Appendix A
Vendor Engine Technology Brochures and Emissions Data

Appendix A.1
Wartsila Brochure

WÄRTSILÄ 34SG

Engine technology 16 and 20V34SG

WÄRTSILÄ

Engine technology

Ringköping, Denmark
Engine type: 1 x Wärtsilä 20V34SG
Total electrical output: 7.9 MW
Total heat output: 9.7 MW
Total efficiency: >95%.

In 1992, Wärtsilä started the development of lean-burn, spark-ignited Otto gas engines. The first 34SG engine was released in 1995 and now the product range of lean-burn gas engines has been expanded by introducing the new WÄRTSILÄ® 34SG. These engines take the power output of the 34SG series up to 9 MW.

The Wärtsilä 34SG is a four-stroke, spark-ignited gas engine that works according to the Otto process and the lean-burn principle. The engine has ported gas admission and a prechamber with a spark plug for ignition.

The engine runs at 720 or 750 rpm for 60 or 50 Hz applications and produces 6950 to 9000 kW of mechanical power, respectively. The efficiency of the Wärtsilä 34SG is the highest of any spark-ignited gas engines today. The natural gas fuelled, lean-burn, medium-speed engine is a reliable, high-efficiency and low-pollution power source for co-generation plants.

Design philosophy

The Wärtsilä 34SG was developed in response to the market need for bigger gas engines. Its design principles are based on the well-proven technology of the 18V version but with substantial improvements. The Wärtsilä 34SG lean-burn gas engine utilizes the frame of the new Wärtsilä 32 diesel/heavy fuel engine with its advanced integrated lube oil and cooling water channels. The bore has been increased to 340 mm to fully utilize the power potential of this engine block.

The Wärtsilä 34SG meets current and future requirements for overall cost of ownership. It is designed for flexible manufacturing methods and long maintenance-free operating periods. The engine is fully equipped with all essential ancillaries and a thoroughly planned interface to external systems.

The Wärtsilä 34SG combines high efficiency with low emissions. This is achieved applying state-of-the-art technology with features including:

- use of a lean gas mixture for clean combustion
- individual combustion control and monitoring, providing even load on all cylinders
- stable combustion, ensured by a high-energy ignition system and pre-combustion chamber
- self-learning and self-adjustable functions in the control system
- efficient heat recovery design
- minimal consumables.

The lean-burn concept

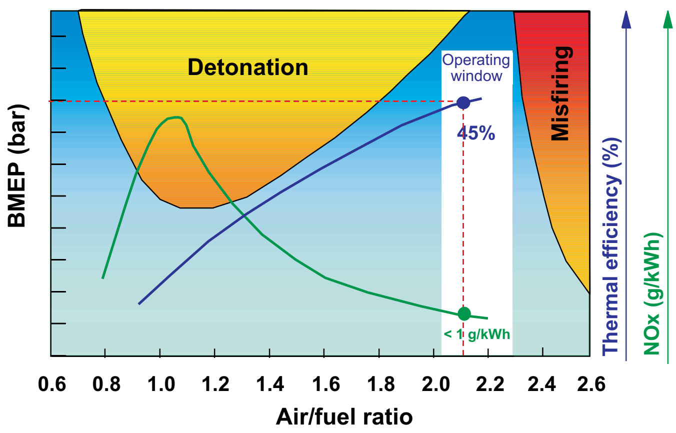
In a lean-burn gas engine, the mixture of air and gas in the cylinder is lean, i.e. more air is present in the cylinder than is needed for complete combustion. With leaner combustion, the peak temperature is reduced and less NO_X is produced. Higher output can be reached while avoiding knocking and the efficiency is increased as well, although a too lean mixture will cause misfiring.

Ignition of the lean air-fuel mixture is initiated with a spark plug located in the prechamber, giving a high-energy ignition source for the main fuel charge in the cylinder. To obtain the best efficiency and lowest emissions, every cylinder is individually controlled to ensure operation at the correct air-fuel ratio and with the correct timing of the ignition.

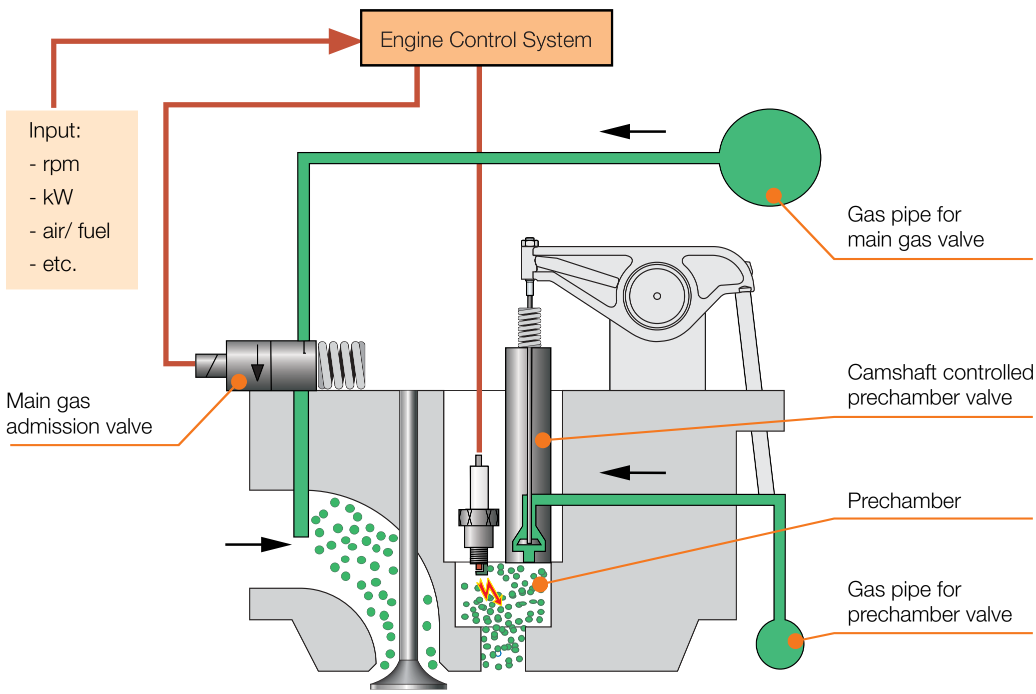
Stable and well-controlled combustion also contributes to less mechanical and thermal load on engine components. The specially developed Engine Control System is designed to control the combustion process in each cylinder, and to keep the engine within the operating window, by optimizing the efficiency and emissions level of each cylinder under all conditions.

Low emissions

The main parameters governing the rate of NO_X formation in internal combustion engines are peak temperature and residence time. The temperature is reduced by the combustion chamber air-fuel ratios: the higher the air-fuel ratio the lower the temperature and consequently the lower the NO_X emissions.



In the Wärtsilä 34SG engine, the air-fuel ratio is very high and is uniform throughout the cylinder, due to premixing of the fuel and air before introduction into the cylinders. Maximum temperatures and subsequent NO_X formation are therefore low, since the same specific heat quantity released by combustion is used to heat up a larger



mass of air. Benefiting from this unique feature of the lean-burn principle, the NO_X emissions from the Wärtsilä 34SG are extremely low, and comply with the most stringent existing NO_X legislation.

Gas admission system

The Wärtsilä 34SG engine fully controls the combustion process in each cylinder. The "brain" for controlling the combustion process and the whole engine is the Engine Control System.

The gas admission valves located immediately upstream of the inlet valve are electronically actuated and controlled to feed the correct amount of gas to each cylinder. Since the gas valve is timed independently of the inlet valve, the cylinder can be scavenged without risk of the gas escaping directly from the inlet to the exhaust. Various parameters like engine load, speed and cylinder exhaust temperatures are monitored and work as inputs to the Engine Control System. With this arrangement, each cylinder always works within the operating window for the best efficiency at the lowest emission levels.

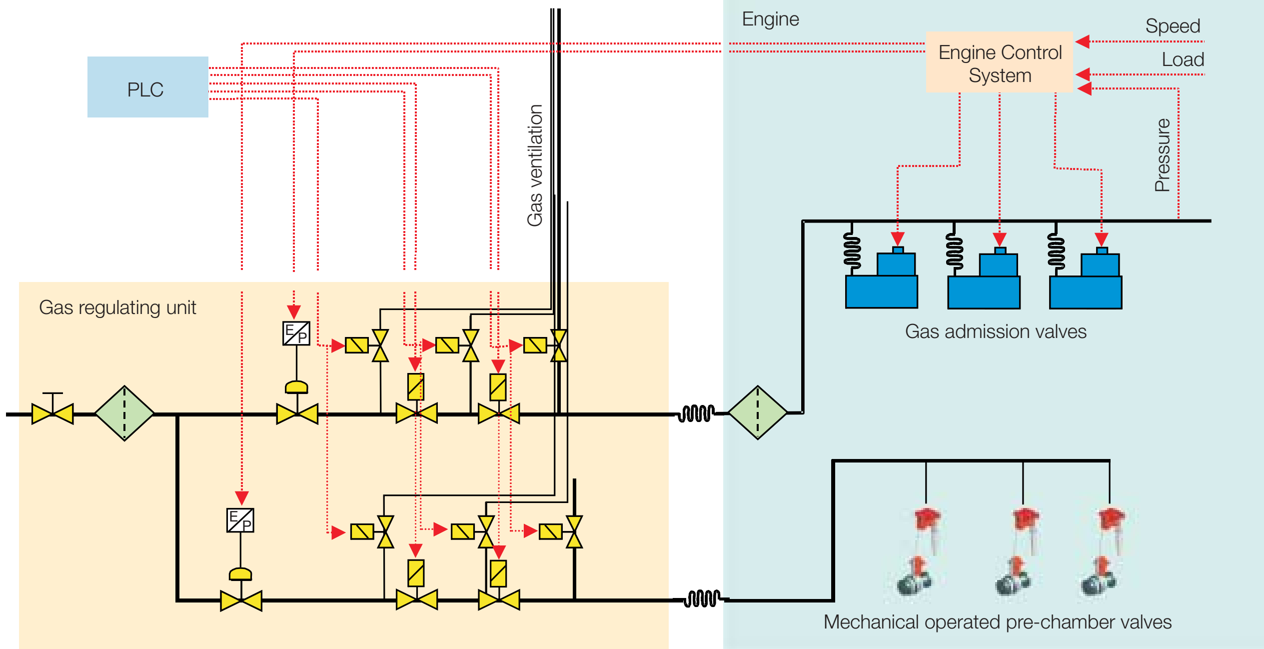
The ported gas admission concept gives:

- high efficiency
- good load response
- lower thermal loading of engine components
- no risk of backfire to the air inlet manifold.

Gas supply system

Before the natural gas is supplied to the engine it passes through a gas-regulating unit, including filter, pressure regulators, shut off valves and ventilating valves. The external pressure regulator regulates the gas pressure to the correct value under different loads; however, the maximum pressure needed is not more than 4.5 bar(a) under full load.

In the engine, the gas is supplied through common pipes running along the engine, continuing with individual feed pipes to each main gas admission valve located on each cylinder head. There are two common pipes per bank, one for the main and one for the prechamber gas supply. A filter is placed before every gas admission valve to prevent particles from entering the valve.

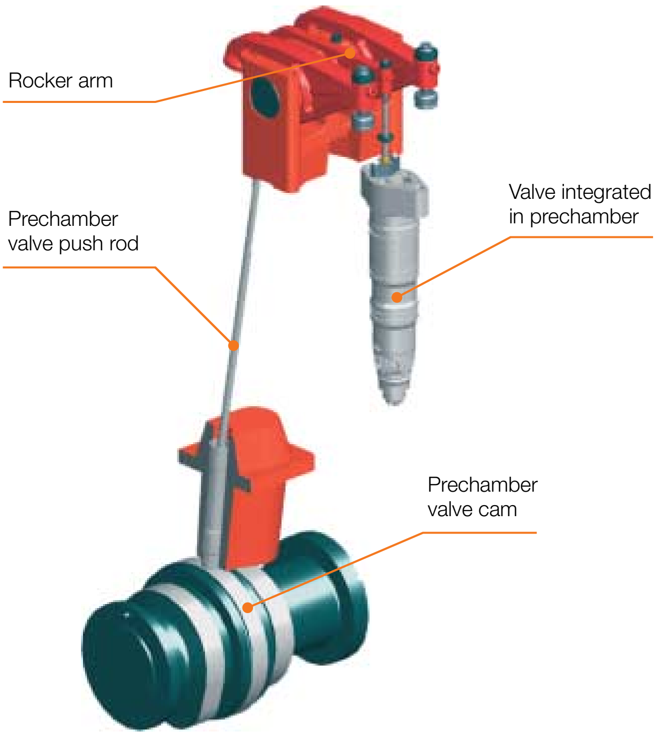


Prechamber

The prechamber is the ignition source for the main fuel charge and is one of the essential components of a lean-burn spark-ignited gas engine.

The prechamber should be as small as possible to give low NO_X values, but big enough to give rapid and reliable combustion. Some of the design parameters considered are:

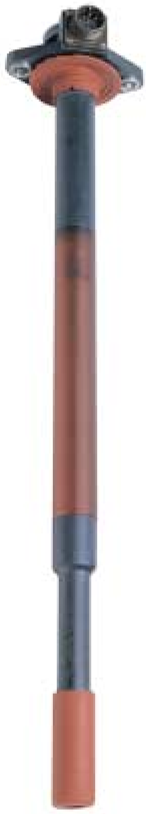
- shape and size
- mixing of air and fuel
- gas velocities and turbulence at the spark plug
- cooling of the prechamber and the spark plug
- choice of material.



