235
Lubricating Oil	kJ/kWh	**500**	530	575	800
Jacket Cooling Water	kJ/kWh	**535**	530	525	425
Exhaust Gas	kJ/kWh	**1895**	2070	2370	3100
Radiation	kJ/kWh	**160**	160	165	175

Remarks

1) Reference condition based on ISO 3046/1 (air press. 1 bar, intake air temp. 25 °C, cooling water temp. 25 °C)
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Lub. Oil pump	88
L.T Cooling water pump	44
H.T. Cooling water pump	44

3) Heat dissipation tolerance ±10% for cooler, ±15% for heat recovery.
Heat dissipation of charge air is based on HT cooling water system " HT CW (Cylinder jacket -> Air cooler)"

1. Engine Performance Data

Rated Power : 500 kW/cyl. at 750 rpm

Performance Data - 750 rpm		Engine Load (%)			
		100	90	75	50
CYLINDER DATA					
Cylinder Output	kW	**500**	450	375	250
Mean Effective Pressure	bar	**20.8**	18.7	15.6	10.4
GAS MIXTURE DATA 1)					
Air Consumption	kg/kWh	**5.47**	5.57	5.62	5.73
Heat Rate 2)	kJ/kWh	**7579**	7645	7829	8441
Pressure after Compressor (abs.)	bar	**4.5**	4.1	3.4	2.3
Temperature after Compressor	°C	**225**	215	195	140
Temperature after Cooler	°C	**45**	45	45	45
EXHAUST GAS DATA 1)					
Mass Flow	kg/kWh	**5.64**	5.74	5.80	5.92
Gas Temperature after Cylinder, MV	°C	**485**	475	470	475
Gas Temperature before Turbine	°C	**520**	510	505	515
Gas Temperature after Turbine	°C	**335**	340	360	420
HEAT BALANCE DATA 3)					
Charge Air, Stage 1(HT)	kJ/kWh	**785**	735	585	230
Charge Air, Stage 2(LT)	kJ/kWh	**285**	305	325	355
Lubricating Oil	kJ/kWh	**500**	530	575	800
Jacket Cooling Water	kJ/kWh	**535**	530	525	425
Exhaust Gas	kJ/kWh	**1895**	2070	2370	3100
Radiation	kJ/kWh	**160**	160	165	175

Remarks

1) Reference condition based on ISO 3046/1 (air press. 1 bar, intake air temp. 25 °C, cooling water temp. 25 °C)
Mass flow tolerance +/-5%, gas temperature tolerance -/+25 °C
Heat Rate tolerance +5% at 100% load based on TA Luft
Engine driven pumps attached : Lube oil pump, HT-pump, LT-pump
Fuel gas based on LNG, LCV 36 MJ/Nm³ (≒50MJ/kg), MN 80
Warranted at 100% load

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Pump Type	Heat Rate [kJ/kWh]
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Heat dissipation of charge air is based on HT cooling water system " HT CW (Air cooler -> Cylinder jacket)"

1. Engine Performance Data

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Gas Temperature before Turbine	°C	**520**	510	505	515
Gas Temperature after Turbine	°C	**335**	340	360	420
HEAT BALANCE DATA 3)					
Charge Air, Stage 1(HT)	kJ/kWh	**720**	705	615	360
Charge Air, Stage 2(LT)	kJ/kWh	**350**	340	295	225
Lubricating Oil	kJ/kWh	**500**	530	575	800
Jacket Cooling Water	kJ/kWh	**535**	530	525	425
Exhaust Gas	kJ/kWh	**1895**	2070	2370	3100
Radiation	kJ/kWh	**160**	160	165	175

Remarks

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L.T Cooling water pump	44
H.T. Cooling water pump	44

3) Heat dissipation tolerance ±10% for cooler, ±15% for heat recovery.
Heat dissipation of charge air is based on HT cooling water system " HT CW (Cylinder jacket -> Air cooler)"

General

HiMSEN H35G(V) is designed for environment-friendly engine with lean-burn technology, more air is supplied in the cylinder than is needed for complete combustion, as a result of lean-burn, the maximum temperature in the cylinder is reduced and less NOx is produced.
With avoiding knocking, higher power could be reached, and efficiency is also increased. In order to get the highest efficiency and lowest emissions, each cylinder is separately controlled to ensure air-fuel ratio and timing of the ignition, additionally well controlled combustion also reduces the mechanical and thermal load on engine components.

Application

HiMSEN H35G(V) is designed to cover all below NOx Emission Guideline as applying lean burn concept explained above, therefore HiMSEN H35G(V) is available for all country of the world for stationary engine.

NOx Guideline for Gas Enigne

World Bank Guideline
- 200 mg/Nm^3 @ 15% O_2

UN-ECE Gothenburg Protocol
- 250 mg/Nm^3 @ 5% O_2 (> 1 MWth)

Germany - TA Luft
- 500 mg/Nm^3 @ 5% O_2

Finland
- 1600 mg/Nm^3 @ 15% O_2
  (Engine internal measures)
- 750 mg/Nm^3 @ 15% O_2
  (Methods outside the engine)

France
- 250 mg/Nm^3 @ 5% O_2
  (Operating time > 500 h/year)
- 625 mg/Nm^3 @ 5% O_2
  (Operating time $\leq$ 500 h/year)

Italy
- 100 mg/Nm^3 @ 3% O_2

Switzerland
- 400 mg/Nm^3 @ 5% O_2

IMO (for marine)
- No regulation for GAS engine

Japan
- 600 ppm @ 0% O_2

General

Correction for ambient condition (Gas operation)

Heat rate of the gas operation normally refers to the ISO 3046-1 standard condition.

However, for the condition other than ISO 3046-1:2002 standard condition,
the heat rate at maximum continuous rating can be estimated according to the below mentioned formula.

First, there is a relationship between the Heat Rate and the Efficiency, the heat rate is the inverse of the effic

Heat Rate (kJ/kWh) = Thermal Energy Input (kJ/h*) / Engine Output (kW)
Efficiency [%] = 3600 / Heat Rate [kJ/kWh] x 100

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

where :

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

Notice)
1) Maximum value of dEff is 1.
2) Between ISO and ambient condition, same operating parameters must be used.
3) If there is a change of main component, this correction should be updated.
4) The Heat Rate is a term commonly used for consumption of thermal energy in gaseous fuels,
LCV (Lower Calorific Value) of gaseous fuel is not corrected.

Example,
Intake air temperature (T_{intake}) : 30 ℃
Pamb : 990 [mbar]
Charge air temperature(Tcharge) : 47℃
EffISO : 48.38 [%] at 720[rpm], MCR (Total Heat rate : 7,441 [kJ/kWh])
then, dEff = 0.9985 and the efficiency (Effamb) at site condition will be decreased to 48.31[%]
for the heat rate at site condition will be increased to 7,452 [kJ/kWh].

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

Calculation of fuel gas flow

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

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

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

Correction of additional fuel gas consumption

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

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

Remark)

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

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

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

Load	100 ~ 25%	Under 25%
x	1.15	1.28

General

Available output at site can be reduced by local conditions. De-rating of power output is related to the ambient condition, the gas properties, the gas supply condition, and the charge air temperature after intercooler.

De-rating Factors

HHI H35G(V) gas engine de-rating of the power output is dependent on the following three de-rating factors.

1) Air Amount (K1)

Generally low ambient pressure (high altitude) and/or high ambient air temperature can cause lack of air to use combustion. As a result, the rated power output may decrease. This characteristic can be changed by the specification of turbocharger and the NOx limit of the site. There is a factor of K1 regarding this parameter, see Figure 1.

2) Gas Supply (K2)

The required input heating value from the fuel gas to the engine is determined by a gas supply pressure and a LHV. Shortage of gas supply decreases a rated power. Main gas supply pressure depends on a charge air pressure, so this factor also can be changed by the specification of turbocharger and the NOx limit of the site. Required gas flow is represented by the factor of K2, see Figure 2.

3) Knock (K3)

Knock is a representative abnormal combustion and damages parts in the cylinder. If knock is occured by site conditions, service power reduction is inevitable. Methane number (MN) of the gaseous fuel effects on a tendency of the knock combustion. Lower MN increases a knock combustion, which means to be de-rated. A charge air temperature to the combustion chamber is also related to the knock property. Higher temperature causes a de-rating due to knock.These characteristic is expressed as the factor of K3, see Figure 3.

4) The Other Factors

Beside above mentioned 3 de-rating factors, relative humidity and the glycol content for an anti-freezing can reduce the engine maximum power.

Calculation of De-rating

The actual power in the site is determined by the factor K that is derived from K1, K2, and K3.

$$K = min [K1 , K2 , K3]$$

$$POWER_{site} = POWER_{ISO} * K$$

Notice

1) These de-rating factors should be used a guidance only, explicitly non-binding and subject to changes without futher notice.

2) These de-rating factors are made for the NOx value of TA-Luft (500mg/Nm3@5% dry O2). In case that a different level of NOx must be applied at the site, lower NOx optimized engine (due to a regulation) needs more de-rating.

3) Regarding gas supply pressure, following definitions should be recognized;

- The unit of gas pressure is an absolute pressure (not relative or gauge pressure).
- The measuring position of gas pressure is before GRU (not after GRU)

4) All design modifications related to the combustion may change characteristics of de-rating. For example;

- Tubocharger specification
- Compression ration of cylinder
- Piston design
- Etc.

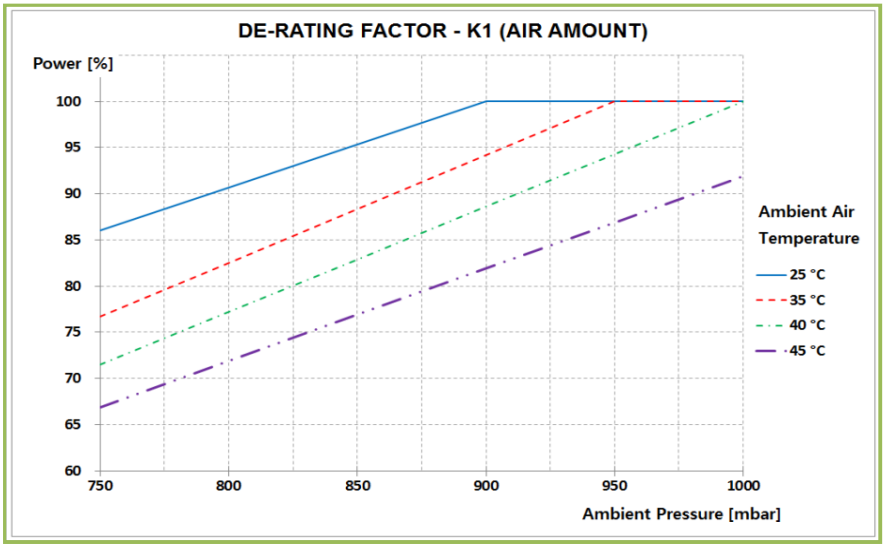


Figure 1. De-rating factor K1

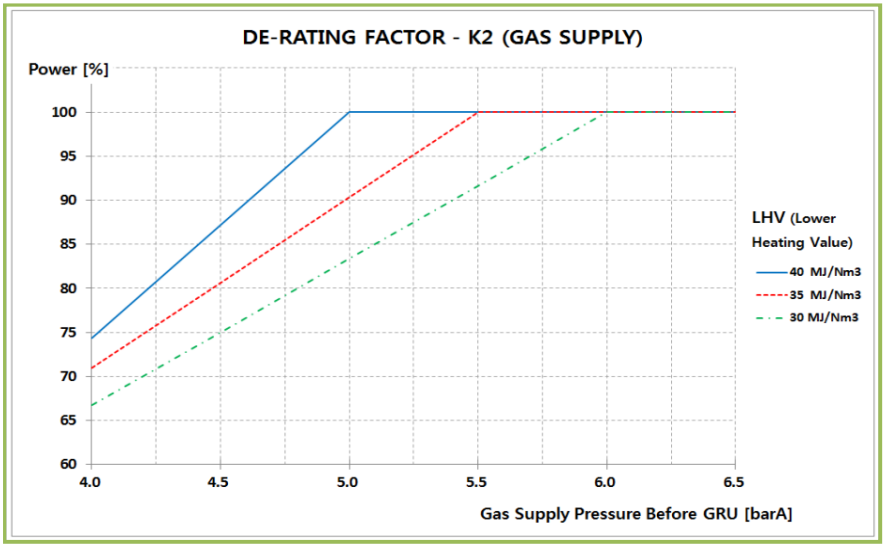


Figure 2. De-rating factor K2

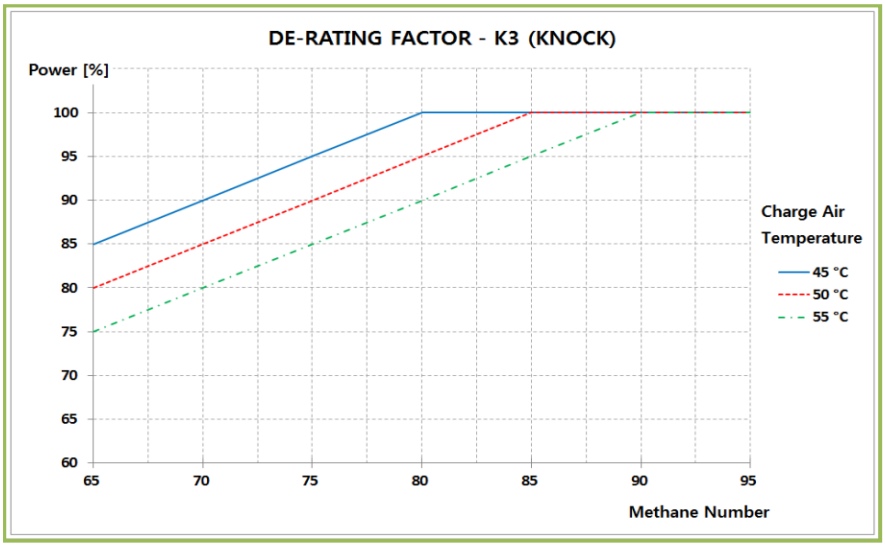


Figure 3. De-rating factor K3

Engine Type	Speed	External Forces and Moments				Guide Force Moments		
		Order		Moment		Order		Moment
				Horizontal	Vertical			
	rpm	No.	Hz	kNm	kNm	No.	Hz	kNm
12H35/40GV	720	1	12.0	0.0	0.0	3	36.0	20.3
		2	24.0	0.0	0.0	6	72.0	29.8
	750	1	12.5	0.0	0.0	3	37.5	18.7
		2	25.0	0.0	0.0	6	75.0	29.8
14H35/40GV	720	1	12.0	14.4	25.7	3.5	42.0	6.3
		2	24.0	17.7	31.9	7	84.0	20.3
	750	1	12.5	15.6	27.9	3.5	43.8	6.3
		2	25.0	19.2	34.6	7	87.5	20.3
16H35/40GV	720	1	12.0	0.0	0.0	4	48.0	21.8
		2	24.0	0.0	0.0	8	96.0	10.2
	750	1	12.5	0.0	0.0	4	50.0	21.6
		2	25.0	0.0	0.0	8	100.0	10.2
18H35/40GV	720	1	12.0	10.4	18.6	4.5	54.0	43.6
		2	24.0	9.6	17.3	9	108.0	2.9
	750	1	12.5	11.3	20.2	4.5	56.3	43.6
		2	25.0	10.5	18.8	9	112.5	2.9
20H35/40GV	720	1	12.0	0.0	0.0	5	56.0	57.2
		2	24.0	0.0	0.0	10	120.0	0.3
	750	1	12.5	0.0	0.0	5	56.0	57.3
		2	25.0	0.0	0.0	10	120.0	0.3

Engine Type	Speed	Rating	Moments of Inertia ; J 1)				
			Engine	Flywheel		Alternator	Total
			MOI	MOI	Mass	MOI 2)	MOI
	1/min	kW	kg㎡	kg㎡	kg	kg㎡	kg㎡
12H35/40GV	720	5760	736.9	400.0	1309.0	1372.7	2509.6
	750	5760	736.9	400.0	1309.0	1372.7	2509.6
14H35/40GV	720	6720	841.9	600.0	2015.0	1524.8	2966.7
	750	6720	841.9	600.0	2015.0	1524.8	2966.7
16H35/40GV	720	7680	946.9	400.0	1309.0	1829.7	3176.6
	750	7680	946.9	400.0	1309.0	1829.7	3176.6
18H35/40GV	720	8640	1052.0	600.0	2015.0	2026.7	3678.7
	750	8640	1052.0	600.0	2015.0	2026.7	3678.7
20H35/40GV	720	9600	1157.0	850.0	2794.2	2026.7	4033.7
	750	9600	1157.0	850.0	2794.2	2026.7	4033.7

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

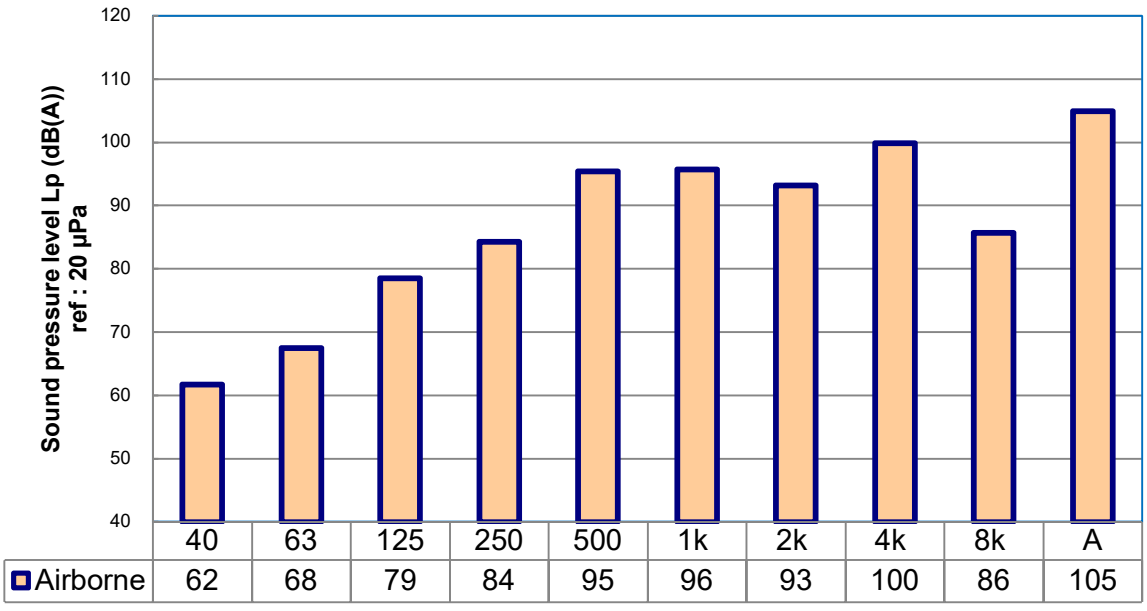
2) Recommended values, the case of different MOI should be confirmed by a torsional vibration analysis.

General

The airborne noise of the engine is defined as a sound pressure level according to ISO6798 and ISO 8528-10.
A total 19 measuring points at distance 1 m away from the engine surface at full load.
The values are average with A-weighting in one octave band.

In the octave level diagram the minimum and maximum octave levels of all meassuring points have been limked by results.
The data will change, depending on the acoustical properties of the environment.

Mean values with tolerance ± 3dB



	40	63	125	250	500	1k	2k	4k	8k	A
Airborne	62	68	79	84	95	96	93	100	86	105

Octave band center frequency [Hz]

1. General

H35/40G(V) is a gas engine that can run in various site conditions. However, there are some recommendations to maintain good performance and reliability consistently.

2. Starting Condition

2.1. Normal starting condition

Lub. Oil

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

Cylinder Cooling Water

- Starting temp. : over 40 ℃ (Preheated)

Combustion Air

- Air temperature : between 0 ℃ and 45 ℃.

Fuel Gas

- Temperature : 0~50℃
- Min. required gas pressure: Refer to fig. 4-1-1 and 4-1-2 for required gas pressure.
- Max. allowable gas pressure at GRU inlet: Normally 6 bar. If required, 8 bar is possible by changing component.
- Max. allowable gas pressure fluctuation: Refer to fig. 4-1-3 for allowable variation of pressure.

2.2. Emergency cold starting condition

Cylinder Cooling Water : minimum 5℃

Lub. Oil : minimum 10℃ prelubricated.

3. Operating modes

3.1. Engine operating mode

Mains parallel operation

- The genset is connected to an infinite bus: changes in engine power do not affect the bus frequency.
- In mains parallel operation the ECS controls the engine's power output, engine speed is determined by the bus frequency.

Island operation

- The genset is connected to a finite bus: changes in engine power do affect bus frequency.
- ECS controls the engine's speed: load is determined by the external load.
- The island operation mode is activated via the digital input »DI Island operation«. Island operation is active when the contact is open.
- In multi engine operation, load sharing can be managed by each engine's reference speed adjustment in droop mode.

3.2. ECS operating mode

Automatic mode

- In Automatic mode, engine start and stop are initiated by external signals.
- Engine set speed (in island operation) or engine set power (in mains parallel operation) are defined from external.

Manual mode

- In Manual mode, engine start and stop are controlled by user interactions on the ECS operator interface. Additionally, the ECS operator can manage synchronization, set values for speed and power control, and handle unloading the engine.

