POWER HOUSE	Date	2016-04-07

Technical Overview of Mitsubishi LNG Marine Auxiliary Solutions

Note: The purpose of the document is to give a general picture of the product range and basic understanding of its design. It is in some aspects general/preliminary and not a full technical documentation. For further details please get in touch with sales@powerhouse.se or see www.powerhouse.se/contact

Issuer:	
Christian Johansson / Technical manager	

Power House AB
Talattagatan 10, 426 76 Västra Frölunda, Sweden
Tel: +46 31 762 56 00, Fax: +46 31 69 30 72, info@powerhouse.se
www.powerhouse.se

Marine Gas Solutions from 300 kW to 1500 kW


Turbocharger


Cylinder heads

Applications
- Tug
- Ferry
- Coasters
- Inland Cargo Vessels
- Offshore Supply Vessels
- LNG carriers and many more

Features
- Higher thermal efficiency
- Highly efficient turbocharger
- Lower exhaust gas emissions
- Ultra lean burn gas - to - air ratio

Specifications
- Gas electric propulsion / auxiliary use
- Equipped with high-performance proprietary turbochargers

MITSUBISHI MARINE ENGINE

		GS6R-MPTK	GS6R2-MPTK	GS12R-MPTK	GS16R-MPTK	GS16R2-MPTK
Type		4-cycle, intercooled, Natural Gas engine	4-cycle, intercooled, Natural Gas engine	4-cycle, intercooled, Natural Gas engine	4-cycle, intercooled, Natural Gas engine	4-cycle, intercooled, Natural Gas engine
Aspiration		Turbocharged	Turbocharged	Turbocharged	Turbocharged	Turbocharged
Number of cylinders		6	6	12	16	16
Bore x stroke mm		170x180	170x220	170x180	170x180	170x220
Displacement Ltr		24,51	29,96	49,03	65,37	79,9
Combustion system		Prechamber, Spark Ignited	Prechamber, Spark Ignited	Prechamber, Spark Ignited	Prechamber, Spark Ignited	Prechamber, Spark Ignited
Fuel		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas
Dry weight (engine only) **50Hz / 60Hz** kg		2400	2650	5375	6770	8105
Maximum output kWm	50Hz 1500rpm	368	On request	722	959	1563
	60Hz 1200rprn	315	394	632	845	1250
Emission compliance		–	–	–	–	–
Dimensions (engine only) mm	L x H x W	1797 x 1638 x 1088	1864 x 1718 x 1063	2371 x 2137 x 1820	2841 x 2137 x 1820	3423 x 2122 x 2164

Introducing new built-to-last, dependable Marine Gas Engine Solutions

We offer high performance Natural Gas marine engines which are available in 6, 12 and 16 cylinders and an output range from 300 kW to 1500 kW. We have been able to accomplish this by applying the Miller Cycle to the engine coupled with high efficiency turbochargers and efficient marine gas engine control technology.

Complete Solutions

We offer complete marine gas sets by Mitsubishi. Our engines can be delivered with various classifications e.g. Bureau Veritas, DNV-GL and Lloyd's Register. Our solutions are proven, evidenced by our references.

Proximity and Ease

All new engine models are equipped with high performance turbochargers. Our turbochargers are manufactured at the same plant in which the engines are produced. This close proximity of design and production results in the ideal turbocharger match for each engine, maximizing overall performance.

References

Mitsubishi marine gas engines power the world's first LNG-fuelled RoRo passenger ferry, Norway's 94m Glutra, operating in Møre and Romsdal since 2000. Built at the former Langstein Aker Yards, the ferry features four Mitsubishi lean burn LNG marine engines, each generating 675 kW.

Other deliveries include the Moldefjord (built by Poland's Remontowa) and the Tidekongen (built by STX France Lorient). We offer marine gas engine solutions from 300 kW to 1500 kW.

Mitsubishi Marine Gas Set

GL ISO 9001 ISO 14001 GL Systems Certification

Mitsubishi Turbocharger and Engine Europe B.V.
Headquarters Engine, Genset & Powerplant Division Europe, Middle East and Africa

Damsluisweg 2
1332 EC Almere
P.O. Box 30101
1303 AC Almere
The Netherlands

Phone: +31 (0)36 5388311
Fax: +31 (0)36 5388342

www.mtee.eu

Gas engine concept

TABLE OF CONTENTS

ENGINE CONCEPT

Application

The GSR engines are suitable for use in marine applications as a source of, both, auxiliary power and gas-electric propulsion power. They must be utilized as part of a multi-engine installation, with each of the GSR engines contained within its own ESD-protected machinery space.

Basic functional description

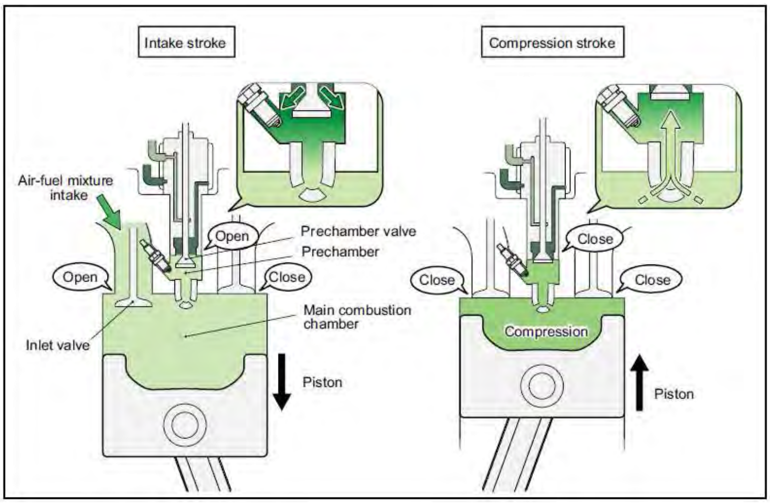
The GSR engines have a Lean-burn Miller cycle design. They are spark ignited gas engines designed to operate on a low pressure gaseous fuel supply (at or below 3.0 bar) by utilizing air-fuel induction-mixing.

Despite using air-fuel induction-mixing, the engine control system ensures that an air/fuel mixture is present within the intake manifold of the engine only during the period of engine operation. Fuel or an air/fuel mixture is never stored within engine and nor are they allowed to accumulate for any duration of time. However, the engines do not use double walled fuel systems and as such will need to be installed in an ESD-protected area.

The stoichiometric AFR is the ratio of air and fuel at which both the fuel and oxygen in the air are completely consumed by the combustion. A lean burn gas engine is a gas engine that runs with an air-to-fuel mass ratio (AFR) that is greater than the stoichiometric AFR, giving an excess of air in the combustion chamber. The AFR of the Mitsubishi lean burn engine is approximately twice that of the stoichiometric AFR.

<u>Combustion cycles of gas engine</u>

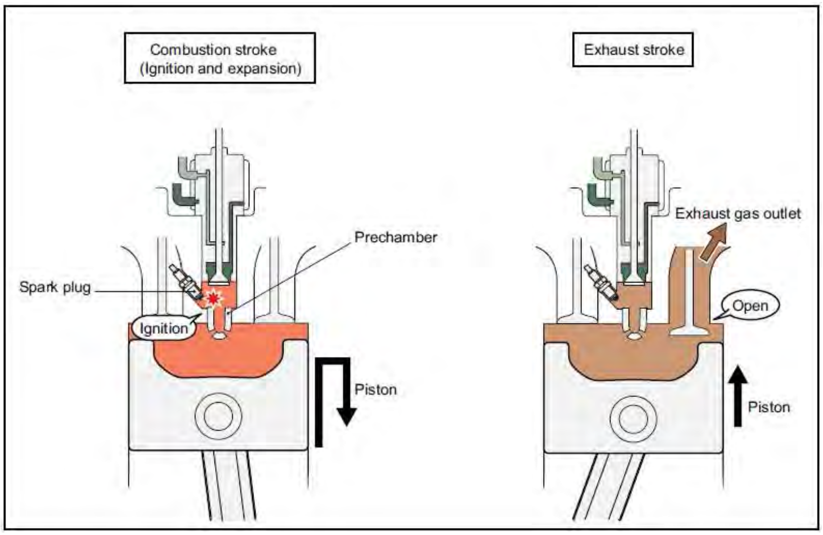
- Intake stroke. The intake valve opens and admits a lean air-fuel mixture into the main combustion chamber. The pre-chamber valve opens in synchronism with the intake valve and supplies the fuel gas to the combustion pre-chamber.



- Compression stroke. The intake valve and pre-chamber valve close, and the air-fuel mixture in the main combustion chamber is compressed and fed into the combustion pre-chamber. The fuel gas delivered to the combustion pre-chamber will have been of an amount that will ensure that, when the air-fuel mixture from the main combustion chamber is mixed with it in the pre-chamber, the AFR in the pre-chamber will be at a level that can be ignited with the spark plug (i.e. approximately stoichiometric). Note: During starting, the air-fuel mixture supplied to the main chamber is adjusted to an AFR by the fuel flow control valve (TECJET) that means no extra fuel gas needs to be supplied to the combustion pre-chamber in order to guarantee ignition.

- Combustion stroke (ignition and expansion). At the desired crank angle (usually just before the compression top dead center) is reached, the spark plug ignites the air-fuel mixture in the combustion pre-chamber and starts its combustion. The flame of the air-fuel mixture ignited by the spark plug passes through the nozzle hole into the main combustion chamber and acts as the ignition source for the lean mixture in the main combustion chamber. The resulting pressure increase in the combustion chamber from the heat release of the combustion pushes the piston down and turns the crankshaft.

- Exhaust stroke. The exhaust gas is released through the exhaust valve.



FUEL

The performance of the engine can be negatively affected not only by the Methane number, but also by the fuel composition therefore it is necessary that the gas components are checked on a case-by-case basis.

Natural Gas is a naturally occurring gas mixture, consisting mainly of methane, but the exact composition will depend upon the gas field that it was extracted from. Likewise, the composition of Liquefied Natural Gas (LNG) will be influenced by the source of the gas but also from the liquefaction process and even the storage and transportation methods. In order for the engine to calculate correct AFR values for stable combustion, the composition of the gas is required to be known. Mixing different types of LNG together is not recommended as stratification in the fuel tank can occur, leading to layers of gas for which the assumed composition is no longer valid. This can ultimately result in unstable engine operation.

As a first step, the customer should use the MHI guideline below to evaluate if the gas could be suitable or not.

JL2014L026 2/2

Natural Gas Composition Guideline for MHI Gas Engine

Methane	CH_4	Vol %	81-100
Ethane	C_2H_6	Vol %	0-6
Propane	C_3H_8	Vol %	0-4
Butane	$i\text{-}C_4H_{10}$	Vol %	0-4
Pentane	$i\text{-}C_5H_{12}$	Vol %	0-0.3
Hexane	C_6H_{14}	Vol %	0-0.3
Heptane	C_7H_{16}	Vol %	0-0.1
Carbon Dioxide	CO_2	Vol %	0-6
Nitrogen	N_2	Vol %	0-6
Total		Vol %	100
Methane Number			>60

Note: This guideline is to be used to check if the gas is applicable for Mitsubishi gas engine or not.
Confirm with factory for the result is recommended.

Subsequently, in order to assure safe and reliable operation, the customer needs to present information on the gas fuel composition that will be typically used and MHI Japan will then judge if the fuel is acceptable for use with the engine.

A copy of the MHI Inquiry check sheet which is used to collect gas fuel composition is shown below:

Table 4 Gas Engine Inquiry Check Sheet (1/2)

MITSUBISHI HEAVY INDUSTRIES, LTD.

MITSUBISHI
GAS ENGINE

Gas Quality and Contaminants Data Sheet

1. Gas Analysis

Gas		Unit	Data	Remarks
Methane	CH_4	Volume %		
Ethane	C_2H_6			
Ethylene	C_2H_4			
Propane	C_3H_8			
Propylene	C_3H_6			
Iso-Butane	Iso-C_4H_{10}			
Nor-Butane	Nor-C_4H_{10}			
Iso-Pentane	Iso-C_5H_{12}			
Nor-Pentane	Nor-C_5H_{12}			
Neo-Pentane	Neo-C_5H_{12}			
Hexane	C_6H_{14}			
Heptane	C_7H_{16}			
Octane	C_8H_{18}			
Nonane	C_9H_{20}			
Carbon Monoxide	CO			
Carbon Dioxide	CO_2			
Hydrogen	H_2			
Oxygen	O_2			
Nitrogen	N_2			
Helium	He			
Hydrogen Sulfide	H_2S			
	Total		*100*	

2. Temperature and Pressure

Contaminant	Unit	Limit	Data	Remarks
Maximum Temperature	℃	60		
Minimum Temperature	℃	10		
Maximum Pressure	kPa	(300)		
Minimum Pressure	kPa	100		
Fuel Pressure Fluctuation	kPa(+/-)	1.7		

3. Fuel Gas Calory

	Unit	Limit	Data	Remarks
Calory Fluctuation	% (+/-)	< 5.0		
Cycle of Fluctuation	minutes	> 5		

Table 4 Gas Engine Inquiry Check Sheet (2/2)

4. Contaminants

Contaminant	Unit	Limit	Data	Remarks
Sulfur Compounds as H_2S	ppm	10		*1
Halide Compounds as Cl	mgCl/MJ	0		*2
Nitrogen Compounds as NH_3	mgNH3/MJ	0		
Oil Content	mg/MJ	1.19		
Particulates	mg/MJ	0.80		*3
Particulate Size in Fuel	micron	50		
Silicon Compounds as Si	mgSi/MJ	0.10		
Water Content	%(RH)	80		

*1 Sulfur compounds are those which contain sulfur.
Total sulfur level should account for all sulfure and be expressed as hydrogen sulfide.

*2 Halide compounds are those which contain chlorine,fluorine,iodide, or bromine.
Total halide level should account for all halides and be expressed as chlorine.

*3 Total particulate level must include inorgainic silicon.
Limit shown for silicon must account for the total organic (siloxanes, etc) and inorganic silicon content.

At low temperatures, hydrocarbon fuels may condense and enter the engine.
Liquids are never permitted in the fuel.

ENGINE SYSTEMS

Gas supply system

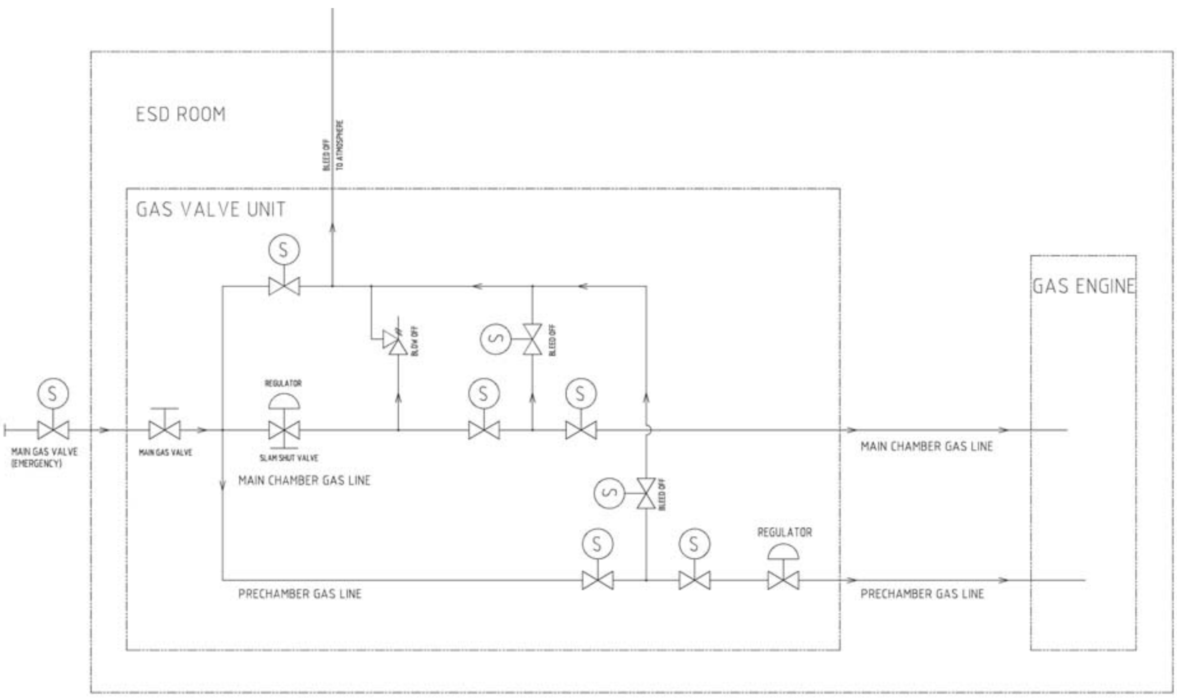
The gas fuel is pressure regulated before being fed to the engine. The gas fuel is split into two paths (main chamber gas line and pre-chamber gas line) which work independently but feed the engine simultaneously.

A series of valves and regulators known as the Gas Valve Unit (GVU) has the purpose of dividing the fuel supply between the two fuel paths and regulating the pressure of gas supplied to the engine.