The prechamber of the Wärtsilä 34SG is already optimized at the design stage using advanced three-dimensional, computerized fluid dynamics. In practice, the results can be seen as:

- reliable and powerful ignition
- high combustion efficiency and stability
- extended spark plug life
- very low NO_X levels.

Gas is admitted to the prechamber through a mechanical, camshaft-driven valve. This solution has proved to be extremely reliable and gives an excellent mixture into the prechamber.



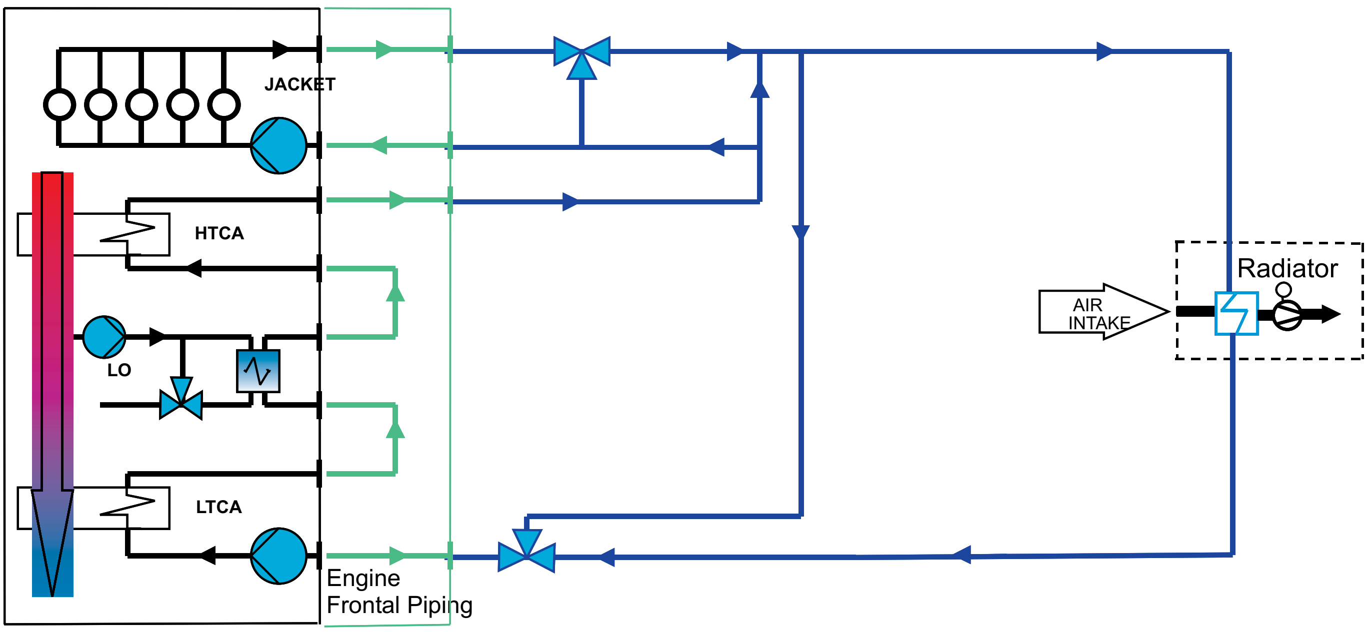
Ignition system

The Wärtsilä 34SG ignition system is tailor-made for the engine type and integrated in the Engine Control System. The ignition module communicates with the main control module, which determines the global ignition timing. The ignition module controls the cylinder-specific ignition timing based on the combustion quality. The cylinder-specific control ensures the optimum combustion in every cylinder with respect to reliability and efficiency.

The ignition coil is located in the cylinder cover and is integrated in the spark plug extension. The coil-on-plug design ensures a reliable solution with a minimum of joints between the spark plug and the ignition coil. The spark plug has been especially developed for long lifetime and to withstand the high cylinder pressure and temperature related to the high engine output.

Air-fuel ratio

To always ensure correct performance of the engine, it is essential to have the correct air-fuel ratio under all types of conditions. The Wärtsilä 34SG uses an exhaust gas wastegate valve to adjust the air-fuel ratio. Part of the exhaust gases bypasses the turbocharger through the waste-gate valve. This valve adjusts the air-fuel ratio to the correct value regardless of varying site conditions under any load.



Cooling system

The Wärtsilä 34SG engine is designed with a Wärtsilä open-interface cooling system for optimal cooling and heat recovery. The system has four cooling circuits: the cylinder cooling circuit (Jacket), the charge air low-temperature (LTCA) and high-temperature (HTCA) cooling circuits, and the circuit for the lube oil cooler (LO) built on the engine.

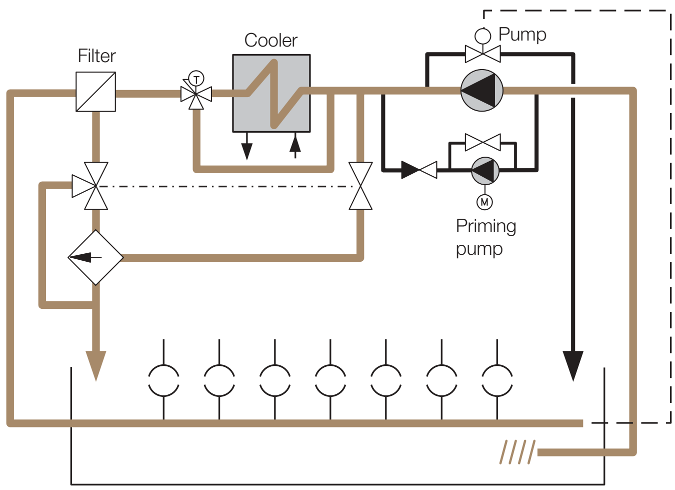
The LTCA cooling circuit and Jacket cooling circuit have water pumps integrated in the cover module at the free end of the engine. The LO circuit has its own thermostatic valve built on the engine. The water temperature into the LTCA cooler and the water temperature out from the Jacket cooling circuit are controlled by external thermostatic valves.

The default cooling system is a single-circuit radiator cooling system where the cooling circuits on the engine are connected in series. For heat recovery applications each cooler can be individually connected to an external cooling system. The open interface allows full freedom in cooling and heat recovery system design.

Lubricating oil system

The Wärtsilä 34SG is equipped with a wet oil sump, an engine-driven main pump, electrically driven pre-lubricating pump, cooler, full flow filter and centrifugal filter. The pumps, pressure regulation valves and safety valves are integrated into one module fitted at the free end of the engine. Filter, cooler and thermostatic valves make up another module.

The lube oil filtration is based on an automatic back-flushing filter requiring a minimum of maintenance. The filter elements are made of a seamless sleeve fabric with high temperature resistance. A centrifugal filter is mounted in the back-flushing line, acting as an indicator for excessive dirt in the lube oil. The engine uses a pre-lubricating system before starting to avoid wear of engine parts. For running in, provision has been made for mounting special running-in filters in front of each main bearing.



Starting system

The Wärtsilä 34SG engine is provided with pneumatic starting valves in the cylinder heads of one bank. The valves are operated by air from a distributor at the end of the camshaft. A starting limiter valve prevents the engine from starting if the turning gear is engaged.

Piston

Pistons are of the low-friction, composite type with forged steel top and aluminium skirt. The design itself is tailored for an engine of this size and includes a number of innovative approaches. Long lifetime is obtained through the use of Wärtsilä's patented skirt-lubrication system, a piston crown cooled by "cocktail-shaker" cooling, induction hardened piston ring grooves and the low-friction piston ring.

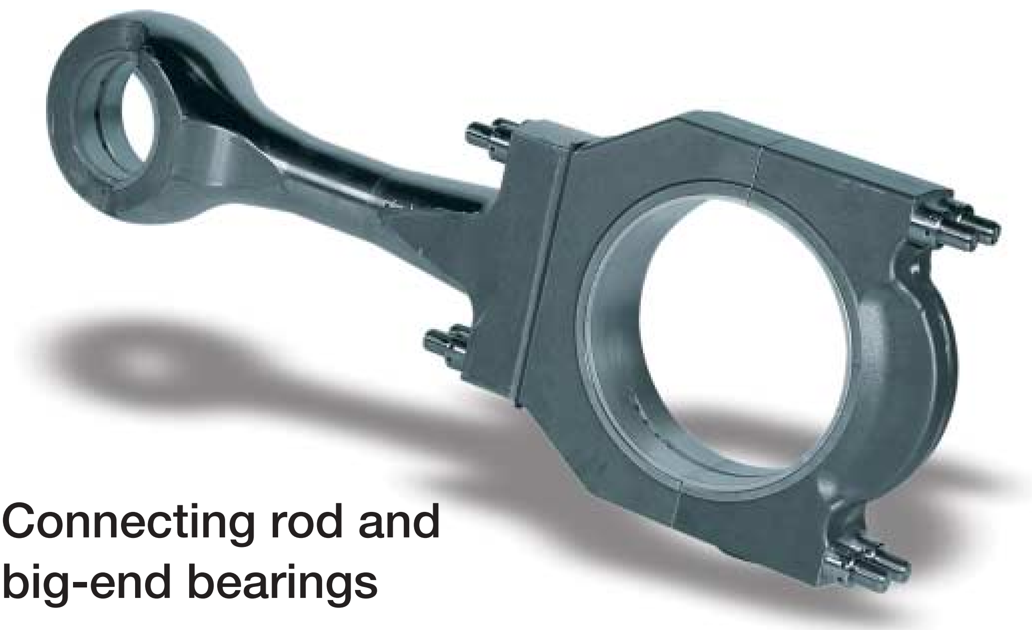
Piston ring set

The two compression rings and the oil control ring are located in the piston crown. This three-ring concept has proved its efficiency in all Wärtsilä engines. In a three-pack, every ring is dimensioned and profiled for the task it must perform. Most of the frictional loss in a reciprocating combustion engine originates from the piston rings. A three-ring pack is thus optimal with respect to both function and efficiency.

Cylinder head

Wärtsilä successfully employs four-screw cylinder head technology. At high cylinder pressure it has proved its superiority, especially when liner roundness and dynamic behaviour are considered. In addition to easier maintenance and reliability, it provides freedom to employ the most efficient air inlet and exhaust outlet channel port configuration.

A distributed water flow pattern is used for proper cooling of the exhaust valves, cylinder head flame plate and the prechamber. This minimizes thermal stress levels and guarantees a sufficiently low exhaust valve temperature. Both inlet and exhaust valves are fitted with rotators for even thermal and mechanical loading.



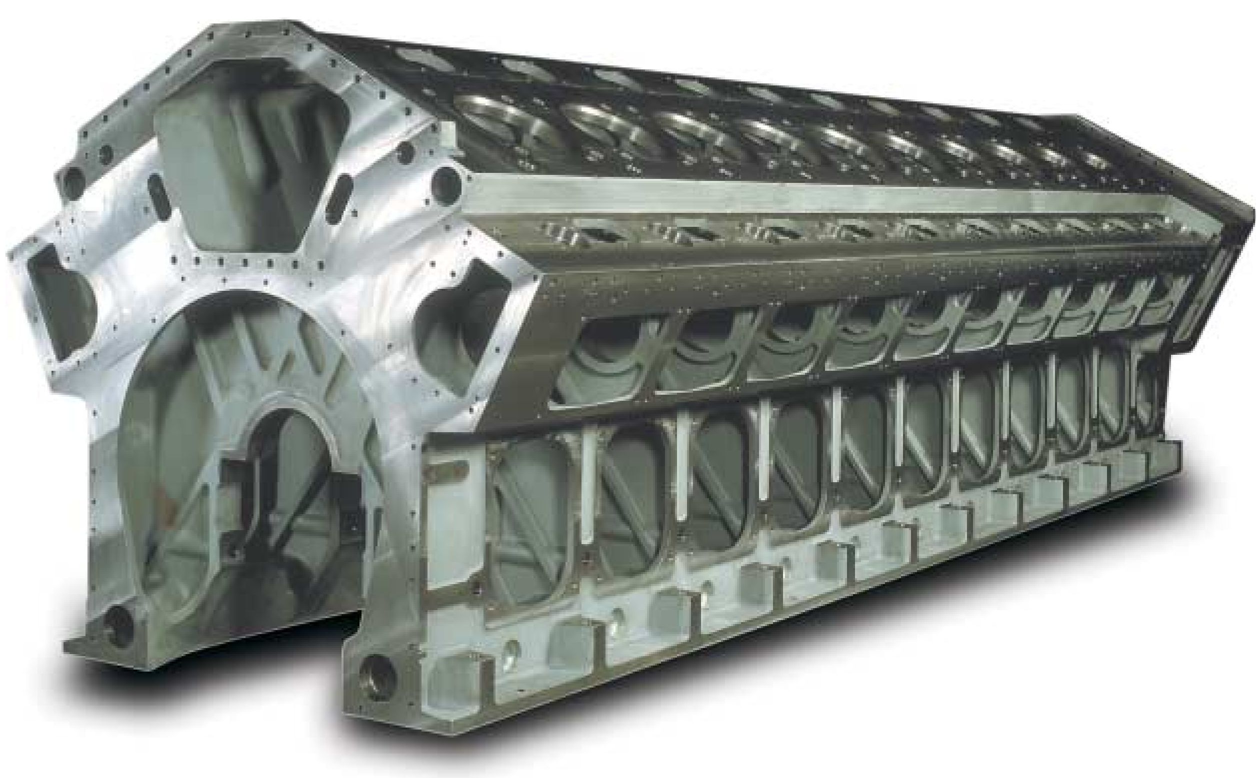
Connecting rod and big-end bearings

The connecting rod is designed for optimum bearing performance. It is a three-piece design, in which combustion forces are distributed over a maximum bearing area and relative movements between mating surfaces are minimized. Piston overhaul is possible without touching the big-end bearing and the big-end bearing can be inspected without removing the piston.