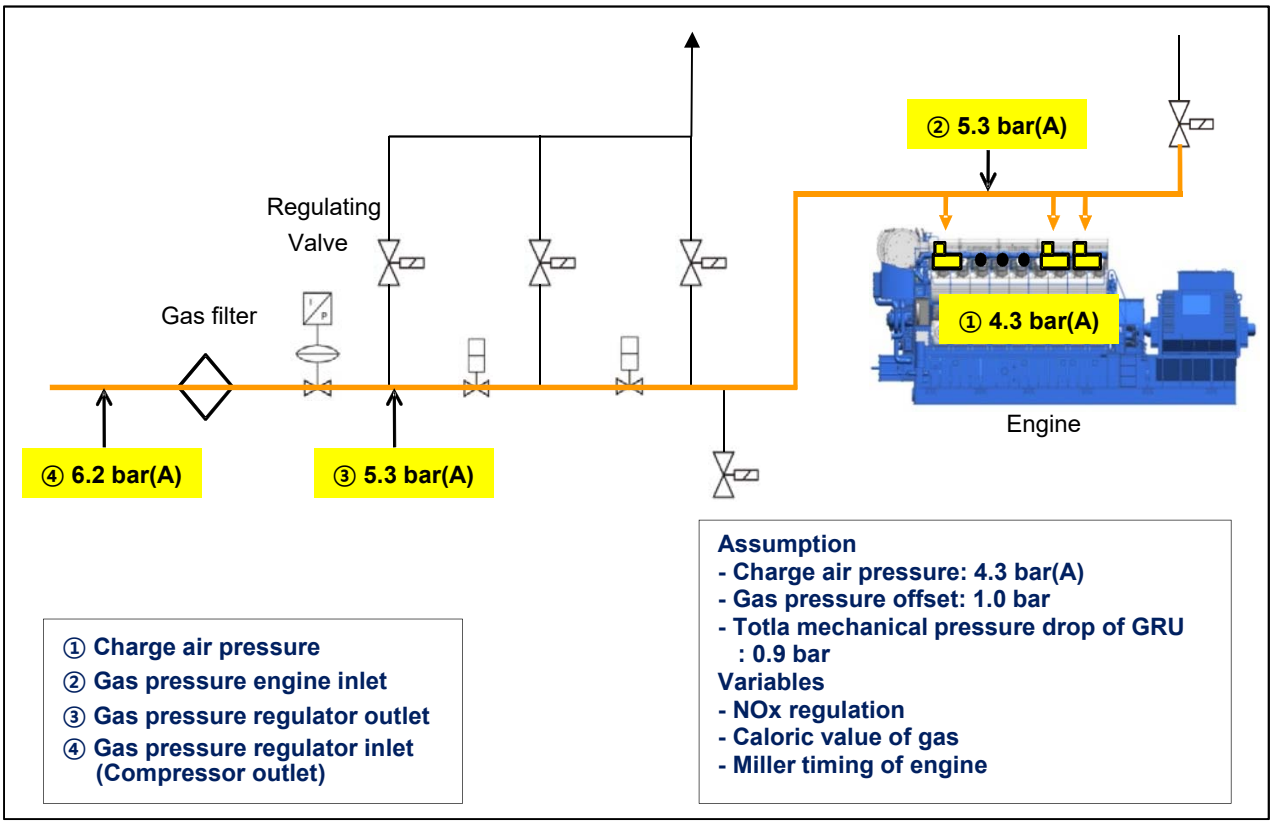


Fig. 4-1-1 Min. required gas pressure for 100% load operation at GRU inlet

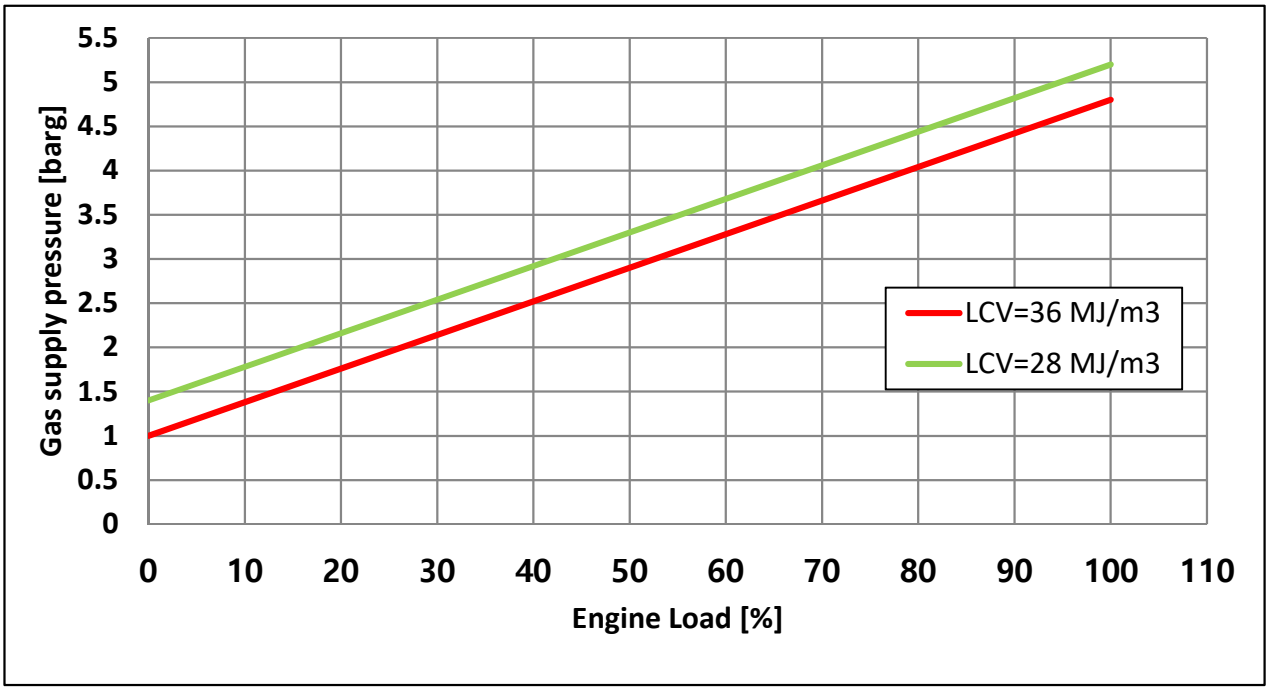


Fig. 4-1-2 Load dependant min. required gas pressure (Engine inlet)

- Gas supply pressure should be higher against low LCV.
- Gás supply pressure between 36 MJ/Nm^3 and 28 MJN/m^3 can be interpolated.

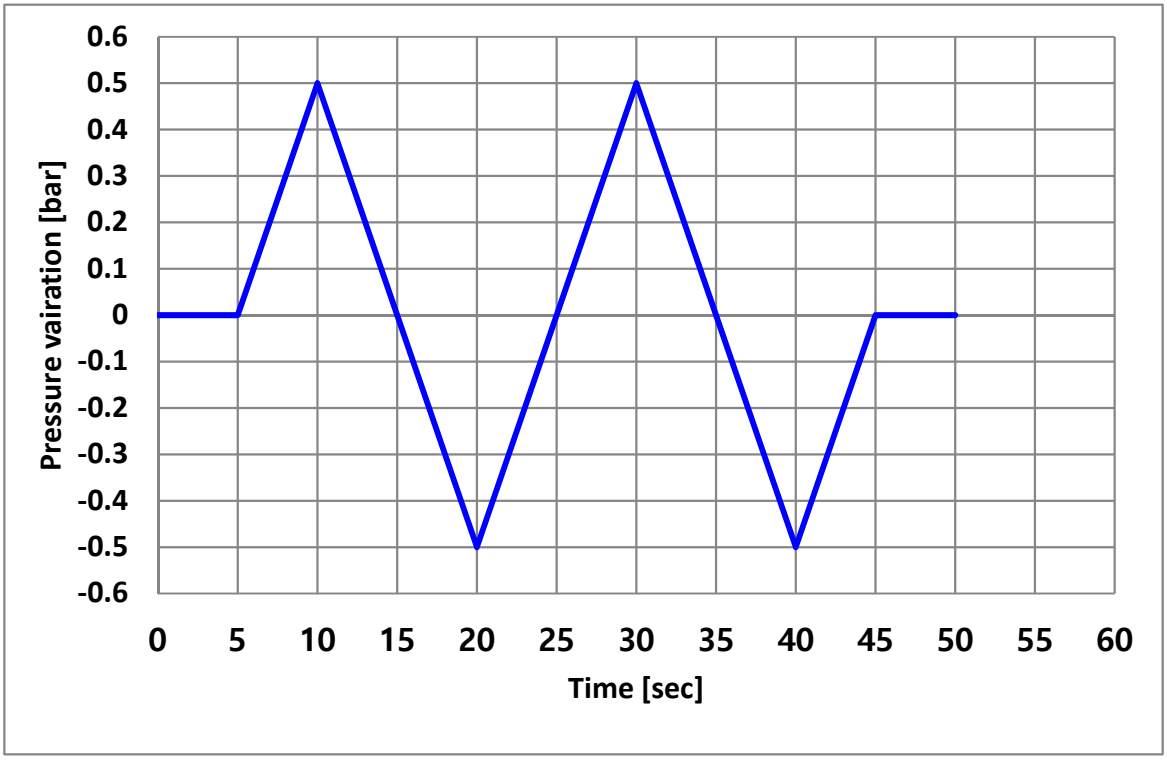


Fig. 4-1-3 Permissible gas supply pressure fluctuation

- Less than 0.1 bar/sec of pressure fluctuation (peak ±0.5 bar) can be absorbed in GRU and no effect on engine operation.
- Always the min. pressure in fluctuation should be higher than required gas supply pressure at corresponding engine operation condition.

4. Engine Start

4.1. Engine Start Ready

Engine start ready condition is indicated in local and remote. The engine is recommanded in warm condition before engine start.

Start Block Signals

- Lub. Oil priming, low pressure (≤ 0.3 bar in T/C inlet)
- Turning gear, engaged
- Run down time has not expired
- System test mode enabled
- Under processing exhaust gas ventilation
- Start air inlet, low pressure below the start block limit
- Start blocking from remote
- Slow turning, failure
- Stop command, activated
- Start failed
- No reset after engine trip
- External start block from remote
- Other installation dependent start blocks

4.2. Engine Start

An air starting motor is installed on engine side and operated by compressed air controlled by pneumatic solenoid valve.

Engine Start

- After start command is triggered from local or remote, ECS check start block condition once again for a few second.
- Air starting motor is engaged and turn the flywheel.
- Ignition system is activated and gas shut-off valves are open. Gas injection is activated and chamber is fired.
- As soon as combustion chamber is fired, speed is rapidly increased and the air starting motor is disengaged.
- At idle speed, warm-up condition is checked and engine run until warm-up condition is satisfied.
- After warm-up phase is completed, the speed is ramp up to rated speed automatically.
- Circuit breaker can be closed within1 min. if engine start at warm condition.

4.3. Engine start from different stop mode

An engine stop mode can be selected from remote. Operator can select engine stop mode considering the purpose and the period of engine stop.

Engine stand-by mode

- When engine is stopped for relatively short period of time and is planned to start soon.
- Slow turning is skipped during engine start phase.
- Cyclic slow turning is performed at engine stop. (every 30 min, 2 revolution)

Engine stand-still mode

- When engine is stopped relative long period of time e.g. for maintenance work.
- Slow turning is performed for 2 revolution before fast turning during engine start.
- No cyclic slow turn performed.

In case of slow turning failure due to any reason, the alarm is released and operator should check what factor cause this failure.

5. Engine Load-Up

For load operation of HiMSEN Gas engine, both continuous and step by step load up should be taken carefully for stable and safe operation of engine.

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

5.1. Restriction for low load operation

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

5.2. Continuous Load-Up

Emergency Load-Up of Engine

Gradually increase load up to 75% load within 90 sec. and up to 100% load in another 60 sec. It will require about 1 and half min. from 0% load to 100% load. The engine should be in warm condition and for more robust engine operation and longer life time of mechanical Part, this rapid loading is not recommended.

Normarl Load-Up with Warm Engine

Gradually increase load up to 25% load within 30 sec. and up to 100% load in another 330 sec. It will require about 6 min. from 0% load to 100% load. Sudden load-up will take a few seconds to achieve stable frequency. The cylinder cooling water temperature should be minimum 60 ℃ to load-up to 100% load.

Normal Load-Up with Cold Engine

Gradually increase load up to 25% load within 1 min. and up to 100% load in another 9 min. It will require about 10 min. from 0% load to 100% load. The cylinder cooling water temperature should be minimum 60 ℃ to load-up to 100% load.

Above load-up procedures are applied at island operation mode when external system manages the power output of genset.

Please see Fig. 4-1-4 for comparison of different load-up procedure at different engine condition.

Load-Up in main parallel operation mode

When the genset is connected to the infinite bus, engine run at main parallel operation mode and ECS is able to adjust the power output of engine. In this case, 15% of load is applied as soon as synchronization to be protected from reverse power.
The load ramp up rate is defined in ECS as 15% per min. 100% load can be reached in less than 6 min. and the engine should be in warm condition for this.
When target load is commanded to ECS, ECS trace the target load by ramping up the load in defined rate.

Please see Fig. 4-1-5 engine loading procedure in main parallel operation mode.

5.3. Overload operation

Normally in gas engine, overload operation is not allowed.

Overload operation limit

- Engine load > rated power + 2 % (more than 5 min): Alarm released
- Engine load > rated power + 2 % (more than 10 min): Engine shutdown
- Engine load > rated power + 5% (more than 5 sec): Engine shutdown

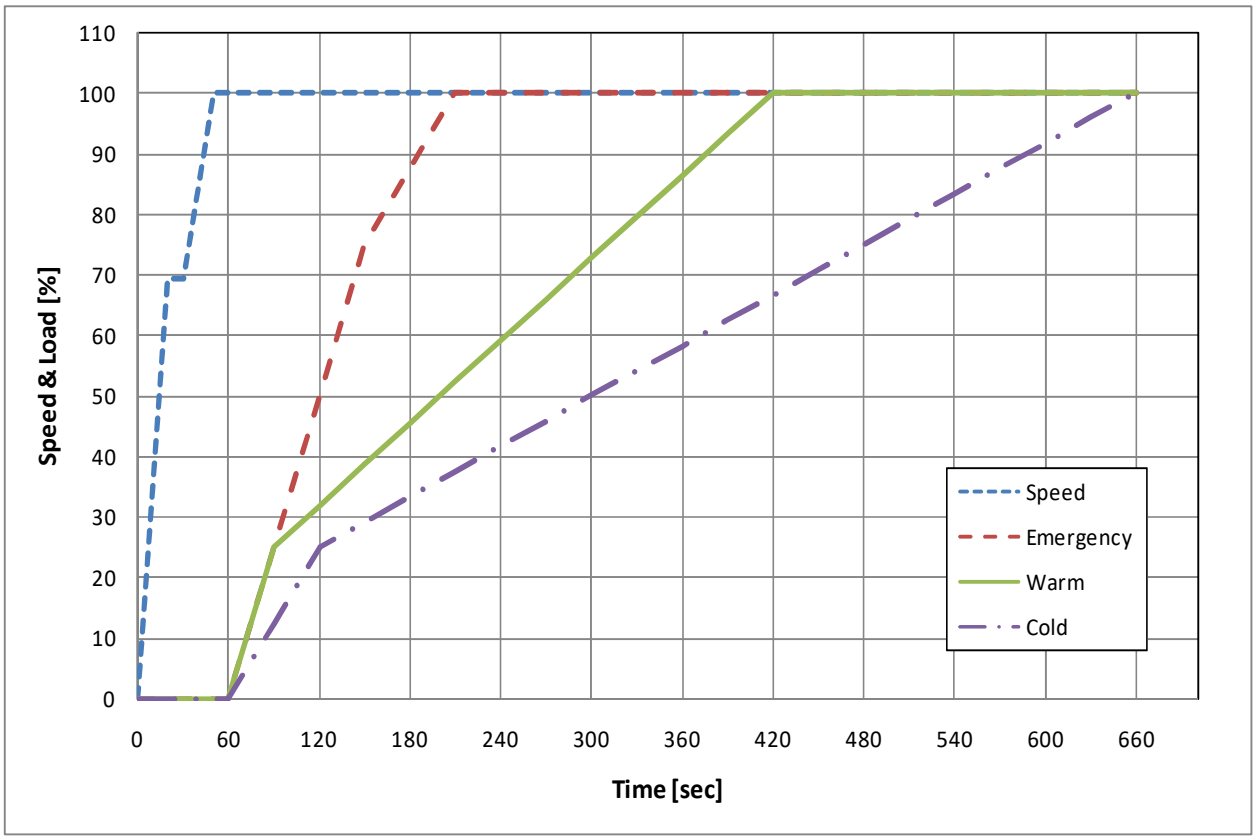


Fig. 4-1-4 Engine load up capacity in ramp

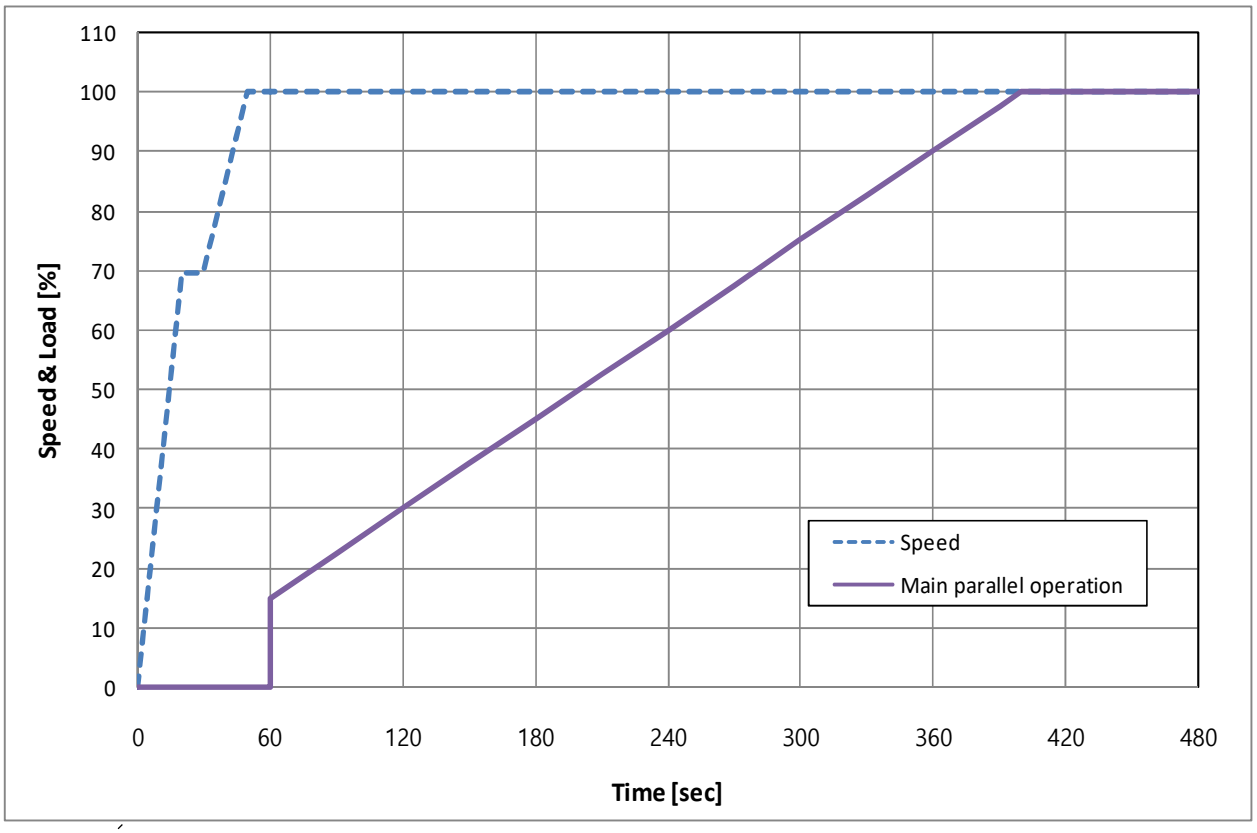


Fig. 4-1-5 Engine load up in main parallel operation

5.4. De-load of engine

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

In main parallel operation mode, C.B is opened at approx. 5% load to be protected from reverse power.

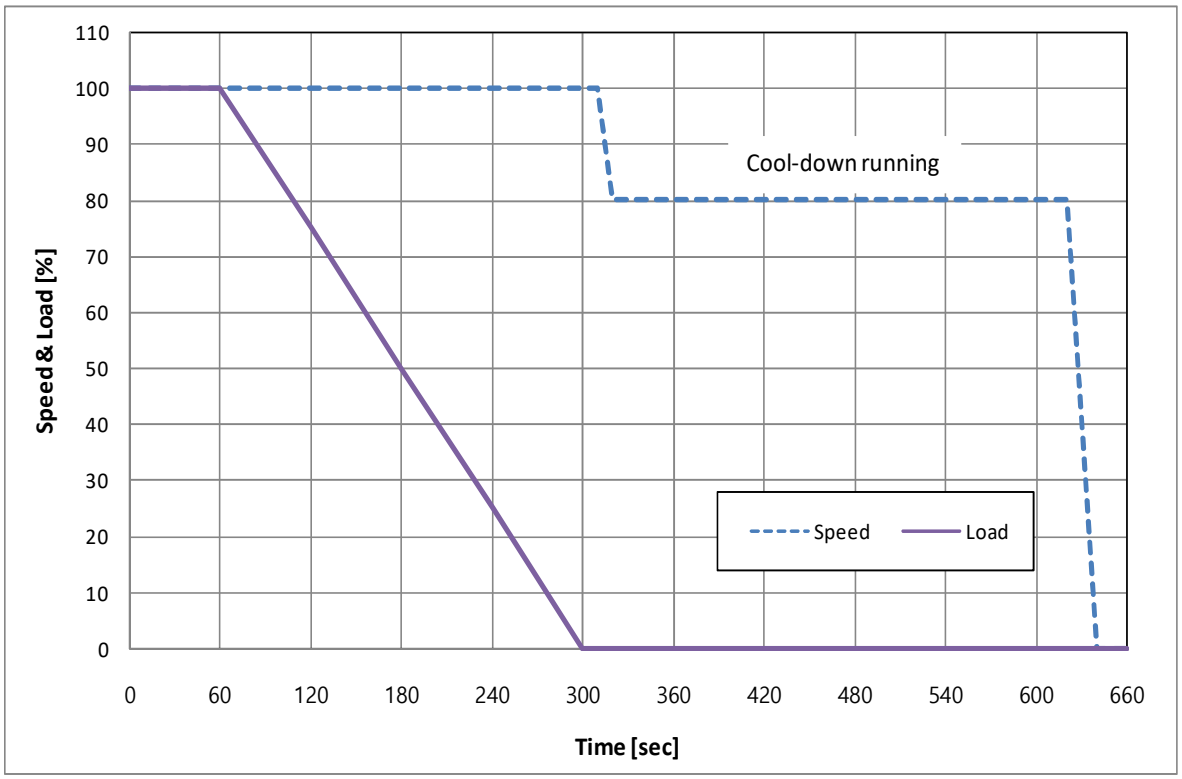


Fig. 4-1-6 Engine de-load and stop sequence including cool-down operation

5.5. Step by Step Load-Up in island mode

Considering the time and safety required for stablilizing the frequency due to sudden load up, it is recommended to load up from idle to full load by more five steps. For this operation, the engine should be in warm condition.

Frequency deviation and recovery time when loading up by step is refered in Fig. 4-1-7.

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

This graph is only valid at island operation mode. In main parallel operation mode, load increase / decrease is always in ramp.

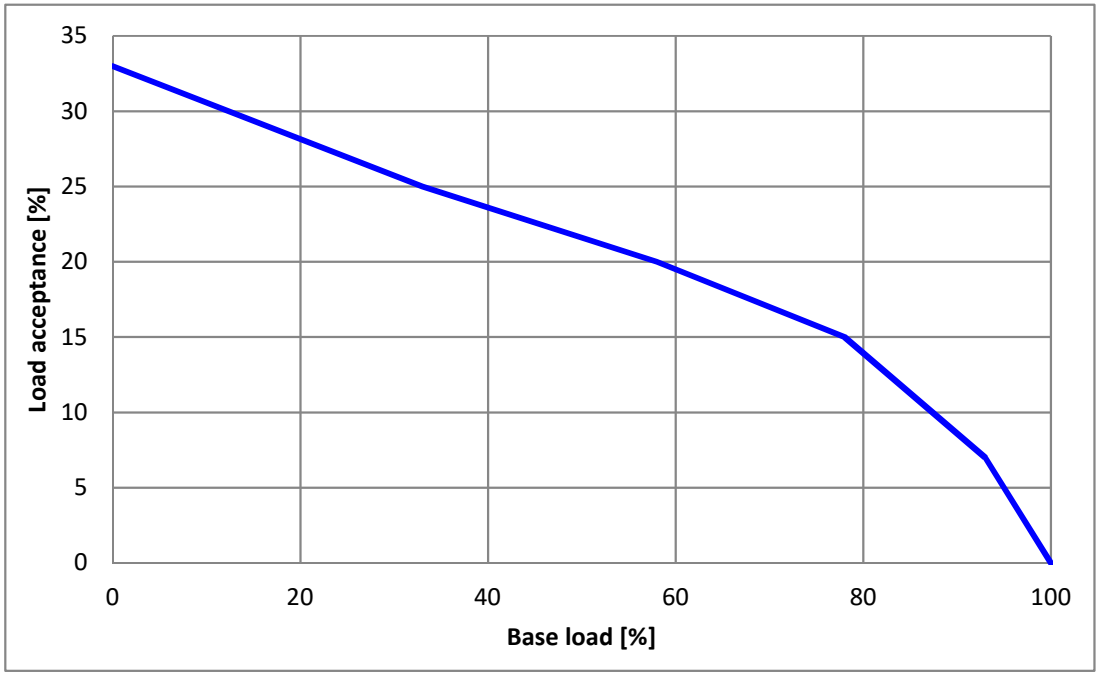


Fig. 4-1-7 Step load acceptance

① Max instant load step : 0-33-58-78-93-100

② Max speed variation ≤ 10%

③ Steady-state speed bend ≤ 1.5%

④ Recovery time ≤ 10 sec

⑤ Time between next load step ≥ 15 sec

6. Engine Stop

Normal Stop

In island operation mode, the external system should de-load and open the circuit breaker before stop command. In main parallel operation mode, as soon as stop commend is triggered, ECS decreases the load itself and stops the engine.
It is recommended to cool-down the engine by running the enigne at no load state for 5 min. to dissipate the residual heat in engine. Operator can activate this sequence automatically from ECS.
During engine stop, the gas valves are closed, gas admission and ignition system remains active until predefined speed to burn the rest of gas in the system. After engine stop, Prelub. Oil pump is activated for post lubrication.