<u>Gas Valve Unit</u>

The GVU contains only fuel and is classed as "low pressure" equipment (< 10 Bar). The dedicated pre-chamber fuel supply is regulated to a pressure of 3.0bar while the main chamber gas line is controlled to a pressure between 0.14bar and 0.30bar.

For added safety, there must be an additional shut down valve upstream of the GVU to isolate the ESD-protected room.



Overview of Gas Valve Unit (main) components

- 2 pre-chamber gas shut-off solenoid valves – serve to shut off the fuel gas flow in the pre-chamber gas line
- 2 main chamber gas shut-off solenoid valves - serve to shut off the fuel gas flow of the main chamber gas line
- 3 bleed-off solenoid valves – serve to bleed off the gas from GVU pipes after an emergency shut down.

- Safety blow-off valve – in case of high peak pressure occurs for any reason, it will open and allow gas into the bleed-off pipe
- Main Chamber Gas Regulator (incl. slam shut valve) – serves to reduce the pressure of the fuel gas to the set value. The slam shut will activate at sudden pressure variations in order to protect the equipment installed downstream.
- Pre-chamber Gas Regulator – serves to reduce the pressure of the fuel gas to the set value.

Engine governing system

The purpose of any engine governing system is to control the speed of the engine. Mitsubishi Gas Engine governing system will control and regulate the engine speed by making use of the following items:

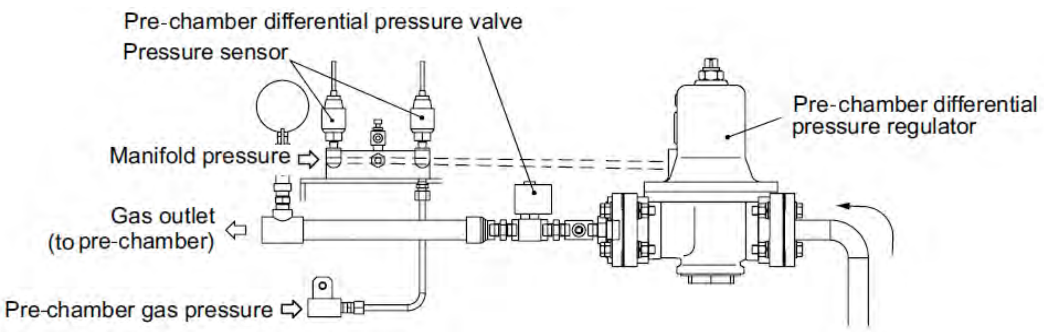
- Fuel Controller (ECM3)
- Differential pressure valve
- Gas metering valve (also known as Fuel gas control valve)
- Throttle valve
- Sensors:
  - Manifold Air Pressure (MAP) sensor
  - Manifold Air Temperature (MAT) sensor
  - Pre-chamber Gas Pressure (PGP) sensor
  - Differential pressure (DP) sensor

<u>Fuel Controller</u> (ECM3). The main functions of the fuel controller are as follows:

- Speed control
- Air fuel ratio control for main chamber
- Fuel gas flow control for pre-chamber
- Transient response control

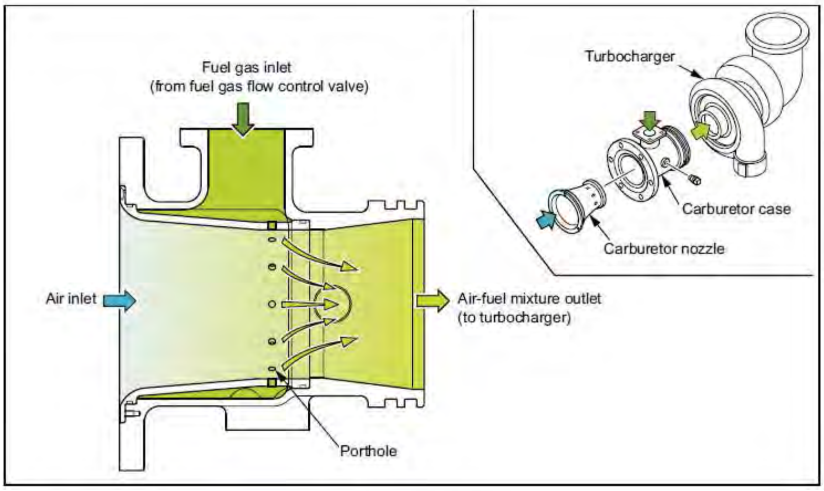
The ECM3 processes the information received from relevant sensors and then controls the differential pressure valve (ASCO valve), the gas metering valve (TECJET) and the throttle valve (PROACT) in order to achieve good performance. The ECM3 has additional control functions (error processing and communication) related to the control system.

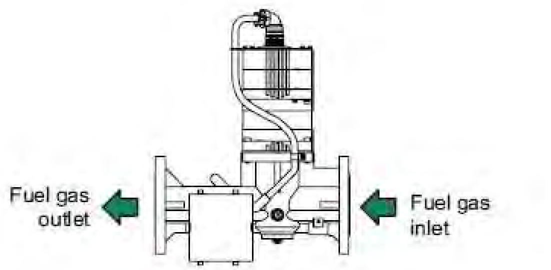
<u>Differential pressure valve</u> – (also known as ASCO valve) is installed on the pre-chamber gas line and it adjusts the pre-chamber fuel gas to a flow rate that matches the engine speed and load.

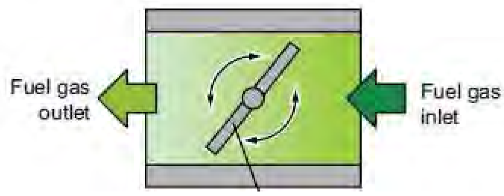


This unit adjusts the fuel flow into pre-chamber and maintains the air-fuel ratio at desired value by controlling the pressure difference between manifold air pressure (MAP) and pre-chamber gas pressure, according to the control logic from ECM3.

Fuel gas flow control valve (TECJET) – is installed in the main chamber gas line and controls the flow rate of the fuel gas. The TECJET is a throttling butterfly valve; the valve is tilted to change the area of the gas flow path and control the supply rate of the fuel gas to the main combustion chamber.







The fuel gas flow control valve (TECJET) also sends information back to the controller (ECM3).

The gas flow is then fed through a Venturi Mixer, also referred to as a "carburetor", where air and fuel enter and mix before being fed to the compressor side of the turbocharger.

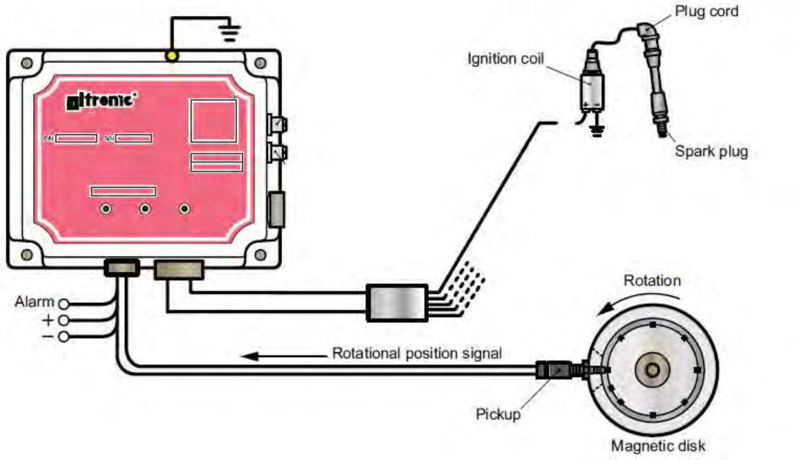
The carburetor atomizes the fuel gas from the fuel gas flow control valve (TECJET) and mixes it with air to form a homogeneous air-fuel mixture. The air drawn into the carburetor passes through a constricted flow path (venturi). When the air pipe is partly constricted into the venturi, the air flow speed increases and at the same time the air pressure decreases as it passes through the venturi. Gas supply portholes are provided where the air pressure becomes lowest. The higher the volume flow of air, the lower the air pressure will be at the gas supply portholes, creating a larger differential pressure across the holes and increasing the amount of gas supplied to match the higher flow of air.

Throttle valve (PROACT) – is installed in the air-fuel mixture supply line, after the venturi and before the charge air cooler. This valve will adjust the flow of the mixture to the main chamber to match the load demand on the engine.

Ignition system

The ignition system ignites the air-fuel mixture in the combustion pre-chamber at accurate timing. The ignition system consists of:

- Controller (Altronic CD200D digital ignition controller)
- Hall effect pickup
- Magnetic disk
- Ignition coils
- High tension cords
- Spark plugs

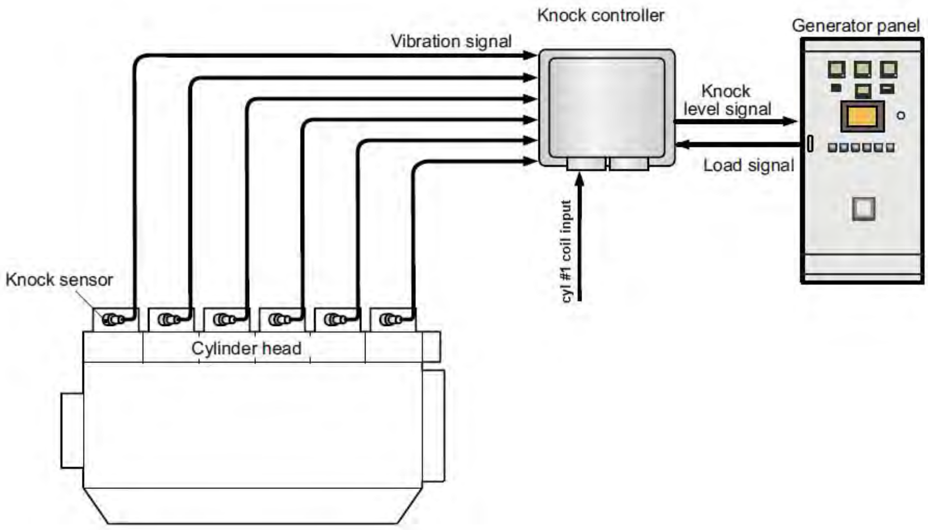


The camshaft position signal is generated by the magnetic disk and pickup and is sent to the controller. The controller calculates the desired ignition timing for the operating conditions and energizes the ignition coil at the appropriate timing based on the camshaft position signal. The high-voltage generated by the ignition coil is applied to the spark plug through the plug cord and ignites the air-fuel mixture in the pre-chamber.

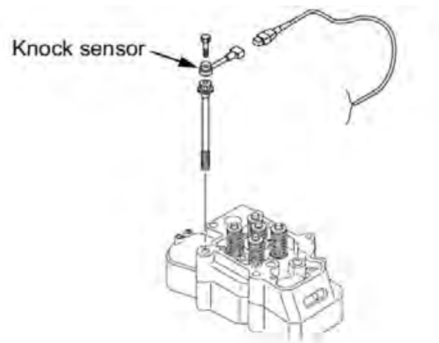
Misfire detection and knocking detection system

This is an independent system that monitors the combustion process.

The misfire detection and knocking detection system consist of:
- Sensing monitor (Altronic DET-1600)
- Knock sensors (piezoelectric sensors)



DET-1600 uses the ignition signal from the ignition coil of cyl 1 to sense rotation, calculate rpm and for an angular reference. The knock detection system collects the vibration signals, detects the occurrence of knock from the vibration measurements and sends the knock level signal to the generator control panel.



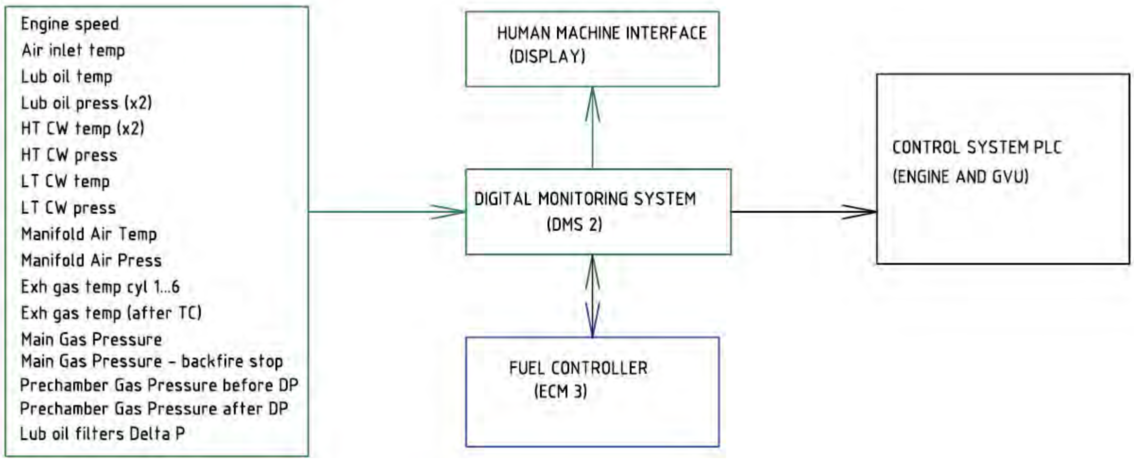
Each cylinder is individually monitored by a knock sensor. The piezoelectric sensors will detect engine vibrations (under the influences of combustion, piston reciprocation, etc).

The vibration levels are sent to the monitoring unit, which will process these signals and determine if the engine operates normally or not: high vibration will indicate knocking, while low vibration will indicate misfiring or a broken sensor.

At certain operating conditions (load below 50%), the signal of a broken sensor is identical to the signal given by misfiring condition. The logic in the generator panel is set up to ignore bad sensor and misfire alarms at low load. The exhaust temperature for each cylinder, which will deviate in the case of misfire, but not in case of a bad sensor, is also monitored. The exhaust temperature deviation alarm is always active, never to be ignored.

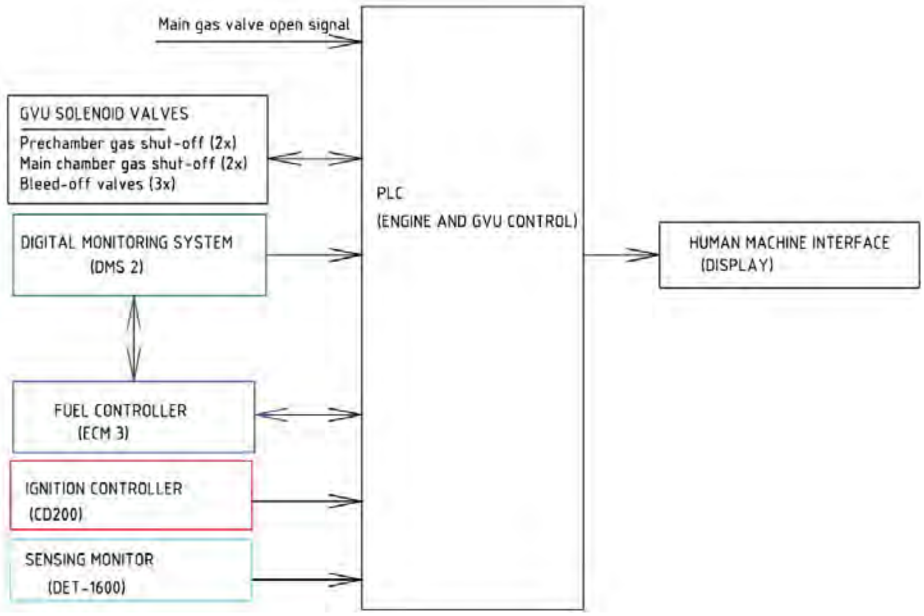
Control system and monitoring system

The Engine Digital Monitoring System (DMS) is an independent system that will continuously monitor engine health and operational parameters. It receives signals from the sensors and the Fuel Controller and outputs information concerning the health of the engine to the Fuel Controller, to the Generator panel (Engine and GVU PLC) and to its own display. The output signals sent to the PLC include normal engine start and stop signals, alarm signals and an emergency engine-shutdown signal.