The three-piece design also reduces the height required for piston overhauling. The big-end bearing housing is hydraulically tightened, resulting in a distortion-free bore for the corrosion-resistant precision bearing. The three-piece connecting rod design allows variation of the compression ratio to suit gases with different knocking resistance.

Engine block

Nodular cast iron is the natural choice for engine blocks today due to its strength and stiffness properties. The Wärtsilä 34SG makes optimum use of modern foundry technology to integrate most oil and water channels. The result is a virtually pipe-free engine with a clean outer exterior. The engine has an underslung crankshaft, which imparts very high stiffness to the engine block, providing excellent conditions for main bearing performance. The engine block has large crankcase doors allowing easy maintenance.



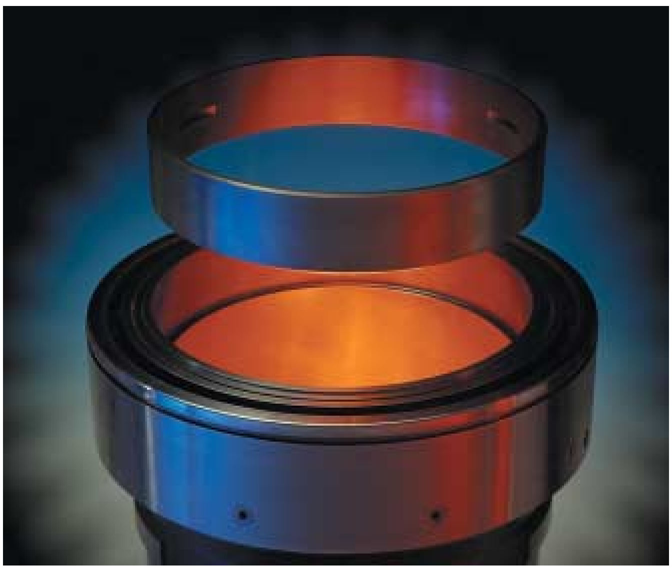
Crankshaft and bearings

The latest advance in combustion development requires a crank gear that can operate reliably at high cylinder pressures. The crankshaft must be robust and the specific bearing loads maintained at acceptable levels. Careful optimization of crankthrow dimensions and fillets achieve this.

The specific bearing loads are conservative, and the cylinder spacing, which is important for the overall length of the engine, is minimized. In addition to low bearing loads, the other crucial factor for safe bearing operation is oil film thickness. Ample oil film thickness in the main bearings is ensured by optimal balancing of rotational masses and, in the big-end bearing, by ungrooved bearing surfaces in the critical areas.

Cylinder liner and anti-polishing ring

The cylinder liner and piston designs are based on Wärtsilä's extensive expertise in tribology and wear resistance acquired over many years of pioneering work in heavy-duty diesel engine design. An integral feature is the anti-polishing ring, which reduces lube oil consumption and wear. The bore-cooled collar design of the liner ensures minimum deformation and efficient cooling. Each cylinder liner is equipped with two temperature sensors for continuous monitoring of piston and cylinder liner behaviour.



Turbocharging system

Every Wärtsilä 34SG is equipped with the Spex turbocharging system. The system is designed for minimum flow losses on both the exhaust and air sides. The interface between the engine and turbocharger is streamlined to avoid all the adaptation pieces and piping frequently used in the past. The Wärtsilä 34SG engine uses high-efficiency turbochargers with inboard plain bearings, and the engine lube oil is used for the turbocharger.

Multiduct

The multiduct replaces a number of individual components in traditional engine designs. These include:

- air transfer from the air receiver to the cylinder head
- exhaust transfer to the exhaust system
- cooling water outlet after the cylinder head
- cooling water return channel from the engine
- gas fuel mixing into the combustion air.

Additional functions are:

- introduction of an initial swirl to the inlet air for optimal part-load combustion
- insulation / cooling of the exhaust transfer duct
- support for the exhaust system and its insulation.

Automation system

The Engine Control System is an engine-mounted distributed system. The various electronic modules are dedicated to different functions and communicate with each other via a CAN databus. All parameters handled by the Engine Control System are transferred to the operator interface and the plant control system. Its features are:

- easy maintenance and high reliability due to rugged engine-dedicated connectors, CIB´s (cabling interface boxes) and high quality cables
- less cabling on and around the engine
- easy interfacing with external system via a databus
- digitized signals giving immunity from electromagnetic disturbance
- built-in diagnosis for easy troubleshooting.

Main control module

The main control module, the core of the Engine Control System, reads the information sent by all the other modules. Using this information it determines reference values for the main gas admission to control the engine's speed and load.

The main control module also uses the information sent from the different distributed modules to control the global air-fuel ratio and global ignition timing in order to obtain the best performance and reliable operation in different site conditions, such as varying ambient temperature and methane number.

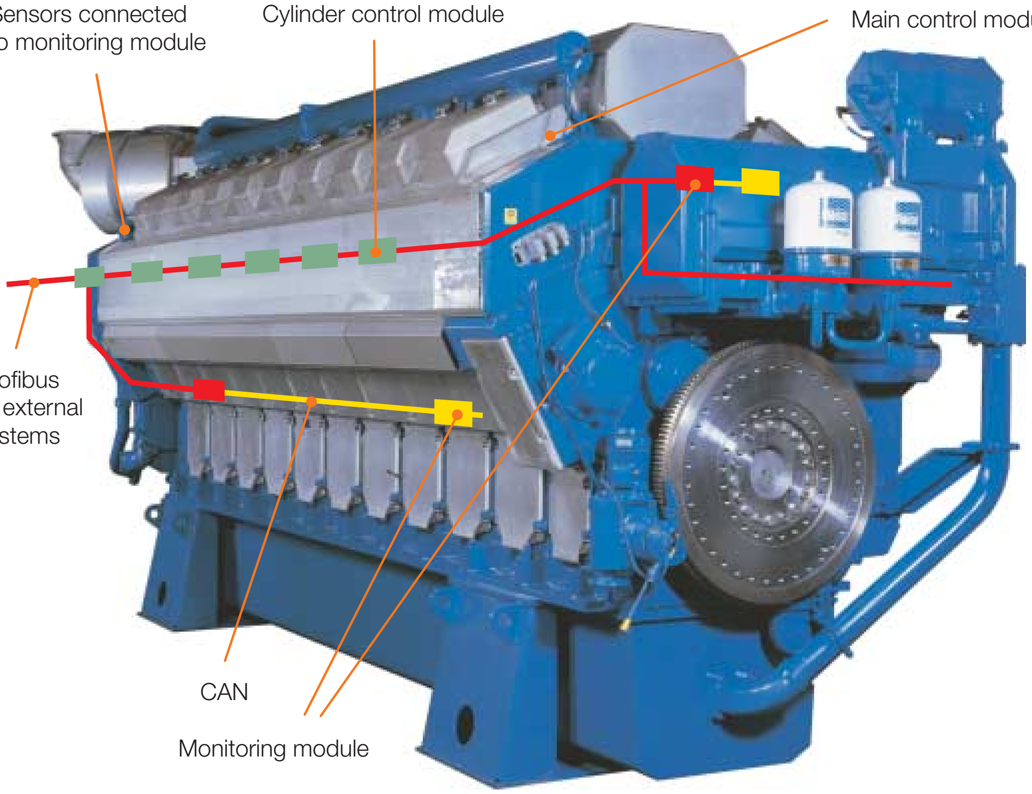
The main control module automatically controls the start and stop sequences of the engine and the engine safety. It also communicates with the plant control system (PLC).

The cylinder control module also monitors the exhaust gas and cylinder liner temperatures of all cylinders.

Cylinder control module

Each cylinder control module monitors and controls three cylinders. The cylinder control module controls the cylinder-specific air-fuel ratio by adjusting the gas admission individually for all cylinders. This ensures optimal combustion in all cylinders.

The cylinder control module also measures the knock intensity i.e. uncontrolled combustion in all cylinders. Information on knock intensity is used to adjust the cylinder-specific ignition timing by the cylinder control module. Light knocking leads to automatic adjustment of the ignition timing and air-fuel ratio. Heavy knocking leads to load reduction and ultimately to shut-down of the engine if heavy knocking does not disappear.



Monitoring modules

Several monitoring modules are located close to groups of sensors, which reduces cabling harness on the engine. The monitored signals are transmitted to the main control module and used for the engine control or safety system. The monitored values are also transferred to the operator interface and the plant control system. The cylinder control module also monitors the exhaust gas and cylinder liner temperatures of all cylinders.

Easy maintenance

The service life of Wärtsilä 34SG engine components and the time between overhauls are very long due to the purity of the gas. The design incorporates efficient and easy maintenance. In combination with the long intervals between overhauls, the hours spent on maintenance are reduced to a minimum. There is greater accessibility to all the components because the number of pipes is minimized and the components are ergonomically designed.

For ease of maintenance, the engine block has large openings to the crankcase and camshaft. All bolts requiring high tension are hydraulically tightened. Hydraulics is extensively used for many other operations as well. Since the main bearing caps are relatively heavy, each bearing cap is equipped with a permanently fitted hydraulic jack for easy manoeuvring of the cap. During delivery test runs, a running-in filter is installed to prevent the bearings from being scratched by any particles left in the oil system.

- The multiduct arrangement allows the cylinder head to be lifted without having to remove gas pipes or water pipes. The slide-in connections allow lifting of the cylinder head without the need to remove oil or air pipes.

- The water pumps are easy to replace thanks to the cassette design principle and water channel arrangement in the pump cover at the free end of the engine.
- A rigid and tight but easily removable insulating box surrounds the exhaust system.
- Easy access to the piping system is obtained by removing the insulating panels.
- The camshaft is built of identical cylinder segments bolted to intermediate bearing pieces.
- A wide range of special tools and measuring equipment specifically designed to facilitate service work are also available.
- Access to and maintenance of the spark plug and prechamber gas valve in the prechamber is easy. The prechamber does not need to be removed. For spark plug replacement, the valve cover does not need to be removed.
- Use of electrically controlled gas admission valves means few mechanical parts and less need for periodic adjustments.
- The three-piece connecting rod allows inspection of the big-end bearing without removal of the piston, and piston overhaul without dismantling the big-end bearing.

Main technical data

Cylinder bore	340 mm
Piston stroke	400 mm
Speed	720 / 750 rpm
Mean effective pressure	20.0 / 19.8 bar
Piston speed	9.6 / 10 m/s
Natural gas specification for nominal load	
Lower heating value	≥ 28 MJ/m^3_N

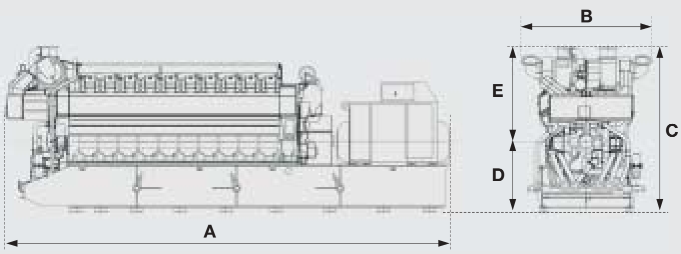
Technical data Compression ratio 12		Unit	16V34SG		20V34SG	
Speed/Hz	NO_X	mg/Nm^3 at 5 % O_2	500	250	500	250
	Methane number		>80	>70	>80	>70
720 rpm 60 Hz	Electrical power	kW	6751	6751	8439	8439
	Electrical efficiency	%	46.5	45.1	46.5	45.1
750 rpm 50 Hz	Electrical power	kW	6984	6984	8730	8730
	Electrical efficiency	%	46.5	45.1	46.5	45.1

Technical data Compression ratio 11		Unit	16V34SG		20V34SG	
Speed/Hz	NO_X	mg/Nm^3 at 5 % O_2	500	250	500	250
	Methane number		>65	>55	>65	>55
720 rpm 60 Hz	Electrical power	kW	6751	6751	8439	8439
	Electrical efficiency	%	45.5	44.1	45.5	44.1
750 rpm 50 Hz	Electrical power	kW	6984	6984	8730	8730
	Electrical efficiency	%	45.5	44.1	45.5	44.1

Electrical power at generator terminals, including engine-driven pumps, ISO 3046 conditions and LHV. Tolerance + 5%. Power factor 0.8.

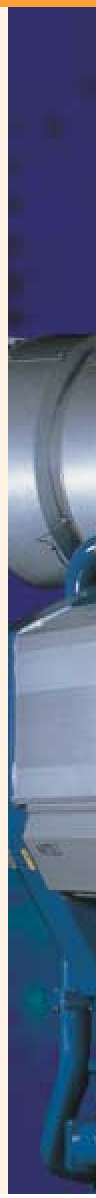
Principal genset dimensions (mm) and weights (tonnes)

Engine type	A	B	C	D	E	Engine weight	Genset weight
16V34SG	11692	3233	4348	1998	2648	66.5	115
20V34SG	12466	3233	4348	1998	2648	76.4	137.5



For more specific information, please contact Wärtsilä.