Engine Shutdown

When the engine enters predefined shutdown condition due to certain abnormality, the engine is stopped immediately and the circuit breaker is opened automatically without de-load. As soon as shutdown is triggered, the shut-off valves and venting valves at gas regulating unit are activated and gas circuit on engine is purged with inert gas. The ignition is active until predefined speed to burn the rest of gas in chamber.
The shutdown condition is specified in P.04.400 Operation Data & Alarm Points.

Emergency stop

When emergency stop signal is entered by pushing the switch on panel, or engine overspeed is detected, the engine is stopped immediately. The stop procedure is similar with shutdown except that ignition system is deactivated at once.

7. Engine Safety

The engine control system monitors the signals from all sensors on engine and takes an appropriate action against abnormality of engine for safe operation. All engine reaction and its delay are predefined in engine control system based on safety functional list.
Below figure is layout of HiMSEN Gas engine safety system.

All signals scope of HiMSEN Gas safety functional list are connected to HiMSEN Gas ECS and those implement safety functions written hereinafter

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

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

Alarm (PR)
ECS releases alarm message and the load is reduced automatically (in main parallel operation mode) or request to reduce the load to its power management system (in island mode). Admissible engine load limited to 80% as long as Alarm (PR) is active.

Alarm (SD)
ECS releases alarm message and the engine will be shutdown after 30 min. After alarm (SD) occur and 30 min. is elapsed without any normal stop, the load is reduced and engine stopped automatically (in main parallel operation mode) or engine is shutdown (in island operation mode). The engine will run in normal condition, if the alaram (SD) condition is acknowledged in 30 min.

Shutdown
ECS releases failure message and the engine is shutdown. Ignition system is alive until injection-off speed to burn the rest of gas in engine.

Emergency stop
ECS releases emergency stop message and the engine is shutdown immediately.

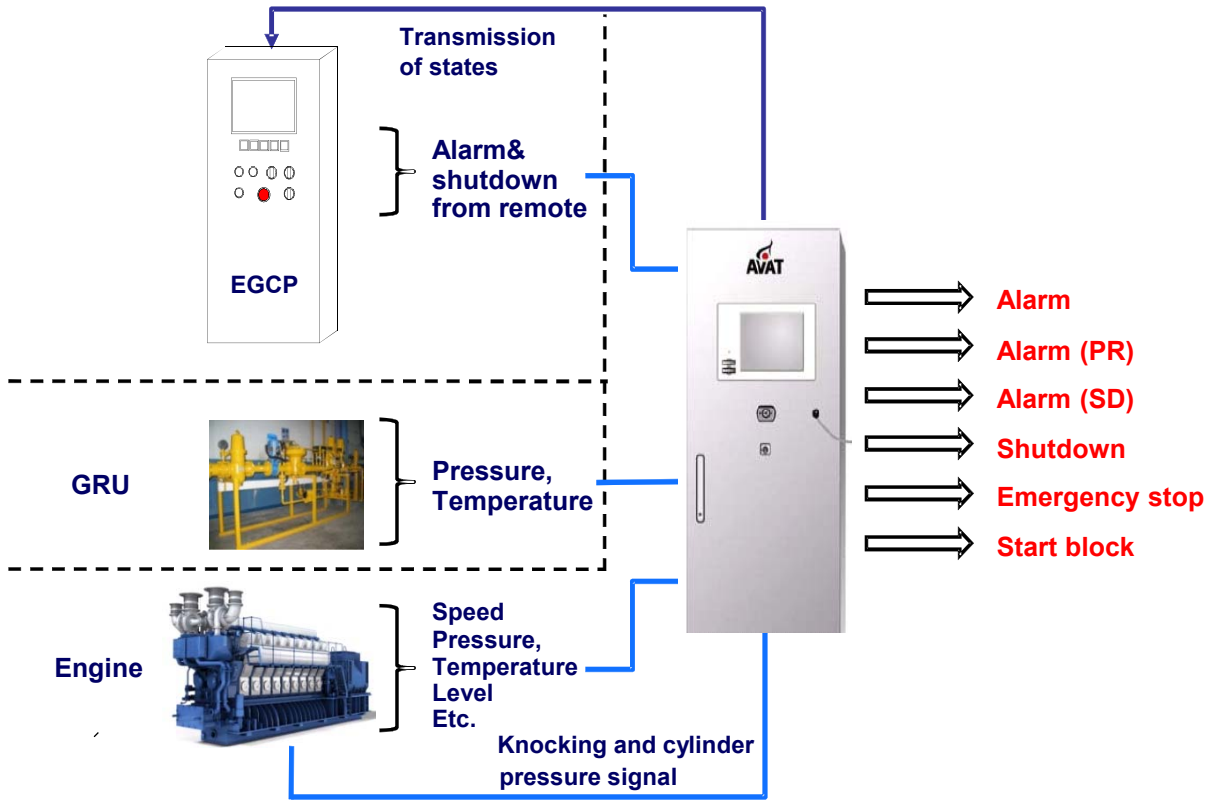


Fig. 4-1-8 H35G(V) Safety function layout

1. General

HiMSEN Gas Engine Control System (HiMSEN Gas ECS) consists of ECS panel and Ignition control panel.

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

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

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

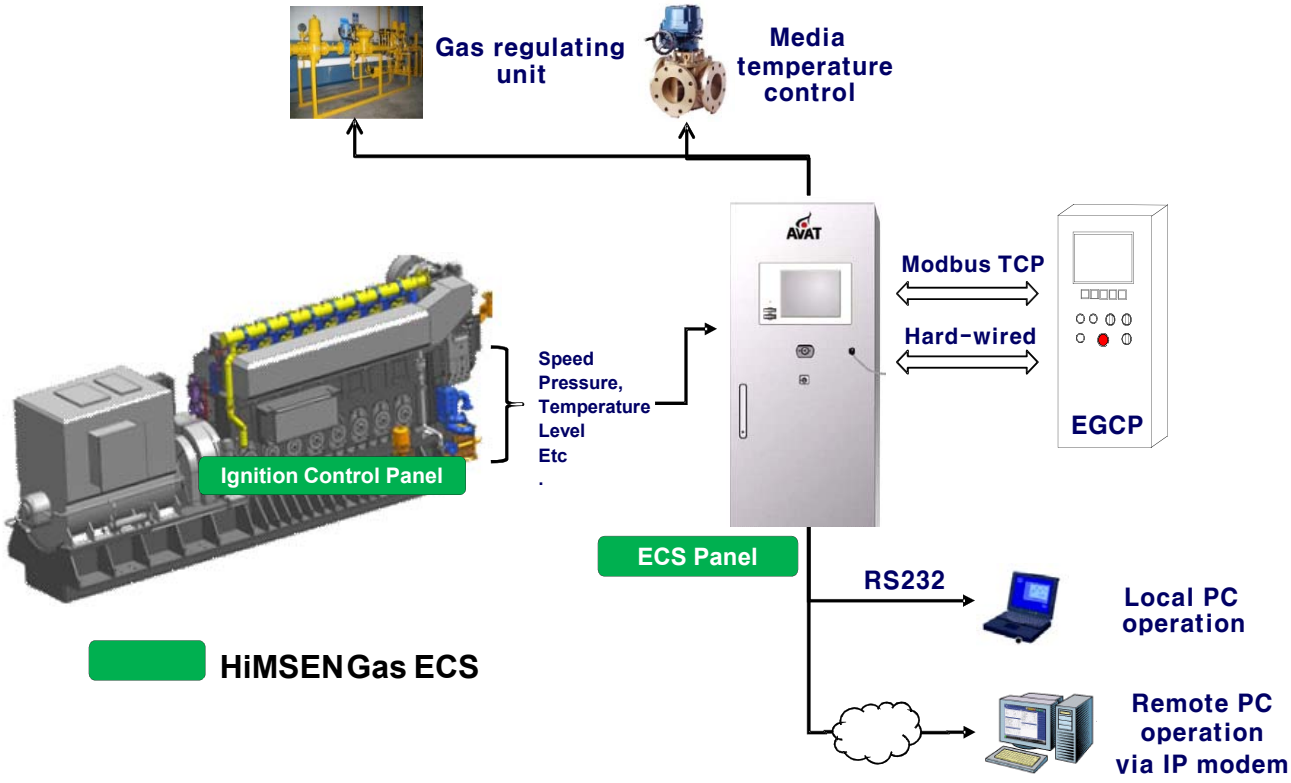


Fig. 4-2-1 HiMSEN Gas ECS Overview

2. Hardware description

ECS panel

ECS panel is the central control unit of HiMSEN Gas ECS which controls main control function of engine. ECS panel is connected with not only internal system but also external system via hardwire or communication. Operators can monitor engine status and manage the engine through the touch screen on this panel.

- Location : Standalone in engine room (1 per engine), recommended cable length from engine < 15 meter
- Consist of
  - Powerful main control module
  - I/O modules and terminals
  - HMI touch panel PC
  - Emergency stop button
- Responsible for
  - Main control function of engine
  - interface with external system
  - Engine safety function
  - Engine operation
  - Engine data monitoring (option)

- IP grade: IP54
- Power requirement: 24VDC
  Power consumption: 400 W
- Enviromental condition:
  - Operating temp.: +5...+55°C
  - Atmospheric moistur : 0...90% relative humidity, no condensation

Fig. 4-2-2 ECS panel

Ignition Control Panel (ICP)

ICP is mounted on the engine and connected to gas admission valves and ignition coils on each cylinder. In order to regulate the timing and duration of each valve and injector, ECS sends the global and individual offset signals to ICP.

- Location : Mounted on engine
  (1 for all cylinder)
- Consist of
  - Driver for gas admission valve
  - Driver for ignition coil
  - Terminals and relays
- Responsible for
  - Actuating gas admission valve
  - Ignition of spark plug

- IP grade: IP54
- Power requirement: 24VDC
  Peak consumption: 1.3 kW
  Average consumption: 400 W
- Enviromental condition:
  - Operating temp.: -40...+70°C inside panel
  - Atmospheric moistur : 0...95% relative humidity, no condensation

Fig. 4-2-3 Ignition Control Panel

Engine Generator Control Panel

EGCP is interfaced with ECS and installed in control room. This panel is in charge of not only control of generator but also management of auxiliaries and remote monitoring and operation of engine. This panel is not scope of supply of engine manufacturer.

- Location : Control room (1 per engine)
- Consist of
  - HMI touch panel PC
  - Switches, buttons and lamps for engine operation
- Responsible for
  - Automatic voltage regulating
  - Management of plant auxiliaries
  - Generator set operation
  - Generator set monitoring
  - Etc.

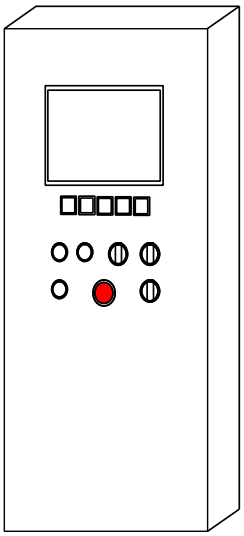


Fig. 4-2-4 Engine Generator Control Panel

3. Local and Remote Operation of Engine

3.1. Local operation of engine

For local operation of engine, the manual mode should be selected on ECS panel. Engine start and stop are triggered by user interactions on the ECS operator interface.

3.2. Remote operation of engine

For remote operation of engine, the automatic mode should be selected on ECS panel. Engine operation and monitoring is possible in remote control room.

※Remote access via IP modem

With IP modem, remote access to ECS's visualization and operation via the internet or via TCP/IP is allowed.
This function provides more powerful engine diagnostics and trouble shooting by engine manufacturer's office.
For more detailed information, please contact HHI-EMD.

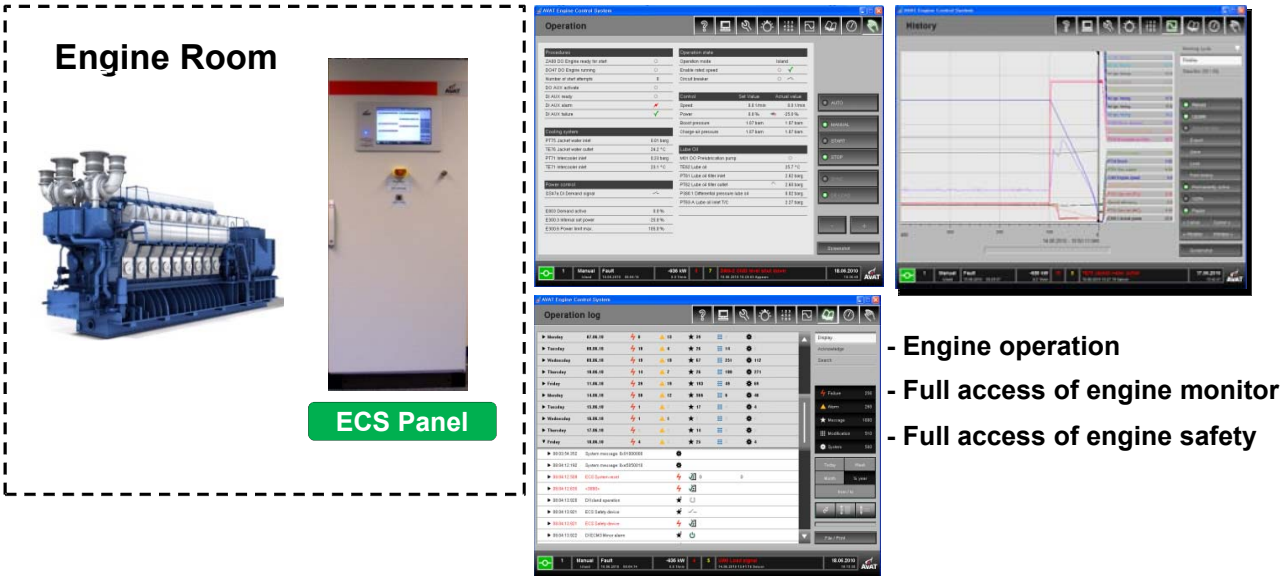


Fig. 4-2-5 Engine operation at local (engine side)

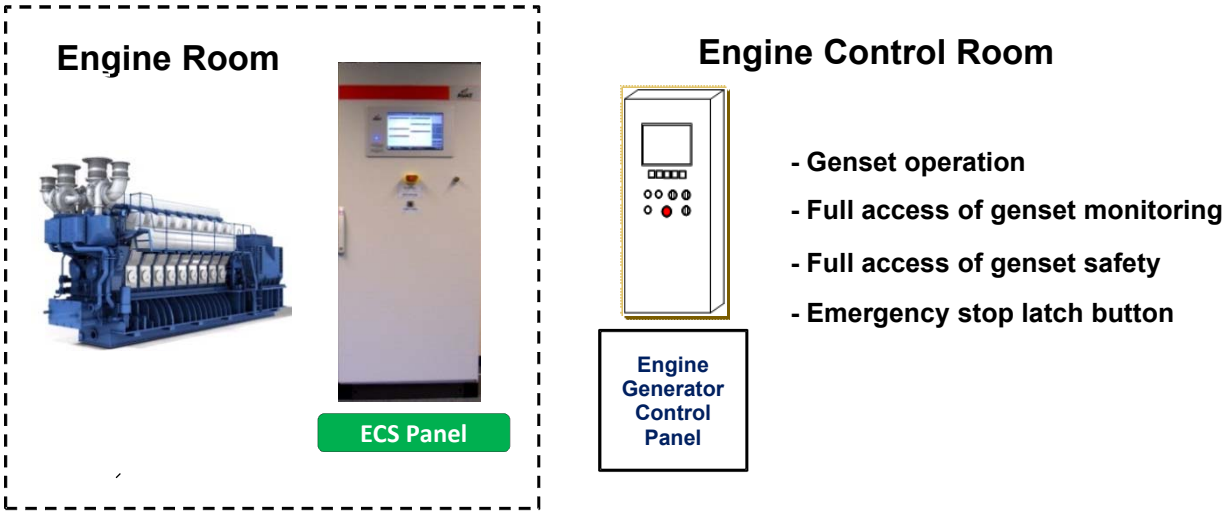


Fig. 4-2-6 Engine operation at remote (engine control room or yard system)

4. Functional Description

Speed & Power Control

ECS adjusts the amount of injected gas by regulating the duration of gas admission valve for speed & power control.

Air Fuel Ratio Control

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

Ignition System Control

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

Gas Pressure & Valve Control

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

Knocking and Cylinder Balancing Control

Knock dectection system and cylinder pressure monitoring system are integrated in HiMSEN Gas ECS, and cylinder pressure and knocking signal are transmitted to the panel. This concept guarantees sophisticated anti-knocking control and cylinder combustion balancing control.

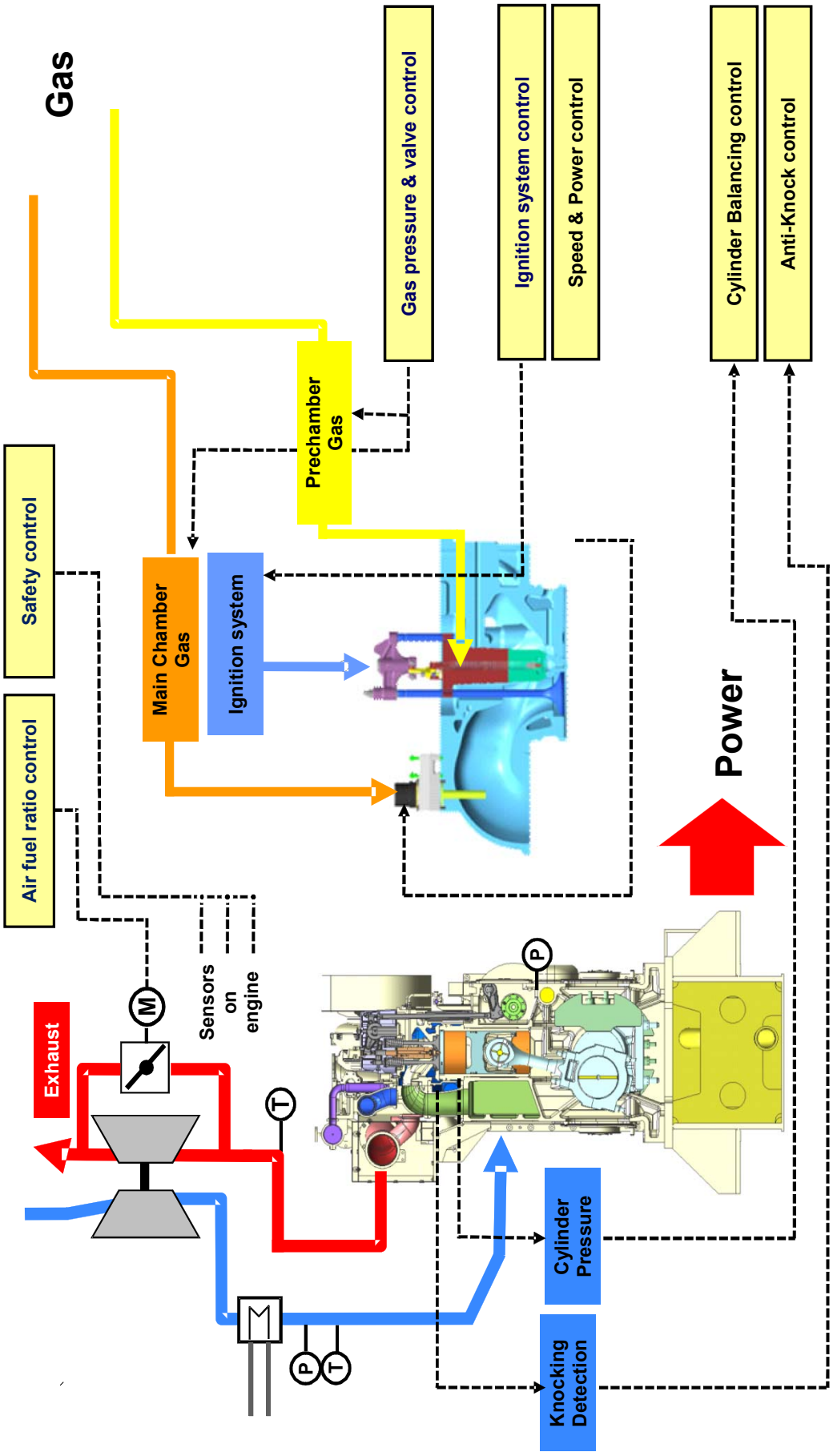


Fig. 4-2-8 Functional description of HiMSEN Gas Engine

1. General

HiMSEN Gas ECS is closely interfaced with external system and provide full capability for optimum operation.

Below fig. 4-3-1 is the example of system interface and layout. This can be changed depending on project.

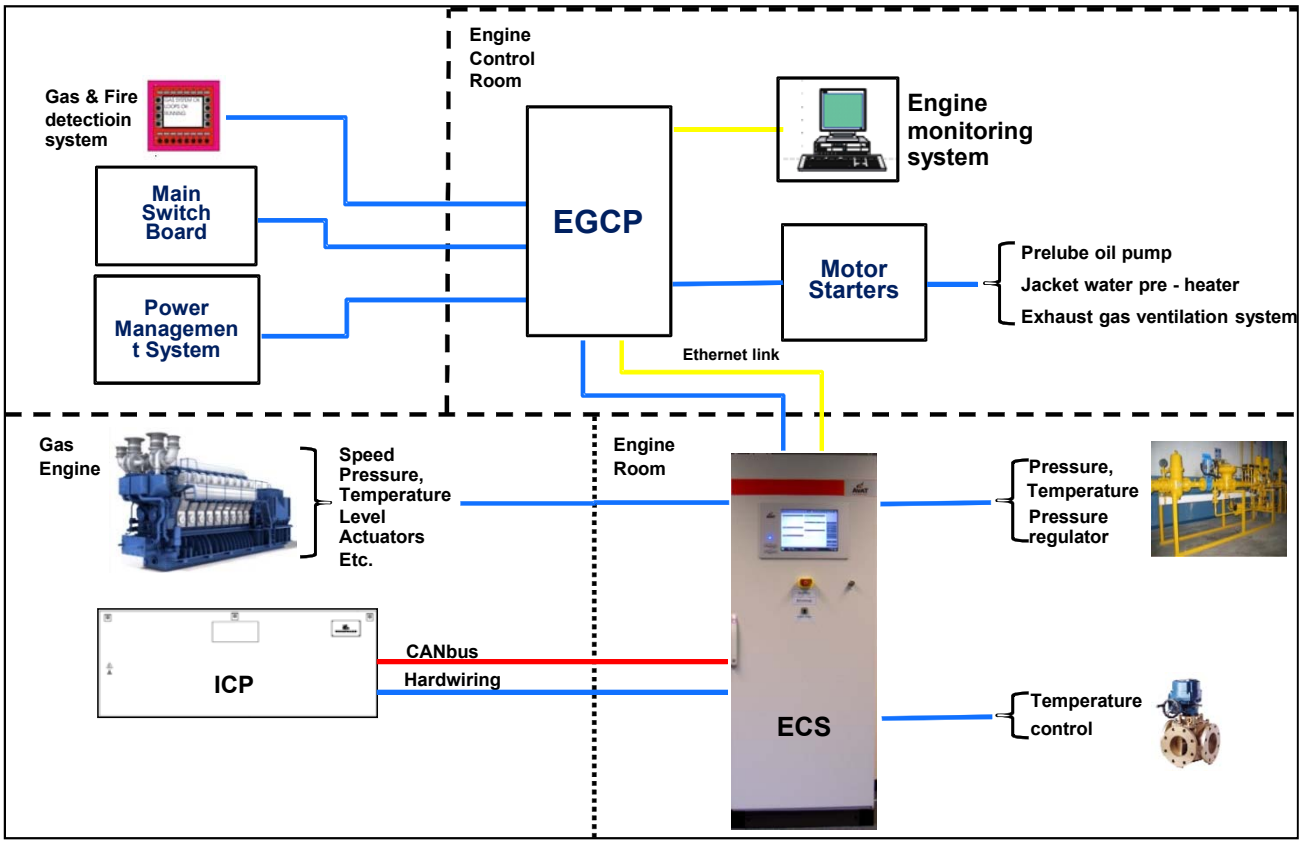


Fig. 4-3-1 Example of plant system layout

2. Plant Interface

The figure below shows an overview for the exchanged signals between plant control system (e.g. EGCP) and ECS. Those signals can be classified into analogue I/O (hardwired), digital I/O (hardwired) and data exchanged over Modbus TCP.