The generator panel (control system of engine and GVU) is responsible to:

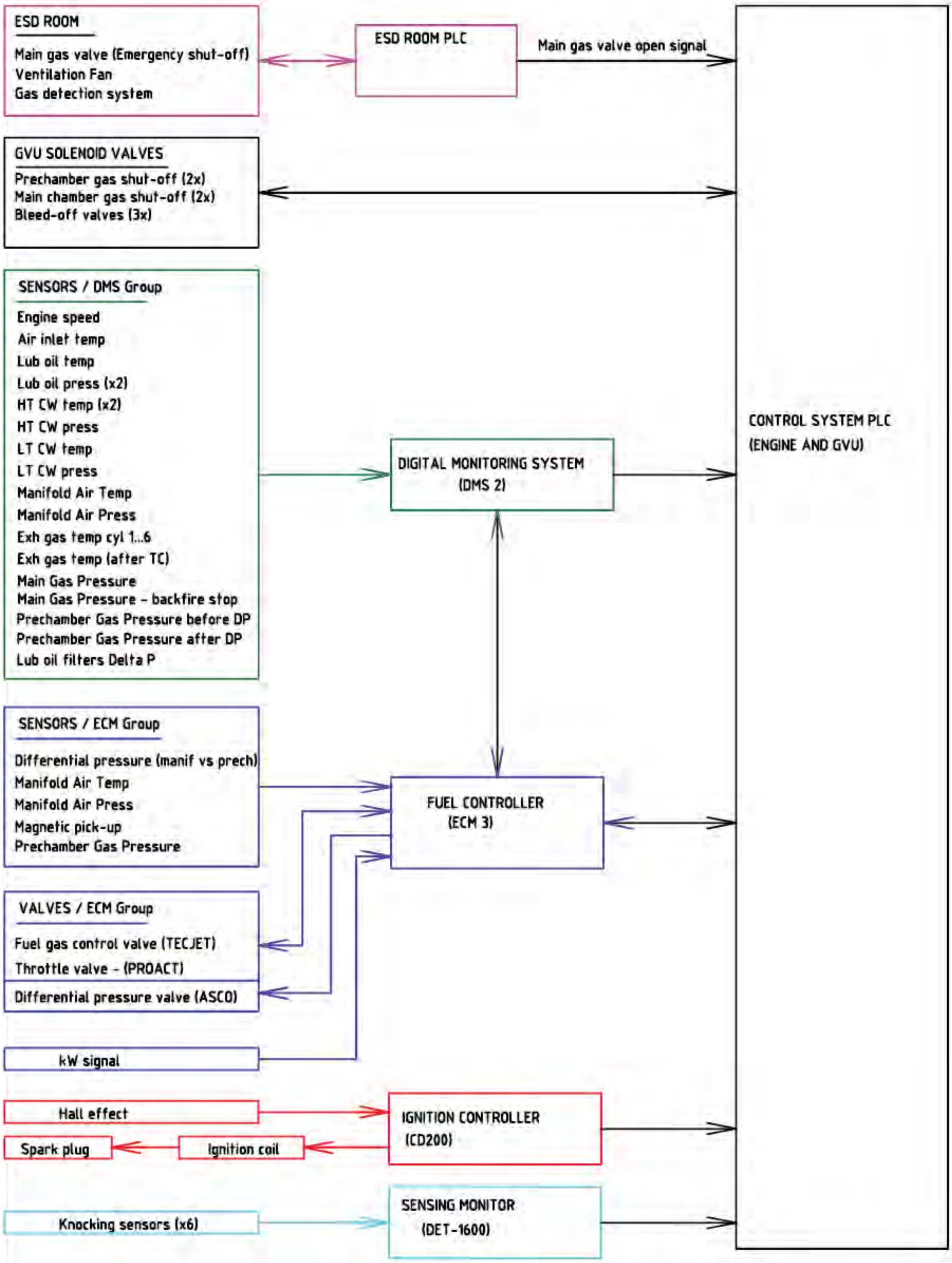
- Collect information (from sensors, GVU valves and other systems)
- Process the information in order to evaluate the engine condition
- Feedback information to the Fuel Controller (ECM3)
- Operate the GVU valves (during starting or shutting down sequence)
- Activate alarms and/or stop the engine in case any abnormal situation is detected
- Display information



Control system of ESD room

This system, integrated in ship`s automation system, must control the safety features of the engine room: the gas detection system, the ventilation fan and the emergency shutdown gas valve.

General Block Diagram

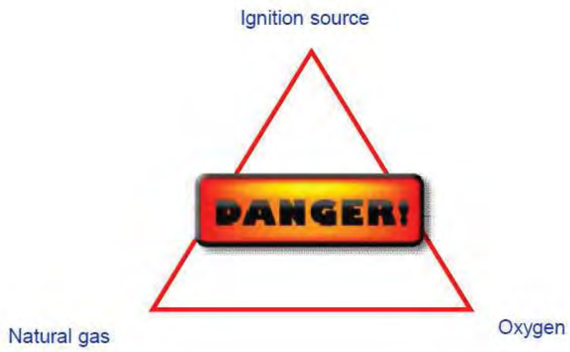


List of controllers and sensors

Group	Component	
Governing system	Fuel controller	ECM3
	Fuel gas control valve	TECJET
	Throttle valve actuator	PROACT
	Differential pressure valve	ASCO
	Differential pressure sensor	DPT
	Manifold Air Temperature sensor	MAT-1
	Manifold Air Pressure sensor	MAP-1
	Engine speed sensor	MPU-1
	Prechamber Gas Pressure sensor	PGP
Ignition system	Ignition controller	CD200D
	Ignition coils	-
	Spark plug	-
	Engine phase sensor	HE
GVU	Gas train	GVU
Knock detection	Sensing monitor	DET-1600
	Knocking sensors (x6)	KS-C1 /.../ KS-C6
DMS	Engine speed sensor	MPU-2
	Air inlet temperature sensor	AIT
	Lub oil temperature sensor	LOT
	Lub oil pressure sensor (x2)	LOP-1 / LOP-2
	Cooling water (HT) temp sensor (x2)	CWHTT-1 / CWHTT-2
	Cooling water (HT) press. Sensor	CWHTP
	Cooling water (LT) temp sensor	CWLTT
	Cooling water (LT) press. sensor	CWLTP
	Manifold Air Temperature sensor	MAT-2
	Manifold Air Pressure sensor	MAP-2
	Cylinder Exhaust Gas Temp (x6)	EGT-C1 / ... / EGT-C6
	Exh. Gas Temp. (After TC) sensor	EGT-A-TC
	Main Gas Pressure sensor	MGP
	Main Gas Pressure (Backfire) sensor	MGP-B
	Prechamber Gas Pressure sensor	PGP-2
	Prechamber Gas Pressure sensor	PGP-3
	Differential pressure sensor (oil filters)	DP(OF)
	DMS 2	
Control System (Engine and GVU)	PLC	WAGO

SAFETY CONSIDERATIONS

Explosions may occur when the combustion of certain concentrations of flammable substances such as gases, vapors, mists or dust in air is triggered by an ignition source of sufficient energy. Explosions involve a very rapid self-sustaining propagation of the combustion reaction with a build-up of high pressure. The damage caused by explosions to persons and property is due to the violent emission of flames, thermal radiation, pressure waves, flying debris and hazardous substances.



The severity of the potential damage depends mainly on the quantity of explosive mixture present and its nature.

Preventing the risk of explosion involves a combination of:

- avoiding the accumulation of explosive mixtures in areas in or around the engine, or by permanently maintaining their concentration at values outside the lower or upper explosion limits;
- avoiding the presence of ignition sources in hazardous areas;
- reducing the concentration of oxygen in hazardous areas (insofar as this does not give rise to an additional risk for persons).

Where the risk of explosion cannot be completely prevented, complementary protective measures shall be taken to limit the consequences of an explosion. Such measures include, for example, explosion-resistant design, fitting explosion relief devices, gas detection systems, automatic explosion detection and/or devices to prevent the propagation of flame and explosion.

Engine room

The GSR engine is suitable only for installation inside an ESD-protected room. The ESD-protected room must always be designed in accordance with the class regulations.

The ESD room must have the following safety features:

- High ventilation rate: above 30 air changes / hour
- Gas detection system (continuous monitoring of LEL level)
- Automatic shut-down of gas supply (master valve outside the room) in case LEL level is above 20% inside the ESD room
- Automatic disconnection of non ex-proof equipment

During normal operation, if all the above features are present, the ESD-protected room can be considered as a non-hazardous area. In the event of gas leakage, the classification of the space will be considered as Hazardous Zone 1.

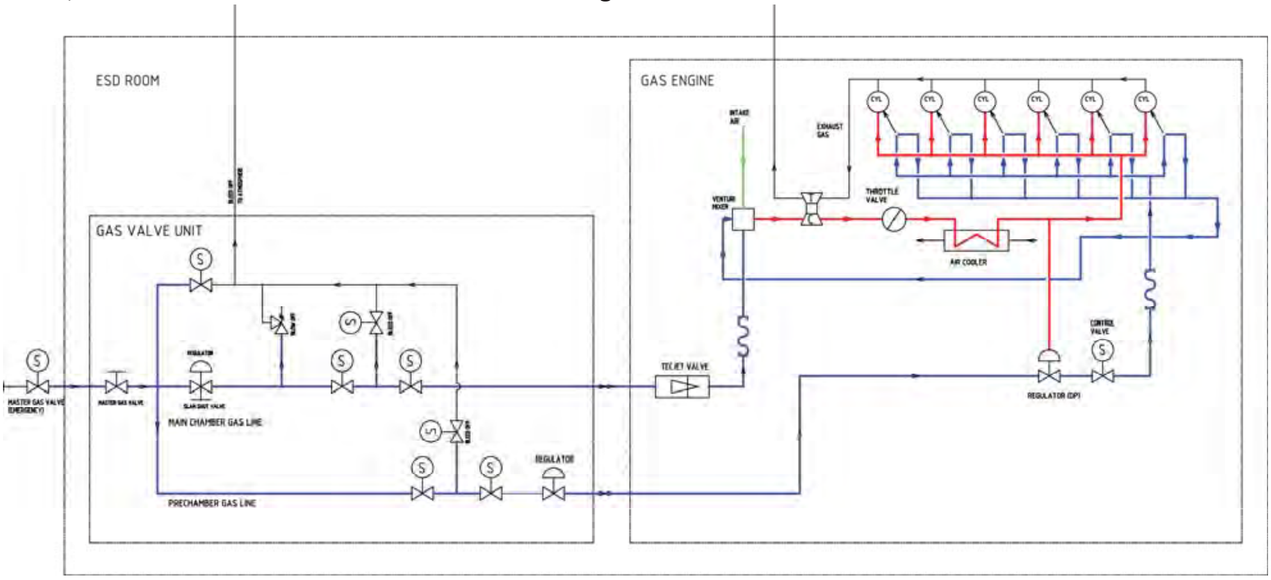
Inside an ESD-protected room, it is allowed that the gas supply pipes are single walled. However, it should be noted, that any piping containing gaseous fuel that is outside the ESD-protected space must be double walled.

Classification of engine zones into hazardous areas

The classification of engine zones for the GSR engine is closely linked to the ESD-protected room concept and in the case that the engine is not installed inside an ESD-protected room, this classification becomes invalid.

<u>Fuel and air intake system</u>

For easier identification of the hazardous zones, the fuel supply and air intake system is split into 3 areas, illustrated in different colors in the next diagram:



- Air atmosphere – illustrated in green.
  This area includes all pipes that contain only air during normal operation. The air is drawn from the ESD-protected room so the atmospheres inside these pipes are classified exactly the same: non-hazardous in normal operation and change to Zone 1 in the event of a gas leakage.

- Pure gas atmosphere – illustrated in blue.
  This area includes pipes that contain pure gas during normal operation and therefore classified as Zone 0. The gas is continuously flowing, it is never stored within pipes and it is not allowed to accumulate for any duration of time. The atmospheres inside these pipes are not explosive because they contain gas only, oxygen is not present and

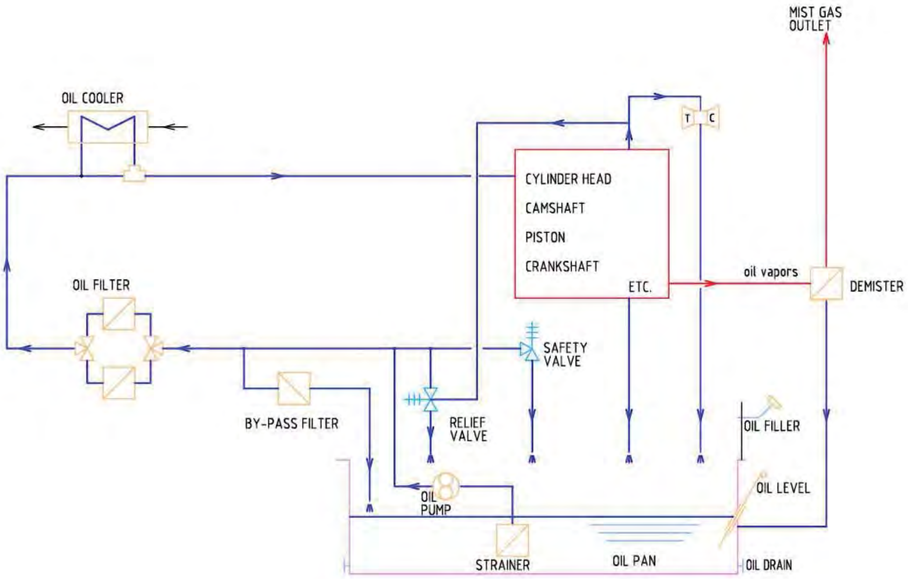
furthermore, it is impossible that explosive mixtures are formed here during engine operation, either normal or abnormal.

- Air-fuel mixture area – illustrated in red.
  This area includes all engine components that contain air-fuel mixture during normal operation. The mixture is continuously flowing, it is never stored within these components and it is not allowed to accumulate for any duration of time. The atmospheres inside these components are explosive and therefore classified as Zone 0.

<u>Exhaust gas system</u>
The exhaust gas is continuously pushed out of the engine during operation and this is not an explosive gas during normal operation. The exhaust gas will only become explosive during misfire of 4 or more cylinders. Considering that misfire can happen only for short period of time and it can be reliably detected, the exhaust gas system is classified as Zone 2.

<u>Cooling system (LT and HT)</u>
The cooling water does not contain unburned gas in normal operation and if fuel will leak into the cooling system (for any reason) it will naturally accumulate in the expansion tank. Considering that the expansion tank must be monitored for the accumulation of unburned gas, any gas leak of this type will only go undetected for a short period of time. As such, the cooling system is classified as Zone 2.

<u>Lubrication oil system</u>
The lubrication system is illustrated in blue in the next diagram. The oil system does not contain unburned gas in normal operation and if gas will leak into the oil system (for any reason) it will naturally accumulate in the crankcase. Because of this, the oil system is classified as Zone 2.



<u>Crankcase and crankcase breather pipe</u>
Unburned gas from many different sources, e.g. blow by, leakage in oil system, etc., can accumulate in the crankcase. A breather line, which is located at one of the highest points of the crankcase, is fitted with the intention of allowing any gas, which is lighter than air, to escape to a safe location.

However, this can be a slow process and, therefore, during operation the crankcase is classified as Zone 0 as the atmosphere inside is likely to be an explosive mixture.

Management of dangerous situations

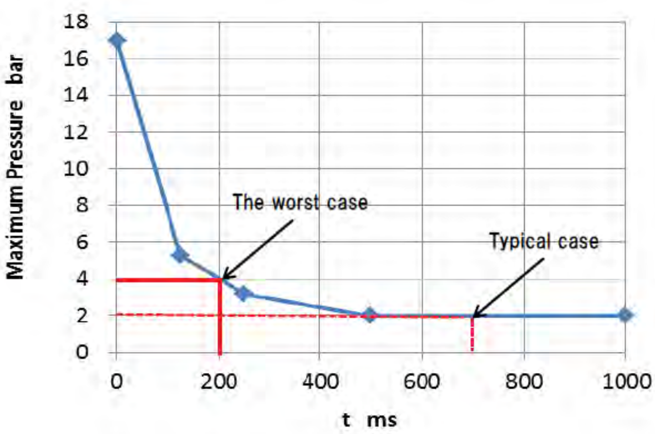
Fuel and air intake system

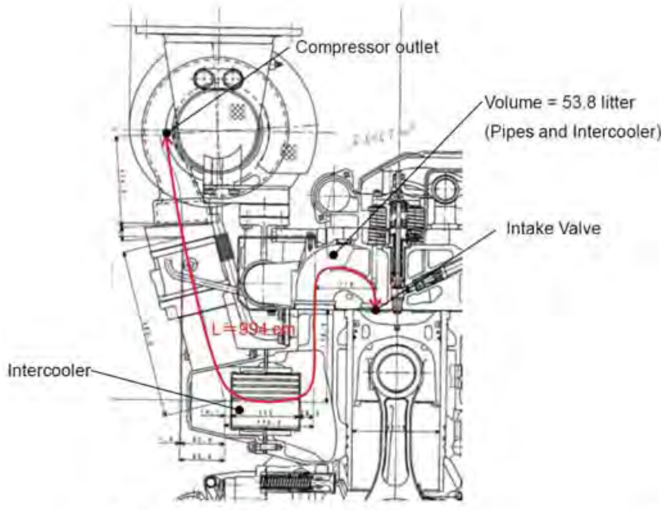
Potential hazardous situations can be created by gas leaks or by sparks. With regards to the fuel and air intake system, potentially hazardous situations can be created by either gas leakage from the intake system or from unintentional ignition sources occurring within the intake system.

In the event of a gas leak, gas may be released into other engine zones or into the ESD-protected room. In the case where there is a gas leak into the ESD-protected room, as soon as gas is detected at a LEL concentration above 20%, an emergency stop is initiated and the following actions occur:

- the master gas valve (outside the ESD room) and the GVU shut-off valves are closed and shut off the gas supply to the engine.
- the bleed-off valves of the GVU are opened, to allow ventilation of GVU gas pipes
- all electrical equipment which does not comply with Hazardous Zone 1 requirements is shut off immediately, in order to remove any potential ignition sources.
- the ESD-protected room is continuously force ventilated with fresh air to ensure that the ESD-protected room is quickly restored to a non-explosive atmosphere.