06.2005 / Bock's office / Waasa Graphics



Wärtsilä is a leading provider of power plants, operation and lifetime care services in decentralized power generation.

Wärtsilä is The Ship Power Supplier for builders, owners and operators of vessels and offshore installations. Our own global service network takes complete care of customers' ship machinery at every lifecycle stage.

For more information visit www.wartsila.com

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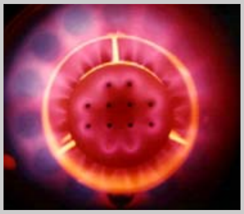
WÄRTSILÄ

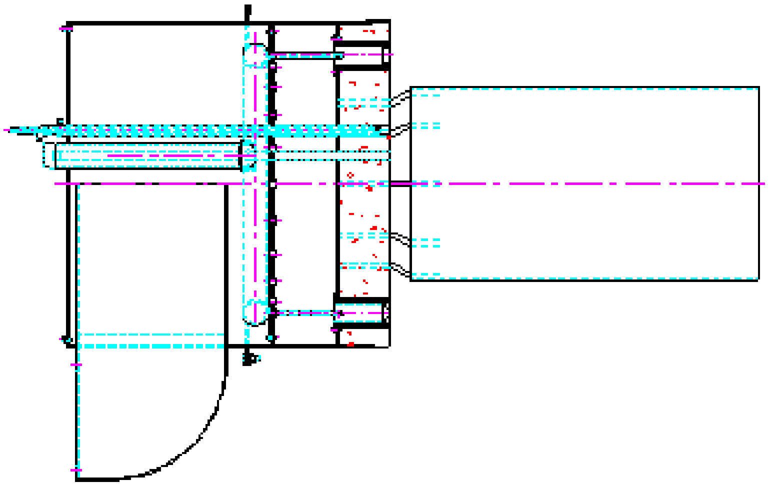
Appendix A.2
Johnston FIR Burner Brochure

JOHNSTON BURNER COMPANY
AN AFFILIATE OF JOHNSTON BOILER COMPANY

FIR BURNER

FORCED INTERNAL RECIRCULATION BURNER





JOHNSTON BURNER COMPANY
AN AFFILIATE OF JOHNSTON BOILER COMPANY
300 Pine Street
P.O. Box 300
Ferrysburg, MI 49409-0300

Ph: 616-842-5050
Fax: 616-842-1854
www.johnstonboiler.com

Ultra Low NOx without external FGR! The Johnston FIR burner reduces emissions of NOx and CO from natural gas combustion. The burner can reach levels of less than 10 PPMv NOx and <50 PPMv CO at design turn-down with no decrease in efficiency. To maintain the burner/boiler thermal efficiency, the burner is setup to operate at between 3 to 4% O_2 over the complete operating range. This minimizes dry gas losses and maximizes burner performance.

The patented FIR Burner through Gas Technology Institute, Chicago, IL, combines staged, premixed combustion with forced internal flue gas recirculation to minimize the formation of both thermal and prompt NOx. The unique burner design provides excellent flame retention for stable combustion at the sub 9 PPM NOx levels. The low levels if NOx and CO will meet the stringent emission requirements found in California, Houston and other non-attainment zones.

Testing & Operating

An Ohio Special boiler installed at GTI's Lab running at 250 BHP.

Using the FIR burner, boilers can operate at low excess air levels without external FGR, resulting in higher thermal efficiencies than are achievable with competing technologies. The burners use non-proprietary, single point positioning controls to reduce cost and downtime.

The burners also meet CSD-1, FM, IRI and NFPA-85 approval codes.

Fullerton College, Fullerton, CA
Two - 250 BHP

JOHNSTON BURNER COMPANY
AN AFFILIATE OF JOHNSTON BOILER COMPANY

300 Pine Street
P.O. Box 300
Ferrysburg, MI 49409-0300

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Appendix A.3
Caterpillar Generator Brochure

DIESEL GENERATOR SET

CATERPILLAR®

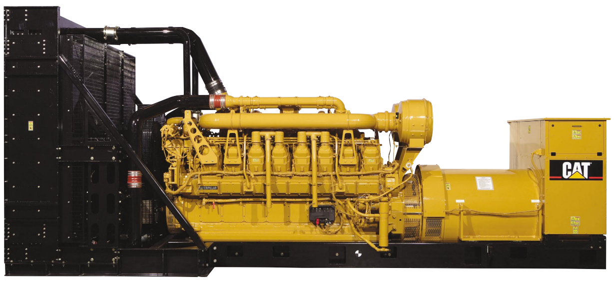


Image shown may not reflect actual package.

STANDBY
2000 ekW 2500 kVA
60 Hz 1800 rpm 480 Volts

Caterpillar is leading the power generation marketplace with Power Solutions engineered to deliver unmatched flexibility, expandability, reliability, and cost-effectiveness.

FEATURES

EMISSIONS STRATEGY
EPA Tier 2

UL 2200
• UL 2200 Listed configuration available

FULL RANGE OF ATTACHMENTS
• Wide range of bolt-on system expansion attachments, factory designed and tested

WORLDWIDE PRODUCT SUPPORT
• Caterpillar® dealers provide extensive post sale support including maintenance and repair agreements • Caterpillar dealers fill 99.7% of parts orders within 24 hours • Caterpillar dealers have over 1,600 dealer branch stores operating in 200 countries • The Cat® S•O•S℠ program cost effectively detects internal engine component condition, even the presence of unwanted fluids and combustion by-products

CAT 3516C TA DIESEL ENGINE
• Reliable, rugged, durable design
• Field-proven in thousands of applications worldwide
• Four-stroke-cycle diesel engine combines consistent performance and excellent fuel economy with minimum weight

CAT SR4B Generator
• Matched to the performance and output characteristics of Caterpillar engines
• 2/3 winding
• Single point access to accessory connections
• UL 1446 recognized Class H insulation

CAT EMCP3 CONTROL PANELS
• Controls designed to meet individual customer needs:
• EMCP 3 provides the option for full-featured power metering and protective relaying
• Segrated low voltage, AC/DC accessory box provides single point access to accessory connections

STANDBY 2000 ekW 2500 kVA

60 Hz 1800 rpm 480 Volts

CATERPILLAR®

FACTORY INSTALLED STANDARD & OPTIONAL EQUIPMENT

System	Standard	Optional
Air Inlet	• Single element canister type air cleaner • Service indicator	• Dual element & heavy duty air cleaners (with pre-cleaners) • Air inlet adapters & shutoff
Cooling	• Radiator with guard (43°C) • Coolant drain line with valve • Fan and belt guards • Caterpillar Extended Life Coolant • Low coolant level & high temperature alarm or shutdown	• Radiator duct flange • Jacket water heater
Exhaust	• Dry exhaust manifold • Flanged faced outlets	• Mufflers and Silencers • Stainless steel exhaust flex fittings • Elbows, flanges, expanders & Y adapters
Fuel	• Secondary fuel filters • Fuel priming pump • Flexible fuel lines • Fuel cooler* *Not included with packages without radiators	• Water separator • Duplex fuel filter
Generator SR4B	• Permanent magnet excited • 2/3 Pitch • Class H insulation • Class F temperature (105°C prime/130°C standby) • Winding temperature detectors(select models)	• Oversize & premium generators • Anti-condensation space heaters • Bearing temperature detector • Stator temperature detector
Power Termination	• Bus bar (NEMA and IEC meachanicallug holes) -right side standard • Top and bottom cable entry	• Circuit breakers, UL listed, 3 pole with shunt trip, 80% or 100% rated, choice of trip units, manual or electrically operated (low voltage only) • Circuit breakers, IEC compliant, 3 or 4 pole with shunt trip (low voltage only), choice of trip units, manual or electrically operated • Shroud cover for bottom cable entry • Power terminations can be located on the left and/or rear as an option. Also, multiple circuit breakers can be ordered (up to 3)
Governor	• ADEM™ 3	• Load share module
Control Panels	• User Interface panel (UIP) - rear mount (standard) • EMCP3.1 Genset Controller • Speed adjust (on panel) • AC&DC customer wiring area (right side) • CAT digital voltage regulator (CDVR) with KVAR/PF control, 3-phase sensing • Emergency Stop Pushbutton	• EMCP 3.3 • Option for right or left mount UIP • Local & remote annunciator modules • Load share module • Discrete I/O module • Generator temperature monitoring & protection • Voltage Adjust (on panel)
Lube	• Lubricating oil and filter • Oil drain line with valves • Fumes disposal • Gear type lube oil pump	• Oil level regulator • Deep sump oil pan • Electric & air prelube pumps • Manual prelube with sump pump • Duplex oil filter
Mounting	• Structual steel tube • Anti-vibration mounts (shipped loose)	• Isolator removal
Starting/Charging	• 24 volt starting motor(s) • Batteries with rack and cables • Battery disconnect switch	• Battery chargers (10&20AMP) •45 amp charging alternator • Oversize batteries • Ether starting aid • Heavy duty starting motors • Barring device (manual) • Air starting motor with control & silencer
General	• Right-hand service • Paint - Caterpillar Yellow except rails and radiators are gloss black • SAE standard rotation • Flywheel and flywheel housing - SAE No. 00	• CSA certification • EU Certificate of Conformance
Note	Standard and optional equipment may vary for UL 2200 Listed Packages. UL 2200 Listed packages may have oversized generators with a different temperature rise and motor starting characteristics.	

SPECIFICATIONS

CAT GENERATOR

Frame..825
Excitation... Permanent Magnet
Pitch...0.6667
Number of poles...4
Number of bearings.................................... Single Bearing
Insulation....................... UL 1446 Recognized Class H with tropicalization and antiabrasion
IP Rating..Drip Proof IP22
Alignment..Pilot Shaft
Overspeed capability... 125%
Wave form... 2%
Paralleling kit/Droop transformer.........................Standard
Voltage regulator.3 Phase sensing with selectible volts/Hz
Voltage regulation ....Less than +/- 1/2% (steady state)
Less than +/- 1/2% (w/3% speed change)
Telephone influence factor...............................Less than 50
Harmonic distortion...Less than 5%

CAT DIESEL ENGINE

Bore... 170.00 mm (6.69 in)
Stroke.. 190.00 mm (7.48 in)
Displacement..69.00 L (4210.64 in^3)
Compression Ratio.. 14.7:1
Aspiration..TA
Fuel System.................................... Electronic unit injection
Governor Type.. ADEM3

CAT EMCP3 CONTROL PANELS

EMCP 3.1 (standard)
EMCP 3.2 & 3.3 (Optional)
24 Volt DC control
Generator insturments designed to meet UL/CSA/CE
Integral generator terminal box
Single location for customer connection
MODBUS isolated data link (RS0485 half-duplex) supports serial communication at data rate up to 33.6 kbaud
Auto start/stop control
True RMS metering, 3-phase
• Digital indication for:
-RPM
-Operating hours
-Oil pressure
-Coolant temperature
- System DC volts
--L-L volts, L-N volts, phase amps, Hz
-Ekw, kVA, kVAR, kW-hr, %kW, PF
• Shutdowns with indicating lights for:
-Low oil pressure
-High coolant temperature
- Low coolant level
- Overspeed
-Overspeed
-Emergency stop
- Failure to start (over crank)
• Programmable protective relay functions:
- Under and over voltage
- Under and over frequency
- Reverse power
- Overcurrent (phase & total)
-• Programmable kW level relay

CATERPILLAR®

TECHNICAL DATA

Open Generator Set - - 1800 rpm/60 Hz/480 Volts	DM8263	
EPA Tier 2		
Generator Set Package Performance		
Genset Power rating @ 0.8 pf	2500 kVA	
Genset Power rating with fan	2000 ekW	
Coolant to aftercooler		
Coolant to aftercooler temp max	50 ° C	122 ° F
Fuel Consumption		
100% load with fan	525.7 L/hr	138.9 Gal/hr
75% load with fan	408.2 L/hr	107.8 Gal/hr
50% load with fan	294.2 L/hr	77.7 Gal/hr
Cooling System[1]		
Ambient air temperature	46 ° C	115 ° F
Air flow restriction (system)	0.12 kPa	0.48 in. water
Air flow (max @ rated speed for radiator arrangement)	2480 m^3/min	87580 cfm
Engine Coolant capacity with radiator/exp. tank	475.0 L	125.5 gal
Engine coolant capacity	233.0 L	61.6 gal
Radiator coolant capacity	242.0 L	63.9 gal
Inlet Air		
Combustion air inlet flow rate	180.3 m^3/min	6367.2 cfm
Exhaust System		
Exhaust stack gas temperature	405.4 ° C	761.7 ° F
Exhaust gas flow rate	428.6 m^3/min	15135.9 cfm
Exhaust flange size (internal diameter)	203.2 mm	8.0 in
Exhaust system backpressure (maximum allowable)	6.2 kPa	24.9 in. water
Heat Rejection		
Heat rejection to coolant (total)	765 kW	43505 Btu/min
Heat rejection to exhaust (total)	1804 kW	102593 Btu/min
Heat rejection to aftercooler	666 kW	37875 Btu/min
Heat rejection to atmosphere from engine	137 kW	7791 Btu/min
Heat rejection to atmosphere from generator	74.7 kW	4248.2 Btu/min
Alternator[2]		
Motor starting capability @ 30% voltage dip	4647 skVA	
Frame	825	
Temperature Rise	130 ° C	266 ° F
Lube System		
Sump refill with filter	401.3 L	106.0 gal
Emissions (Nominal)[3]		
NOx g/hp-hr	5.39 g/hp-hr	
CO g/hp-hr	.29 g/hp-hr	
HC g/hp-hr	.11 g/hp-hr	
PM g/hp-hr	.026 g/hp-hr	

[1] Ambient capability at 300 m (984ft) above sea level. For ambient capability at other altitudes, consult your Caterpillar dealer.
[2] UL 2200 Listed packages may have oversized generators with a different temperature rise and motor starting characteristics. Generator temperature rise is based on a 40 degree C ambient per NEMA MG1-32.
[3] Emissions data measurement procedures are consistent with those described in EPA CFR 40 Part 89, Subpart D & E and ISO8178-1 for measuring HC, CO, PM, NOx. Data shown is based on steady state operating conditions of 77°F, 28.42 in HG and number 2 diesel fuel with 35° API and LHV of 18,390 btu/lb. The nominal emissions data shown is subject to instrumentation, measurement, facility and engine to engine variations. Emissions data is based on 100% load and thus cannot be used to compare to EPA regulations which use values based on a weighted cycle.