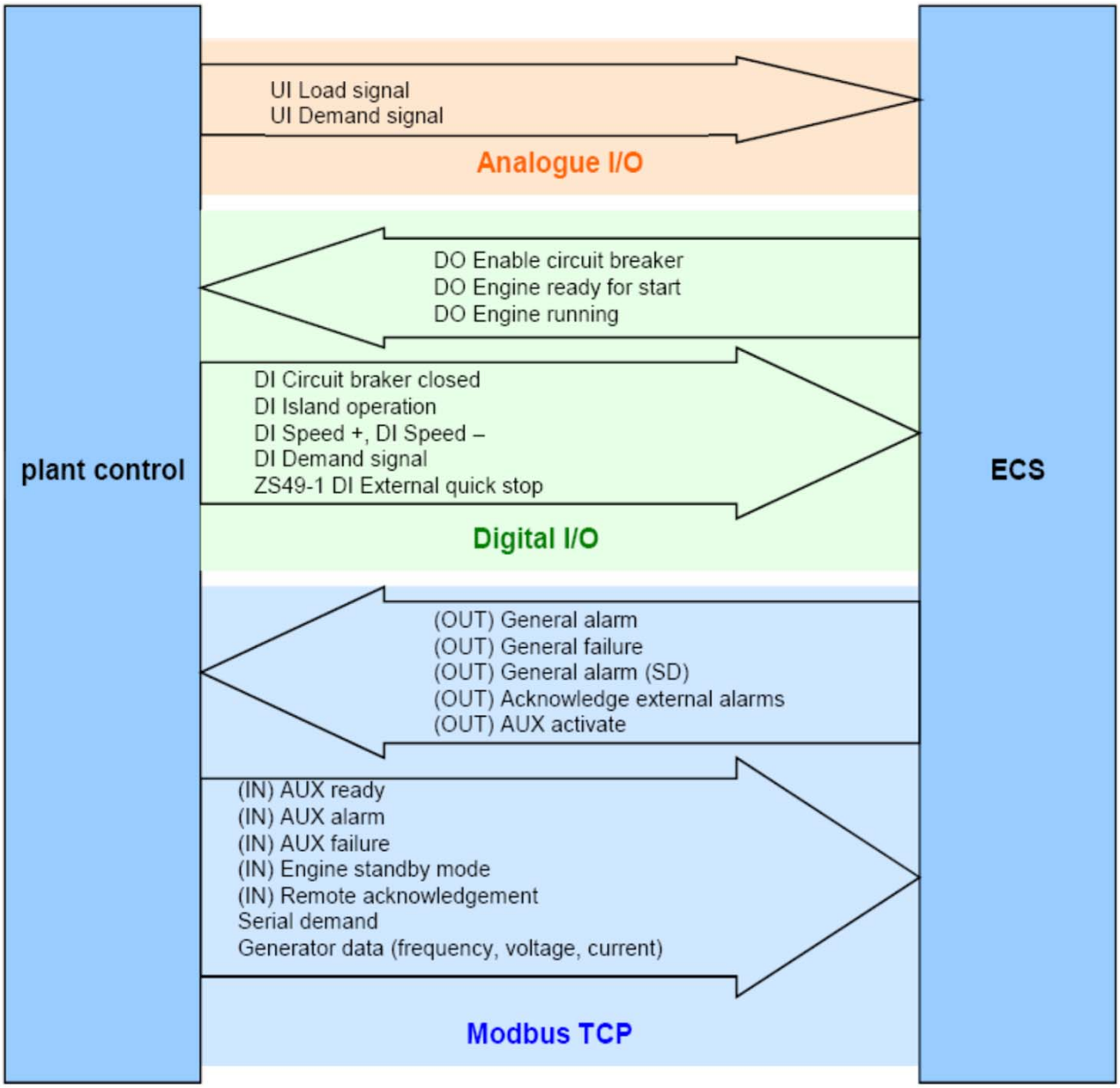


Fig. 4-3-2 Hardwire Interface

2.1 Hardwired signal interface with Plant system

Digital input

- DI circuit breaker closed: feedback of circuit breaker closed. Contact is closed when C.B closed.

- DI Island operation: distinguishes island operation and main parallel operation. Contact is closed when main parallel operation.

- DI speed +/- : increases or decreases engine speed.

- DI demand signal: demands the engine operation is automatic mode. The contact has to be closed during operation. Opening the contact in island mode will stop the engine and in main parallel mode, ECS will de-load the genset and then stop it.

- DI external quick stop: emergency stop button in plant system activates this signal. Contact is opened when quick stop is active.

- DI droop mode: this input distinguishes isochronous mode and droop mode. Contact is opened when droop mode is active.

Analogue input

- UI load signal: actual load value should be sent to ECS in 4...20 mA signal.

- UI demand signal: power demand from plant system. Signal scailing can be configured in 4...20 mA. Only active when analogue demand signal input is valid.

Digital output

- DO enable circuit breaker: active when ECS try to be synchronized. After receiving this signal from ECS, plant system should perform the synchronization and close the C.B. 24V is energized when synchronization and generator connection are enable.

- DO engine ready for start: releases engine start ready condition to plant system. 24V is energized when engine is ready for start.

- DO engine running: this signal is set to 24V as long as the engine speed is higher than 200 rpm.

2.2 Modbus communication interface with Plant system

A Modbus TCP interface serves for the communication of the ECS with an plant system via fieldbus.
Modbus TCP communication will be specified in a separate document. In summary, the EGCP system will be able to

- Read out variables measured by the ECS (e.g. temperatures, pressures)
- Read out ECS alarms and failures
- Acknowledge ECS alarms
- Initiate engine start or engine stop
- transmit data to ECS

The physical interface will be as follows:

- Transfer medium: Ethernet
- Cable: RJ45 Ethernet cable

Input commad from plant system via Modbus TCP

- (IN) AUX alarm: active when alarm from plant auxiliaries is pending. Engine start and operartion are allowed.

- (IN) AUX failure: active when failure from plant auxiliaries is pending. Engine start and operation is not possible.

- (IN) AUX ready: after ECS has demanded external start preparations via signal "Aux activate", the signal "Aux ready" signals whether the start sequence can be continued or not.

- (IN) Engine standby mode: distinguishes the stop mode is in "Stand-by mode" or in "Stand still mode". Please refer to P.04.100 4.3 Engine start from different stop mode for more information about the stop mode.

- (IN) Remote acknowledgement: active when operator try to acknowledge ECS alarm in remote.

- Serial demand: In main parallel operating mode, where ECS power control is active, plant control can preset engine power. Then power can be demanded via modbus. Only active when demand signal via modbus is valid.

- Generator data: The generator data (voltage, current, frequency) is sent from plant system via modbus to the ECS. ECS only displays those values.

Output commad to plant system via Modbus TCP

- (OUT) General alarm: active when there's alarm from engine.

- (OUT) General failure: active when there's shutdown signal from engine.

- (OUT) General alarm (SD): active when there's alarm (SD) from engine. During an alarm (SD), engine will be shut down with a defined delay time.

- (OUT) Acknowledge external alarms: active when ECS try to acknowledge the alarms and failures from plant system.

- (OUT) AUX activate: after engine start has been triggered, ECS sets signal active. The start sequence won't be continued until the input "AUX ready" is active. By this, activation of auxiliaries like exhaust flaps, pumps, ventilators etc. can be confirmed and they are activated if they have not been in active. The output is set until the engine is stopped again.

Operation data of the engine is listed below.
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	SE11	720 rpm/ 750 rpm	SAH11	112.6% MCR Rated speed	SSH11	113% MCR Rated speed
	Turbochager rpm	SE14	21,500rpm	SAH14	Depends on T/C Type	SSH14	Depends on T/C Type
Fuel Gas System	Gas regulator inlet	PT81	5.5~6.0 bar	PAL81	(A)+0.8 bar	PSL81	(A)+0.5 bar
				PDAH8081	0.5 bar		
						PSH81	7.0 bar
	Main chamber gas pressure	PT82-1	4.0~5.0 bar	PDAH82-1	0.3 bar dev from ref	PSH82-1	0.3 bar dev from ref
				PDAL82-1	0.3 bar dev from ref		
						PDSH82-1	0.5 bar dev from ref
	Prechamber gas pressure	PT82-2	4.0~5.0 bar	PDAH82-2	0.3 bar dev from ref		
				PDAL82-2	0.3 bar dev from ref		
	GVU control air	PT83	6.0~10 bar	PAL83	4.5 bar	PSL83	4.0 bar
	Gas pressure at main gas pipe	PT87	4.0~5.0 bar	PDAH87	0.3 bar dev from ref	PDSH87	0.5 bar dev from ref
				PDAL87	0.3 bar dev from ref		
						PDSH2187	(A)+1.5 bar
						PDSL2187	(A)-1.5 bar
	Fuel gas temperature	TE82	5~40℃	TAL82	5 ℃		
				TAH82	50 ℃		
Lub. Oil System	Press. drop across filter			PDAH61-62	1.5 bar		
	Press. before filter(★)	PT61	5.0-6.0 bar				
	Press. inlet engine	PT62	4.0-5.0 bar	PAL62	mapped	PSL62	mapped
					3.3 bar | 900rpm		3.0 bar | 900rpm
					2.8 bar | 700rpm		2.5 bar | 700rpm
					2.3 bar | 500rpm		2.0 bar | 500rpm
					1.8 bar | 250rpm		1.4 bar | 250rpm
	Temp. inlet engine, SAE40	TE62	60~70℃	TAH62	80 ℃		
	Press. inlet T/C	PT63	2.5-3bar	PAL63	1.5		
	Lub. oil level in base frame	LS68		LAL/H68	Low/High		
	Main bearing temperature	TE05	75~90℃	TLRH05	95 ℃	TSH05	100℃
	Oil mist detector (★)	LS92		LLRH92	High level	LSH92	High level
Cooling Water System	LT water press. inlet engine	PT71	1.5-5.0bar	PAL71	mapped		
					1.8 bar | 900rpm		
					1.3 bar | 750rpm		
					0.8 bar | 500rpm		
					0.8 bar | 250rpm		
	LT water temp. inlet engine	TE71	30-40℃	TAH71	55 ℃		
	HT water press. inlet engine	PT75	2.0-5.0bar	PAL75	mapped		
					2.0 bar | 900rpm		
					1.5 bar | 750rpm		
					1.0 bar | 500rpm		
					1.0 bar | 250rpm		
				PLRL75	mapped		
					1.8 bar | 900rpm		
					1.3 bar | 750rpm		
					0.8 bar | 500rpm		
					0.8 bar | 250rpm		

System	Descriptions		Normal Operation Range at Rated power		Alarm & Sensor		Autostop of Engine	
Cooling Water System	HT water temp. outlet engine		TE76	75-85℃	TAH76	90 ℃	TSH76	95 ℃
					TLRH76	92 ℃		
	HT water temp. air cooler outlet		TE77		TAH77	105 ℃	TSH77	110 ℃
Combustion Gas/Air System	Ambient temp. before air filter		TE29	20~30℃	TAH21	50 ℃		
	Charge air pressure		PT21	4.0~4.5 barA			PSH21	4.5 barA
					PDAH21	0.5 bar dev from ref	PDGTH21	0.5 bar dev from ref
	Charge air temperature		TE21	40~50℃	TAH21	55 ℃	TSH21	65℃
					TLRH21	60 ℃		
	Exh. gas temp. of cylinders		TE25	450~530℃	TAD25	Dev ± (B)		
						80 ℃| 75% load		
						80 ℃| 50% load		
						100 ℃| 25% load		
						150 ℃| 0% load		
	Exh. gas temp. inlet T/C		TE26	480-560℃	TAH26	600 ℃	TSH26	620℃
					TLRH26	610 ℃		
	Exh. gas temp. outlet T/C		TE27	300-400℃	TAH27	550 ℃		
Compressed Air system	Air inlet pressure	Control Air	PT41	6~7 bar	PAL41	4.0 bar	PSL41	3.5 bar
		Starting Air	PT40	20~30 bar	PAL40	16 bar		
					PSBL40	14 bar		
Cylinder Monitoring System	Knock sensor cylinder		LT94	No knocking	LAH94	(C)≥4° Crankangle	LSH94	(C)≥7° Crankangle
	Cylinder pressure sensor		PT24	135~165 bar	PAH24	170 bar	PSH24	180 bar
					PDA24	Dev from mean		
							PLS24	Misfire detection

Remark : (A). Charge air pressure
(B). Depending on cylinder No. and T/C maker and type
(C). Average exhaust temperature
(D). Number of knocking control trial.
★). Can be applied as an option.

T/C maker	T/C type	LO	
		Pressure range	Low alarm
		[bar]	[bar]
KBB	ST(EP)-Series	2.0 - 4.0	1.5
ABB	TPS-Series	2.0 - 3.0	1.5
	A130-145	3.2 - 4.5	3.0
	A150-155	1.5 - 2.5	1.3
	TPL-Series	1.5 - 2.5	1.3
Napier	Na-Series	1.5 - 2.5	1.3

Note:

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

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.

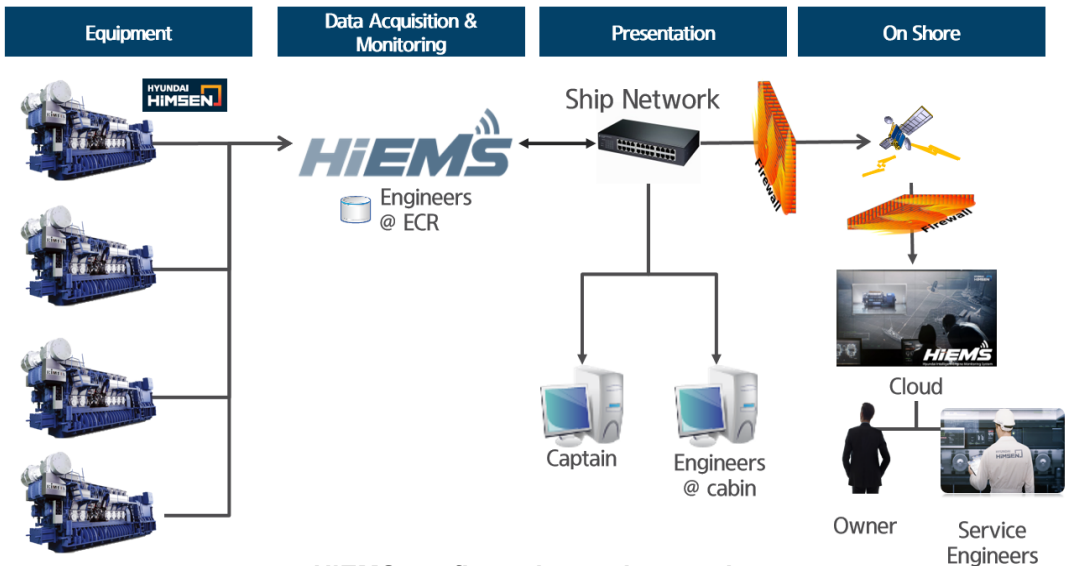
4. License policy

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

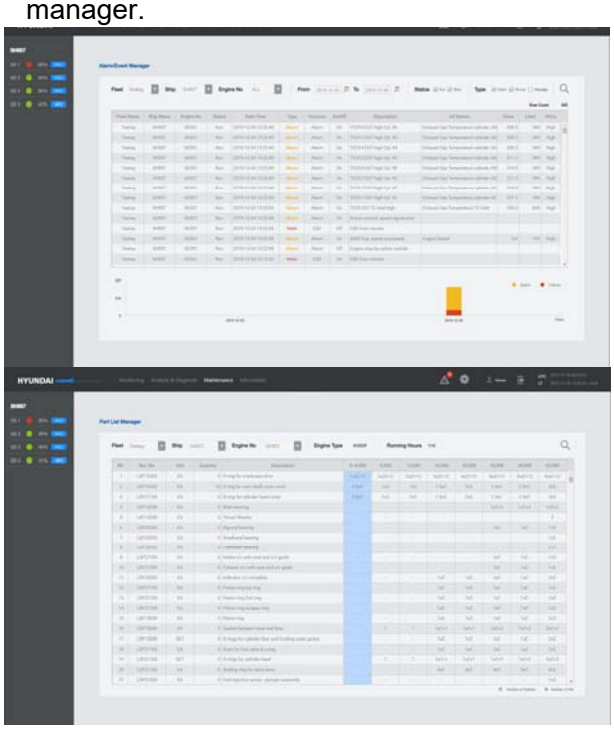
Real-time status monitoring of the HiMSEN engine

- 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

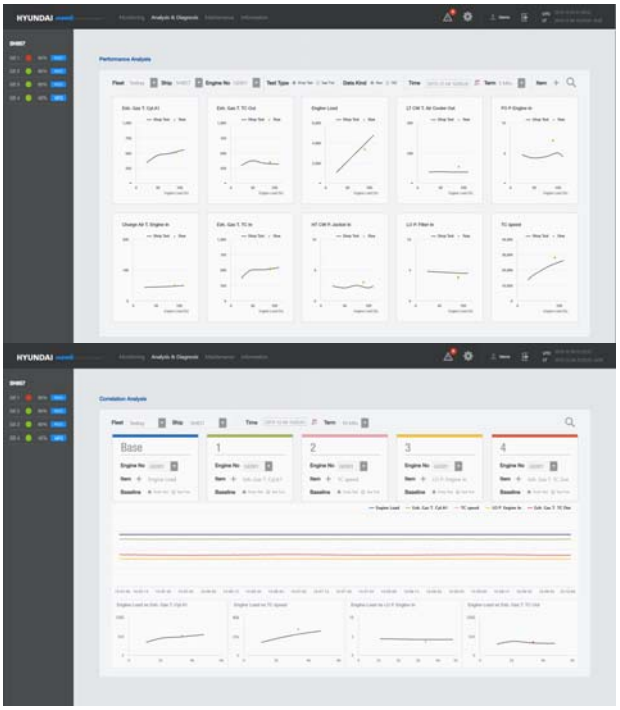
- Alarm/Event, maintenance, wearing parts manager.



5.3 Analysis & Diagnosis

Analysis tools for engine data

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



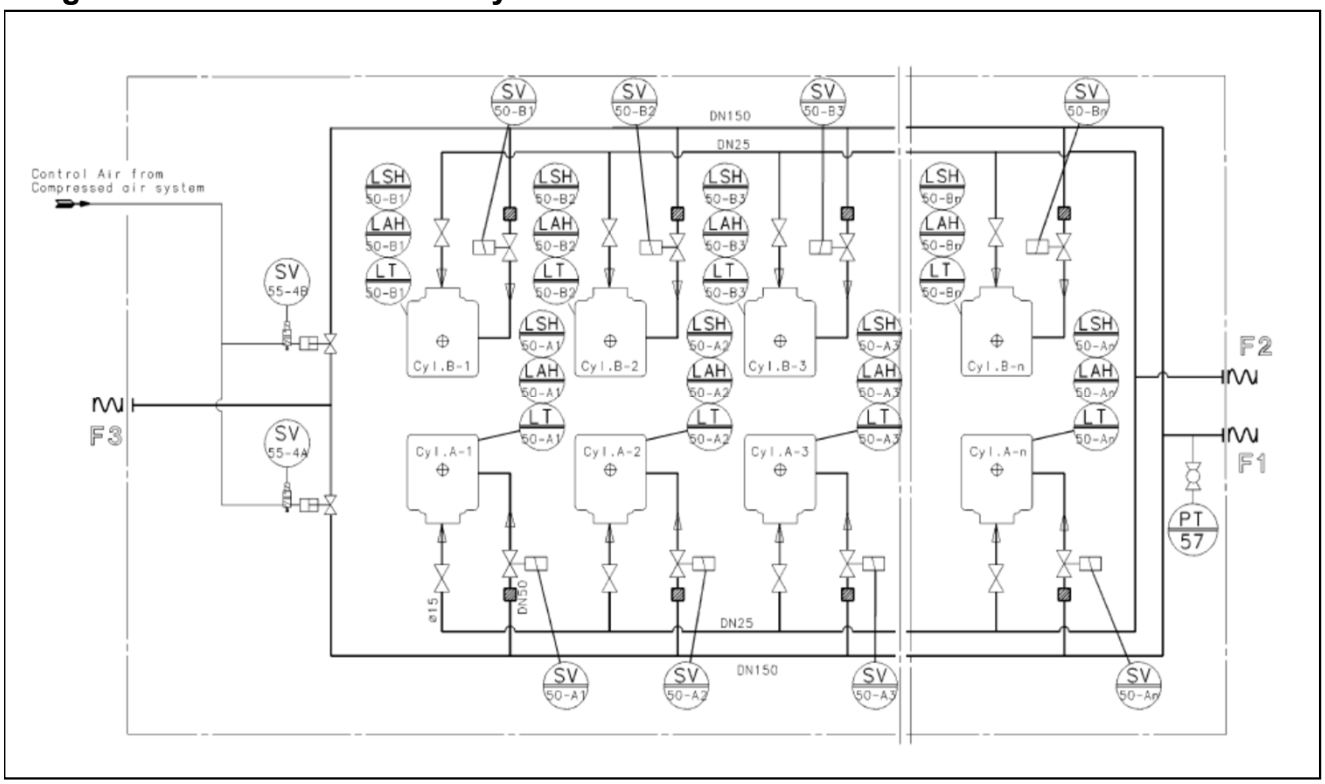
5.4 Fleet Management(Option)

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 Gas System



1. General Description

The engine fuel gas which is regulated by the external gas system is supplied to the two gas rails for the prechambers and main chambers of each
cylinder.

The rich gas is injected into the prechamber via the check valve wihich is actuated by the cam mechanism and the injected gas is burned by the ignition device in prechamber. Flames in the prechamber efficiently causes combustion in cylinder with main gas which is supplied from the gas admission valve into the intake of cylinder with
air.

2. Gas Admission Valve

Gas admission valve releases the gas into the air intake of cylinder head. It is controlled eletronically by engine control system to regulate engine speed and power. It is normally closed by a spring, but when there is electronic signal it is opened with suitable timing and duration. That makes it possible to control the amount of gas fed to each cylinder for speed and load blancing of the

3. Check valve

Check valve in prechamber is controlled by the spring loaded linkage via camshaft moving. It is sealed closely with several O-rings. If it has any leakage gas, it releases the gas through the vent line for
safety.