With the necessity for all non-zone 1 electrical equipment to be shut off during an emergency shutdown, the power to the control cabinet and the ignition system will be cut immediately and the engine speed will gradually drop from rated speed to standstill. With the absence of an ignition source, the activation of the fuel shut-off valves and the forced ventilation of the ESD-protected room, the inertial rotation of the engine will ensure that the engine zones which usually have an air-fuel atmosphere are safely flushed with fresh air and any gas present in the engine at the moment of emergency shutdown is vented into the exhaust pipe and then to the outside atmosphere. When the engine has come to a complete standstill, the inlet system can be considered to no longer contain an explosive atmosphere.





Sectional view of the GS6R natural gas engine

Potential sources of unintentional ignition in the intake system include the sensors and combustion in the main chamber. The sensors fitted in the air-fuel atmosphere must be ATEX Zone 0 (intrinsically safe) classified in order to be sure there is no risk of a spark occurring in the explosive mixture.

In the event that the air-fuel mixture in the inlet system is ignited through the intake port (by a flame generated in the combustion chamber), the flame will propagate through the air-fuel intake system and the mixture will burn in 200 ms, generating a maximum pressure of 4bar. All of the components of this system have been designed to withstand pressures greater than 4bar and, as such, can be considered being explosion proof, negating the requirement for explosion relief valves to be fitted.

However, the air intake path does need to be equipped with a flame arrester in order to prevent any flame from reaching the ESD-protected room.

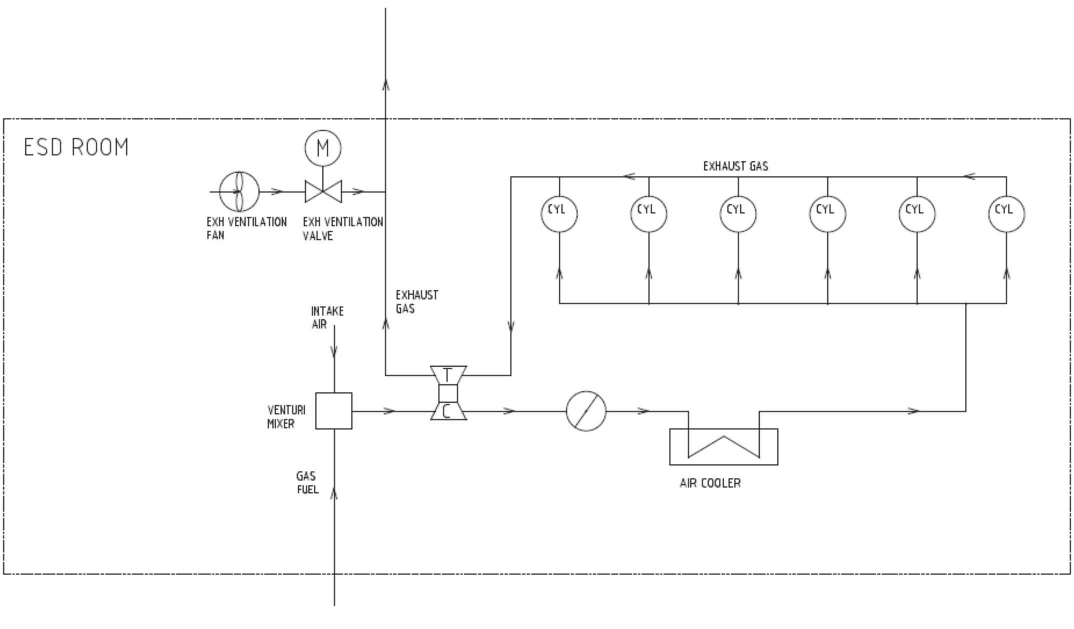
The atmospheres inside the gas pipes are not explosive as they contain gas only, oxygen is not present. However, as extra safety precautions all sensors (pressure and temperature) in these gas pipes must be of intrinsically safe type Ex-ia.

Exhaust gas system

The sensors fitted in the exhaust pipes need to be Zone 2 certified. Under certain scenarios unburned gas will be released into the exhaust pipe.

The risk of explosion cannot be totally excluded so the exhaust pipe downstream of the turbocharger has to be fitted with an explosion relief valve in order to minimize the consequences in case an explosion occurs. The size of this relief valve needs to be selected based on the capacity of the entire exhaust system.

After each engine shut-down the exhaust system needs to be purged with air in order to remove the unburned hydrocarbons. In case the purging air is taken from the ESD room, sufficient means must be installed to prevent engine exhaust gas to enter the ESD room.



Cooling system (LT and HT)

The cooling systems must be equipped with vent lines connected to the expansion tanks. The expansion tanks of the vessel cooling systems must be monitored for the presence of gas, must be vented to a safe location (i.e. outside ship) and the vent pipes should be equipped with flame arrestors.

Lubrication oil system
The sensors which are in contact with the lubrication oil need to be Zone 2 certified.
Since the unburned gas will not remain in the oil system, but instead it will collect in the crankcase, no additional safety measures are needed for the lubrication oil system.

Crankcase and crankcase breather pipe
In order to minimize the effects of a potential explosion, the crankcase is fitted with an explosion relief valve and the breather pipe is fitted with a flame arrester. The breather line must be vented to a safe location i.e. outside of the ship. Due to the design of the crankcase, pockets of gas are able to accumulate and as a result the natural venting process can be slow. In order to provide additional safety measures, one of the crankcase cover doors has a flange connection point with the intention of providing an access point for both, sampling the gas in the crankcase, and flushing the crankcase with inert gas if required.

Digital monitoring system and Control system
All electrical equipment must be certified for usage onboard vessels and must be certified for usage in hazardous areas, when required due to their installation location.

A wide range of potential failure scenarios leading to an unsafe engine operation are monitored by the Digital Monitoring System and by the Control system. The engine will be immediately stopped by closing the GVU valves if a dangerous situation is detected.

It is considered that the following situations will be leading to an unsafe engine operation and therefore the engine will be shut-down:

- engine overspeed detected
- engine speed sensor failure
- low lube oil pressure
- high lube oil temperature
- high cooling water temperature (HT system)
- low cooling water pressure (HT system)
- high exhaust gas temperature after turbocharger
- exhaust gas cooling water temperature (HT system)
- deviation of individual cylinder exhaust gas temperature
- low pre-chamber gas pressure and closed ASCO valve
- low main gas chamber pressure
- high temperature of air/fuel mixture
- high pressure of intake manifold air/fuel mixture
- misfire detected
- detonation detected
- knock sensor failure
- internal failure of detonation monitor
- TECJET internal error
- TECJET position error
- TECJET communication error

- engine speed (phase) sensor failure
- ignition controller failure
- multiple sensor failure
- PLC internal error

List of sensors, controllers and their safety requirements

Group	Component			Required ATEX* certification	Current ATEX* certification	Certificate nr
Governing system	Fuel controller	ECM3	Woodward ECM3	No	Zone 2	CSA no. 1801919
	Fuel gas control valve	TECJET	Woodward TECJET 52	Zone 0	Zone 2****	CSA no. 1975931
	Throttle valve actuator	PROACT	Woodward PROACT	Zone 0	Zone 2****	CSA no. 1167451
	Differential pressure valve	ASCO	SCXB202A036V	Zone 0	-***	-
	Differential pressure sensor	DPT	ABB 266 MST Differential	Zone 0	Zone 0	FM 09 ATEX 0070X
	Manifold Air Temperature sensor	MAT-1	Danfoss MBT 5250	Zone 0	S/A**	Danfoss
	Manifold Air Pressure sensor	MAP-1	MBS 4251	Zone 0	Zone 0	DEMKO 01 ATEX 127938X
	Engine speed sensor	MPU-1	-	No	-	-
	Prechamber Gas Pressure sensor	PGP	MBS 4251	Zone 0	Zone 0	DEMKO 01 ATEX 127938X
Ignition system	Ignition controller	CD200D	Altronic CD200D	No	-	-
	Ignition coils	-	Altronic 501061	No	-	-
	Spark plug	-	Denso GK2-2	No	-	-
	Engine phase sensor	HE	Altronic 791039	No	-	-
GVU	Gas train	GVU	Dungs	Zone 0	Zone 1***	GL Reg 30979
Knock detection	Sensing monitor	DET-1600	Altronic DET1600	No	-	-
	Knocking sensors (x6)	KS-C1 /.../ KS-C6	261231040	No	-	-
DMS	Engine speed sensor	MPU-2	DYNT10100	No	-	-
	Air inlet temperature sensor	AIT	Danfoss MBT 5250	No	S/A**	Danfoss
	Lub oil temperature sensor	LOT	Danfoss MBT 5250	Zone 2	S/A**	Danfoss
	Lub oil pressure sensor (x2)	LOP-1 / LOP-2	Danfoss MBS 3150	Zone 2	Zone 2	CSA no 1786330
	Cooling water (HT) temp sensor (x2)	CWHTT-1 / CWHTT-2	Danfoss MBT 5250	Zone 2	S/A**	Danfoss
	Cooling water (HT) press. Sensor	CWHTP	Danfoss MBS 3150	Zone 2	Zone 2	CSA no 1786330
	Cooling water (LT) temp sensor	CWLTT	Danfoss MBT 5250	Zone 2	S/A**	Danfoss
	Cooling water (LT) press. sensor	CWLTP	Danfoss MBS 3150	Zone 2	Zone 2	CSA no 1786330
	Manifold Air Temperature sensor	MAT-2	Danfoss MBT 5250	Zone 0	S/A**	Danfoss
	Manifold Air Pressure sensor	MAP-2	Danfoss MBS 4251	Zone 0	Zone 0	DEMKO 01 ATEX 127938X
	Cylinder Exhaust Gas Temp (x6)	EGT-C1 / ... / EGT-C6	Tempcontrol MTK-6/S	Zone 2	S/A**	Tempcontrol
	Exh. Gas Temp. (After TC) sensor	EGT-A-TC	Tempcontrol MTK-6/S	Zone 2	S/A**	Tempcontrol
	Main Gas Pressure sensor	MGP	Danfoss MBS 4701	Zone 0	Zone 0	DEMKO 01 ATEX 127938X
	Main Gas Pressure (Backfire) sensor	MGP-B	Danfoss MBS 4701	Zone 0	Zone 0	DEMKO 01 ATEX 127938X
	Prechamber Gas Pressure sensor	PGP-2	Danfoss MBS 4701 (before)	Zone 0	Zone 0	DEMKO 01 ATEX 127938X
	Prechamber Gas Pressure sensor	PGP-3	Danfoss MBS4251 (after)	Zone 0	Zone 0	DEMKO 01 ATEX 127938X
	Differential pressure sensor (oil filters)	DP(OF)	DeltaP type 5.02	Zone 2	S/A**	-
	DMS 2			No	-	-
Control System (Engine and GVU)	PLC	WAGO	WAGO 750-880	No	Zone 2	DEKRA 11 ATEX 0203X

*or equivalent

** simple apparatus

*** protection level is sufficient because it is impossible that explosive mixture will occur inside the pipes in which these components operate

**** protection level is sufficient because there is sufficient mechanical separation between electrical components and gas mixture

Working procedures

In order to assure safety onboard, it is very important that people are properly trained and procedures are always followed.

Starting procedure

A safe starting procedure must make sure that gas is allowed only if the ignition system is active and functional, so the starting sequence must integrate the following steps, in this exact order:

1. the engine is flushed with air, to make sure no unburned gas is left over in the air/fuel system or in the combustion chamber
2. the ignition system must be turned on and its health check report must confirm it is fully functional
3. the gas valves are opened to allow gas. Note: gas valves to be opened only if above steps have been successfully performed. Otherwise starting sequence to be aborted.

Shutting down procedure

A safe shutting down sequence must integrate the following steps, in this exact order:

1. gas valves are closed
2. ignition system is turned off
3. the engine is flushed with air, to make sure no unburned gas is left over in the air/fuel system or in the combustion chamber

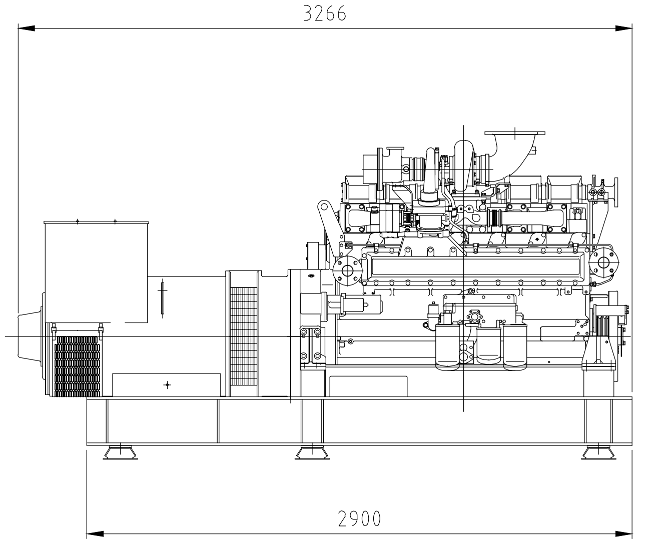
Preparation for inspection or maintenance

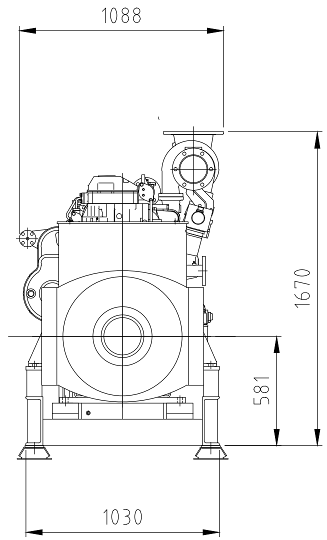
The mechanic must read and follow the safety instructions as presented in the Operation and Maintenance Manuals and Service Manual.

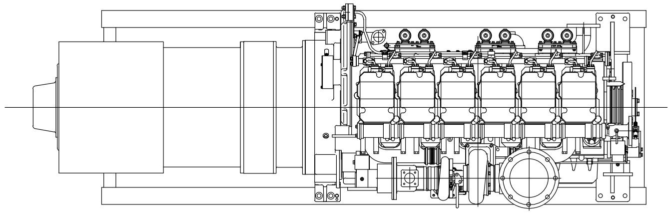
The intake system of the gas engine should be purged with a volume of air before maintenance, to make sure no unburned gas is left over in the air-fuel intake system or in the combustion chamber. The easiest way to do this is to crank the engine and keep the gas valves closed.

Prior to opening the crankcase, the mechanic must measure the LEL concentration of the crankcase atmosphere and purge the crankcase until it is below 20% LEL. The engine room ventilation fan should also be on thereby flushing the area.

Description	Drw.	App.	Date	Rev.





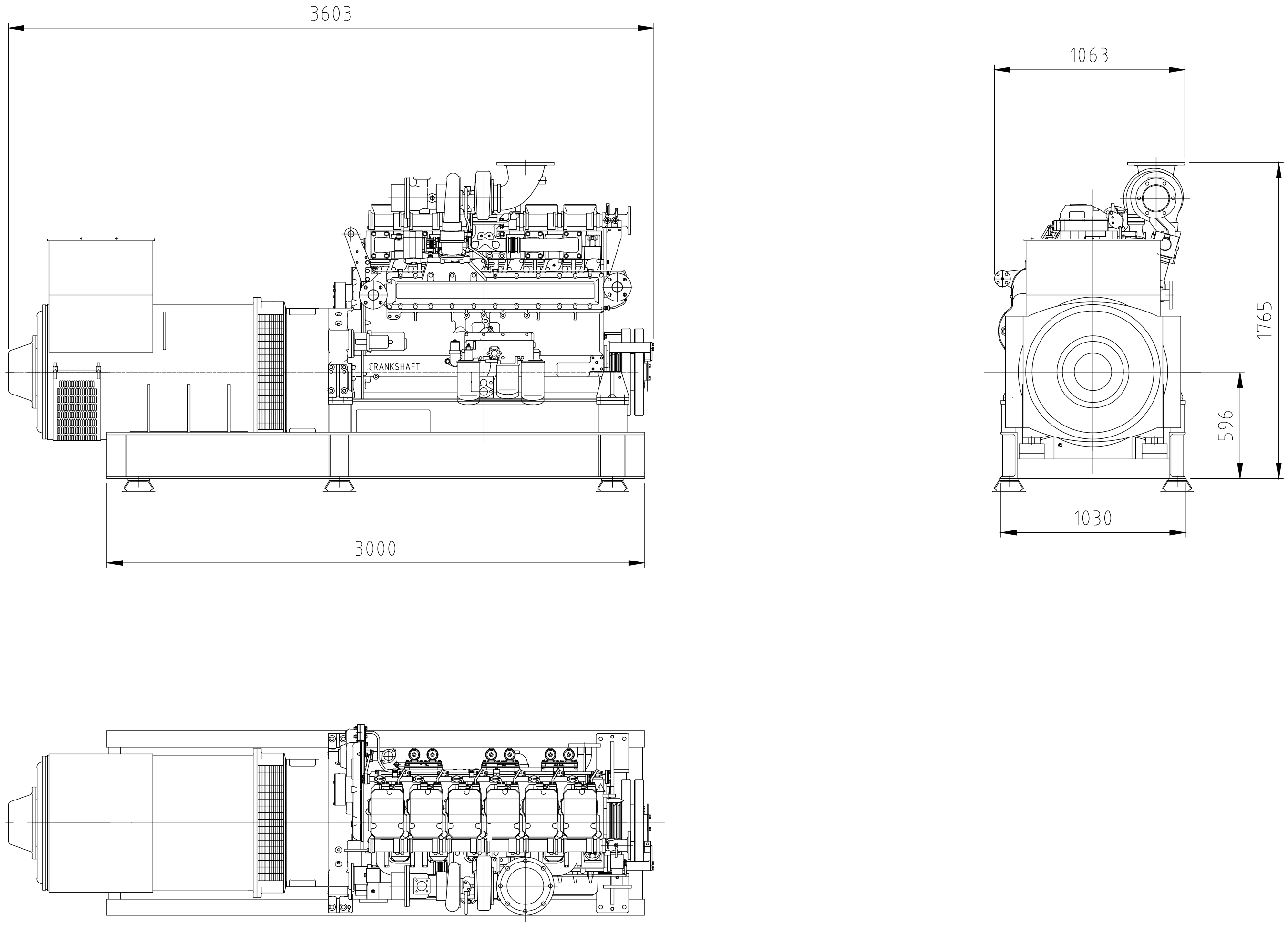


Preliminary

Dry Weight approx. = 4300kg

Description Genset General Arrangement GS6R-MPTK+HCM534E2	Project no. Standard drawing Drawing no. GPMG341-GS6RTK		GAS & DIESEL POWER POWER GENERATION SPECIALIST TEL.3129 1940 e-mail:firmapost@dieselpower.no www.dieselpower.no
Customer ref.	Drawn by IBL	Date 18.08.2015	
	Approved by	Date	Scale / Rev. / Page

Description	Drw.	App.	Date	Rev.