RATING DEFINITIONS AND CONDITIONS

Meets or Exceeds International Specifications: AS1359, AS2789, CSA, EGSA101P,IEC60034, ISO3046, ISO8528,NEMA MG 1-32, UL508, 72/23/EEC, 89/336/EEC, 98/37/EEC.
Standby -Output available with varying load for the duration of the interruption of the normal source power. Standby power in accordance with ISO8528. Fuel stop power in accordance with ISO3046, AS2789, and BS5514. Standby ambient temperatures shown indicate a coolant top tank temperature just below shutdown at 100 percent load.
Prime - Output available with varying load for an unlimited time. Prime power in accordance with ISO8528. 10% overload power in accordance with ISO3046, AS2789, and BS5514. Prime ambient temperatures shown indicate a coolant top tank temperature just below shutdown at 100 percent load.

Ratings are based on SAE J1995 standard conditions. These ratings also apply at ISO3046 standard conditions.
Fuel Rates are based on fuel oil of 35° API [16° C (60° F)] gravity having an LHV of 42 780 kJ/kg (18,390 Btu/lb) when used at 29° C (85° F) and weighing 838.9 g/liter (7.001 lbs/U.S. gal.). Additional ratings may be available for specific customer requirements. Consult your Caterpillar representative for details.

CATERPILLAR®

DIMENSIONS

Package Dimensions		
Length	6424.6 mm	252.94 in
Width	2450.2 mm	96.46 in
Height	2929.2 mm	115.32 in
Weight	17 307 kg	38,155 lb

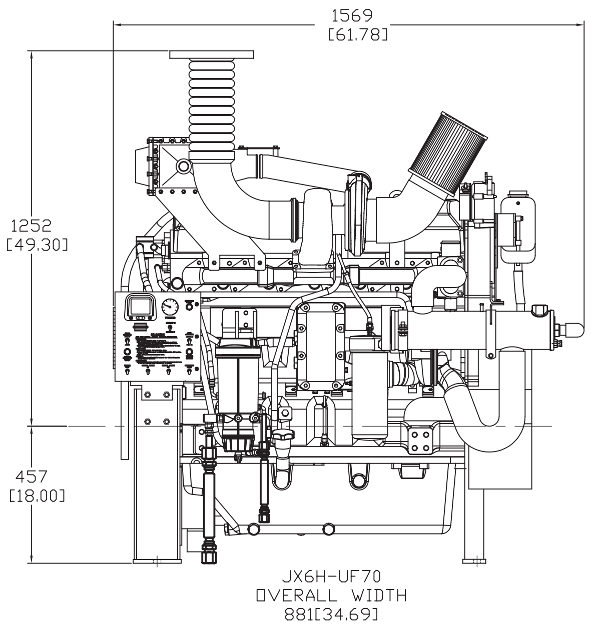
Note: Do not use for installation design. See general dimension drawings for detail (Drawing #2846051).

Appendix A.4
Clarke Fire Pump Brochure

CLARKE
FIRE PUMP DRIVERS

MODELS
JX6H-UF30
JX6H-UF40
JX6H-UF50
JX6H-UF60
JX6H-UF70

FM-UL-cUL Approved Ratings BHP/*kW*			
JX6H MODEL	OPERATING SPEED		
	1470	1760	2100
UF30	350 *261*	420 *313*	430 *322*
UF40	380 *283*	460 *343*	485 *362*
UF50	405 *302*	485 *362*	510 *380*
UF60	430 *321*	510 *380*	525 *392*
UF70	485 *362*	575 *429*	575 *429*



Engine Equipment

Equipment	Standard	Optional
Air Cleaner	Direct Mounted, Washable, Indoor Service	Disposable, Drip proof, Indoor Service Outdoor Type
Alternator	24V-DC, 40 Amps; w/Belt Guard	
Coupling	Faulk Coupling, Engine Half 1090T10 Coupling	Drive Shaft & Guard; SC2140 for UF30 & UF40 models, SC2155 for UF50, UF60 & UF70 models
Droop	9%	4% 0%
Exhaust Blankets	For Manifolds & Turbocharger	
Exhaust Flex Connection		SS Flex, 150# Flange
Flywheel Housing	S.A.E. #2	
Flywheel Power Take Off	11.5" S.A.E. Industrial Flywheel Connection	
Fuel Connections	Fire Resistant Flexible Supply & Return Lines	
Fuel Filter	Primary Filter w/Priming Pump	
Fuel Injection System	Unit Injectors w/electronic control	
Engine Heater	230V-AC, 2500 Watt	115V-AC, 2500 Watt
Governor, Speed	Electronic	
Heat Exchanger	Tube & Shell Type, 60 PSI w/NPTF Connections	

Equipment	Standard	Optional
Instrument Panel	Multimeter to display: Tachometer, Hourmeter, Water Temperature & Oil Pressure. Voltmeter with selector switch	
Junction Box	Integral with Instrument Panel; For DC Wiring Interconnection to Engine Controller	
Lube Oil Cooler	Engine Water Cooled, Plate Type	
Lube Oil Filter	Full Flow w/By-Pass Valve	
Lube Oil Pump	Gear Driven, Gear Type	
Manual Start Controls	On Instrument Panel	
Overspeed Control	Electronic w/Reset	
Raw Water Solenoid Operation	Automatic from Engine Con-troller & from Instrument Panel	
Run Solenoid	24V-DC Energized to Stop (ETS)	
Run-Stop Control	On Instrument Panel With Control Position Warning Light	
Starter	One (1) 24V-DC	
Throttle Control	Adjustable Speed Control by increase/decrease button, Tamper Proof	
Water Pump	Gear Driven, Centrifugal Type	

Note: Diesel Controller needs to add 2 signals: Injector Failure, Alternate ECM Selected

LISTED 513Y

meets NFPA-20 Requirements

FM approved 1333

CLARKE
FIRE PUMP DRIVERS

MODELS
JX6H-UF30 JX6H-UF40 JX6H-UF50 JX6H-UF60 JX6H-UF70

Specifications

Item	JU6H Models				
	UF30	UF40	UF50	UF60	UF70
Number of Cylinders	6				
Aspiration	TJWA	TRWA			
Rotation*	Clockwise (CW)				
Weight - lb (kg)	3150 (1429	3250 (1474)			
Compression Ratio	16:1				
Displacement - cu. in. (l)	766 (12.5)				
Engine Type	4 Cycle - Inline				
Bore & Stroke - in. (mm)	5.00 (127) x 6.50 (165)				
Installation Drawing	D - 546				
Wiring Diagram	C07957				
Engine Series	John Deere 6125 Series				

Abbreviations: CW – Clockwise TJWA – Turbocharged with Jacket Water Aftercooling TRWA – Turbocharged with Raw Water Aftercooling

*Rotation viewed from Heat Exchanger / Front of engine CCW Rotation is not available.

Engine intended for Indoor use or inside weatherproof enclosure only

† ENGINE RATINGS BASELINES

Engines are rated at standard SAE conditions of 29.61 in. (7521 mm) Hg barometer and 77˚F (25˚C) inlet air temperature [approximates 300 ft. (91.4 m) above sea level] by the testing laboratory (*see SAE Standard J 1349*).

A deduction of 3 percent from engine horsepower rating at standard SAE conditions shall be made for diesel engines for each 1000 ft. (305 m) altitude above 300 ft. (91.4 m).

A deduction of 1 percent from engine horsepower rating as corrected to standard SAE conditions shall be made for diesel engines for every 10˚F (5.6˚C) above 77˚F (25˚C) ambient temperature.

CERTIFIED POWER AT ANY SPEED

Although FM-UL Certified BHP ratings are shown at specific speeds, Clarke engines can be applied at any intermediate speed. To determine the intermediate certified power, make a linear interpolation from the Clarke FM-UL certified power curve. Contact Clarke or your Pump OEM representative to obtain details.

CLARKE

www.clarkefire.com

Fire Protection Products

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3133 E. Kemper Rd.
Cincinnati, Ohio 45241
United States of America
Tel +1-513-771-2200 Fax +1-513-771-0726

CLARKE UK, Ltd.
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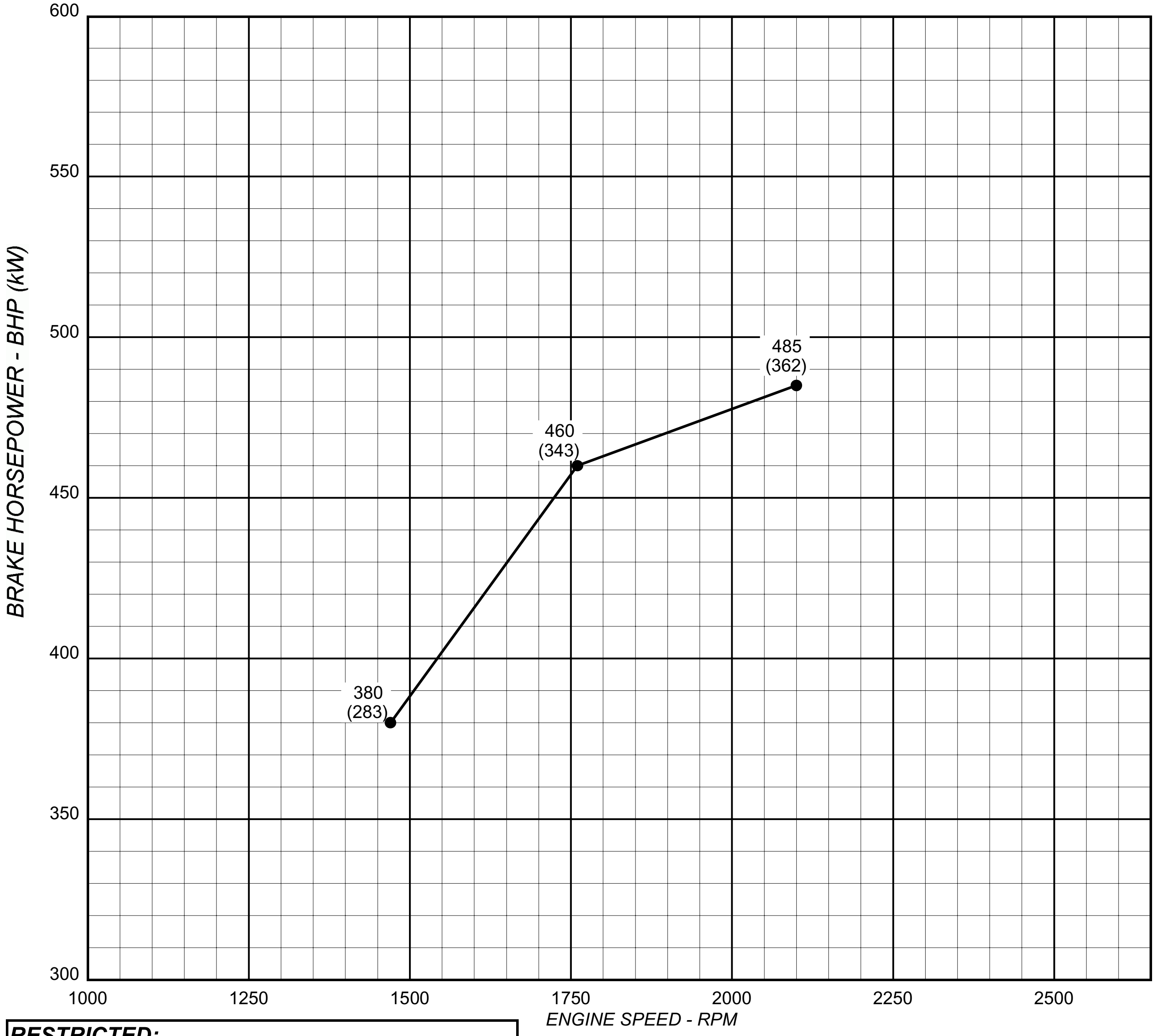
C131121 4/05 Specifications and information contained in this brochure subject to change without notice. Printed in U.S.A.

Fire Protection Products, Inc.