4. Venting valve

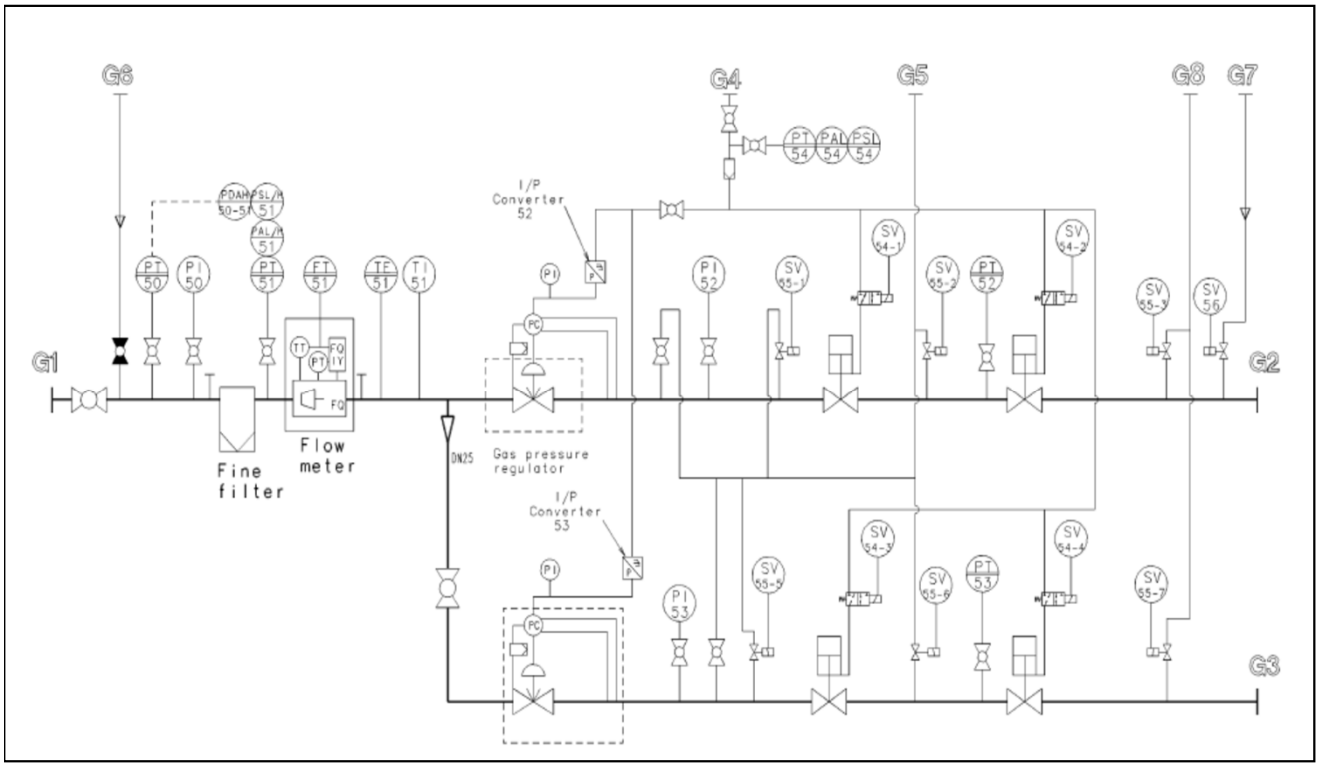
Venting valve purges the gas from the main gas feed rails. The valve is actuated pneumatically and controlled by ECS when engine stop

5. Sizes of External Pipe Connections

Code	Description	Pipe size
G1	Fuel gas inlet to mian chamber	80A
G2	Fuel gas inlet to pre-chamber	25A
G3	Fuel gas venting	25A

Size of Connections are standard according to JIS B 2220.

Diagram for External Fuel Gas System



1. General Description

For the gas supply to the engine, it passes through external fuel gas system in order to ensure the safety operation to maintain the desired pressure in the rails for main gas feed and prechamger gas feed.

The external fuel gas systetm adjusts the gas pressure via the pneumatic regulator which is controlled by the engine control system.

The system comprsies followings.

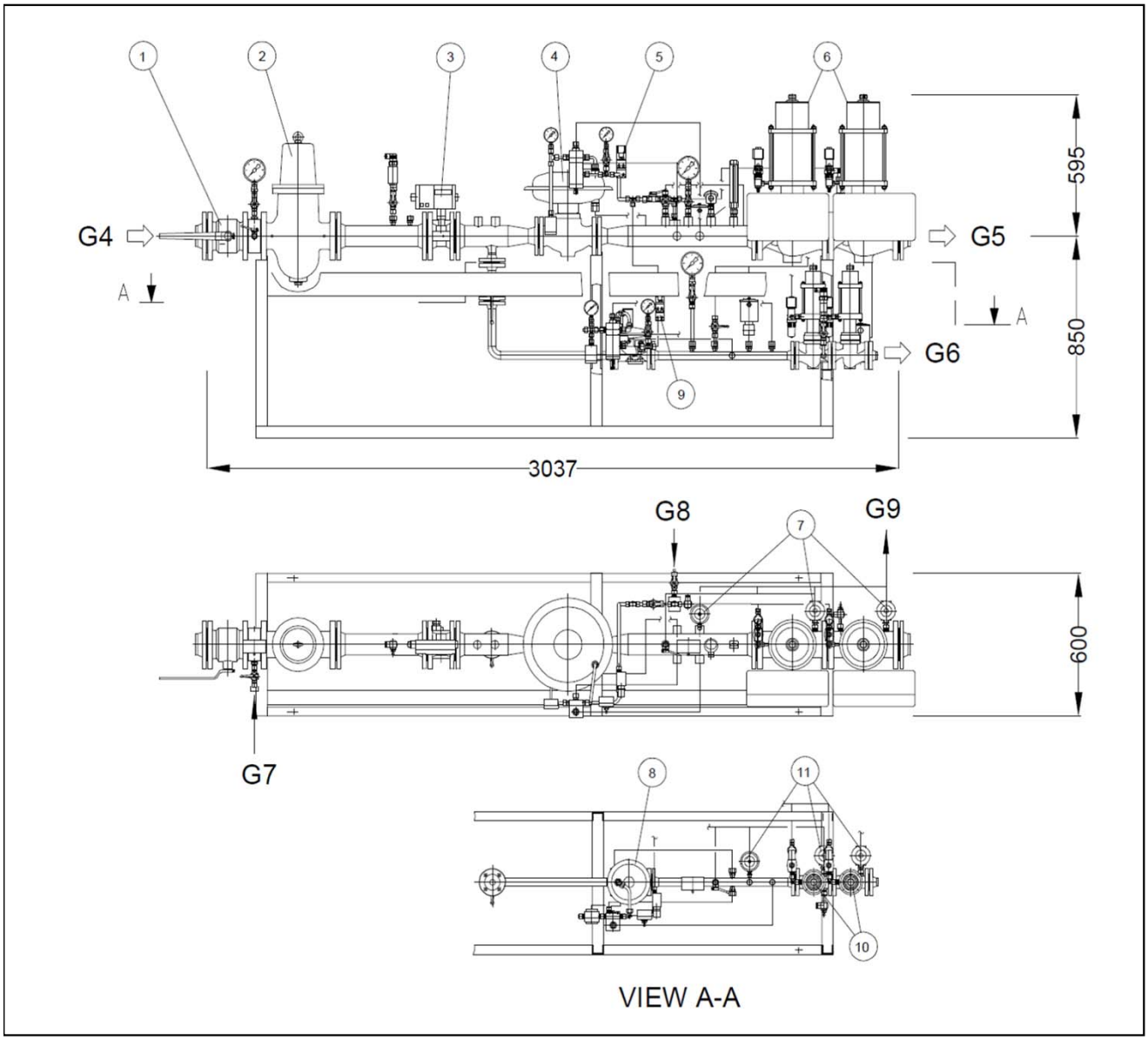
- Manual shut-off valve
- Gas filter
- Flow meter
- Gas pressure regulators
- Double block valves
- Gas venting valves
- Pressure gauge & transmitter
- Thermometer

2. Sizes of External Pipe Connections

Code	Description	Pipe size
G1	Fuel gas inlet to GRU unit	80A
G2	Fuel gas to main chamber	80A
G3	Fuel gas to pre-chamber	25A
G4	Control air to GRU unit	ϕ12
G5	Fuel gas venting	ϕ12
G6	Inert gas inlet to gas filter	ϕ12
G7	Inert gas inlet to engine	ϕ12
G8	Fuel gas venting	ϕ12

Size of Connections are standard according to JIS B 2220.

Typical drawing of Gas Train Unit



No.	Components	Specification
1	Manual shut-off valve	DN 80, PN 16, Ball valve
2	Gas filter with magnetic insert	DN 80, PN 16
3	Gas flow meter	DN 80, PN 16
4	Gas pressure regulator for main gas feed	DN 50, PN 16
5	I/P-converter for main gas feed	¼"NPT
6	Double block valves for main gas feed	DN 80, PN 16, Electro-pneumatic
7	Gas venting valves for main gas feed	OD12mm, Electro-magnetic valves
8	Gas pressure regulator for prechamer gas feed	DN 25, PN 16
9	I/P-converter for prechamer gas feed	¼"NPT
10	Double block valves for prechamer gas feed	DN 25, PN 16, Electro-pneumatic
11	Gas venting valves for prechamber gas feed	OD12mm, Electro-magnetic valves

1. Gas filter

Gas filter protects downstream equipments of a pressure regulator from impurities such as dust, rust, and other solid particles. It fillters out the particles of 2um and over, and the filtration degree is 99%.

2. Flow meter

Flow meter directly measures the flow rate at measurement condition and integrates the measured values. As a result, the gas volume which flowed through the meter is registered by an electronic totalizing unit.

3. Double block valves

Double block valves cut off gas supply to the engine when the engine is not running or in emergency. The two valves are activated by electonic signal from the engine control system. When the signal is switched on (or off), they are opened (or closed) automatically.

After the double blolck valves are closed, the gas venting valves are opened immediately and de-pressurizes the gas train unit. That makes the gas blocking operation more effective and safe.

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

4. Gas pressure regulator

Gas pressure regulator adjusts the gas feed pressure to the setpoint and keeps independent of disturbing influences like inlet pressure or flowrate changes. It is controlled by the engine control system via I/P-converter, which transforms the computed electronic signal into the control air pressure.

General description

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

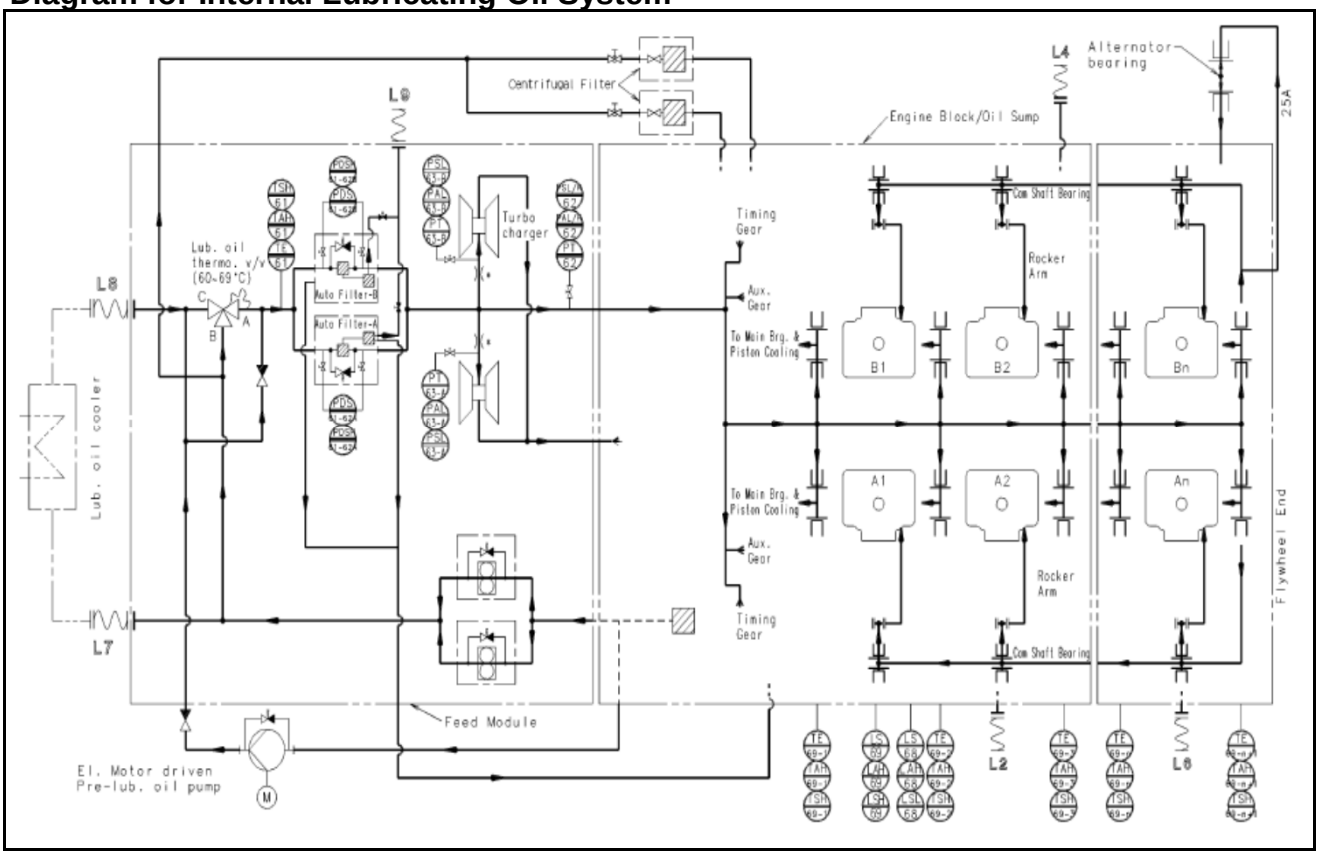
Fuel gas specification

Property	Unit	Value
Lower calorific value (LCV), min.	MJ/Nm^3 1)	28
Methane Number (MN), min.	-	80
Particles or solids at engine inlet (max. size)	μm	5
Particles or solids at engine inlet	mg/Nm^3	50
Hydrogen sulphide content (H_2S), max	mg/Nm3	30
Gas inlet temperature	°C	0 ~ 50

1) Reference conditioin for the volume designation Nm^3
(temp. 25℃, Atmospheric press. 1.013 bar)

2) Not allowed the condensated water or liquids at engine inlet

Diagram for Internal Lubricating Oil System



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 mounted directly on Feed Module without pipe connections.

The system comprises following equipments;

1. Lubricating oil cooler
2. Engine driven Lubricating oil pump
3. Electric motor driven pre-lubricating pump
4. Lubricating oil thermostatic valve
5. Lubricating oil fine filter
6. Oil pressure regulating valve
7. Wet sump tank
8. Centrifugal oil filter (Option)

2. Sizes of External Pipe Connections

Code	Description	Pipe size
L1	Oil vapor discharge	125A
L2	Lub. oil from heater	65A
L4	Lub. oil to heater	65A
L6	Lub. oil filling	65A
L7	Lub. oil to L.O cooler	125A
L8	Lub. oil from L.O cooler	125A
L9	Dirty L.O to waste tank	25A

Size of Connections are standard according to JIS B 2220.

3. Quantity of Lubricating Oil

Total quantity of lubricating oil inside the engine

Engine type	Oil quantities in liter	
	720/750 rpm	
	min.	max.
12H35/40GV	4530	6110
14H35/40GV	5000	6810
16H35/40GV	5480	7510
18H35/40GV	5950	8210
20H35/40GV	6430	8910

4. Lubricating Oil consumption

SLOC : 0.4 g/kWh

Tolerance : +25% depending on the operating condition.
Only MCR should be used to evaluate the lub. Oil consumption.

5. Engine Driven Lubricating Oil Pump

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

6. Pre-lubricating Oil Pump

The pre-lubricating pump is an electric motor driven gear type and this is operated automatically when engine is stopped.

Pre-lubrication is recommended during engine stop period if ready to start condition.

7. Lubricating Oil Cooler

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

8. Thermostatic Valve

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

9. Lubricating Oil Filter

The lubricating oil filter is automatic filter type, mounted on the feed module of the engine. Each filter has Full-flow chamber and diversion chamber. .

- Full-flow chamber finess : 34㎛
- Diversion chamber finess : 34㎛

10. Pressure Regulating Valve

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

11. Centrifugal Oil Filter (Option)

Centrifugal oil filter can be mounted on engine. The 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 on Gas or 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 x 1.4 x n / t

F = required flow (l/h),
p = total engine output
(kW),
n = number of oil circulation per day,
(4 for GAS, 5 for MDO, 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 x p (l/h)

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

V = F / B (l/h)

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

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

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)

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

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

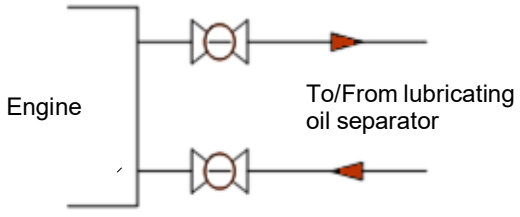


Fig. 1 Principle lay-out for direct separating on a single plant

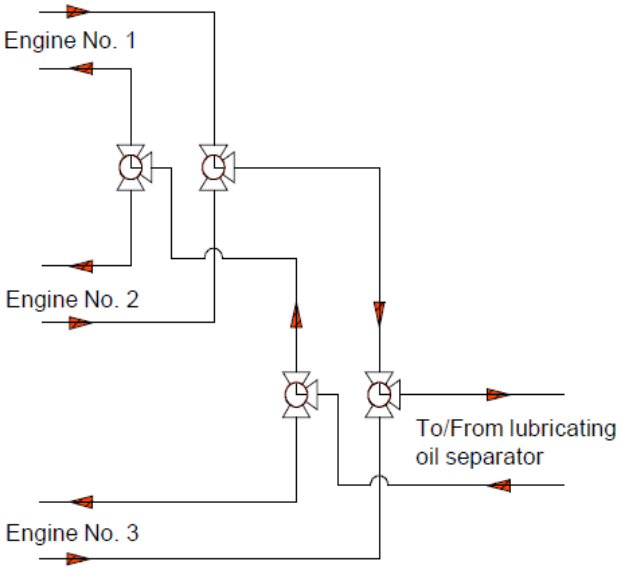


Fig. 2 Principle lay-out for direct separating on a multi plant

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 syphon effect, the overflow pipe from sump to overflow tank should have a continuous downward gradient of minimum 10 degrees without high and low point.

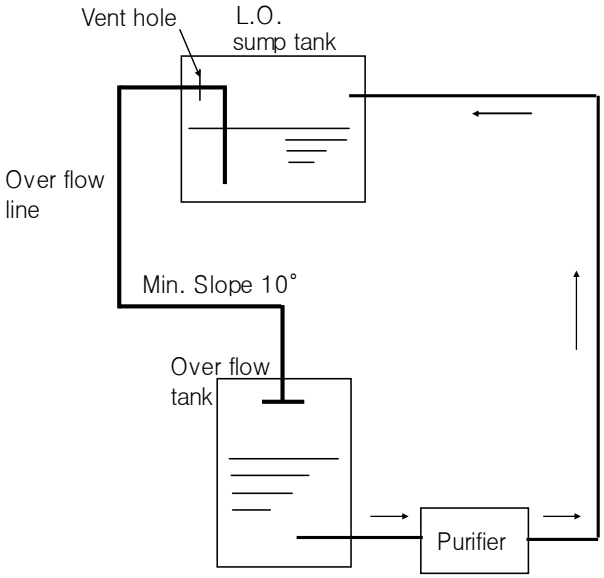


Fig. 3 Principle lay-out for overflow system

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 pipe from each engine is led independently to the top of the funnel.
- 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 connectionis 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:

- 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 40 mmWC at MCR.

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

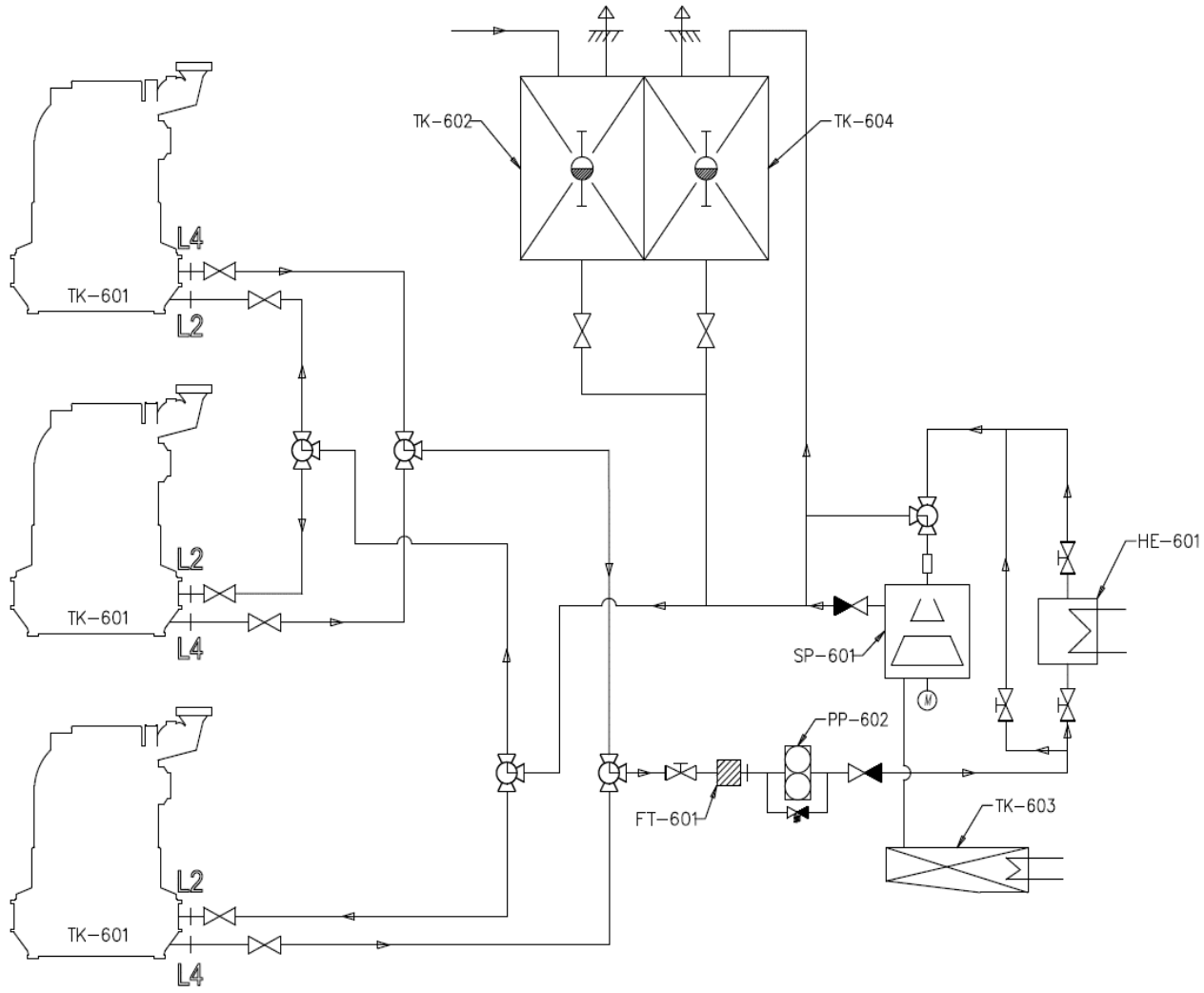


Fig. 4 External lubricating oil system (Wet Sump) for multi-engine installation (B91-314112-7.1)

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'.

TBN - Value

Total Base Number (TBN) is a measure of the alkalinity or basicity of the oil and is expressed in milligrams of potassium hydroxide per gram of oil (mg KOH/g). TBN for different engines will fall at a varying rate, determined by the consumption of alkaline additives combined with refilling of new oil. TBN should be 4~7 mg KOH/g for a gas engine.