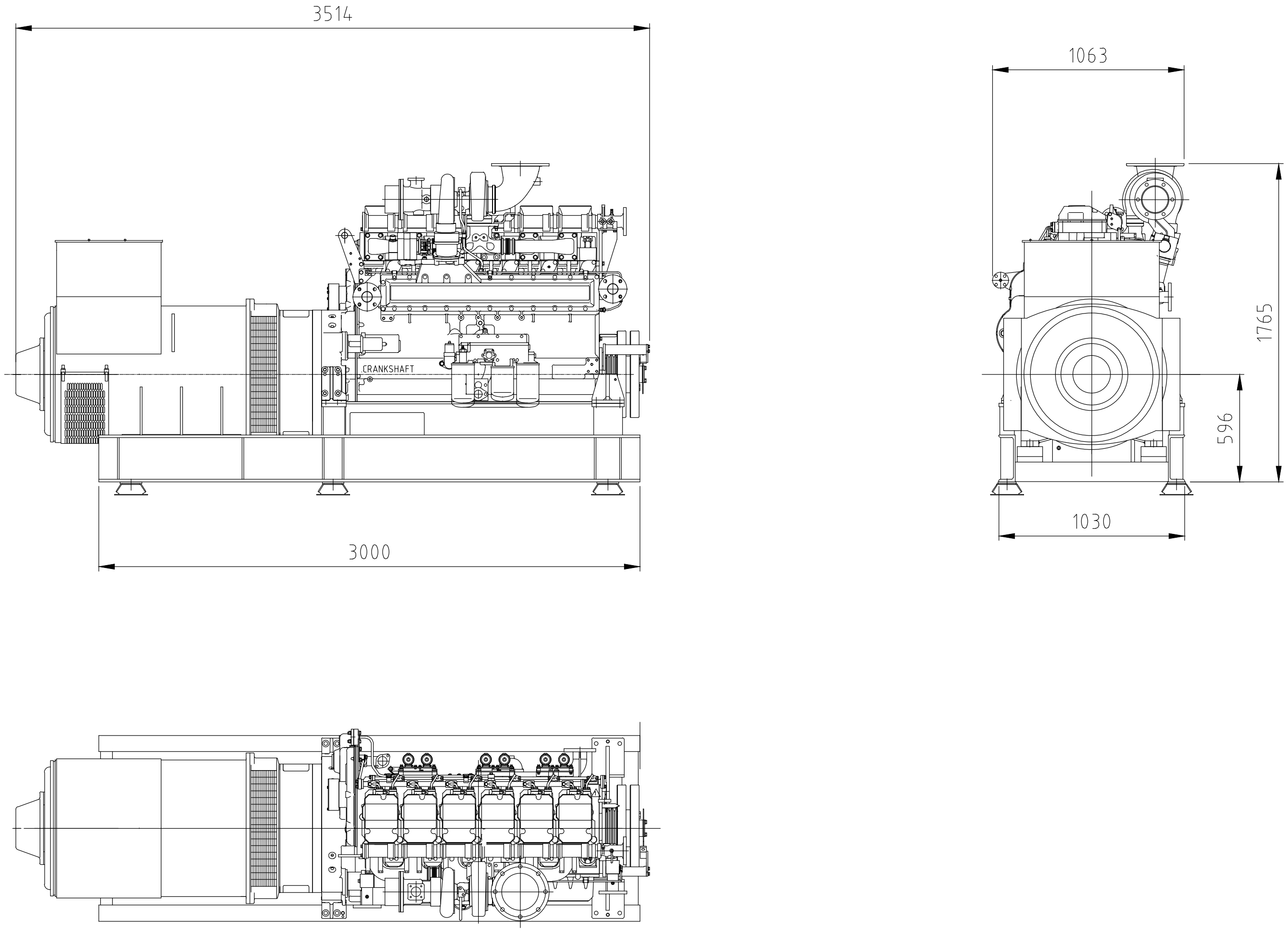


Preliminary

Dry Weight approx. = 5400kg

Description	Project no.		Gas & Diesel Power
Genset General Arrangement GS6R2-MPTK+HCM636K2	Standard drawing		POWER GENERATION SPECIALIST
	Drawing no. GPMG372-GS6R2TK		TEL.3129 1940 e-mail:firmapost@dieselpower.no www.dieselpower.no
Customer ref.	Drawn by IBL	Date 13.08.2015	
	Approved by	Date	Scale / Rev. / Page

Description	Drw.	App.	Date	Rev.

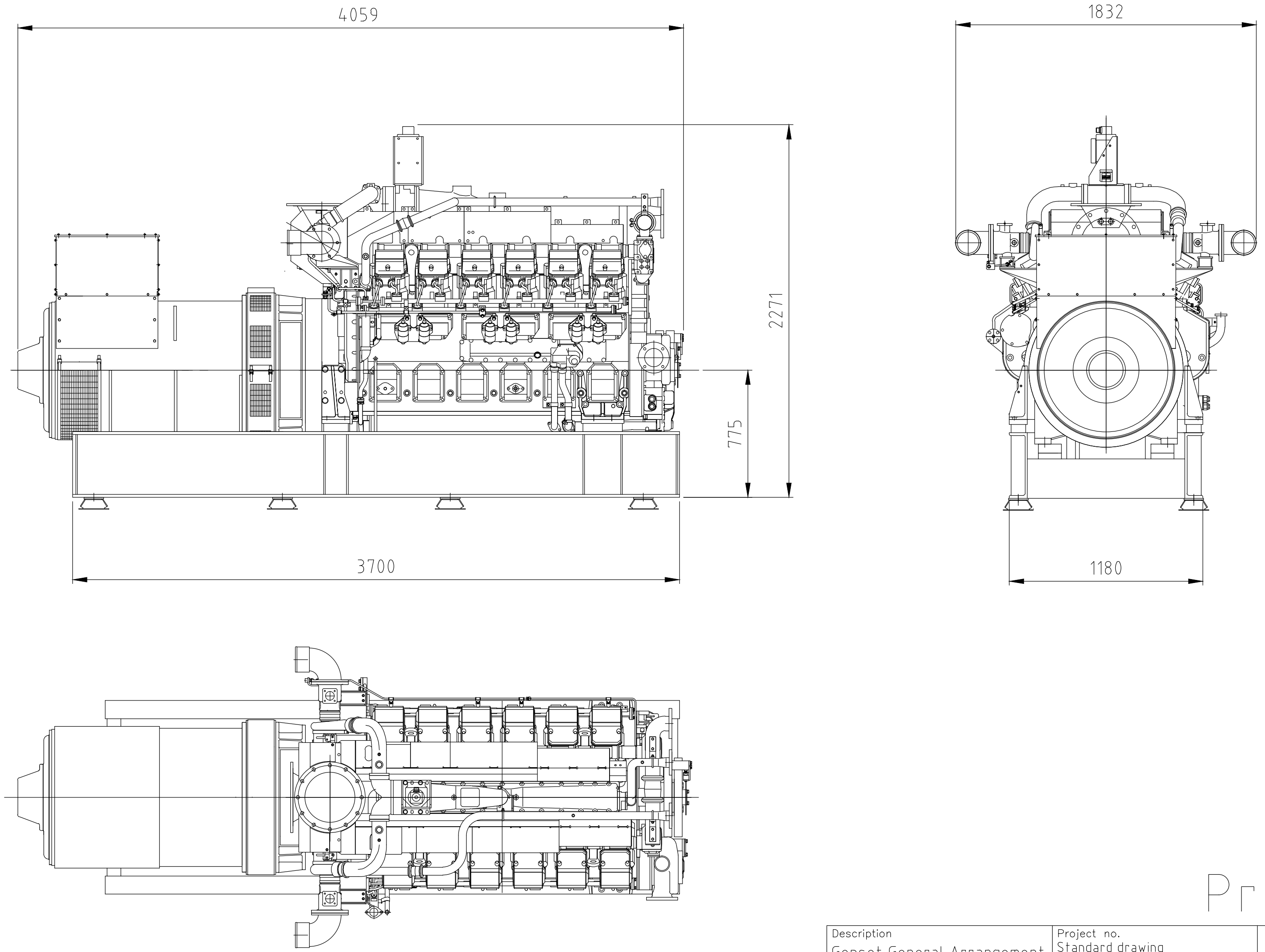


Preliminary

Dry Weight approx. = 5100kg

Description Genset General Arrangement GS6R2-MPTK+HCM634G2	Project no. Standard drawing		GAS & DIESEL POWER POWER GENERATION SPECIALIST TEL.3129 1940 e-mail:firmapost@dieselpower.no www.dieselpower.no
	Drawing no. GPMG450-GS6R2TK		
Customer ref.	Drawn by IBL	Date 13.08.2015	
	Approved by	Date	Scale / Rev. / Page

Description	Drw.	App.	Date	Rev.

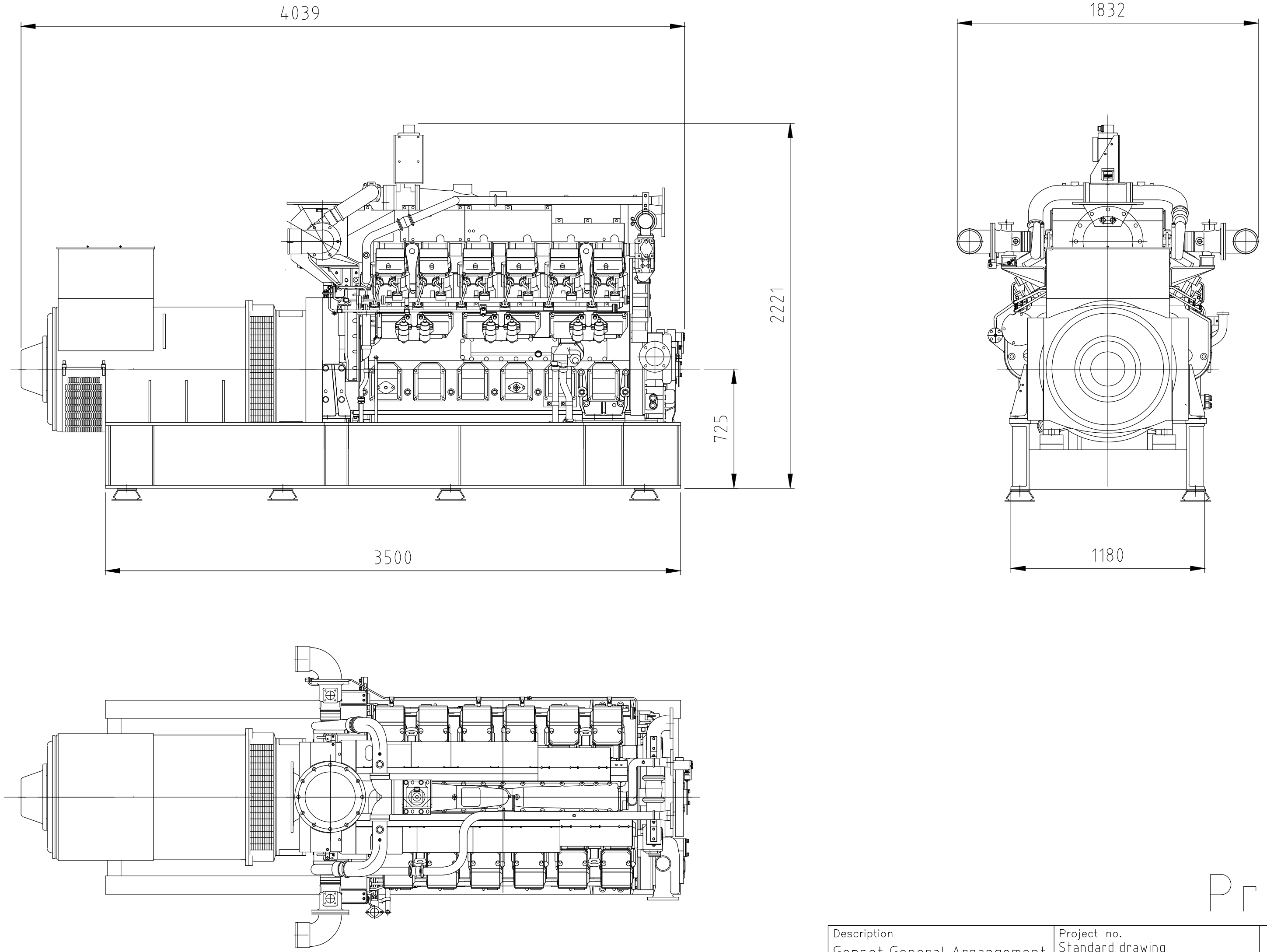


Preliminary

Dry Weight approx. 8800kg

Description	Project no.		
Genset General Arrangement	Standard drawing		
GS12R+PM736B2	Drawing no. GPMG601-GS12RTK		
Customer ref.	Drawn by IBL	Date 17.08.2015	
	Approved by	Date	Scale / Rev. / Page

GAS & DIESEL POWER
POWER GENERATION SPECIALIST
TEL.3129 1940
e-mail:firmapost@dieselpower.no
www.dieselpower.no



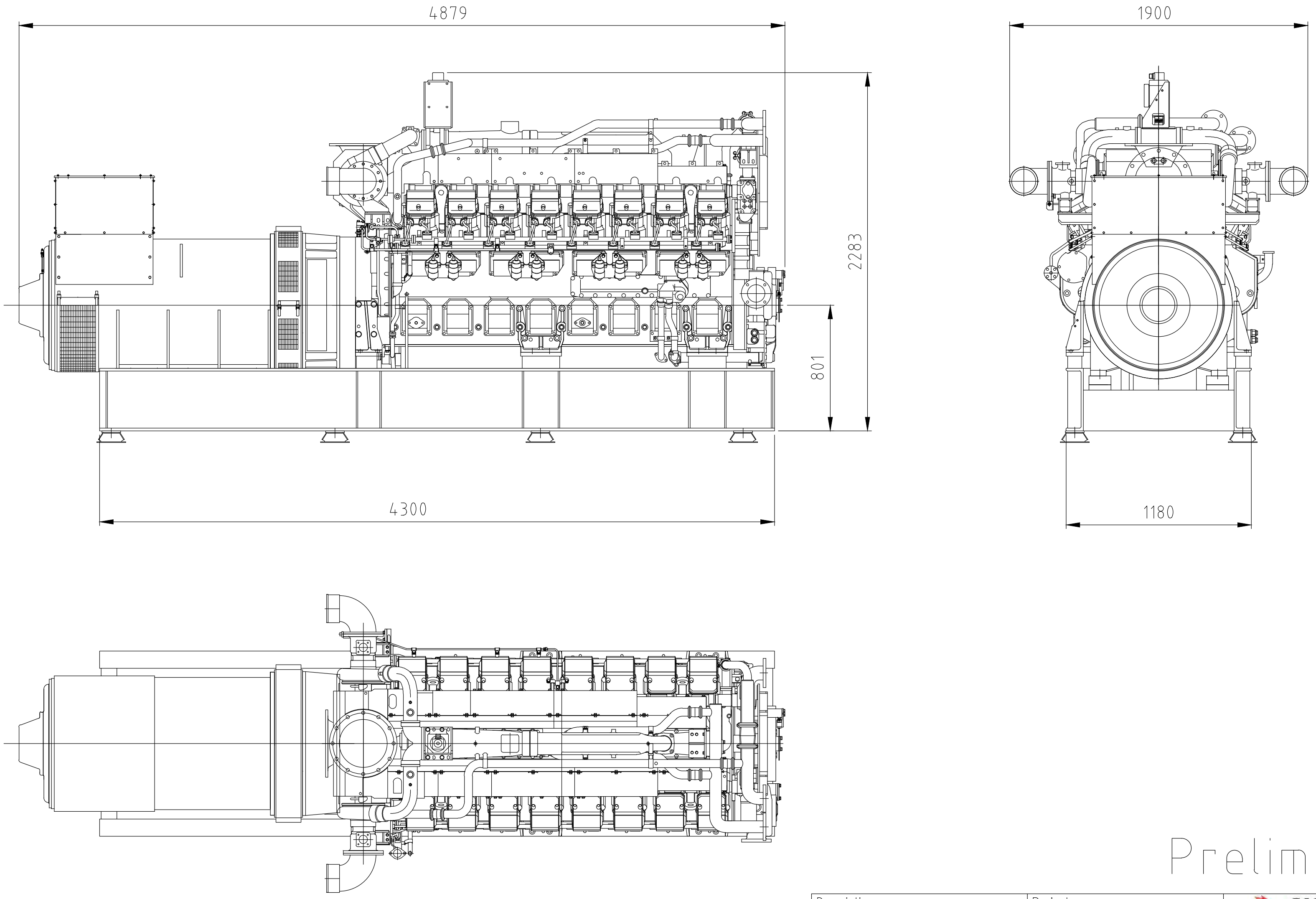
Description	Drw.	App.	Date	Rev.