FIRE PUMP MODEL: JX6H-UF40
Heat Exchanger Cooled
RE501587 Turbocharger
Raw Water Charge Cooling



RESTRICTED:
USE ONLY FOR STAND-BY FIRE PUMP APPLICATIONS

ENGINE PERFORMANCE:
STANDARD CONDITIONS: (SAE J1349, ISO 3046)
77°F (25°C) AIR INLET TEMPERATURE
29.61 IN. (751.1MM) HG BAROMETRIC PRESSURE
#2 DIESEL FUEL (SEE C13940)

KEN WAULIGMAN 10MAY04

●——● *NAMEPLATE BHP (MAXIMUM PUMP LOAD)*

CREATED	DATE CREATED 05/10/04	
ENGINE MODEL JX6H-UF40		
DRAWING NO. C131084		REV A

JX6H-UF40
INSTALLATION & OPERATION DATA

Basic Engine Description

Engine Manufacturer	John Deere Co.
Ignition Type	Compression (Diesel)
Number of Cylinders	6
Bore and Stroke - in.(mm)	5.00 (127) x 6.50 (165)
Displacement - in.^{3} (L)	763 (12.5)
Compression Ratio	14.7:1
Valves per cylinder - Intake	2
Exhaust	2
Combustion System	Unit Injection
Engine Type	In-Line, 4 Stroke Cycle
Aspiration	Turbocharged
Firing Order (CW Rotation)	1-5-3-6-2-4
Charge Air Cooling Type	Raw Water Cooled
Rotation (Viewed from Front) - Clockwise	Standard
Counter-Clockwise	Not Available
Engine Crankcase Vent System	Open
Installation Drawing	D-546

Cooling System

	1470	1760	2100
Engine H_2O Heat -Btu/sec.(kW)	86 (91)	113 (119)	122 (129)
Engine Radiated Heat - Btu/sec.(kW)	43 (45)	54 (57)	56 (59)
Heat Exchanger Minimium Flow			
60°F (15°C) Raw H_2O - gal/min. (L/min.)	16 (61)	20 (76)	22 (83)
95°F (35°C) Raw H_2O - gal/min. (L/min.)	20 (76)	26 (98)	28 (105)

Heat Exchanger Maximum Cooling H_2O	
Inlet Pressure - bar (lb./in.^{2}) (kPa)	4 (60) (400)
Flow - gal./min (L/min.)	80 (302)
Thermostat, Start to Open - °F (°C)	180 (82)
Fully Opened - °F (°C)	202 (94)
Engine Coolant Capacity - qt. (L)	29.6 (28)
Coolant Pressure Cap - lb./in.^{2} (kPa)	10 (69)
Maximum Engine H_20 Temperature - °F (°C)	212 (100)
Minimum Engine H_20 Temperature - °F (°C)	160 (71)

Electric System - DC

System Voltage (Nominal)	24
Battery Capacity for Ambients Above 32°F (0°C)	
Voltage (Nominal)	12
Qty. per Battery Bank	2
SAE size per J537	8D-900
CCA @ 0°F (-18°C)	900
Reserve Capacity - Minutes	430
Battery Cable Circuit*, Max Resistance - ohm	0.0012
Battery Cable Minimum Size	
0 -120 in. Circuit* Length	0
121 - 160 in. Circuit* Length	0
161 - 200 in. Circuit* Length	0
Charging Alternator Output - Amp	40
Starter Cranking Amps - @ 60°F (15°C)	600

**Positive and Negative Cables Combined Length*

NOTE: This engine is Intendend For Indoor Installation Or In A Weatherproof Enclosure.

(Continued)

JX6H-UF40
INSTALLATION & OPERATION DATA (Continued)

Exhaust System	1470	1760	2100
Exhaust Flow - $ft.^3/min.$ ($m^3/min.$)	1519 (43)	2175 (62)	2567 (73)
Exhaust Temperature - °F (°C)	928 (498)	841 (450)	793(423)
Maximum Allowable Back Pressure - in. H_20 (kPa)	30 (7.5)		
Minimum Exhaust Pipe Dia. - in. (mm)**	6 (152)		

Fuel System			
Fuel Consumption - gal./hr. (L/hr.)	18 (68)	22 (83)	24 (90)
Fuel Return - gal./hr. (L/hr)			
Total Supply Fuel Flow - gal./hr (L/hr.)			
Fuel Pressure - $lb./in.^2$ (kPa)	3-6 (21-41)		
Minimum Line Size - Supply - in. (mm)**	.75 Sch. 40 - Black		
Minimum Line Size - Return - in. (mm)**	.50 Sch. 40 - Black		
Maximum Allowable Fuel Pump Suction			
With Clean Filter - in. H_20 (mH_20)	100 (2.5)		
Maximum Allowable Fuel Head above Fuel pump, Supply or Retrun - ft(m)	9 (2.7)		
Fuel Filter Micron Size	2		

Heater System			
Jacket Water Heater	Standard		
Wattage (Nominal)	2500		
Voltage - AC, 1P	230 (+5%, -10%)		
Optional Voltage - AC, 1P	115 (+5%, -10%)		
Lube Oil Heater Wattage			
(Required Option When Ambient is Below 40°F (4°C)	150		

Induction Air System			
Air Cleaner Type	Indoors Service Only - Washable		
Air Intake Restriction Maximum Limit			
Dirty Air Cleaner - in. H_20 (kPa)	5.0 (1.2)		
Clean Air Cleaner - in. H_20 (kPa)	1.0 (0.2)		
Engine Air Flow - $ft.^3/min.$ ($m^3/min.$)	651 (18.4)	898 (25.4)	1100 (31.2)
Maximum Allowable Temperature (Air To Engine Inlet) - °F (°C)***	130 (54)		

Lubrication System			
Oil Pressure - normal - $lb./in.^2$ (kPa)	45 (310)		
In Pan Oil Temperature - °F (°C)	239 (115)		
Total Oil Capacity with Filter - qt. (L)	42 (40)		

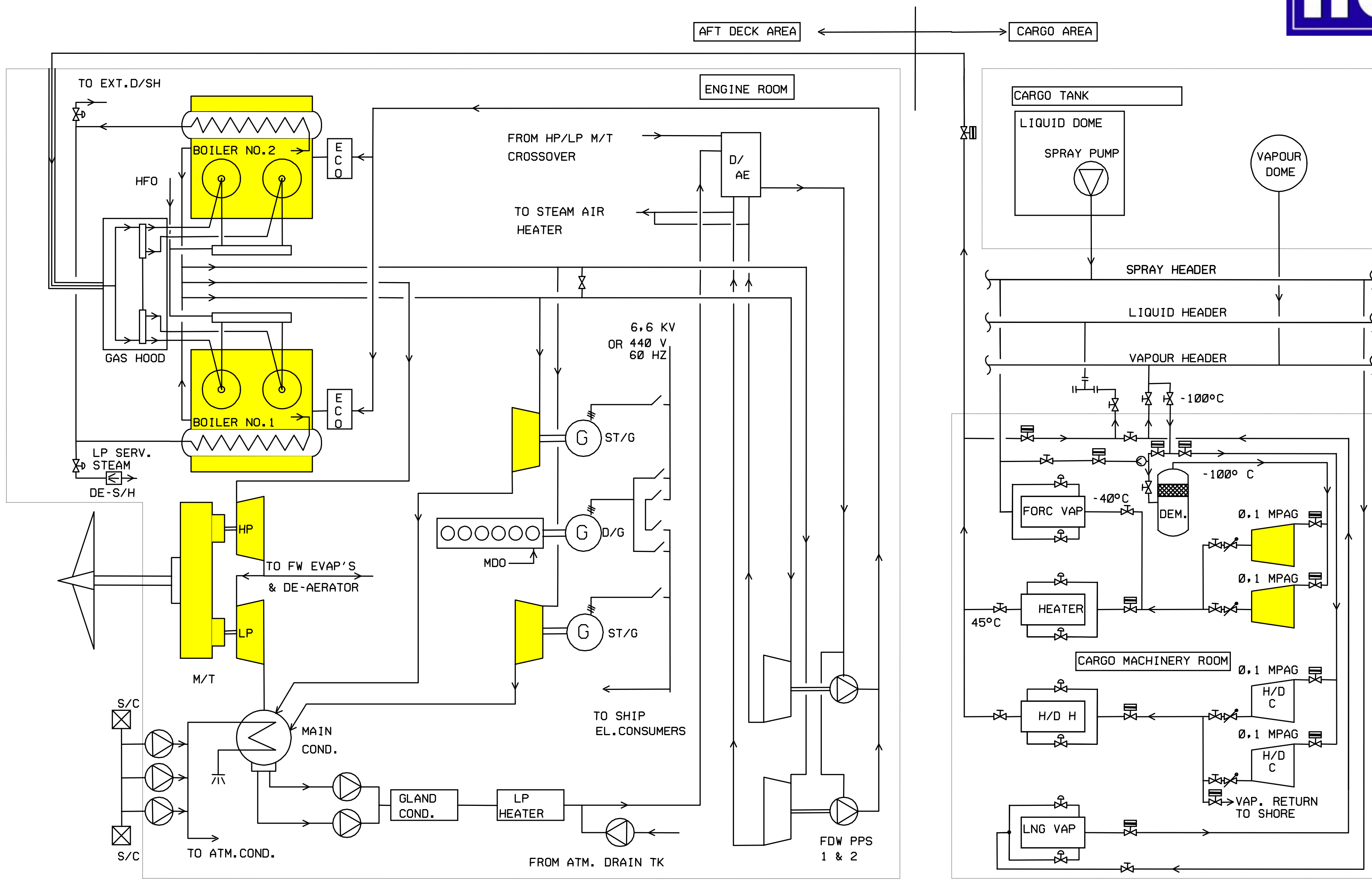
Performance			
BMEP - $lb./in.^2$ (kPa)	342 (2360)	271 (1870)	188 (1296)
Piston Speed - ft./min. (m/min.)	1593 (485)	1907 (581)	2275 (693)
Mechanical Noise - dB(A) @ 1M	C131518		
Power Curve		C131084	

*** Based On Nominal System. Flow Analysis Must Be Done To Assure Adherance To System Limitations. (Minimum Exhaust pipe Diameter is based on 15 feet of pipe, one elbow, and a silencer pressure drop no greter than one half the max. allowable back pressure.)*

**** Review For Power Deration If Air Entering Engine Exceeds °77F (25°C)*

Appendix A.5
LNG Vessel Diagrams

Steam Turbine (150k LNG Carrier)



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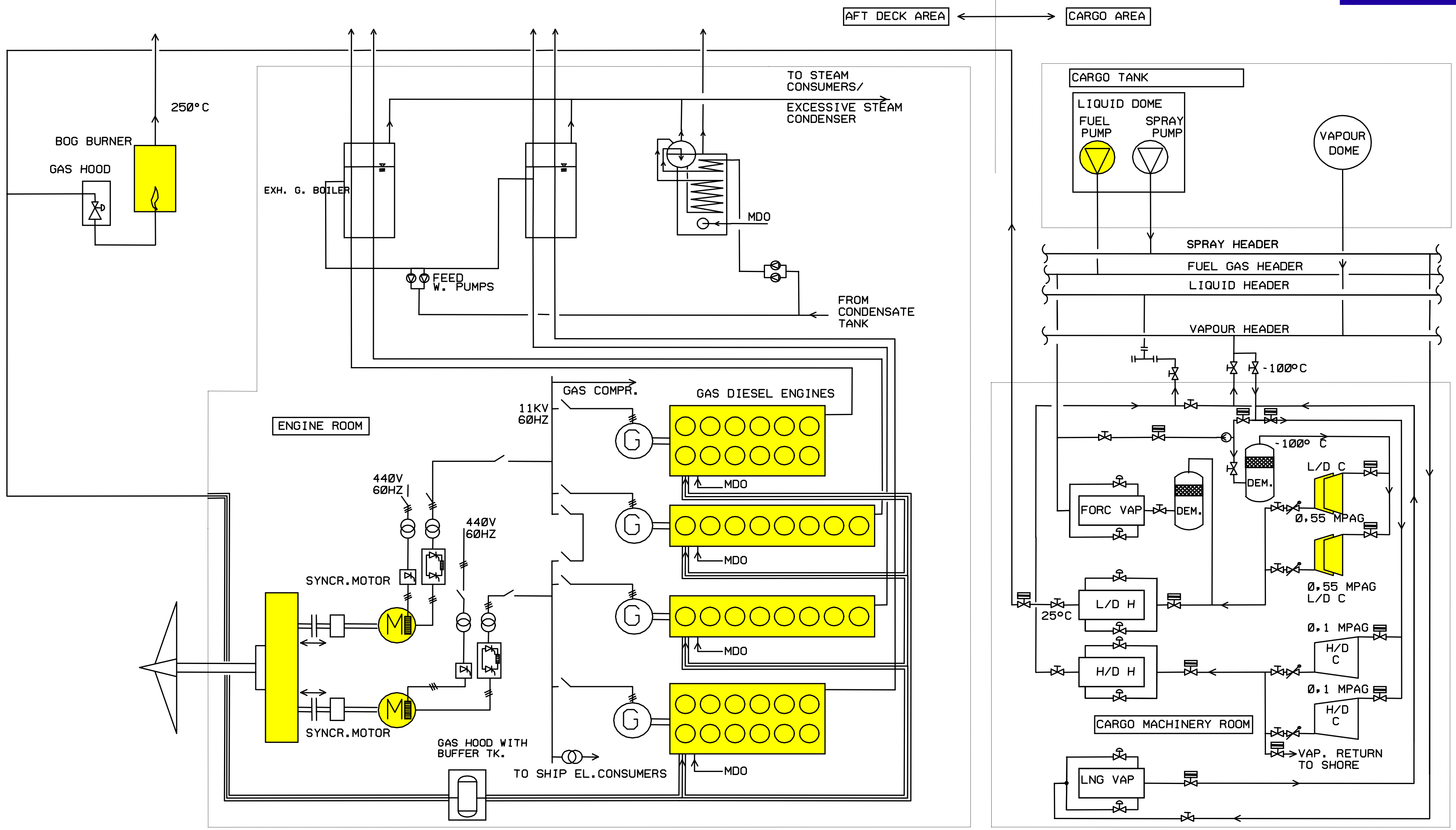
Dual Fuel Diesel-Electric (150k LNG Carrier)