2. Oil Viscosity

The oil viscosity is based on SAE 40 oil and recommended to be min 11 ㎟/sec to max 17 ㎟/sec at 100 ℃.

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

3. Content of metal component parts,

limit values

Al	<	20	mg/kg
Cr	<	10	mg/kg
Cu	<	25	mg/kg
Fe	<	25	mg/kg
Pb	<	20	mg/kg
Sn	<	8	mg/kg

List of Lubricant

Supplier	Brand name	Viscosity	TBN
BP	Energas NGL	SAE 40	4.5
Castrol	Duratex L		4.5
Chevron(Texaco, Caltex)	Geotex LA		5.2
ExxonMobil	Pegasus 705		5.3
	Pegasus 805		6.2
	Pegasus 905		6.2
	Pegasus 1		6.5
Petro-Canada	Sentinel 445		4.7
Shell	Mysella LA 40		5.2
	Mysella S3 N40		5
	Mysella S5 N40		4.5
Total(Lubmarine)	Nateria X 405		5.2
	Aurelia LNG		5
Petronas	Petronas Disrol 50		6
Hyundai Oilbank	Hyundai XTeer HGSL 40		6

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 water 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)

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

2. 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.

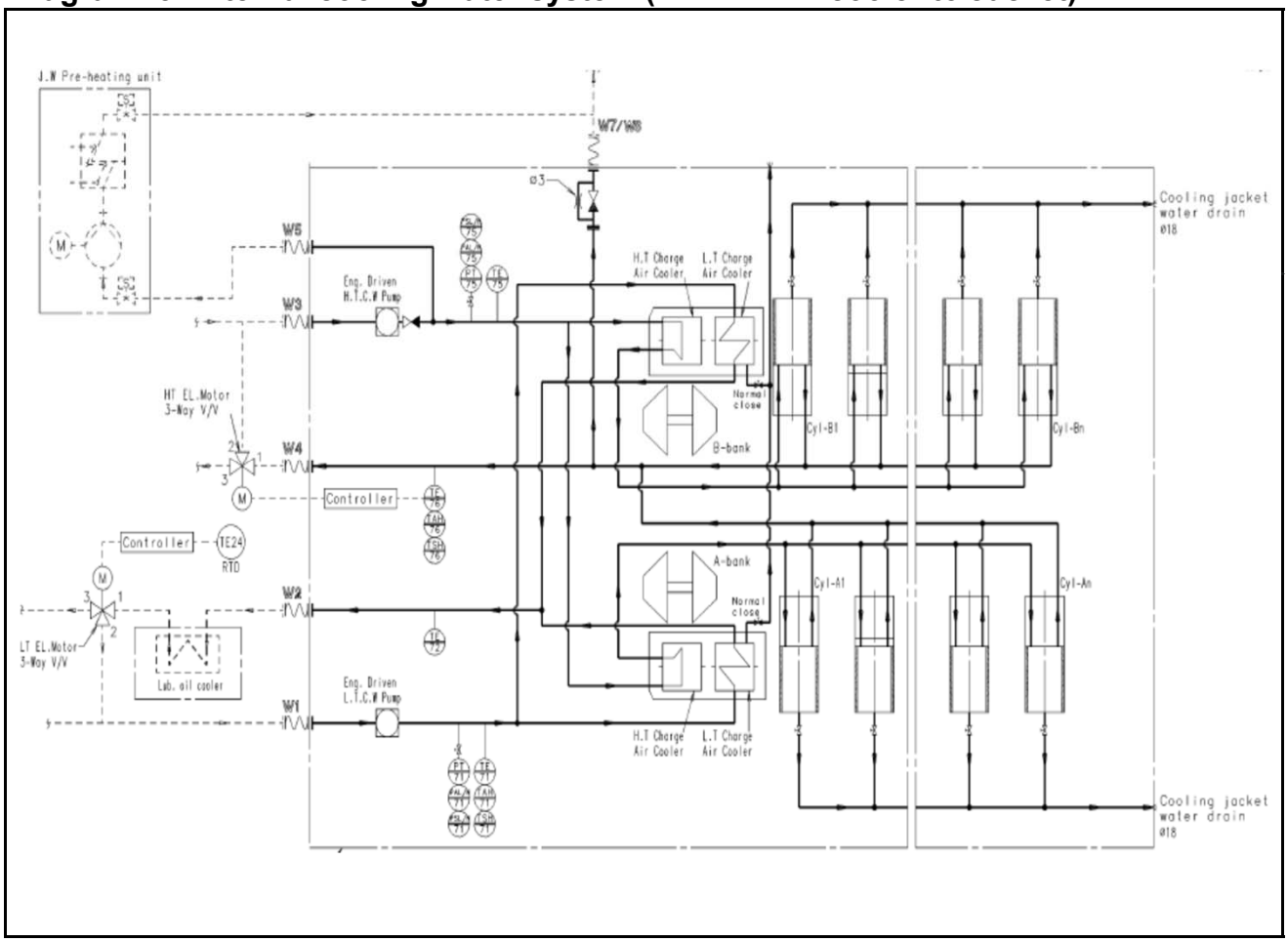
3. Preheating

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 : Min 30℃

Heating capacity : approx. 3.0 kW per cyl.

Diagram for internal cooling water system (HTCW : Air cooler to Jacket)



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
W5	H.T.C.W to pre-heater	40A
W7/ W8	Venting to Expansion Tank	40A
	H.T.C.W from pre-heater	

Size of Connections is standard according to JIS B 2220.

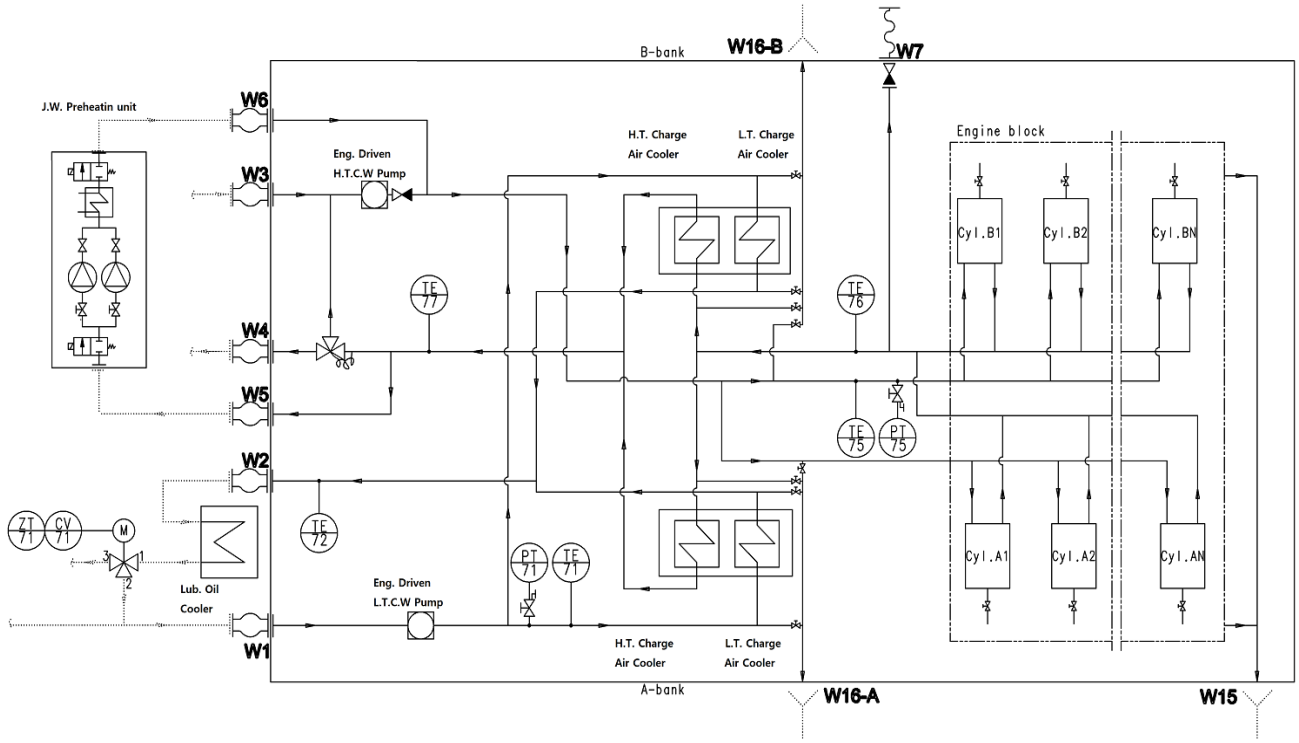
3. Scope of Supply

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.C.W. control thermostatic valve
* 5. J.W. Pre heating unit

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

Diagram for internal cooling water system (HTCW : Jacket to Air cooler)



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
W5	H.T.C.W to pre-heater	40A
W7	Venting to Expansion Tank	40A
W15	H.T.C.W from pre-heater	10A
W16-A	Venting to Expansion Tank	
W16-B	H.T.C.W from pre-heater	

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.C.W. control thermostatic valve
* 5. J.W. Pre heating unit

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

1. Design Data for External Cooling Water System

Pressure drop

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

Fresh Water Velocity

Suction Pipe : 1.5 - 2.0 m/s
Delivery Pipe : 2.0 - 2.5 m/s

Sea Water Velocity

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

Expansion tank

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

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

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

The cooling water volume of the engines;

Engine type	HT & LT Water Volume
12H35/40GV	1164 liter
14H35/40GV	1234 liter
16H35/40GV	1302 liter
18H35/40GV	1372 liter
20H35/40GV	1460 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.

Diagram for External Cooling Water System (Multi-engine installation with an external preheater unit)

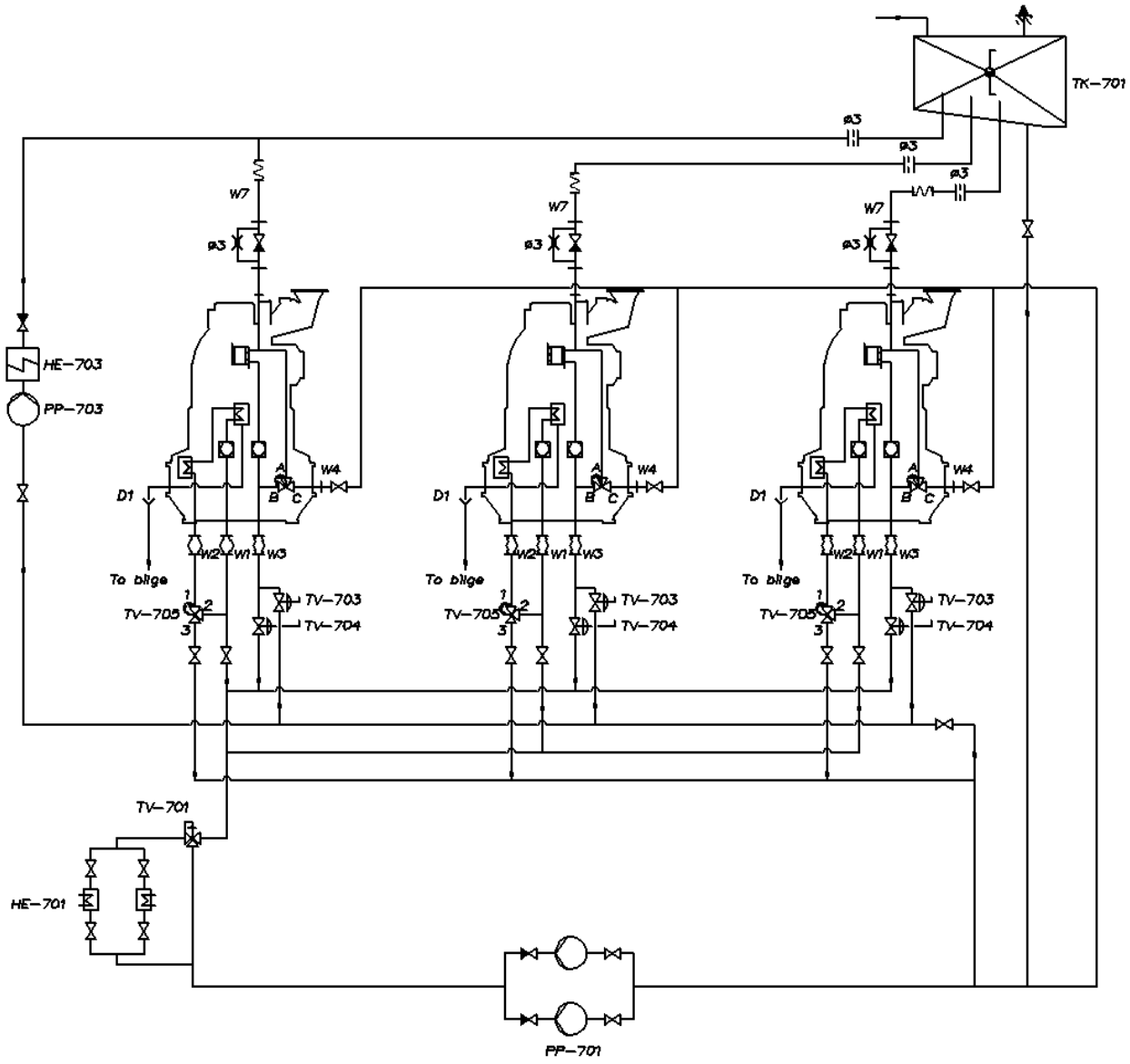


Figure 7-2-1: External cooling water system for multi-engine installation with an external preheater unit

System components

Code	Description	Code	Description
TK-701	Expansion tank	TV-703/704	Auto shut-off valve
HE-701	Central cooler	TV-705	Thermostatic valve for L.T cooling wate
HE-703	Preheater for H.T cooling water	PP-701	Circulation pump for fresh water
TV-701	Thermostatic valve for central cooling	PP-703	Circulation pump for preheating

Pipe connections

Code	Description	Code	Description
W1	L.T cooling water inlet	W4	H.T cooling water outlet
W2	L.T cooling water outlet	W7	H.T cooling water ventilation to expansion tank
W3	H.T cooling water inlet		
W4	H.T cooling water outlet	D1	Water drain

Diagram for External Cooling Water System (Multi-engine installation with electric preheating element)

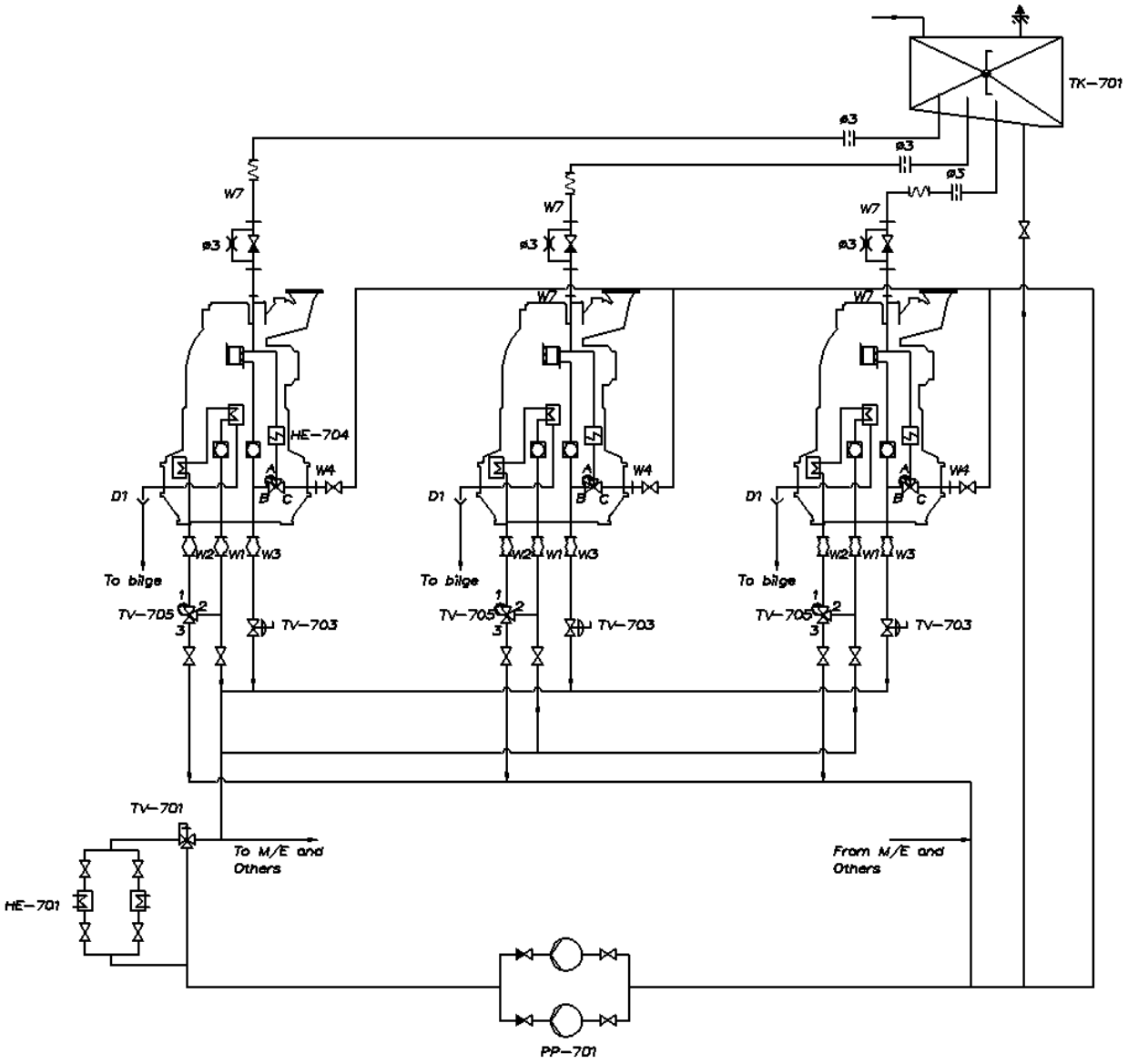


Figure 7-2-2: External cooling water system for multi-engine installation with electric preheating elements

System components

Code	Description	Code	Description
TK-701	Expansion tank	TV-703	Auto shut-off valve
HE-701	Central cooler	TV-705	Thermostatic valve for L.T cooling wate
HE-704	Electric preheating element	PP-701	Circulation pump for fresh water
TV-701	Thermostatic valve for central cooling		

Pipe connections

Code	Description	Code	Description
W1	L.T cooling water inlet	W7	H.T cooling water ventilation to expansion tank
W2	L.T cooling water outlet		
W3	H.T cooling water inlet	D1	Water drain
W4	H.T cooling water outlet		

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.

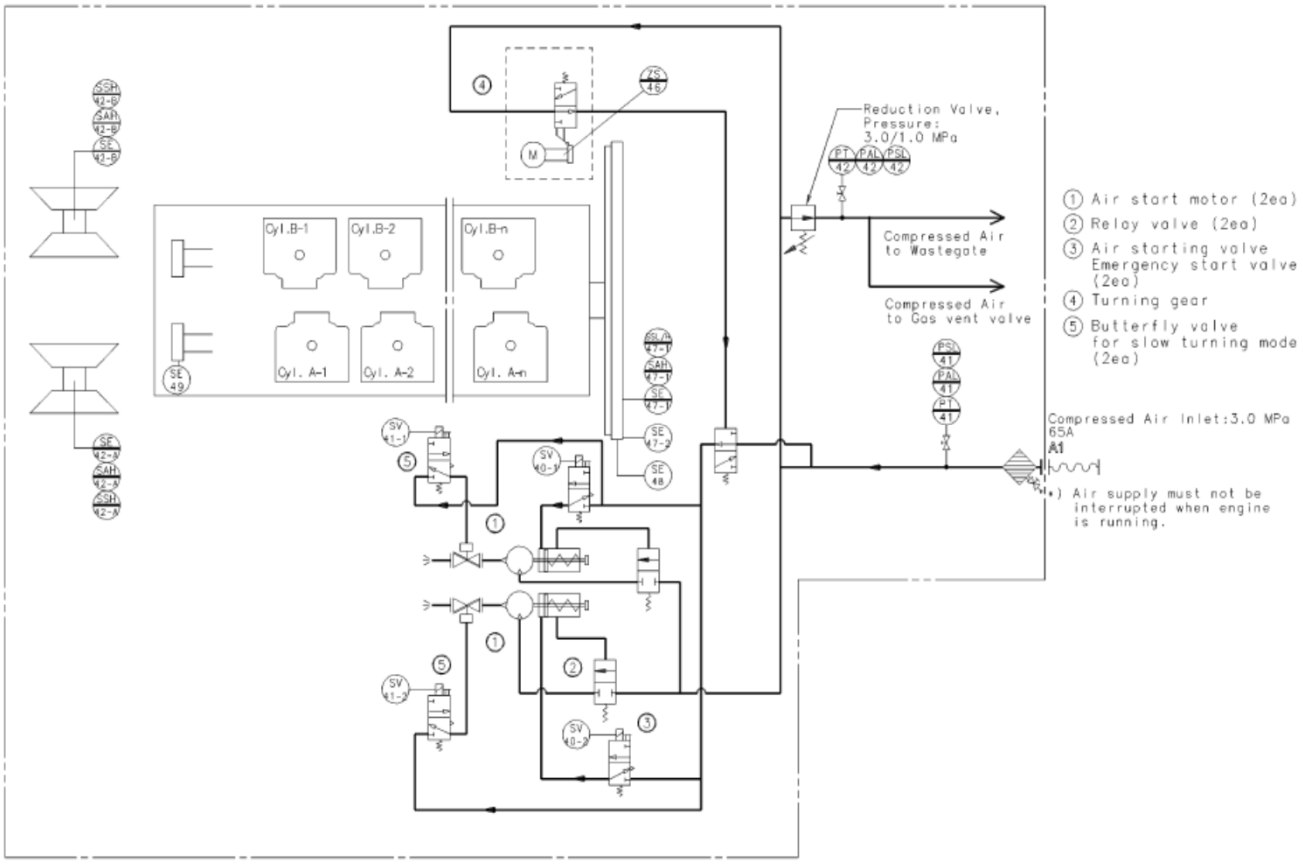
Manufacturer	Brand Name	Constituent	Delivery Form	Recommended Dosage
Chevron (FAMM)	DELO XLI(Havoline XLI)	Carboxylates	Liquid	75 liter / 1,000 liter
VECOM	Cooltreat NCLT	Nitrite	Liquid	48 liter / 1,000 liter
Wilhelmsen Chemicals	Rocor NB	Nitrite, Borate	Liquid	63 liter / 1,000 liter
NALCO	NALCOOL2000,TRAC102	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

Supply of compressed air of max. 30 bar is required for the starting, control and safety system of the engine. Please also refer to 'Engine Control System'.

Air Starter Complete comprises relay valve, air starting valve and starting air motor unit for starting the engine by turning Flywheel with gears.

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. Engine Starter included slow turning valve
2. Turning gear

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.