Preliminary

Description Genset General Arrangement GS12R+HCM634K2	Project no. Standard drawing		GAS & DIESEL POWER POWER GENERATION SPECIALIST TEL.3129 1940 e-mail:firmapost@dieselpower.no www.dieselpower.no
	Drawing no. GPMG686-GS12RTK		
Customer ref.	Drawn by IBL	Date 13.08.2015	
	Approved by	Date	Scale / Rev. / Page

Dry Weight approx. 8700kg

Description	Drw.	App.	Date	Rev.



Preliminary

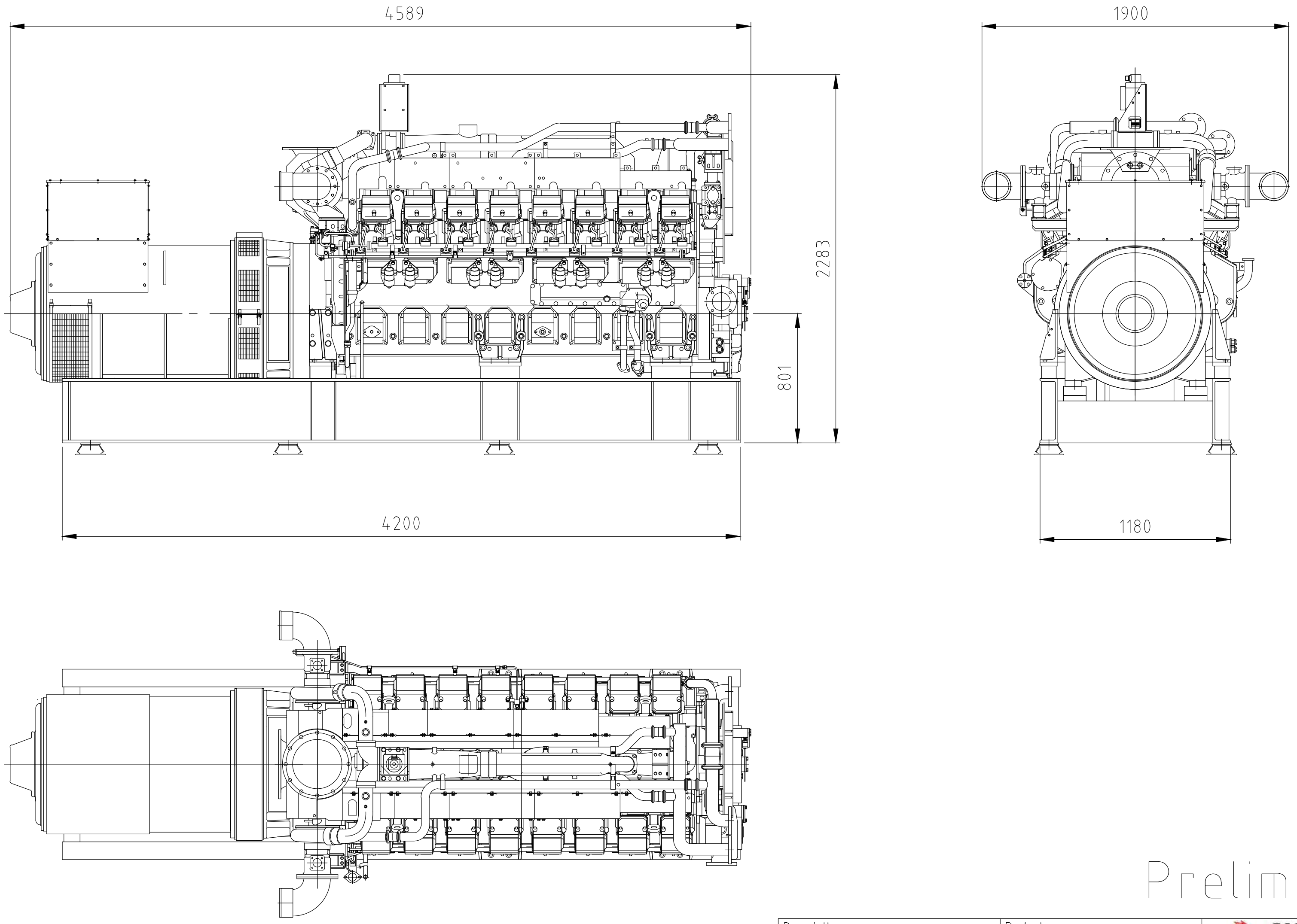
Dry Weight approx. 11 700 kg

Description	Project no.			
Genset General Arrangement GS16R+PM736F2	Standard Drawing			
	Drawing no. GPMG807-GS16RTK			
Customer ref.	Drawn by IBL	Date 19.08.2015		
	Approved by	Date	Scale	Rev.

Page

GAS & DIESEL POWER
POWER GENERATION SPECIALIST
TEL.3129 1940
e-mail:firmapost@dieselpower.no
www.dieselpower.no

Description	Drw.	App.	Date	Rev.

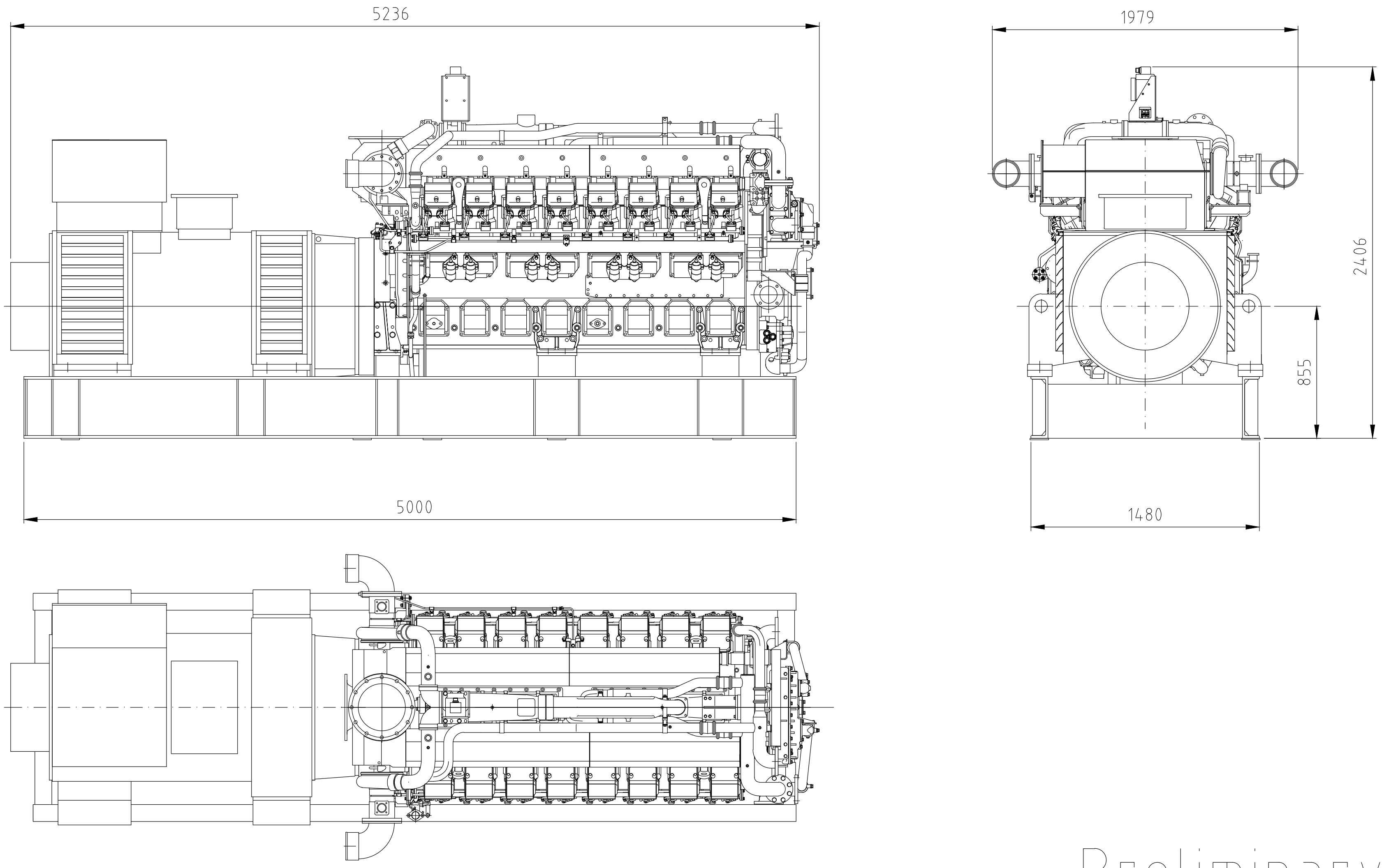


Preliminary

Description	Project no.		
Genset General Arrangement GS16R+PM734C2	Standard Drawing Drawing no. GPMG930-GS16RTK		GAS & DIESEL POWER POWER GENERATION SPECIALIST TEL.3129 1940 e-mail:firmapost@dieselpower.no www.dieselpower.no
Customer ref.	Drawn by IBL	Date 17.08.2015	
	Approved by	Date	Scale / Rev. / Page

Dry Weight approx. 10 800 kg

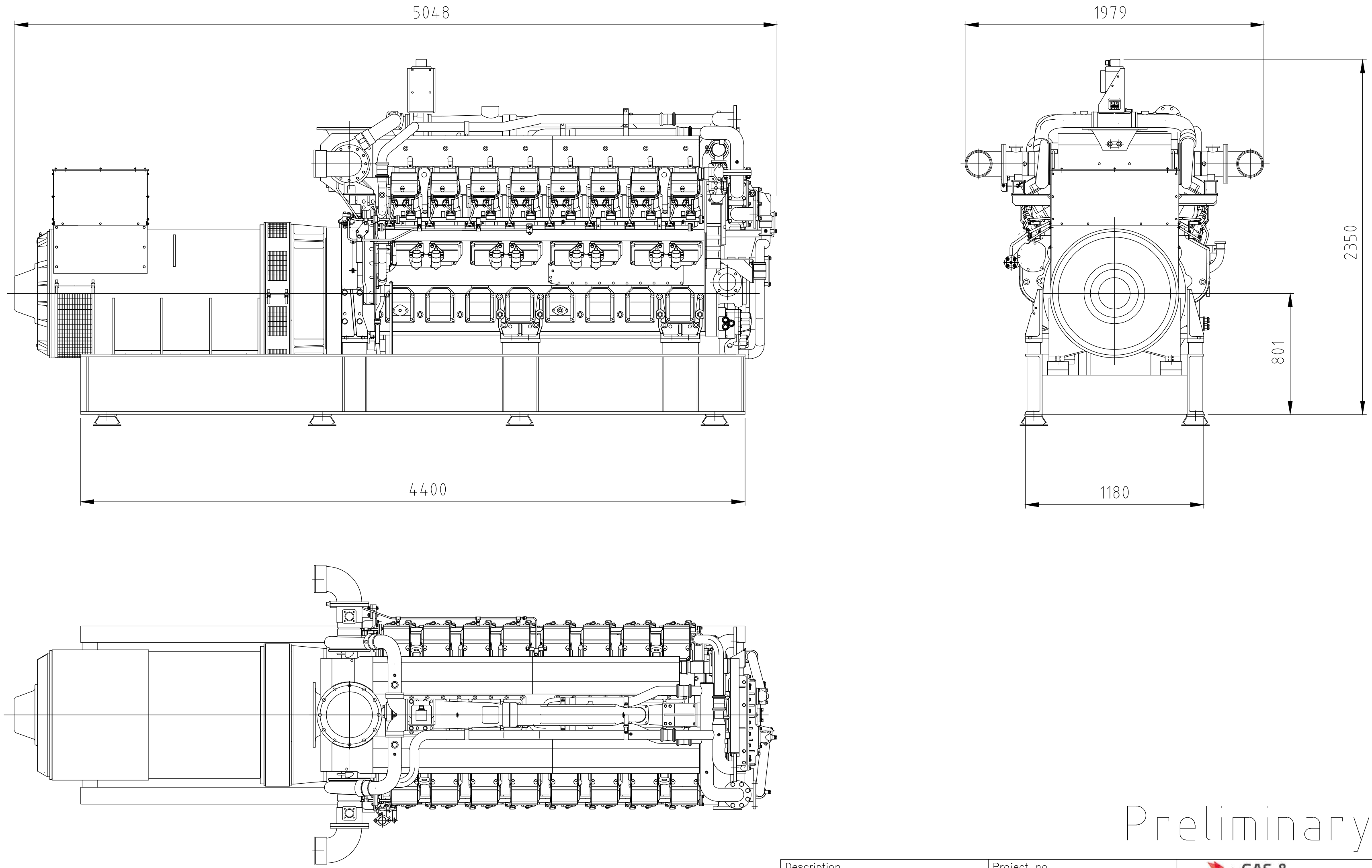
Description	Drw.	App.	Date	Rev.



Preliminary

Dry Weight approx. 15 000 kg

Description	Project no.		GAS & DIESEL POWER
Genset General Arrangement	Standard drawing		POWER GENERATION SPECIALIST
GS16R2-MPTK+DSG 86M1-4	Drawing no. GPMG1200-GS16R2TK		TEL.3129 1940
Customer ref.	Drawn by IBL	Date 28.08.2015	e-mail:firmapost@dieselpower.no www.dieselpower.no
	Approved by	Date	Scale / Rev. / Page



Preliminary

Description	Drw.	App.	Date	Rev.