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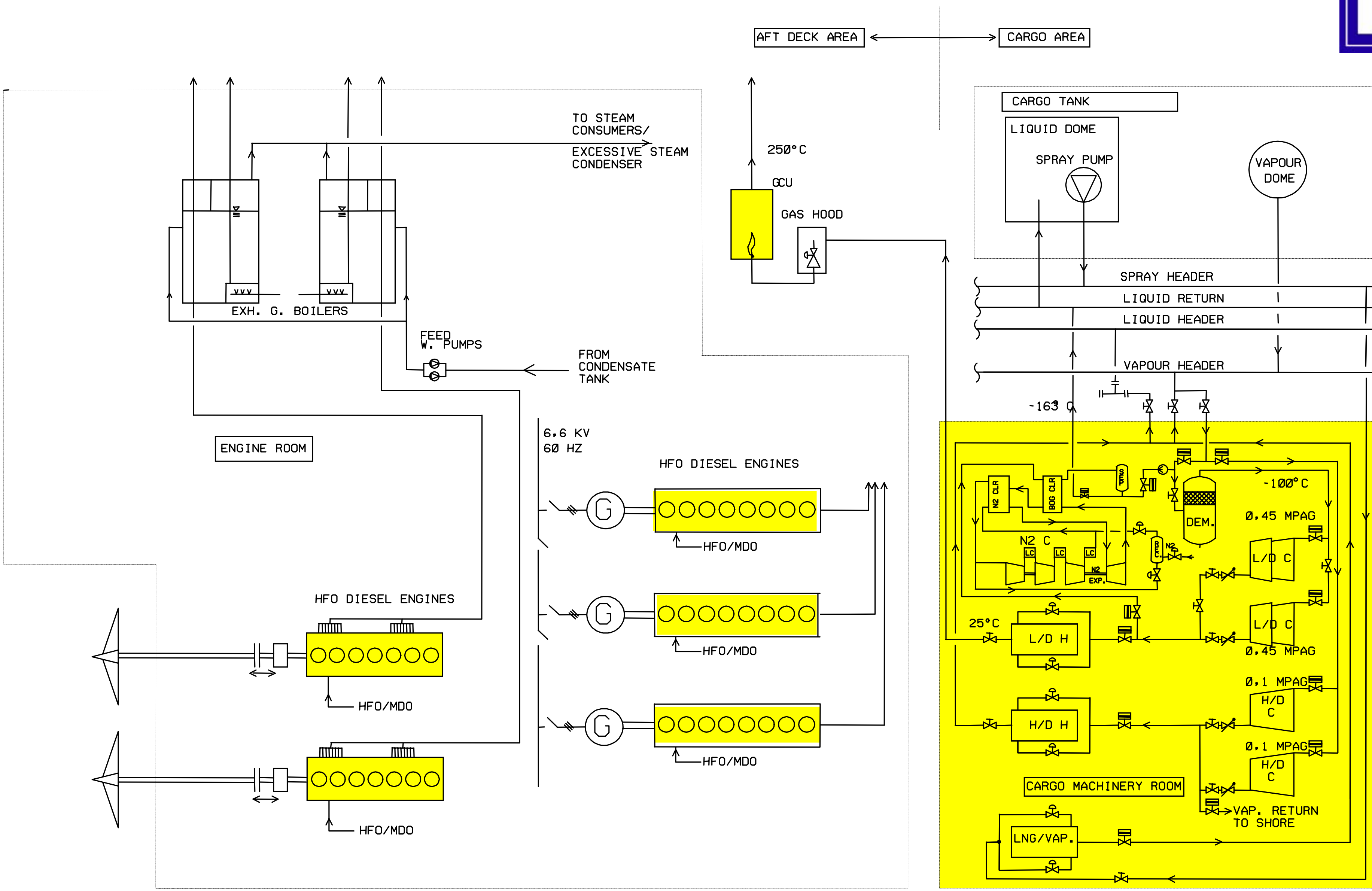
Slow Speed Diesel with Reliquefaction Plant (200k LNG Carrier)



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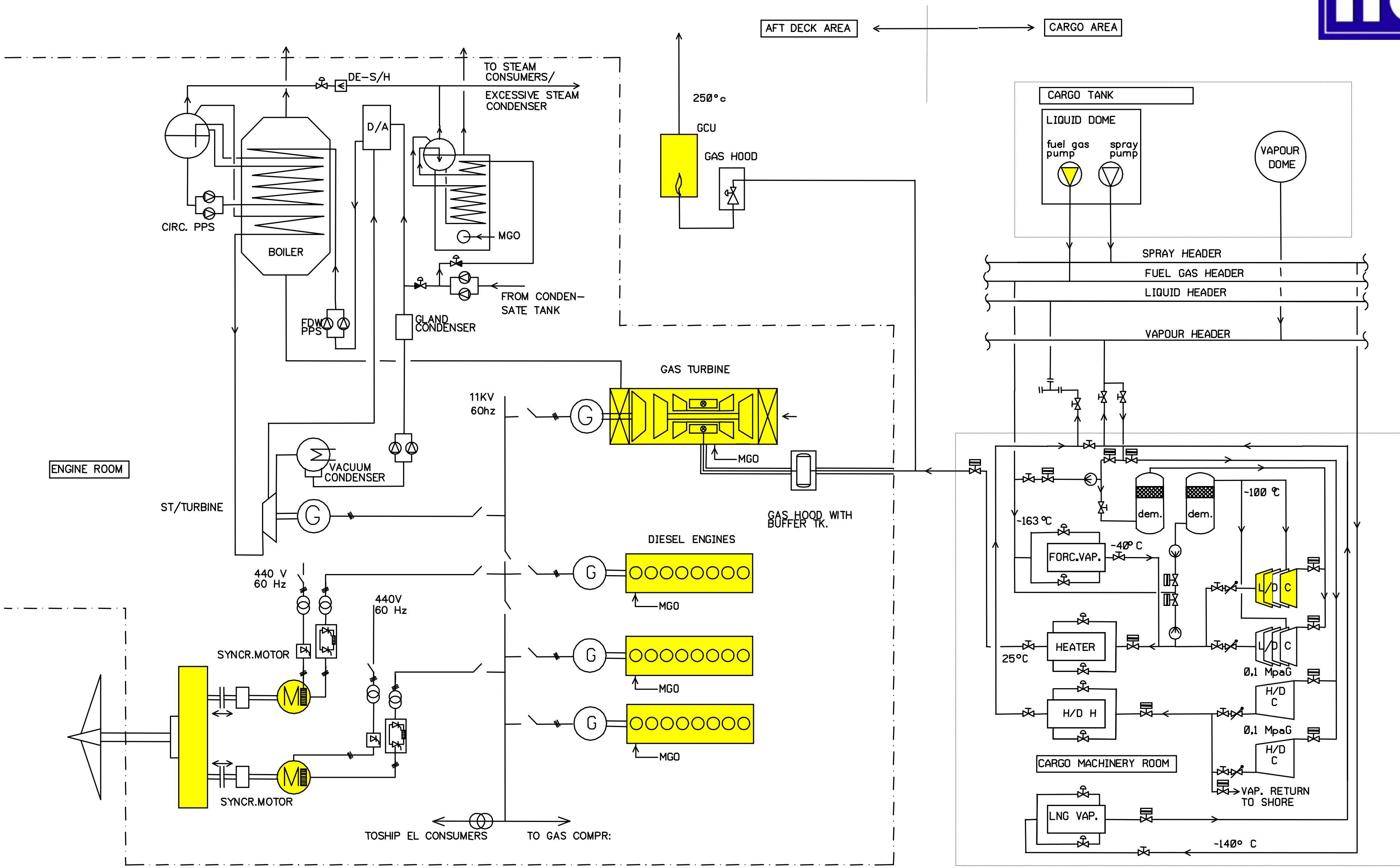
Combined Gas Steam Turbine Electric (200k LNG Carrier)



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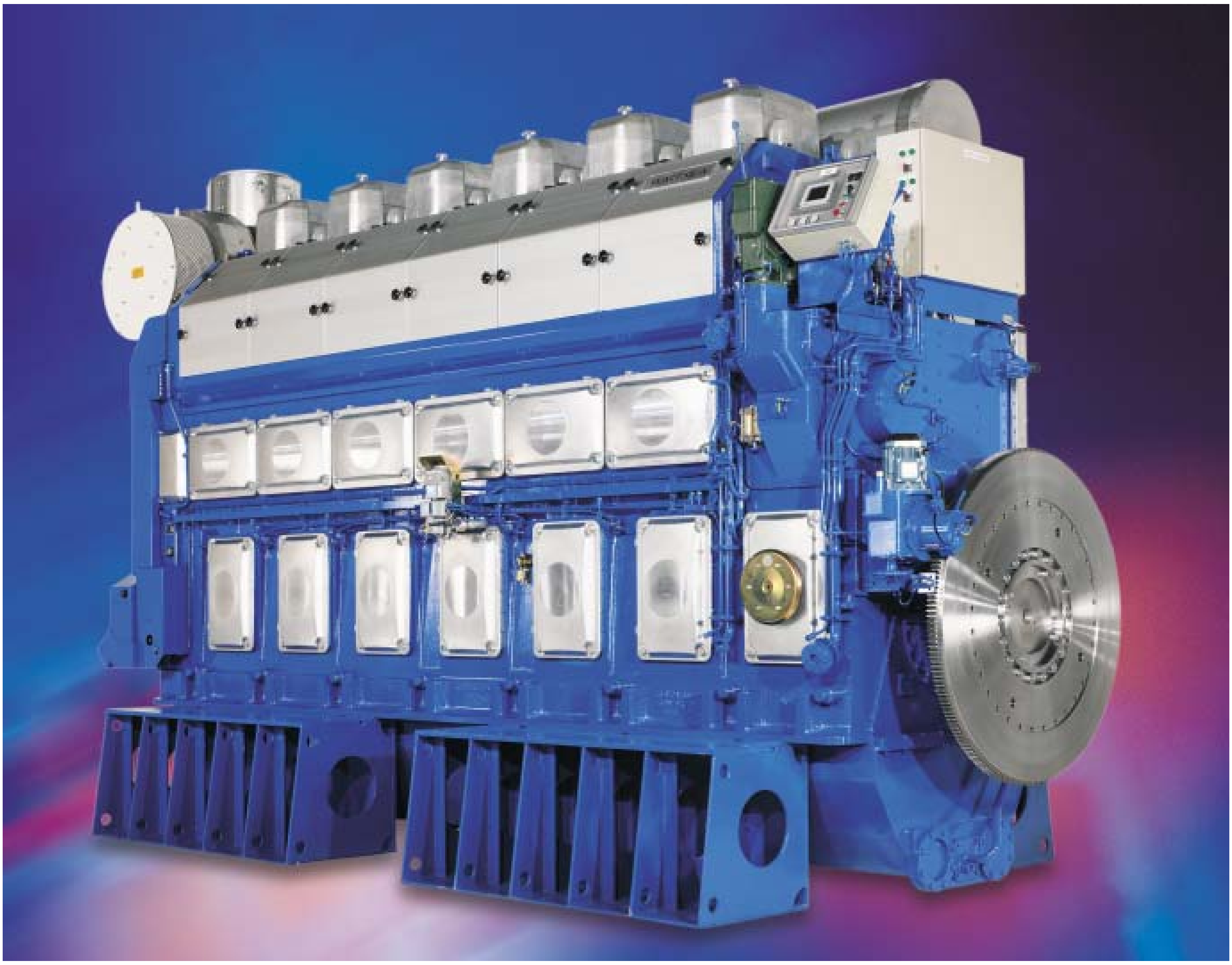
Appendix A.6
DFDE Engine Specifications



Wärtsilä 50DF

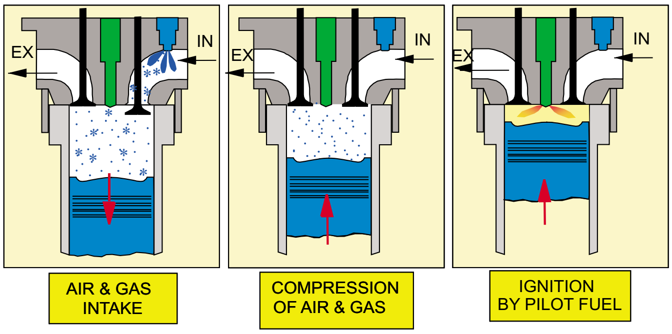
Design

The WÄRTSILÄ® 50DF is a four-stroke dual-fuel engine. The engine can alternatively run on natural gas, marine diesel fuel (MDF) and heavy fuel oil (HFO). The Wärtsilä 50DF is designed to give the same output regardless of whether it is running on natural gas or on liquid fuel. The engine operates according to the lean-burn principle: the mixture of air and gas in the cylinder is lean, which means that there is more air than needed for complete combustion. Lean combustion increases engine efficiency by raising the compression ratio and reducing peak temperatures, and therefore also reducing NO_X emissions. A higher output is reached while avoiding knocking or preignition of gas in the cylinders.