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

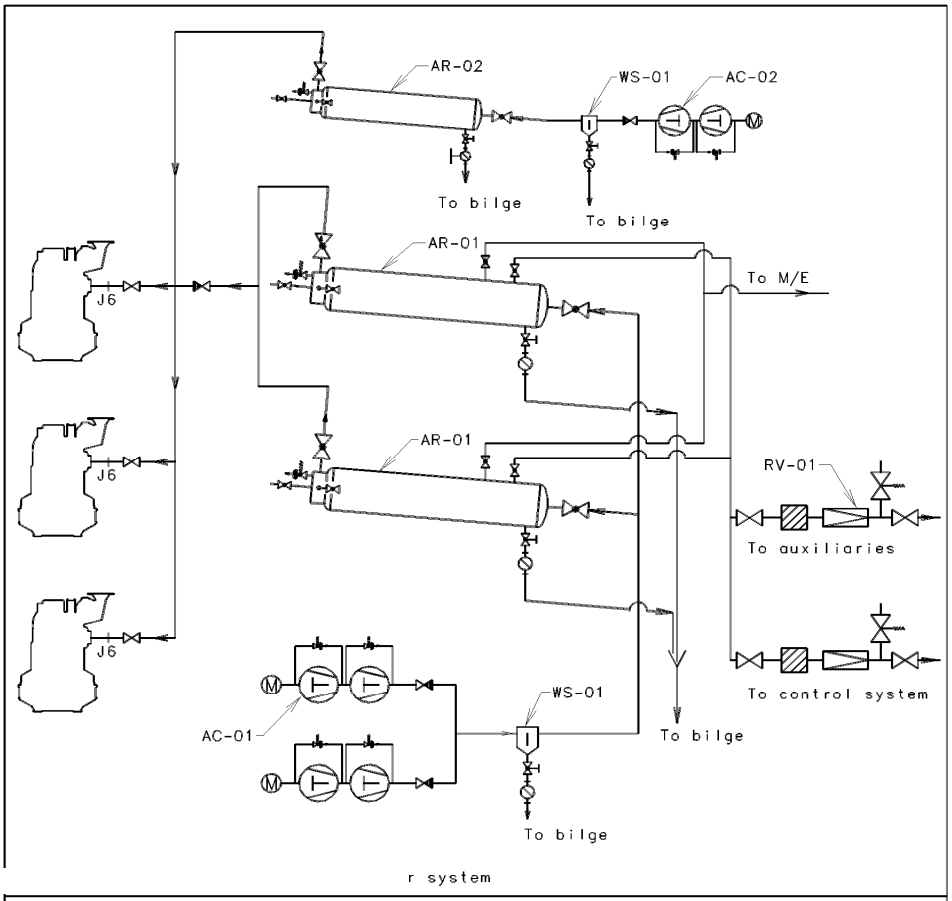
2. Starting Air Vessels

Air consumptions per one start are specified in 'Engine Capacity Data'. The capacity of starting air vessel varies depending on Customers. However, recommended volumes for three starts of three auxiliary engines are as follows;

Enigne type	Volumes
3x12H35GV	2x4000 liter
3x14H35GV	2x4000 liter
3x16H35GV	2x4000 liter
3x18H35GV	2x4000 liter
3x20H35GV	2x4000 liter

- Slow turn is excluded in air volums.

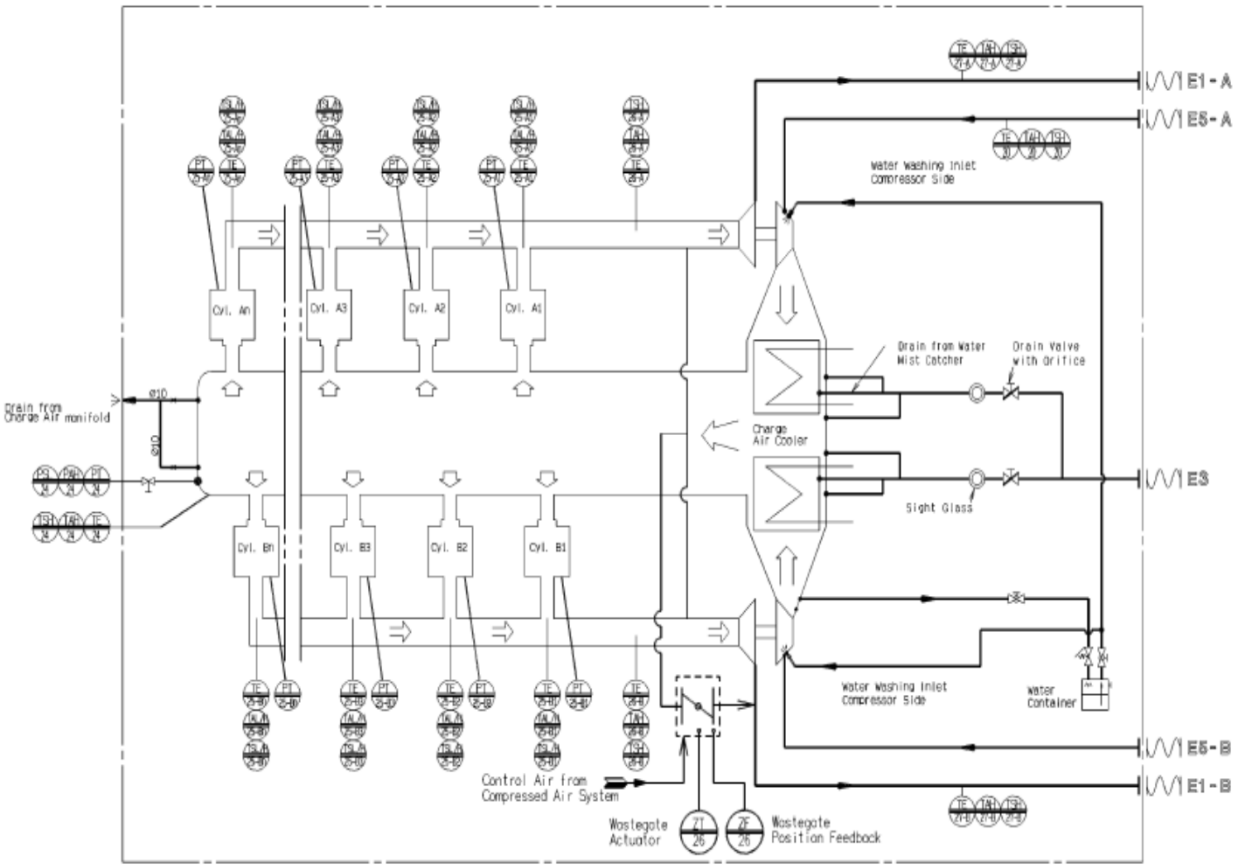
A typical Diagram for External Compressed Air System



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 and mixed with fuel gas in the intake port through a gas admission valve. It is imperative that the combustion air is free from water, dust and fumes etc.

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

Charge Air Cooler is a two stage 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.

Wastegate valve is butterfly valve type controlled by a electro pneumatic actuator.

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 Mono-pipe type, which has better performance at high load and a simple arrangement and easy maintenance.

Water trappers are installed in Water Drain Pipes.

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.

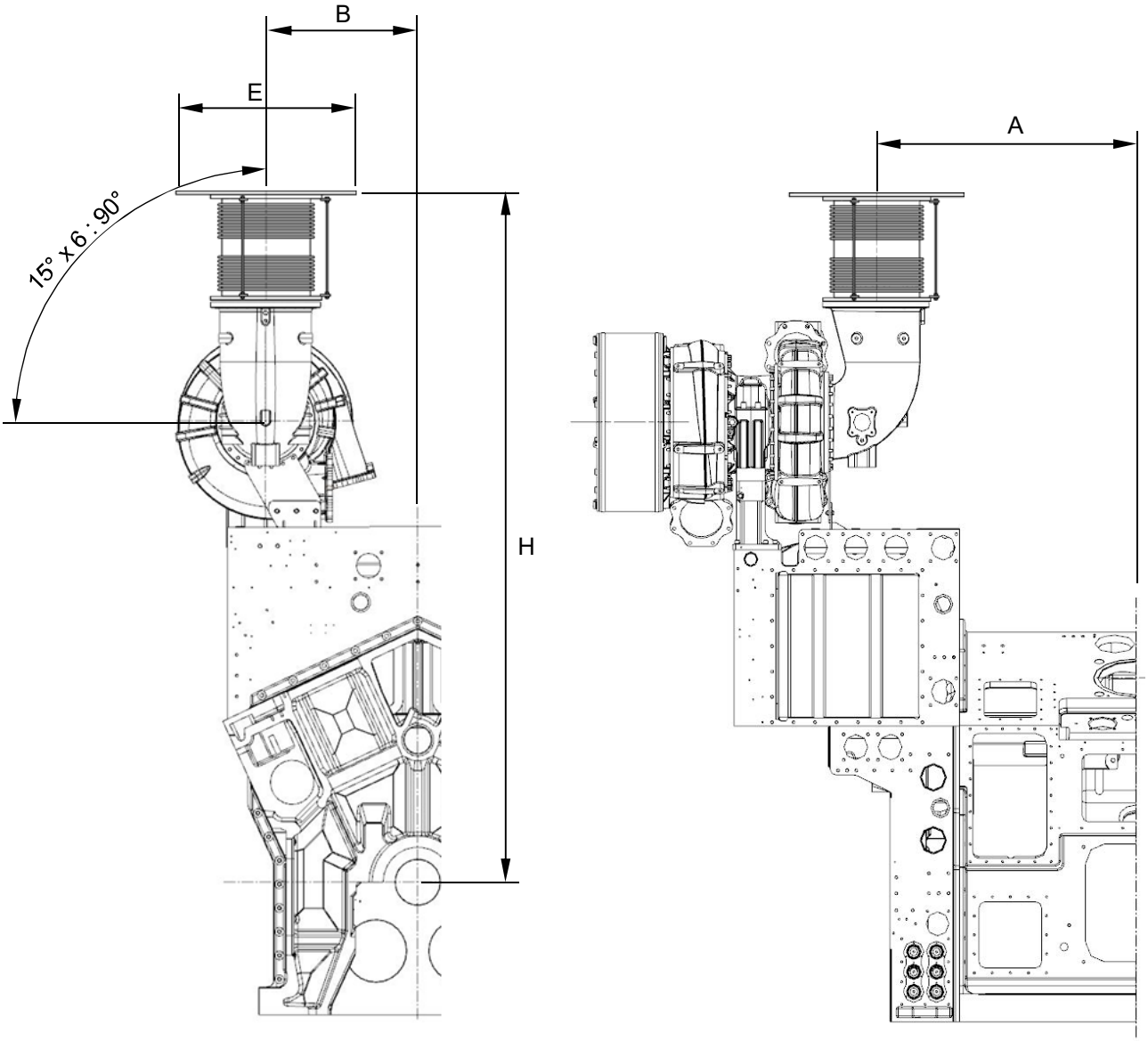
A boiler may be a separate unit for each engine or a common unit with other engines.

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

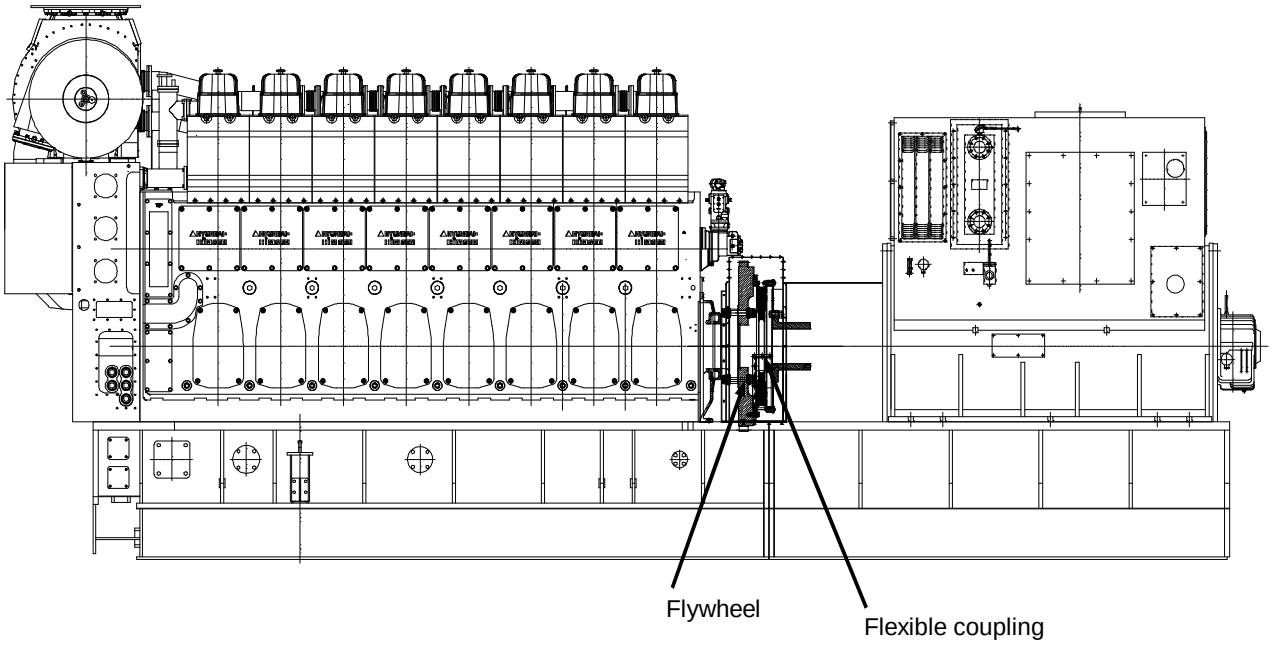
Exhaust Gas Silencer can be supplied as option on request. The noise attenuation of silencer shall be either 25 dB(A) or 35 dB(A). For more information, please refer to the sheets for 'Exh. Gas Silencer (P.08.610/620)'.



Genset for 720 / 750 rpm (480 kW/cyl.)

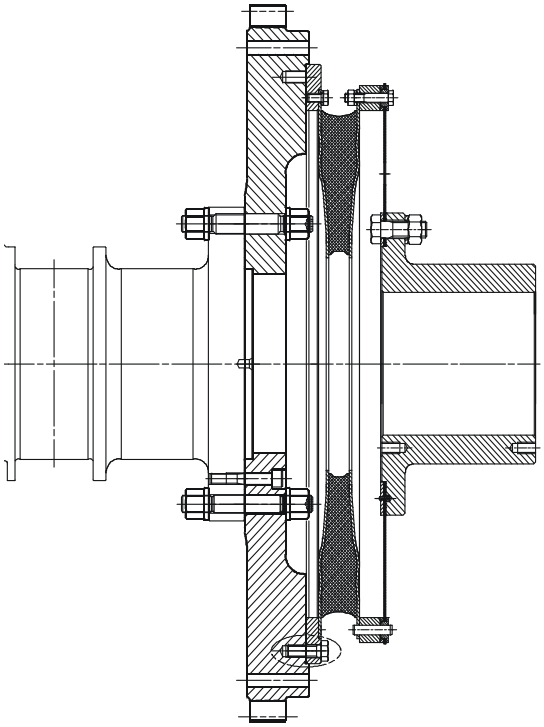
Engine	Exh. Outlet Position(mm)			E	
Type	A	B	H	Size	Standard
12H35/40GV	1,193	555	2,904	600A	JIS F 7805
14H35/40GV	1,193	555	3,475	600A	JIS F 7805
16H35/40GV	1,370	780	3,475	750A	JIS F 7805
18H35/40GV	1,370	780	3,475	750A	JIS F 7805
20H35/40GV	1,370	780	3,475	750A	JIS F 7805

Preliminary dimensions can be changed more detail from turbocharger specification.



Mounting of Generator

As a standard design of H35/40G(V) 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.

Major Overhaul Guidance

Section No.		Description	Overhaul Interval (hours)											Remark
			Others	500 *)	2,000	4,000	8,000	12,000	16,000	20,000	24,000	28,000	32,000	
		Major Fasteners - Confirmation												
M11100	LGV11100	Bolt for Base Frame and Resilient Mount		▲			◆							
G11100	-	Nut for Resilient Mount and Foundation		▲			◆							
M13250	LGV13000	Hyd. Nut for Main Bearing Cap		◆			◆							
M21100	LGV13000	Hyd. Nut for Cylinder Head		◆			◆							
M25000	LGV25000	Bolt and Nut for Camshaft		▲			◆							
M31000	LGV32000	Hyd. Nut for Con-Rod (Shaft)		◆			◆							
M31000	LGV32000	Hyd. Nut for Con-Rod (Big-end)		◆			◆							
M33200	LGV33100	Hyd. Nut for Counter Weight		◆			◆							
M35300	LGV35000	Bolt and Nut for Timing Gear		▲			◆							
M35300	LGV35000	Hyd. Nut for Idle Gear (Only for Vee-type engine)		◆			◆							
-	LGV81000	Bolt and Nut for Turbocharger Mounting		▲			◆							
		Major Bearing												
M13250	LGV13250	Main Bearing					√		■				▣	
M13250	LGV13250	Thrust Washer : Axial Clearance					◎						▣	
M25000/M25300	LGV25300	Camshaft Bearing : Clearance					√		◎				▣	
M32120	LGV32000	Con-Rod Bearing (Big-end)					√		■				▣	
M32130	LGV32000	Con-Rod Bearing (Small-end)					√		■				▣	
M35300	LGV35000	Bearing Bush for Idle Gear : Clearance							◎				▣	
		Resilient Mount												
M11100	LGV11100	Resilient Mount		●			●							
		Cylinder Unit and Con. Rod												
M15100	LGV15000	Cylinder Liner					√		■					
M15100	LGV15000	Flame Ring					√		▣					
M21100	LGV15000/LGV21100	Cylinder Head & Water Jacket Cooling Water Space					√		■					
M21120/M21130 /M21200	LGV21100/LGV21200	Intake/Exhaust v/v Spindle, Seat Ring and v/v Guide					√		▣					
M21210	LGV21200	Intake/Exhaust v/v : Clearance		●	●									
M21210	LGV21200	Rocker Arm Shaft and Bush					√		■					
M21220	LGV21200	Rotocap			○				■					
M31100	LGV31100	Piston Rings					√		▣					
M31100	LGV31100	Piston and Piston Pin					√		■					
M31100/M31101	LGV32000	Con-Rod Bore (Big-end)					√		■					
M31100/M32130	LGV32000	Piston Pin & Con-Rod (Small-end) : Clearance					√		■					
-	LGV32000	Shim Plate for Con-Rod					√		▣					
-	LGV32000	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.

Major Overhaul Guidance

Section No.		Description	Overhaul Interval (hours)										Remark
			Others	500 *)	2,000	4,000	8,000	12,000	16,000	20,000	24,000	28,000	32,000	
Crankshaft and Gears														
M33100	LGV33100	Crankshaft : Deflection					◎							
-	LGV33300/LGV42300	Gear Teeth on Flywheel & Turning Gear					▲							
-	LGV33400	Torsional Vibration Damper : Fluid sampling (Only for Viscous Damper)							◎					(See Manual for T/V Damper)
-	LGV33500	Flexible Coupling	▲											(See Manual for Flex.Coupling)
M35300	LGV35000	Timing Gear and Pump Driving Gear : Clearance and Backlash							◎					
Valve Operating Mechanism														
M23000	LGV23000	Swing Arm Roller Shaft and Bush							■				▣	
M25000	LGV23000/LGV25000	Contact Faces of Cam and Swing Arm Roller Camshaft Bearing		▲			▲							
Control System														
G40001	-	Safety Device : Function Check	○											Monthly
M45200	LGV45200	Engine RPM Pick-up Sensor : Clearance					●							
M45200	LGV45200	Temperature / Pressure Sensor	○											In case of necessity
Ignition System														
M46102	LGV46102	Spark Plug			■	▣								
M46102	LGV46102	Ignition Coil					■						▣	
M52000	LGV52000	O-rings for check Valve Assembly							▣					
M52000	LGV52000	Check Valve Assembly : Clearance		●	●						▣			
Fuel Gas Supply System														
-	LGV46101	Gas admission valve							▣					
G05100	-	Analyze Fuel Gas Properties : Sampling	◎											Weekly during the first 3 months of operation
M50000	-	Gas Regulating Unit	○											(See Manual for Gas Reg. Unit)
Lubricating Oil System														
G06100	-	Analyze Lub. Oil Properties : Sampling	◎											Every 3 month
M61000	LGV61000	Lubricating Oil Pump							■					
M62000	LGV62000	Lubricating Oil Cooler	■											(See Manual for LO Cooler)
M63000	LGV63000	Lubricating Oil Filter (Cartridge Type)	■		▣									If pressure drop reaches limit (See G01400)
-	LGV63000	Auto Backwashing Filter (If Applied)	■											(See Manual for Auto Filter)
M64000	LGV64000	Thermostatic Valve : Clean & Check the Elements							■					(See Manual for Thermo.v/v)
M67000	LGV67000	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.

Major Overhaul Guidance

Section No.		Description	Overhaul Interval (hours)										Remark
			Others	500 *)	2,000	4,000	8,000	12,000	16,000	20,000	24,000	28,000	32,000	
Cooling Water System														
G07100	-	Analyze Cooling Water Properties : Sampling	◎											Weekly : Test Kit Every 3 month : Lab. Test
M71000	LGV71000	Cooling Water Pump							■					
M74000	LGV74000	Thermostatic Valve : Clean & Check the Elements (If applied)							■					(See Manual for Thermo.V/v)
Exhaust Gas System														
M82000	LGV82000	Waste Gate Valve	■											(See Manual for Waste Gate Valve)
Compressed Air System														
O02300	-	Air Running	○											Monthly
G42000	-	Check Starting & Stop Syatem	○											Weekly (Over a Week Stand-still Condition)
M42100	LGV42100	Starting Air Motor	■											(See Manual for Starting Air Motor)
Supercharging System														
M80000	LGV83000	Turbocharger	■											(See Manual for Turbocharger)
		- Clean Air Filter (Only for Filter Silencer type)	■		▣									Every 500hrs running
		- Compressor : Water-washing	●											Every 24~50hrs running
M84000	LGV84000	Charge Air Cooler							■					

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

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

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

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

List of Consumable Parts for one engine

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

Section No.	Parts Description		Quantity for the operating hours							
		set/ea	0-4000	0-8000	0-12000	0-16000	0-20000	0-24000	0-28000	0-32000
	Covers for Engine Block									
LGV13000	Gaskets for gear case cover	set	-	1	1	2	2	3	3	4
LGV19300	O-ring for crankcase cover	ea	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
LGV19300	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
LGV21100	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									
LGV13250	Main bearing (upper & lower)	set	-	-	-	-	-	-	-	0.5xC+1
LGV13250	Thrust washer	ea	-	-	-	-	-	-	-	4
LGV25300	Camshaft bearing	ea	-	-	-	-	-	-	-	1xC+4
LGV32000	Big-end bearing (upper & lower)	set	-	-	-	-	-	-	-	1 x C
LGV32000	Small-end bearing	ea	-	-	-	-	-	-	-	1 x C
LGV35000	Bearing bush for idle gear	ea	-	-	-	-	-	-	-	2
	Cylinder Unit and Con-Rod									
LGV15000	Flame ring	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV15000	O-rings & gasket for cylinder liner / cooling water jacket	set	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
LGV21100	O-ring for cylinder head	ea	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
LGV21100	Sealings for valve guide & exh. valve seat ring	set	-	-	-	1 x C	1 x C	2 x C	2 x C	2 x C
LGV21100 LGV21200	Intake v/v spindle, seat ring and v/v guide	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV21100 LGV21200	Exhaust v/v spindle, seat ring and v/v guide	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV23000	O-rings for push rod cover	set	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
LGV23000	Roller bush for swing arm	ea	-	-	-	-	-	-	-	1 x C
LGV31100	Piston ring-top ring / 2nd ring / scraper ring	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV32000	Shim plate for con-rod	ea	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV32000	Stud for con-rod shaft	ea	-	-	-	-	-	-	-	4 x C
	Gas Supply and Ignition System									
LGV46101	Gas admission valve	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV46102	Spark plug	set	1 x C	2 x C	3 x C	4 x C	5 x C	6 x C	7 x C	8 x C
LGV46102	Igintion coil	set	-	-	-	-	-	-	-	1 x C
LGV46102	Spark extension	set	-	-	-	-	-	-	-	1 x C
LGV46102	Seal for spark extension	set	-	1 x C	1 x C	2 x C	2 x C	3 x C	3 x C	4 x C
LGV45275	Cylinder pressure sensor (if applied)	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV52000	O-rings for prechamber	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV52000	Prechamber tip with gasket	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV52000	O-rings for check valve assembly	set	-	-	-	1 x C	1 x C	1 x C	1 x C	2 x C
LGV52000	Check valve assembly for prechamber	set	-	-	-	-	-	1 x C	1 x C	2 x C