Dry Weight approx. 12 800 kg

Description Genset General Arrangement GS16R2+PM734G2	Project no. Standard Drawing		GAS & DIESEL POWER POWER GENERATION SPECIALIST TEL.3129 1940 e-mail:firmapost@dieselpower.no www.dieselpower.no
	Drawing no. GPMG1500-GS16R2TK		
Customer ref.	Drawn by IBL	Date 27.08.2015	
	Approved by	Date	Scale / Rev. / Page

GS6R-MPTK (AD Miller 1500min^{-1})

MITSUBISHI
GAS ENGINES

SPECIFICATION SHEET

JAN 1 9. 2 0 1 1

GENERAL ENGINE DATA

Type	4-Cycle, Water Cooled Spark-Ignition, Lean-Burn Engine with Pre-chamber
Aspiration	Turbo-Charged, Inter-Cooled (Raw Water to Cooler)
Cylinder Arrangement	Inline
No. of Cylinders	6
Bore —mm (in)	170 (6.69)
Stroke —mm (in)	180 (7.09)
Displacement —liter (cu.in)	24.51 (1496)
Compression Ratio (BTDC BASE)	15.0 : 1
Dry Weight – Engine Only – kg (lb)	2400 (5291)
Wet Weight – Engine Only – kg (lb)	2600 (5732)

PERFORMANCE DATA

Generator Output / Speed —kW/min^{-1}	350/1500
Engine Output / Speed —kW/min^{-1}	368/1500
Generator Efficiency	95.0
Turbo Model	TD13
Steady State Speed Stability Band at any Constant Load Electric Governor — %	±0.2
Maximum Overspeed Capability – min^{-1}	2100
Moment of Inertia of Rotating Components J– kg·m^2 (lb·ft^2) (Includes 18 inch Mass-up Flywheel)	18.21 (432)
Cyclic Speed Variation with Flywheel at 1500 min^{-1}	1/212

ENGINE MOUNTING

Max. Bending Moment at Rear Face of Flywheel Housing – N·m(lb·ft)	1961(1447)

AIR INLET SYSTEM

Maximum Intake Air Restriction With Clean Filter Element – kPa (in.H_2O)	1.5 (6.0)

EXAUST SYSTEM

Maximum Allowable Back Pressure — kPa (in.H_2O)	5.0 (20.1)

LUBRICATION SYSTEM

Oil Pressure at Idle – kPa (psi)	196-294 (28-43)
at Rated Speed – kPa (psi)	490-637 (71-92)
Maximum Oil Temperature — ℃ (° F)	110 (230)
Oil Pan Capacity High—liter (U.S.gal.)	145 (38.2)
Low—liter (U.S.gal.)	115 (30.4)
Total System Capacity (includes Oil Filter) — liter (U.S.gal.)	165 (43.5)
Maximum Angle of Installation (Std.Pan) (Engine only) Front Down	11.5°
Front Up	10°
Side to Side	22.5°

APLICATION : GENERATOR

Pub. No. GS6RADM-1500-G-M001-A

GS6R-MPTK (AD Miller 1500min^{-1})

SPECIFICATION SHEET

JAN 19. 2011

COOLING SYSTEM

Cooling Type ------------------------ External Water Pump Forced Cooling System
Coolant Capacity (Engine Only) – liter (U.S. gal) ------------------------- 50 (13.2)
Maximum External Friction Head at Engine Outlet – kPa (psi) ------------ 34.32 (5.0)
Maximum Static Head of Coolant above Crankshaft Center m (ft) ----------- 10 (32.8)
(＊1) Maximum Outlet Pressure of Engine Water Pump – kPa (psi) (Restricted) -- 255.0 (37.0)
(＊2) Standard Thermostat (modulating) Range – ℃ (° F) (Restricted) -------- 71-85 (160-185)
Minimum Coolant Expansion Space – % of System Capacity ------------ 10
Standard Jacket Water Temperature at Engine Outlet – ℃ (° F) ---------- 91±2(195.8±3.6)
Maximum Coolant Temperature at Intercooler Inlet – ℃ (° F) ------------ 35 (95)
Jacket Water Heater Capacity (AC3φ-220V) – kW x piece --------------- 2x1

FUEL GAS SYSTEM

Fuel Type -- Natural Gas
Heat value (LHV) – MJ / m^3(N) (BTU / ft^3) ------------------------------- 40.63 (1091.2)
Methane Number -- Higher than 60
Fuel Gas Specification ------------------------------------- C_3H_8 : less than 5%
------------------------------------- C_4H_{10} : less than 4%
---------------- Water : The dew point to be lower than 0 deg C
Supply Pressure to Main Fuel Gas –To pressure regulator kPa (psi) ------- 100-300 (14.5-43.5)
–To Tecjet Valve kPa (psi) ----------- 5-15 (0.73-2.18)
–To Engine kPa (psi) ----------------- 1-2.5 (0.15-0.36)
Supply Pressure to Pre-chamber Fuel Gas – kPa (psi) ----------------- 250-300 (36.3-43.5)

STARTING & ELECTRICAL SYSTEM

Starting Motor Capacity – V - kW ------------------------------------ 24 - 7.5
Maximum Allowable Resistance of Cranking Circuit – mΩ --------------- 1.5
Recommended Minimum Battery Capacity
At 5℃ (41° F) and above – Ah ------------------------------------ 200
Below 5℃ (41° F) through –5℃ (23° F) – Ah -------------------- 500

SITE CONDITIONS

Max. Ambient Temperature – ℃ (° F) --------------------------------- 40 (104)
Altitude Capability at 40℃(104° F) ambient, above sea level – m --------- 150

— NOTE —

＊1 ----- w/o Engine driven jacket water pump
＊2 ----- w/o Engine installed cooling water thermostat

The specifications are subject to change without notice

APLICATION : GENERATOR

Pub. No. GS6RADM-1500-G-M001-A

GS6R2-MPTK （Miller 1200min^{-1}）

SPECIFICATION SHEET

Sep 4.2013

GENERAL ENGINE DATA

Type	4-Cycle, Water Cooled Spark-Ignition, Lean-Burn Engine with Pre-chamber
Aspiration	Turbo-Charged, Inter-Cooled (Raw Water to Cooler)
Cylinder Arrangement	Inline
No. of Cylinders	6
Bore －mm (in)	170 (6.69)
Stroke －mm (in)	220 (8.66)
Displacement －liter (cu.in)	29.96 (1829)
Compression Ratio (BTDC BASE)	13.9 : 1
Dry Weight – Engine Only – kg (lb)	2675 (5898)
Wet Weight – Engine Only – kg (lb)	2875 (6339)

PERFORMANCE DATA

Generator Output / Speed －kW/min^{-1}	380/1200
Engine Output / Speed －kW/min^{-1}	394/1200
Generator Efficiency	96.5
Turbo Model	TD13
Steady State Speed Stability Band at any Constant Load Electric Governor － %	±0.2
Maximum Overspeed Capability – min^{-1}	1750
Moment of Inertia of Rotating Components J– kg･m^2 (lb･ft^2) (Includes 18 inch Mass-up Flywheel)	21.38 (507)
Cyclic Speed Variation with Flywheel at 1200 min^{-1}	1/107

ENGINE MOUNTING

Max. Bending Moment at Rear Face of Flywheel Housing – N･m(lb･ft)	1961(1447)

AIR INLET SYSTEM

Maximum Intake Air Restriction With Clean Filter Element – kPa (in.H_2O)	1.5 (6.0)

EXAUST SYSTEM

Maximum Allowable Back Pressure － kPa (in.H_2O)	5.0 (20.1)

LUBRICATION SYSTEM

Oil Pressure at Idle – kPa (psi)	196-294 (28-43)
at Rated Speed – kPa (psi)	490-637 (71-92)
Maximum Oil Temperature － ℃ (° F)	110 (230)
Oil Pan Capacity High－liter (U.S.gal.)	145 (38.2)
Low－liter (U.S.gal.)	115 (30.4)
Total System Capacity (includes Oil Filter) － liter (U.S.gal.)	165 (43.5)
Maximum Angle of Installation (Std.Pan) (Engine only) Front Down	11.5°
Front Up	10°
Side to Side	22.5°

APLICATION : MARINGE GENERATOR

Pub. No. GS6R2M-1200-MG-001

GS12R-MPTK (AD Miller 1500min^{-1})

MITSUBISHI
GAS ENGINES

SPECIFICATION SHEET

JAN 19. 2011

GENERAL ENGINE DATA

Type	4-Cycle, Water Cooled Spark-Ignition, Lean-Burn Engine with Pre-chamber
Aspiration	Turbo-Charged, Inter-Cooled (Raw Water to Cooler
Cylinder Arrangement	60° V
No. of Cylinders	12
Bore —mm (in)	170 (6.69)
Stroke —mm (in)	180 (7.09)
Displacement —liter (cu.in)	49.03 (2990)
Compression Ratio (BTDC BASE)	15.0 : 1
Dry Weight – Engine Only – kg (lb)	5150 (11354)
Wet Weight – Engine Only – kg (lb)	5545 (12225)

PERFORMANCE DATA

Generator Output / Speed —kW/min^{-1}	700/1500
Engine Output / Speed —kW/min^{-1}	721.6/1500
Generator Efficiency	97.0
Turbo Model	TD13
Steady State Speed Stability Band at any Constant Load Electric Governor — %	±0.2
Maximum Overspeed Capability – min^{-1}	2100
Moment of Inertia of Rotating Components J– kg·m^2 (lb·ft^2) (Includes 21 inch Mass-up Flywheel)	54.85 (1302)
Cyclic Speed Variation with Flywheel at 1500 min^{-1}	1/1562

ENGINE MOUNTING

Max. Bending Moment at Rear Face of Flywheel Housing – N·m(lb·ft)	4413(3256)

AIR INLET SYSTEM

Maximum Intake Air Restriction With Clean Filter Element — kPa (in.H_2O)	1.5 (6.0)

EXAUST SYSTEM

Maximum Allowable Back Pressure — kPa (in.H_2O)	5.0 (20.1)

LUBRICATION SYSTEM

Oil Pressure at Idle – kPa (psi)	196-294 (28-43)
at Rated Speed – kPa (psi)	490-637 (71-92)
Maximum Oil Temperature — ℃ (° F)	110 (230)
Oil Pan Capacity High—liter (U.S.gal.)	200 (52.8)
Low—liter (U.S.gal.)	158 (41.7)
Total System Capacity (includes Oil Filter) — liter (U.S.gal.)	230 (60.8)
Maximum Angle of Installation (Std.Pan) (Engine only) Front Down	15°
Front Up	12.5°
Side to Side	45°

APLICATION : GENERATOR

Pub. No. GS12RADM-1500-G-M001-A

COOLING SYSTEM

Cooling Type ------------------------ External Water Pump Forced Cooling System
- Coolant Capacity (Engine Only) – liter (U.S. gal) ------------------------- 125 (33.0)
- Maximum External Friction Head at Engine Outlet – kPa (psi) ------------- 34.32 (5.0)
- Maximum Static Head of Coolant above Crankshaft Center m (ft) ----------- 10 (32.8)
- (* 1) Maximum Outlet Pressure of Engine Water Pump – kPa (psi) (Restricted) -- 196.1 (28.4)
- (* 2) Standard Thermostat (modulating) Range – ℃ (° F) (Restricted) -------- 71-85 (160-185)
- Minimum Coolant Expansion Space — % of System Capacity ----------- 10
- Standard Jacket Water Temperature at Engine Outlet – ℃ (° F) ---------- 91±2(195.8±3.6)
- Maximum Coolant Temperature at Intercooler Inlet – ℃ (° F) ------------ 35 (95)
- Jacket Water Heater Capacity (AC3ϕ-220V) – kW x piece ---------------- 2x2

FUEL GAS SYSTEM

- Fuel Type --- Natural Gas
- Heat value (LHV) – MJ / m^3(N) (BTU / ft^3) ------------------------------ 40.63 (1091.2)
- Methane Number -- Higher than 60
- Fuel Gas Specification -- C_3H_8 : less than 5%
  - -- C_4H_{10} : less than 4%
  - ---------------- Water : The dew point to be lower than 0 deg C
- Supply Pressure to Main Fuel Gas – To pressure regulator kPa (psi) ------- 100-300 (14.5-43.5)
  - – To Tecjet Valve kPa (psi) ----------- 5-15 (0.73-2.18)
  - – To Engine kPa (psi) ----------------- 1-2.5 (0.15-0.36)
- Supply Pressure to Pre-chamber Fuel Gas – kPa (psi) ----------------- 250-300 (36.3-43.5)

STARTING & ELECTRICAL SYSTEM

- Starting Motor Capacity – V - kW ------------------------------------ 24 - 7.5
- Maximum Allowable Resistance of Cranking Circuit – mΩ --------------- 1.5
- Recommended Minimum Battery Capacity
  - At 5℃ (41° F) and above – Ah -------------------------------------- 300
  - Below 5℃ (41° F) through -5℃ (23° F) – Ah -------------------- 600

SITE CONDITIONS

- Max. Ambient Temperature – ℃ (° F) --------------------------------- 40 (104)
- Altitude Capability at 40℃(104° F) ambient, above sea level – m --------- 150

— NOTE —

* 1 ----- w/o Engine driven jacket water pump
* 2 ----- w/o Engine installed cooling water thermostat

The specifications are subject to change without notice

APLICATION : GENERATOR

Pub. No. GS12RADM-1500-G-M001-A

GS16R-MPTK (AD Miller 1500min^{-1})

MITSUBISHI
GAS ENGINES

SPECIFICATION SHEET

JAN 19. 2011

GENERAL ENGINE DATA

Type	4-Cycle, Water Cooled Spark-Ignition, Lean-Burn Engine with Pre-chamber
Aspiration	Turbo-Charged, Inter-Cooled (Raw Water to Cooler)
Cylinder Arrangement	60° V
No. of Cylinders	16
Bore —mm (in)	170 (6.69)
Stroke —mm (in)	180 (7.09)
Displacement —liter (cu.in)	65.37 (3989)
Compression Ratio (BTDC BASE)	15.0 : 1
Dry Weight – Engine Only – kg (lb)	6830 (15058)
Wet Weight – Engine Only – kg (lb)	7340 (16182)

PERFORMANCE DATA

Generator Output / Speed —kW/min^{-1}	930/1500
Engine Output / Speed —kW/min^{-1}	958.8/1500
Generator Efficiency	97.0
Turbo Model	TD13
Steady State Speed Stability Band at any Constant Load Electric Governor — %	±0.2
Maximum Overspeed Capability – min^{-1}	2100
Moment of Inertia of Rotating Components J– kg·m^2 (lb·ft^2) (Includes 21 inch Mass-up Flywheel)	57.94 (1375)
Cyclic Speed Variation with Flywheel at 1500 min^{-1}	1/811

ENGINE MOUNTING

Max. Bending Moment at Rear Face of Flywheel Housing – N·m(lb·ft)	4413(3256)

AIR INLET SYSTEM

Maximum Intake Air Restriction With Clean Filter Element – kPa (in.H_2O)	1.5 (6.0)

EXAUST SYSTEM

Maximum Allowable Back Pressure — kPa (in.H_2O)	5.0 (20.1)

LUBRICATION SYSTEM

Oil Pressure at Idle – kPa (psi)	196-294 (28-43)
at Rated Speed – kPa (psi)	490-637 (71-92)
Maximum Oil Temperature — ℃ (° F)	110 (230)
Oil Pan Capacity High—liter (U.S.gal.)	260 (68.6)
Low—liter (U.S.gal.)	194 (51.2)
Total System Capacity (includes Oil Filter) — liter (U.S.gal.)	290 (76.5)
Maximum Angle of Installation (Std.Pan) (Engine only) Front Down	10.5°
Front Up	9.5°
Side to Side	45°

APLICATION : GENERATOR

Pub. No. GS16RADM-1500-G-M001-A

GS16R-MPTK (AD Miller 1500min^{-1})

SPECIFICATION SHEET

JAN 19. 2011

COOLING SYSTEM

	Cooling Type	External Water Pump Forced Cooling System
	Coolant Capacity (Engine Only) – liter (U.S. gal)	170 (44.9)
	Maximum External Friction Head at Engine Outlet – kPa (psi)	34.32 (5.0)
	Maximum Static Head of Coolant above Crankshaft Center m (ft)	10 (32.8)
(* 1)	Maximum Outlet Pressure of Engine Water Pump – kPa (psi) (Restricted)	196.1 (28.4)
(* 2)	Standard Thermostat (modulating) Range – ℃ (° F) (Restricted)	71-85 (160-185)
	Minimum Coolant Expansion Space – % of System Capacity	10
	Standard Jacket Water Temperature at Engine Outlet – ℃ (° F)	91±2(195.8±3.6)
	Maximum Coolant Temperature at Intercooler Inlet – ℃ (° F)	35 (95)
	Jacket Water Heater Capacity (AC3ϕ-220V) – kW x piece	2x2

FUEL GAS SYSTEM

Fuel Type	Natural Gas
Heat value (LHV) – MJ / m^3(N) (BTU / ft^3)	40.63 (1091.2)
Methane Number	Higher than 60
Fuel Gas Specification	C_3H_8 : less than 5%
	C_4H_{10} : less than 4%
	Water : The dew point to be lower than 0 deg C
Supply Pressure to Main Fuel Gas –To pressure regulator kPa (psi)	100-300 (14.5-43.5)
–To Tecjet Valve kPa (psi)	5-15 (0.73-2.18)
–To Engine kPa (psi)	1-2.5 (0.15-0.36)
Supply Pressure to Pre-chamber Fuel Gas – kPa (psi)	250-300 (36.3-43.5)

STARTING & ELECTRICAL SYSTEM

Starting Motor Capacity – V - kW	24 - 7.5 x 2
Maximum Allowable Resistance of Cranking Circuit – mΩ	1.5
Recommended Minimum Battery Capacity	
At 5℃ (41° F) and above – Ah	300
Below 5℃ (41° F) through –5℃ (23° F) – Ah	600

SITE CONDITIONS

Max. Ambient Temperature – ℃ (° F)	40 (104)
Altitude Capability at 40℃(104° F) ambient, above sea level – m	150

— NOTE —

* 1 ----- w/o Engine driven jacket water pump
* 2 ----- w/o Engine installed cooling water thermostat

The specifications are subject to change without notice

APLICATION : GENERATOR

Pub. No. GS16RADM-1500-G-M001-A

GS16R2-MPTK (Miller 1200min^{-1})

MITSUBISHI
GAS ENGINES

SPECIFICATION SHEET

JAN 19 . 2011

GENERAL ENGINE DATA

Type	4-Cycle, Water Cooled Spark-Ignition, Lean-Burn Engine with Pre-chamber
Aspiration	Turbo-Charged, Inter-Cooled (Raw Water to Cooler)
Cylinder Arrangement	60° V
No. of Cylinders	16
Bore −mm (in)	170 (6.69)
Stroke −mm (in)	220 (8.66)
Displacement −liter (cu.in)	79.9 (4876)
Compression Ratio (BTDC BASE)	13.9 : 1
Dry Weight – Engine Only – kg (lb)	7815 (17230)
Wet Weight – Engine Only – kg (lb)	8415 (18553)

PERFORMANCE DATA

Generator Output / Speed −kW/min^{-1}	1000/1200
Engine Output / Speed −kW/min^{-1}	1030.9/1200
Generator Efficiency	97.0
Turbo Model	TD13
Steady State Speed Stability Band at any Constant Load Electric Governor − %	±0.2
Maximum Overspeed Capability – min^{-1}	1750
Moment of Inertia of Rotating Components J– kg·m^2 (lb·ft^2) (Includes 21 inch Mass-up Flywheel)	59.21 (1405)
Cyclic Speed Variation with Flywheel at 1200 min^{-1}	1/395

ENGINE MOUNTING

Max. Bending Moment at Rear Face of Flywheel Housing – N·m(lb·ft)	4413(3256)

AIR INLET SYSTEM

Maximum Intake Air Restriction With Clean Filter Element − kPa (in.H_2O)	1.5 (6.0)

EXAUST SYSTEM

Maximum Allowable Back Pressure − kPa (in.H_2O)	5.0 (20.1)

LUBRICATION SYSTEM

Oil Pressure at Idle – kPa (psi)	196-294 (28-43)
at Rated Speed – kPa (psi)	490-637 (71-92)
Maximum Oil Temperature − ℃ (° F)	110 (230)
Oil Pan Capacity High−liter (U.S.gal.)	340 (89.8)
Low−liter (U.S.gal.)	260 (68.6)
Total System Capacity (includes Oil Filter) − liter (U.S.gal.)	370 (97.7)
Maximum Angle of Installation (Std.Pan) (Engine only) Front Down	10.5°
Front Up	9.5°
Side to Side	45°

APLICATION : GENERATOR

Pub. No. GS16R2M-1200-G-M001-A

COOLING SYSTEM

Cooling Type ------------------------ External Water Pump Forced Cooling System
Coolant Capacity (Engine Only) – liter (U.S. gal) ------------------------- 200 (52.8)
Maximum External Friction Head at Engine Outlet – kPa (psi) ------------- 34.32 (5.0)
Maximum Static Head of Coolant above Crankshaft Center m (ft) ----------- 10 (32.8)
(＊1) Maximum Outlet Pressure of Engine Water Pump – kPa (psi) (Restricted) -- 196.1 (28.4)
(＊2) Standard Thermostat (modulating) Range– ℃ (° F) (Restricted) -------- 71-85 (160-185)
Minimum Coolant Expansion Space – % of System Capacity ------------ 10
Standard Jacket Water Temperature at Engine Outlet– ℃ (° F) ---------- 91±2(195.8±3.6)
Maximum Coolant Temperature at Intercooler Inlet– ℃ (° F) ------------ 35 (95)
Jacket Water Heater Capacity (AC3ϕ-220V)–kW x piece ---------------- 2x2

FUEL GAS SYSTEM

Fuel Type -- Natural Gas
Heat value (LHV) – MJ / m^3(N) (BTU / ft^3) ------------------------------ 40.63 (1091.2)
Methane Number--- Higher than 60
Fuel Gas Specification -- C_3H_8 : less than 5%
-- C_4H_{10} : less than 4%
---------------- Water : The dew point to be lower than 0 deg C
Supply Pressure to Main Fuel Gas –To pressure regulator kPa (psi) ------- 100-300 (14.5-43.5)
–To Tecjet Valve kPa (psi) ------------ 5-15 (0.73-2.18)
–To Engine kPa (psi) ----------------- 1-2.5 (0.15-0.36)
Supply Pressure to Pre-chamber Fuel Gas – kPa (psi) ------------------ 250-300 (36.3-43.5)

STARTING & ELECTRICAL SYSTEM

Starting Motor Capacity – V - kW ------------------------------------ 24 - 7.5 x 2
Maximum Allowable Resistance of Cranking Circuit – mΩ --------------- 1.5
Recommended Minimum Battery Capacity
At 5℃ (41° F) and above – Ah ------------------------------------- 300
Below 5℃ (41° F) through –5℃ (23° F) – Ah -------------------- 600

SITE CONDITIONS

Max. Ambient Temperature– ℃ (° F) --------------------------------- 40 (104)
Altitude Capability at 40℃(104° F) ambient, above sea level –m --------- 150

— NOTE —

＊1 ----- w/o Engine driven jacket water pump
＊2 ----- w/o Engine installed cooling water thermostat

The specifications are subject to change without notice

APLICATION : GENERATOR

Pub. No. GS16R2M-1200-G-M001-A

DRAFT

HEAT BALANCE DATA

Name of Customer, Project
MEE

Engine Model	GS6R-PTK
Configuration	Miller Cycle
Gen.Output	350 kWe
Engine Speed	1500 min^{-1}
Thermal Efficiency @ Gen	40.0 %
Generator Efficiency	96.5 %
Kind of Fuel Gas	Natural Gas
Fuel Gas LHV	36.62 MJ/m^3N
Altitude	0 m

	Load(%)	100	75	50	25
	Engine Output(kW)	362.7	272.0	181.3	90.7
HEAT BALANCE	Input(MJ/h)	3150.0	2446.5	1750.6	1076.7
	Power(MJ/h)	1305.7	979.3	652.8	326.4
	Jacket Water (MJ/h)	563.4	495.8	426.6	321.2
	Exhaust Gas(MJ/h)	859.9	665.6	484.2	313.1
	Intercooler(MJ/h)	224.3	169.0	75.1	14.5
	Oil cooler(MJ/h)	0.0	0.0	0.0	0.0
	Radiation(MJ/h)	196.7	136.9	111.8	101.5
	Fuel Rate(m^3N/h)	86.0	66.8	47.8	29.4
	Coolant Flow(l/min)	660	660	660	660
	Coolant Flow to I/C(l/min)	170	170	170	170
	Exh.Gas Flow Rate(m^3N/h)	1549.8	1164.5	821.9	525.2
	Exh.Stack Temp.(C)	400	411	423	428
RECOV	Jacket Water (MJ/h)	563.4	495.8	426.6	321.2
	Exhaust Gas(MJ/h)	537.4	422.6	312.4	203.4
	0.8MPa Steam(kg/h)	213	168	124	81

Note)

1. This data is for reference purpose only.
2. This data is based on following conditions:
   (1)Ambient temperature: 40C
   (2)Fuel gas specification:
   - C_3H_8 : Less than 5%
   - C_4H_{10} : Less than 4%
   - Water : The dew point to be lower than 0C.
3. Tolerance
   Output ±3%
   Fuel Rate +5%
   Exh.Gas Flow Rate ±6%
   Exh.Gas Temp. ±8%
   Jacket Water ±12%
   Intercooler ±12%
   Oil Cooler ±10%
4. Exhaust gas heat be recovered to 150C.
5. Reduce 12% from heat rejection data for recoverable heat calculation.
6. Add 17% to heat rejection data for cooling system sizing.
7. Fuel gas LHV variation to be within ±2%.
   Variation cycle to be longer than 5 minutes.

DRAFT

HEAT BALANCE DATA

Name of Customer, Project	Engine Model	GS6R2-PTK	
MEE	Configuration	Miller Cycle	
	Gen.Output	380	kWe
	Engine Speed	1200	min^{-1}
	Thermal Efficiency @ Gen	41.5	%
	Generator Efficiency	96.5	%
	Kind of Fuel Gas	Natural Gas	
	Fuel Gas LHV	36.62	MJ/m^3N
	Altitude	0	m

	Load(%)	100	75	50	25
	Engine Output(kW)	393.8	295.3	196.9	98.4
HEAT BALANCE	Input(MJ/h)	3296.4	2560.2	1832.0	1126.8
	Power(MJ/h)	1417.6	1063.2	708.8	354.4
	Jacket Water (MJ/h)	589.5	518.8	446.5	336.1
	Exhaust Gas(MJ/h)	876.3	678.2	493.4	319.1
	Intercooler(MJ/h)	234.8	176.9	78.6	15.2
	Oil cooler(MJ/h)	0.0	0.0	0.0	0.0
	Radiation(MJ/h)	178.2	123.1	104.7	102.1
	Fuel Rate(m^3N/h)	90.0	69.9	50.0	30.8
	Coolant Flow(l/min)	660	660	660	660
	Coolant Flow to I/C(l/min)	170	170	170	170
	Exh.Gas Flow Rate(m^3N/h)	1621.8	1218.6	860.1	549.6
	Exh.Stack Temp.(C)	390	401	412	417
RECOV	Jacket Water (MJ/h)	589.5	518.8	446.5	336.1
	Exhaust Gas(MJ/h)	539.2	424.3	313.8	204.4
	0.8MPa Steam(kg/h)	214	168	124	81

Note)

1. This data is for reference purpose only.
2. This data is based on following conditions:
   (1)Ambient temperature: 40C
   (2)Fuel gas specification:
   - C_3H_8 : Less than 5%
   - C_4H_{10} : Less than 4%
   - Water : The dew point to be lower than 32F.
3. Tolerance Output ±3%
   Fuel Rate +5%
   Exh.Gas Flow Rate ±6%
   Exh.Gas Temp. ±8%
   Jacket Water ±12%
   Intercooler ±12%
   Oil Cooler ±10%
4. Exhaust gas heat be recovered to 150C.
5. Reduce 12% from heat rejection data for recoverable heat calculation.
6. Add 17% to heat rejection data for cooling system sizing.
7. Fuel gas LHV variation to be within ±2%.
   Variation cycle to be longer than 5 minutes.

DRAFT

HEAT BALANCE DATA

Name of Customer, Project	Engine Model	GS12R-PTK
MEE	Configuration	Miller Cycle
	Gen.Output	610 kWe
	Engine Speed	1200 min^{-1}
	Thermal Efficiency @ Gen	41.2 %
	Generator Efficiency	96.5 %
	Kind of Fuel Gas	Natural Gas
	Fuel Gas LHV	36.62 MJ/m^3N
	Altitude	0 m

	Load(%)	100	75	50	25
	Engine Output(kW)	632.1	474.1	316.1	158.0
HEAT BALANCE	Input(MJ/h)	5330.1	4139.8	2962.2	1821.9
	Power(MJ/h)	2275.6	1706.7	1137.8	568.9
	Jacket Water (MJ/h)	953.3	838.9	721.9	543.4
	Exhaust Gas(MJ/h)	1451.2	1123.3	817.2	528.4
	Intercooler(MJ/h)	379.6	286.0	127.0	24.5
	Oil cooler(MJ/h)	0.0	0.0	0.0	0.0
	Radiation(MJ/h)	270.4	184.9	158.3	156.6
	Fuel Rate(m^3N/h)	145.6	113.0	80.9	49.8
	Coolant Flow(l/min)	1240	1240	1240	1240
	Coolant Flow to I/C(l/min)	250	250	250	250
	Exh.Gas Flow Rate(m^3N/h)	2622.4	1970.4	1390.7	888.7
	Exh.Stack Temp.(C)	399	410	422	427
RECOV	Jacket Water (MJ/h)	953.3	838.9	721.9	543.4
	Exhaust Gas(MJ/h)	905.6	712.2	526.5	342.8
	0.8MPa Steam(kg/h)	359	282	209	136

Note)

1.This data is for reference purpose only.
2.This data is based on following conditions:
(1)Ambient temperature: 40C
(2)Fuel gas specification:
・C_3H_8 : Less than 5%
・C_4H_{10} : Less than 4%
・Water : The dew point to be lower than 0C.
3.Tolerance Output ±3%
Fuel Rate +5%
Exh.Gas Flow Rate ±6%
Exh.Gas Temp. ±8%
Jacket Water ±12%
Intercooler ±12%
Oil Cooler ±10%
4.Exhaust gas heat be recovered to 150C.
5.Reduce 12% from heat rejection data for recoverable heat calculation.
6.Add 17% to heat rejection data for cooling system sizing.
7.Fuel gas LHV variation to be within ±2%.
Variation cycle to be longer than 5 minutes.

DRAFT

HEAT BALANCE DATA

Name of Customer, Project
MEE

Engine Model	GS16R-PTK	
Configuration	Miller Cycle	
Gen.Output	930	kWe
Engine Speed	1500	min^{-1}
Thermal Efficiency @ Gen	40.0	%
Generator Efficiency	96.5	%
Kind of Fuel Gas	Natural Gas	
Fuel Gas LHV	36.62	MJ/m^3N
Altitude	0	m

	Load(%)	100	75	50	25
	Engine Output(kW)	963.7	722.8	481.9	240.9
HEAT BALANCE	Input(MJ/h)	8370.0	6500.8	4651.7	2861.0
	Power(MJ/h)	3469.4	2602.1	1734.7	867.4
	Jacket Water (MJ/h)	1496.9	1317.3	1133.6	853.4
	Exhaust Gas(MJ/h)	2284.8	1768.5	1286.7	832.0
	Intercooler(MJ/h)	596.1	449.1	199.5	38.5
	Oil cooler(MJ/h)	0.0	0.0	0.0	0.0
	Radiation(MJ/h)	522.7	363.8	297.2	269.8
	Fuel Rate(m^3N/h)	228.6	177.5	127.0	78.1
	Coolant Flow(l/min)	1600	1600	1600	1600
	Coolant Flow to I/C(l/min)	500	500	500	500
	Exh.Gas Flow Rate(m^3N/h)	4118.1	3094.2	2183.8	1395.5
	Exh.Stack Temp.(C)	400	411	423	428
RECOV	Jacket Water (MJ/h)	1496.9	1317.3	1133.6	853.4
	Exhaust Gas(MJ/h)	1428.0	1123.0	830.1	540.5
	0.8MPa Steam(kg/h)	566	445	329	214

Note)

1.This data is for reference purpose only.

2.This data is based on following conditions:

(1)Ambient temperature: 40C

(2)Fuel gas specification:

- C_3H_8 : Less than 5%
- C_4H_{10} : Less than 4%
- Water : The dew point to be lower than 0C.

3.Tolerance Output ±3%
Fuel Rate +5%
Exh.Gas Flow Rate ±6%
Exh.Gas Temp. ±8%
Jacket Water ±12%
Intercooler ±12%
Oil Cooler ±10%

4.Exhaust gas heat be recovered to 150C.

5.Reduce 12% from heat rejection data for recoverable heat calculation.

6.Add 17% to heat rejection data for cooling system sizing.

7.Fuel gas LHV variation to be within ±2%.
Variation cycle to be longer than 5 minutes.

Recomended Gas Quality Specification
Mitsubishi GSR series 1200 – 1500 RPM Miller Cycle

CH_4 content > 80%

Lower heating value from 28 to 42 MJ/nm³

C_2H_6 and larger should be less than 12% by mass.

C_3H_8 and larger should be less than 5% by mass.

Less than 1% particles of larger than one micron.

Liquid hydrocarbons must be filtered by coalescing filter.

Liquid water must be removed.

H_2S content < 5 ppm.
Supply pressure 4,5-10 Bar

REFERENCES

M/F GLUTRA

WORLD FIRST 100% LNG DRIVEN COMMERCIAL VESSEL

IN OPERATION SINCE FEBRUARY 2000 – 14 YEARS IN OPERATION

4 X 676 KW GEN SETS FOR ELECTRICAL PROPULSION WITH MITSUBISHI GS12R-MPTK LEAN BURN GAS ENGINES

ACCUMULATED 160.000 RUNNING HOURS IN TOTAL (MARCH 2013)

120 cars, 350 passengers

MITSUBISHI GAS ENGINE

REFERENCES

GAS & DIESEL POWER
POWER GENERATION SPECIALIST

M/S PIONEER KNUTSEN

COASTAL LNG CARRIER W/ELECTRIC PROPULSION
2 x GS16R 900 KW LEAN BURN GAS GEN SETS
PUT IN SERVICE IN APRIL 2004 – MORE THAN 70.000 HRS TOTAL

REFERENCES

M/F KONGEN – M/F PRINSEN – M/F DRONNINGEN

600 Pax PASSENGER FERRY W/ELECTRIC PROPULSION

2 x GS6R-MPTK 330 KW LEAN BURN GAS GEN SETS + 2 x DI16M55 BACK UP DIESEL GEN SETS

PUT IN SERVICE IN FROM JULY TO DECEMBER 2009

REFERENCES

M/V BARENTSHAV – M/V BERGEN – M/V SORTLAND

COASTGUARD AND FISHERIES PATROL W/HYBRID PROPULSION
3 x GS16R 900 KW + 1 x 676 KW GS12R LEAN BURN GAS GEN SETS
PUT IN SERVICE FROM AUGUST 2009 TO JULY 2010

REFERENCES

M/F MOLDEFJORD – M/F FANNEFJORD – M/F ROMSDALSFJORD – M/F KORSFJORD

120 PBE CAR FERRY W/ELECTRIC PROPULSION
2 x 900 KW GS16R LEAN BURN GAS GEN SETS
PUT IN SERVICE IN JANUARY 2010; SISTER VESSELS IN APRIL, AUG AND NOV 2010

REFERENCES

M/F SELBJØRNSFJORD

120 PBE CAR FERRY W/ELECTRIC PROPULSION
GS16R 900 KW+ GS12R 676 KW LEAN BURN GAS GEN SETS
PUT IN SERVICE IN JANUARY 2011

REFERENCES

- **M/F RYFYLKE – M/F HARDANGER**
- 4 x GS16R-MPTK 960 KW MILLER CYCLE GAS
- PUT INTO OPERATION DECEMBER 2013 AND JANUARY 2014

- **Total of 42 Gas Engines delivered to 15 vessels by Gas & Diesel Power AS. 14 years experience!**

Example of ESD enclosure