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	0-4000	0-8000	0-12000	0-16000	0-20000	0-24000	0-28000	0-32000
	Lubricating Oil System									
LGV61000	Bushes for lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LGV61000	O-rings for lub. oil pump	set	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LGV62000	O-ring for lub. oil cooler connection (Installation on engine side)	ea	-	-	-	4	4	4	4	8
LGV63000	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
LGV63000	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
LGV63000	Spare parts for auto backwashing filter (See manual for auto backwashing filter)	set	-	-	-	-	-	-	-	-
LGV64000	O-ring for lub. oil thermostat valve	ea	-	-	-	1 x U	1 x U	1 x U	1 x U	2 x U
LGV64000	Gasket for thermostatic valve cover	ea	-	-	-	1	1	1	1	2
LGV67000	Spare parts for centrifugal filter (See manual for centrifugal filter)	set	-	-	-	-	-	-	-	-
	Cooling Water System									
LGV71000	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
LGV74000	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
LGV74000	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
LGV77000	O-ring for cooling water connection	ea	-	4	4	8	8	12	12	16
LGV78000	O-ring for cyl.head cooling water connection	ea	-	8	8	(4xC)+4	(4xC)+4	(4xC)+12	(4xC)+12	(8xC)+8
	Supercharging System									
LGV81000	Gaskets and O-ring for compressor out	set	-	-	-	1	1	1	1	2
LGV82000	Gasket for connection flange	ea	-	1	1	1xC+1	1xC+1	2xC+1	2xC+1	3xC+1
LGV83000	O-rings and gaskets for T/C connection	set	-	-	-	1	1	1	1	2
	Charge Air Cooler									
LGV84000	O-rings and gaskets for air cooler	set	-	-	-	1	1	1	1	2
	Turbocharger									
	Spare parts for turbocharger (See manual for turbocharger)	set	-	-	-	-	-	-	-	-
	Air filter mat (Engine room air suction)	ea	4	8	12	16	20	24	28	32

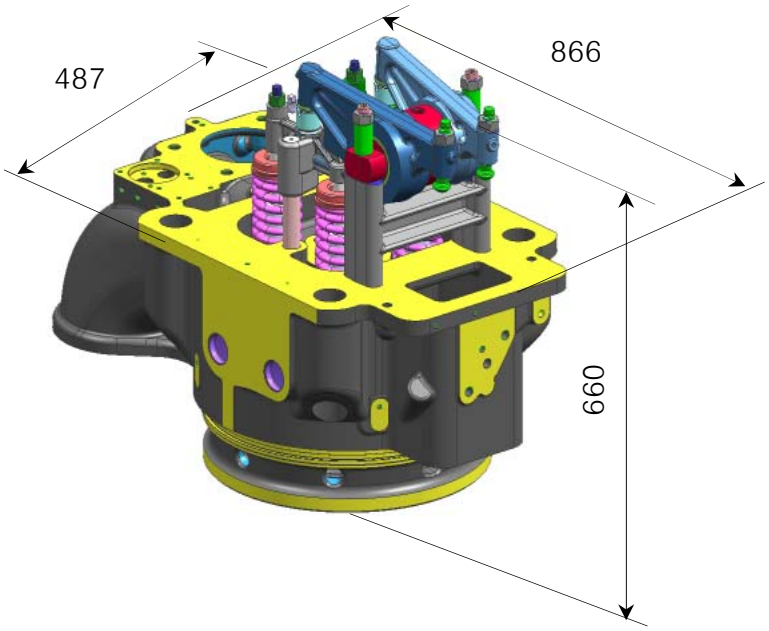
* The list of consumable parts stated above is only for guidance as this depends on the actual service condition, the quality of used fuel or lubricating oil, the treatment of cooling water and so on.

List of minimum Spare Parts for each plant

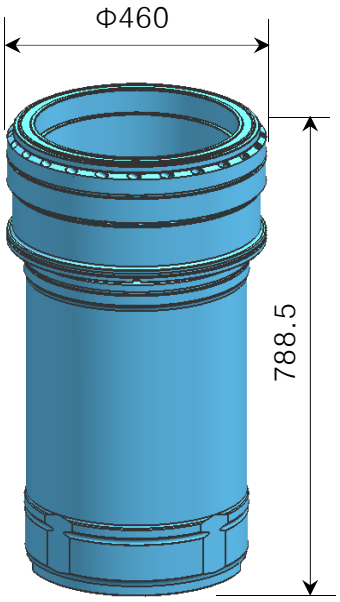
Parts Description	Q'ty	Sec. No.	Item No.	Remark
Engine Block and Covers				
Main bearing stud	2	LGV13000	221	
Nut for main bearing stud	2	LGV13000	222	
Main bearing	1	LGV13250	251	
Thrust washer	4	LGV13250	252	
Oil sealing ring for crankcase cover	1	LGV19300	380	
Cylinder Head and Cylinder Liner				
Sealing ring for cylinder liner	1	LGV15000	191	
O-ring for cylinder liner, D420	1	LGV15000	192	
O-ring for cylinder liner, D440	2	LGV15000	193	
O-ring for cylinder liner, D385	1	LGV15000	194	
O-ring for cooling water jacket, D193	1	LGV15000	901	
O-ring for cooling water jacket, D225	1	LGV15000	902	
O-ring for cooling water jacket, G55	1	LGV15000	922	
O-ring for cooling water jacket, P31	1	LGV15000	923	
Valve seat, inlet	2	LGV21100	111	
Valve seat, exhaust	4	LGV21100	112	
Valve guide, exhaust	4	LGV21100	113	
Valve guide, intake	2	LGV21100	114	
O-ring for exhaust valve seat ring	4	LGV21100	118	
O-ring for valve guide	4	LGV21100	291	
O-ring for cylinder head cover, upper	1	LGV21100	805	
O-ring for cylinder head cover, lower	1	LGV21100	806	
O-ring for cylinder head	2	LGV21100	901	
Valve spindle, intake	2	LGV21200	201	
Valve spindle, exhaust	4	LGV21200	202	
Valve rotator	6	LGV21200	204	
Conical piece	6	LGV21200	206	
Valve spring	6	LGV21200	207	
O-ring, D66.27	4	LGV23000	405	
O-ring for Prechamber, D101	4	LGV52001	915	
O-ring for Prechamber, D98	4	LGV52001	916	
O-ring for Prechamber, D95	8	LGV52001	917	
O-ring for Prechamber, D94	4	LGV52001	918	
Gasket for Prechamber	4	LGV52001	919	
O-ring for cooling water connection, D125	4	LGV78000	715	
Piston, Connecting Rod				
Piston pin complete	1	LGV31100	120	
Piston ring, top	1	LGV31100	151	
Piston ring, 2nd	1	LGV31100	152	
Piston ring, scraper	1	LGV31100	153	
Connecting rod bearing	1	LGV32000	113	
Small and bush for connecting rod	1	LGV32000	114	

List of minimum Spare Parts for each plant

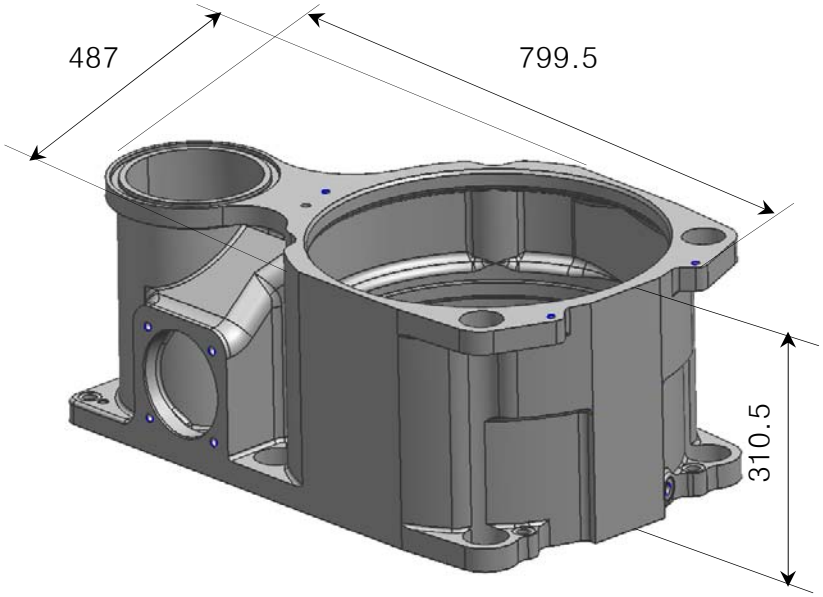
Parts Description	Q'ty	Sec. No.	Item No.	Remark
Connecting rod big end stud, M33	4	LGV32000	191	
Nut for connecting rod, M33	8	LGV32000	192	
Cylindrical pin	4	LGV32000	193	
Connecting rod shaft stud, M33	4	LGV32000	194	
Shim plate for connecting rod	1	LGV32000	195	
Fuel Injection Equipment				
O-ring for Gas Admission Valve D88.5	2	LGV53002	106	
O-ring for Gas Admission Valve D50	2	LGV53002	107	
Ignition System				
Spark Plug	C	LGV46102	960	C = Number of Cylinder.
Ignition Coil	1	LGV46102	962	
Check valve ass'y	4	LGV52001	200	
Gasket for Spark plug	1 set	LGV52001	401	1set(100ea)
Piping System				
Flexible connecting pipe, each type	1 set	LGV98370	-	
Air & Exhaust Gas System				
Lube oil Filter, 1st filter, If applied	1 set	LGV63000	702	
Paper insert for centrifugal filter, If applied	1 set	LGV67000	701	
Gasket for air cooler cover	1	LGV84000	311	
Gasket for air cooler cover	1	LGV84000	312	
Supercharging System				
Air cooler spare kit	1 set	-	-	Maker supply
Turning Equipment				
Turning gear spare kit	1 set	-	-	Maker supply



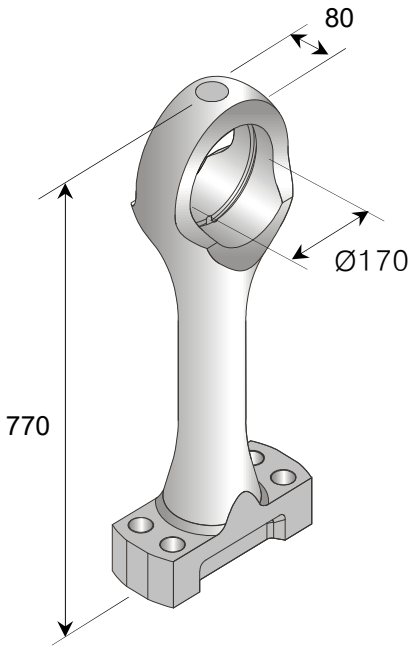
Cylinder head and rocker arms assembly
Approx. 430 kg



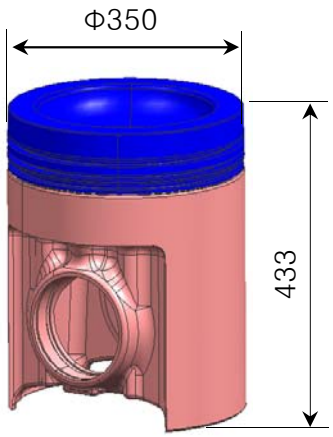
Cylinder liner
Approx. 750kg



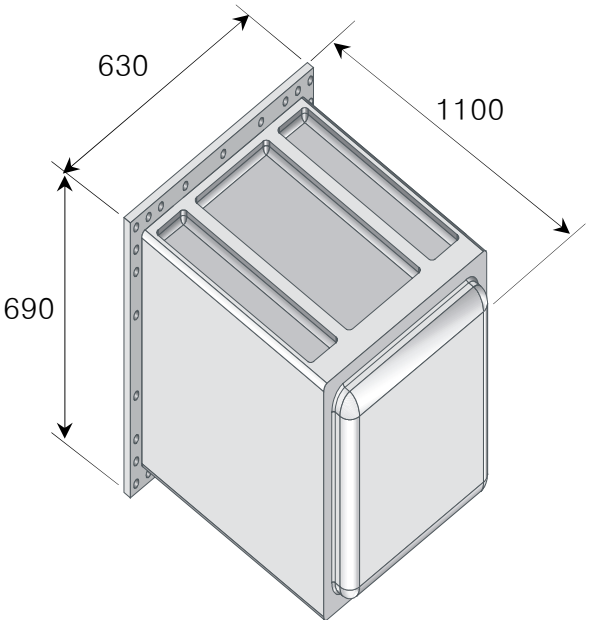
Water jacket
Approx. 92 kg



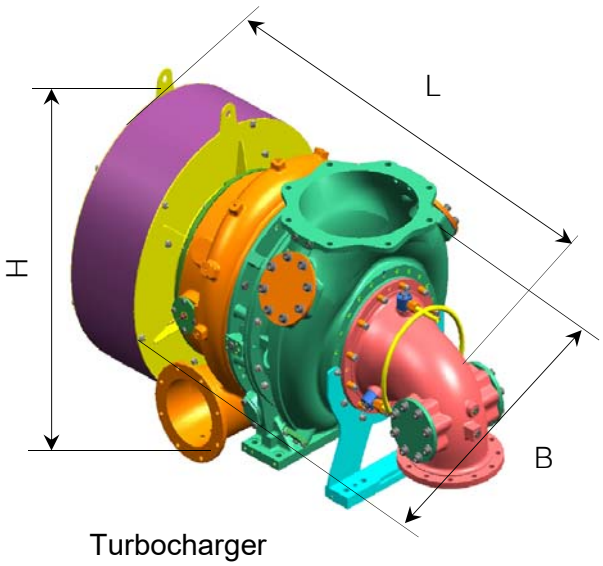
Connecting rod shaft
Approx. 74 kg



Piston
Approx. 93.3 kg



Air Cooler
Approx. 750 kg



Turbocharger

Turbocharger type	B	H	L	Weight(kg)	Remarks
A145	734	827	1574	850	Without insulation
A150	1420	1570	2070	1200	Without insulation
A155	1700	1970	2410	1800	Without insulation
ST6	734	827	1574	582	Without insulation
ST7	890	1045	1930	1270	Without insulation

List of minimum Spare Parts for each plant

Parts Description	Q'ty	Sec. No.	Item No.	Remark
Cylinder Head				
Intake valve seat ring	2	LGV21100	111	
Exhaust valve seat ring	2	LGV21100	112	
Pressure sensor bush	1	LGV21100	600	
Intake valve spindle	2	LGV21200	201	
Exhaust valve spindle	2	LGV21200	202	
Sealing & O-ring				
Gasket for gear case cover	2	LGV13000	902	
Gasket for oil duct cover	1	LGV13000	910	
Metal gasket for cylinder liner	1	LGV15000	191	
O-ring for cylinder liner, D420	1	LGV15000	192	
O-ring for cylinder liner, D440	2	LGV15000	193	
O-ring for cylinder liner, D385	1	LGV15000	194	
O-ring for cooling water jacket, D193	1	LGV15000	901	
O-ring for cooling water jacket, D225	1	LGV15000	902	
O-ring for cooling water jacket, G55	1	LGV15000	922	
O-ring for cooling water jacket, P31	1	LGV15000	923	
Oil sealing ring for crankcase cover	2	LGV19300	380	
Oil sealing ring for camshaft cover	1	LGV19300	390	
Gasker for air chamber rellef valve	1	LGV19300	517	
O-ring for exhaust valve seat ring	2	LGV21100	118	
O-ring for valve guide	2	LGV21100	291	
O-ring for cylinder head cover lower	1	LGV21100	805	
O-ring for cylinder head cover upper	1	LGV21100	806	
O-ring for cylinder head	1	LGV21100	901	
O-ring for push rod cover	4	LGV23000	405	
Packing	2 x C	LGV53000	934	C = Number of Cylinder.
Sealing ring	C	LGV53000	942	C = Number of Cylinder.
Gasker	(2 X C) + 3	LGV53000	943	C = Number of Cylinder.
Sealing ring	C	LGV53000	944	C = Number of Cylinder.
O-ring	C	LGV53000	951	C = Number of Cylinder.
O-ring	C	LGV53000	952	C = Number of Cylinder.
O-ring for cooling water connection, D125	4	LGV78000	715	
O-ring for cooling water connection, D155	1	LGV78000	718	
Packing for air intake duct	2	LGV81000	141	
Bellows				
Gasket for turbocharger outlet	1	LGV82000	103	
Packing for waste gate valve	2	LGV82000	104	
Gasket for exhaust pipe	1	LGV82000	284	
Gasket for exhaust pipe	2	LGV82000	287	
Axial compensator for MPC	1	LGV82000	340	
Axial compensator for turbin inlet	2	LGV82000	350	
Axial compensator for T/C inlet	1	LGV82000	360	
Gasket for air cooler cover	1	LGV84000	111	
Packing for air cooler cover	1	LGV84000	131	

List of minimum Spare Parts for each plant

Parts Description	Q'ty	Sec. No.	Item No.	Remark
Sensors & Solenoid valves				
Eninge RPM pick-up sensor	1	LGV45210	110	
CAM pick-up sensor	1	LGV45210	120	
Oil mist detector	1	LGV45225	920	
Temp. transmitter (PT100, L:80)	1	LGV45230	210	
Temp. transmitter (PT100, L:230)	1	LGV45230	290	
Temp. transmitter for exhaust gas cylinder outlet	2	LGV45235	250	
Temp. transmitter for T/C inlet	1	LGV45236	260	
Temp. transmitter for T/C outlet	1	LGV45237	270	
Temp. transmitter for main bearing	1	LGV45240	050	
Press. transmitter (-30~30mbar)	1	LGV45260	030	
Press. transmitter (10bar(A))	1	LGV45260	210	
Press. transmitter (0~40bar)	1	LGV45260	400	
Press. transmitter (0~10bar)	1	LGV45260	410	
Press. transmitter (0~10bar)	1	LGV45260	620	
Press. transmitter (0~10bar)	1	LGV45260	870	
Cylinder pressure sensor	2	LGV45270	240	
Knock sensor	1	LGV45275	940	
Gas admission Valve	2	LGV46101	870	
Spark plug	8	LGV46102	960	
O-ring for SOGAV(D88.5)	1	LGV53002	106	
O-ring for SOGAV(D50.5)	1	LGV53002	107	

Tool Description	Q'ty	Tool No.	Remark
Cylinder Head and Liner			
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	
Lifting tool for water jacket	1	91.151	
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 (HYD)	1	91.580	
Hydraulic cylinder ram	1	91.582	
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	
Con-rod support for crank pin bearing	2	91.180	
Supporting device for crank pin bearing	1	91.181	
Screw-on plate for crank pin bearing	1	91.182	
Big-end lower support for crank pin bearing	1	91.183	
Big-end upper guide bar for con-rod	1	91.184	
Extension pipe for crank pin bearing	2	91.185	
Guide pipe for crank pin bearing	2	91.186	
Big-end upper support for crank pin bearing	1	91.187	
Con-rod support for crank pin bearing	2	91.188	
Con-rod shaft guide for piston	1	91.190	
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	
General Tools			
Tool for cylinder press sensor	1	91.100	
Torque wrench 22.5Nm	1	91.101	
Torque wrench spanner head 8	1	91.102	
Torque wrench spanner head 16	1	91.103	
Turbocharger cleaning hose valve	1/Eng	91.934	
Turbocharger cleaning hose	1	98.100	

Tool Description	Q'ty	Tool No.	Remark
Fuel injection valve			
Lifting jig for prechamber ass'y	1	91.130	
Seat&tread reconditioner	1	91.370	
Removal tool for prechamber assembly	1	91.390	
Tool for prechamber tip extracting	1	91.391	
Socket for spark plug	1	91.630	
Extension removal tool	1	91.720	
Hydraulic Tools			
Hydraulic Jack (M48x3) for cyl. head/Main bearing cap/Counter weight	4	91.400	
Hydraulic Jack (M39x3) for side stud/Idle gear	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/Counter weight	2	91.460	
Support (hyd. Jack M39) for side stud	2	91.470	
Long 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	91.510	
Extension screw (hyd. Jack M39) for idle gear	1	91.520	
Long Support (hyd. Jack M39) for idle gear	1	91.530	
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	
Turning pin (Φ10)	2	91.600	
Turning pin (Φ6)	2	91.610	
Pneumatic hydraulic pump	1	91.850	
Flexible air hose for pneumatic hydraulic pump	1	91.851	
Standard Tool Box			
Spare & Tool box	5	91.640	
Air cooler tool kit	1 set		
Turning gear tool kit	1 set		

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	
Torque wrench(1500-3000nm)	1	91.845	
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 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	
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	

List of General Tools for Each Plant

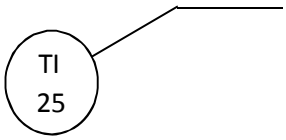
Tool Description	Q'ty	Tool No.	Remark
Crowbar S550A-15	1	99.738	
Extension bar 11x1/2"	1	99.739	
Extension bar 13x1/2"	1	99.740	
Extension bar 14x1/2"	1	99.741	
Extension bar 17x1/2"	1	99.742	
Extension bar 19x1/2"	1	99.743	
Extension bar 22x1/2"	1	99.744	
Extension bar 24x1/2"	1	99.745	
Extension bar 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	
Extension bar 55x1"	1	99.765	
Reducer(from 1 1/2" to 1")	1	99.766	

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

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

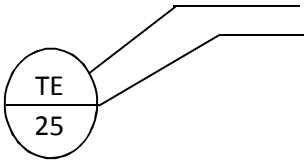
NO.	SYMBOL	SYMBOL DESIGNATION	NO.	SYMBOL	SYMBOL DESIGNATION
5.5		SEPARATOR	5.16		AIR FILTER WITH MANUAL CONTROL
5.6		STEAM TRAP	5.17		AIR FILTER WITH AUTOMATIC DRAIN
5.7		CENTRIFUGAL PUMP	5.18		WATER TRAP WITH MANUAL CONTROL
5.8		GEAR-OR SCREW PUMP	5.19		AIR LUBRICATOR
5.9		HAND PUMP(BUCKET)	5.20		SILENCER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

Symbol explanation



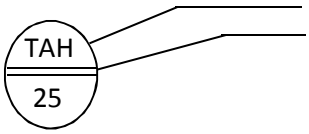
Measuring device
Locally reading

Temperature Indicator
No. 25*



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

Temperature element
No. 25*



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

Temperature Alarm High
No. 25*

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

Specification of letter code for measuring devices	
1st 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

Gas engine / generator

1. Combustion gas system

20 Air at TC inlet
21 Charge air at cooler outlet
24 Charge air at engine inlet
25 Exhaust gas at cylinder outlet
26 Exhaust gas at TC inlet
27 Exhaust gas at TC outlet

2. Compressed air system

40 Air starting valve
41 Compressed air at engine inlet / Slow turning valv
42 Turbocharger speed / Instrument air
46 Micro switch for turning gear
46 Micro switch for turning gear
47 Engine speed
48 Engine TDC
49 Engine Phase / On-off switch for shut down

3. Fuel gas system

50 Fuel gas at GRU filter inlet
51 Fuel gas at GRU filter outlet
52 Main chamber gas rail at GRU
53 Prechamber gas rail at GRU
54 Fuel gas shut off valve / GRU control air
55 Fuel gas venting valve
56 Inert gas valve at GRU
57 Fuel gas at engine inlet

4. Lub. oil system

61 Lub. oil at filter inlet
62 Lub. oil at engine inlet
63 Lub. oil at TC inlet
64 Lub. oil pump
65 Prelubricating
68 Level in base frame
69 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

NOTES

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