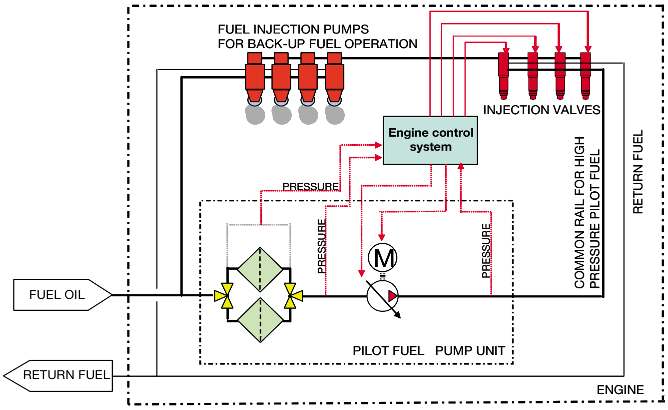
Combustion of the lean air-fuel mixture is initiated by injecting a small amount of MDF (pilot fuel) into the cylinder. The pilot fuel is ignited in a conventional diesel process, providing a high-efficiency ignition source for the main charge.

The fuel oil system on the engine has been divided into two: one for pilot fuel oil and one for the main fuel oil for back-up fuel operation. The equipment used for fuel oil operation is similar to the conventional diesel engine, with camshaft-driven injection pumps at each cylinder. The engine is equipped with a twin-needle injection valve, one main needle used during diesel mode and one for pilot fuel

WÄRTSILÄ



oil. The pilot fuel is elevated to the required pressure by one common pump unit, including filters, pressure regulator and an engine-driven radial piston-type pump. The pilot fuel is distributed through common-rail type piping and injected at approximately 900 bar pressure into cylinders. Pilot fuel injection timing and duration are electronically controlled.



Engine fuel oil system, MDF operation.

When running the engine in gas mode, the pilot fuel amounts to less than 1% of full-load consumption.

The fuel gas system feeding the engine with fuel includes a gas valve unit. This unit includes a pressure regulating valve, gas filter, instrumentation, and the necessary shut-off and venting valves to ensure safe and trouble-free gas supply. The fuel gas feed pressure to the engine is controlled by the pressure regulating valve located on the gas valve unit. The fuel gas pressure is dependent on engine load and the fuel gas calorific value (lower heating value). On full engine load, the required gas pressure to the gas valve unit is about 5 bar(g), depending on gas LHV. On the engine, the electronically actuated and controlled gas admission valves give exactly the correct amount of gas to each cylinder. This enables reliable performance without shutdowns, knocking or misfiring.

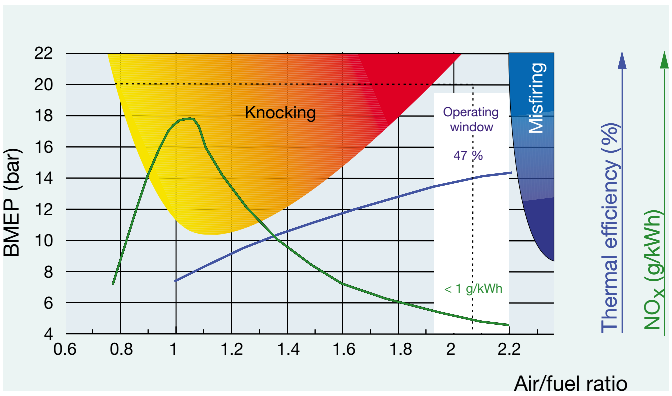
Operation

The Wärtsilä 50DF engine is designed for generating electrical power for ship propulsion. The dual-fuel engine operates on natural gas as main fuel, and on diesel as backup fuel. The Wärtsilä 50DF engine can be switched from gas operation to backup fuel operation at any load. The switchover is instant and the engine has the capability to operate on backup fuel if needed, without interrupting power generation. Fuel oil is always circulating through the engine, ensuring sufficient fuel supply for pilot fuel and for quick switchover to backup fuel operation. The engine can be switched from backup fuel operation to gas operation at loads up to 80% of full load.

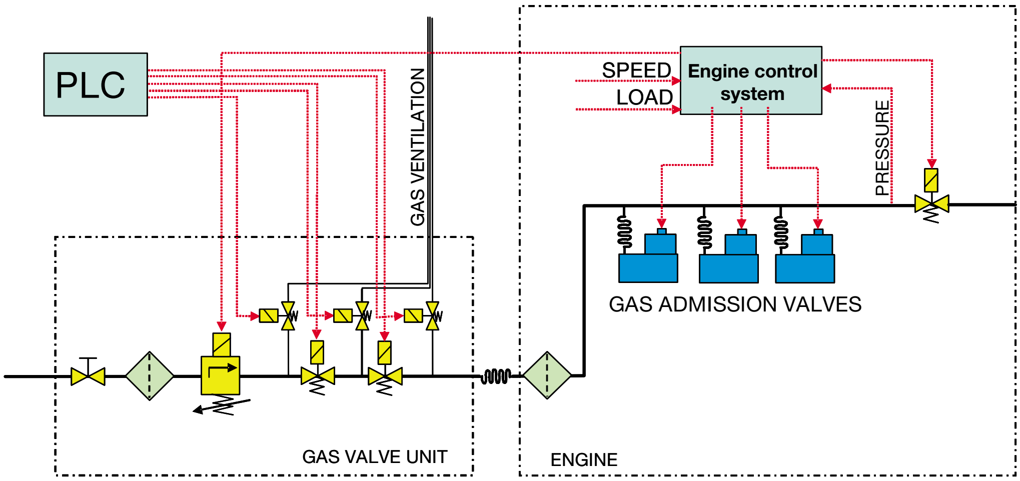
The engine is also capable of running on heavy fuel oil (HFO). The engine can be operated as a conventional diesel engine when running on HFO.

Emissions

In the Wärtsilä 50DF engine, the air-fuel ratio is very high. Since the same specific heat quantity released by combustion



Optimized engine performance.



Fuel gas system.

is used to heat up a larger mass of air, the maximum temperature and consequently NO_X formation are lower.

The engine has a thermal efficiency of 47%, higher than for any other gas engine. This, and the clean fuel used, give engine extremely low CO_2 emissions.

Typical emissions:		
Engine in gas operating mode		
Typical emission levels*	100% load	75% load
NO_x (g/kWh)	1.4	2
CO_2 (g/kWh)	430	450
Engine in diesel operating mode		
Typical emission levels*	100% load	75% load
NO_x (g/kWh)	11.5	12
CO_2 (g/kWh)	630	630

* note that the emission level always depends on the gas composition and that these figures should be seen as indicative only.

Automation

The engine is controlled by a sophisticated engine control system, a fully integrated engine management system designed for harsh environments. It ensures maximum engine performance and safety by monitoring and controlling vital engine functions. The engine control system is a modularized system consisting of hardware modules. The modules communicate through buses based on CAN protocol. The control system monitors temperatures and pressures on the engine through the numerous sensors mounted on the engine.

The engine control system offers the following advantages:

- Easy maintenance and high reliability thanks to rugged engine-dedicated connectors and pre-fabricated cable harness
- Easy interfacing with external systems via a databus
- Reduced cabling on and around the engine
- High flexibility and easy customizing
- Digital signals - free from electromagnetic disturbance
- Built-in diagnostics

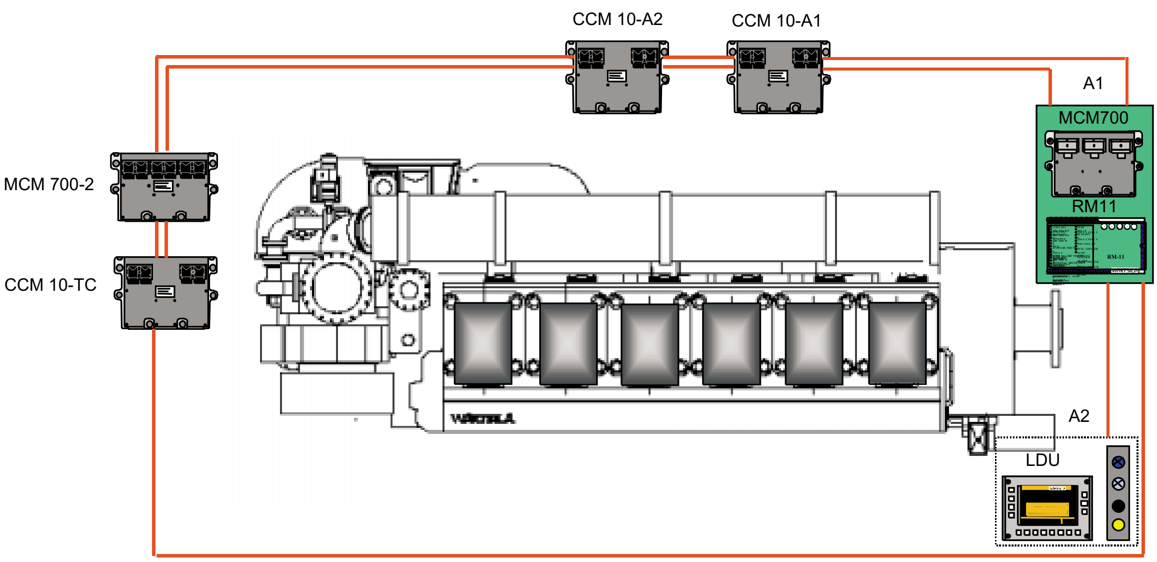
Maintenance / service intervals

Thanks to the purity of gas, Wärtsilä 50DF offers long component lifetime and time between overhauls. The engine has a large opening into the crankcase and camshaft to facilitate checking and maintenance.

References

The dual-fuel engine operates on well-known technology. The Wärtsilä 50DF is closely related to the smaller Wärtsilä 32DF engine, and uses the same techniques and operating principles. Wärtsilä DF engines with over 450,000 accumulated running hours are operating worldwide in marine offshore installations and also in land-based power plants.

Installation/deliv.	Country	Engine type	Output
Atlantique M32 -03	France	4x6L50DF	22.8 MW
Atlantique N32 -04	France	1x6L+3x12V50DF	39.9 MW
Bermeo -04	Spain	1x6L50DF	5.7 MW
Manisa -04	Turkey	3x18V50DF	51.3 MW
Atlantique P32 -05	France	1x6L+3x12V50DF	39.9 MW
HHI 1777 -06	Korea	2x9L+2x12V50DF	39.9 MW
HHI 1778 -07	Korea	2x9L+2x12V50DF	39.9 MW
HHI 1779 -07	Korea	2x9L+2x12V50DF	39.9 MW
HSHI 297 -07	Korea	2x9L+2x12V50DF	39.9 MW
Total		32 engines	319.2 MW



Engine control modules.

Safety aspects

The Wärtsilä 50DF engine is designed for safe operation. The engine is always started on liquid fuel using both main diesel injection and pilot fuel injection. Gas admission is activated only when combustion is stable in all cylinders and all engine parameters are normal.

Before the engine can operate on gas, the fuel gas feed system has to perform a series of tests to ensure the function together with safe and reliable operation. The test procedure is done automatically and this way the engine can be operated safely in both gas and diesel operating mode. Automatic and instant trip to back-up fuel operation is initiated in the case of certain alarm situations.

The engine room is regarded as a safe area free from gas. The gas feed system has venting valves that safely relieve pressure from gas piping when the engine switches over from gas operation. The venting pipes are routed to a safe area away from the engine room. Gas piping on the engine can be of either single wall or double wall type. At double wall gas piping installations, the intermediate space is ventilated by air.

Most major classification societies have prepared or are in a process of preparing new rules for modern low-pressure, dual-fuel engines.

Fuel gas specifications

Property	Unit	Value
Lower heating value (LHV), min [1]	MJ/m³N [2]	28
Methane number (MN), min [3]		80
Methane (CH_4), min	% volume	70
Hydrogen sulphide (H_2S), max	% volume	0.05
Hydrogen (H_2), max [4]	% volume	3
Ammonia, max	mg/m³N	25
Chlorine + fluorines	mg/m³N	50
Particles or solids at engine inlet, max	mg/m³N	50
Particles or solids at engine inlet, max size	µm	5
Gas inlet temperature	°C	0…50
Water and hydrocarbon condensates at engine inlet not allowed [5]		

1) The required gas feed pressure depends on the LHV.

2) Values given in m³N are at 0 °C and 101.3 kPa.

3) The methane number (MN) is a calculated value that gives a scale for evaluation of the resistance to knock of gaseous fuels.

4) A hydrogen content higher than 3% volume must be considered separately for each project.

5) The dew point of natural gas is below the minimum operating temperature and pressure.

Main data

Cylinder bore . . . . 500 mm
Piston stroke. . . . . 580 mm
Cylinder output . . . . 950 kW/cyl
Engine speed . . . . 500, 514 rpm
Mean effective pressure . . . . 23.6, 23.0 bar
Piston speed. . . . . 9.7, 9.9 m/s
Fuel specification:
Fuel oil. . . . . Marine diesel oil
ISO 8217, category ISO-F-DMX, DMA and DMB,
heavy fuel oil 730 cSt/50°C ISO-F-RMK 55
Natural gas. . . . . Methane Number: 80
LHV: min. 28 MJ/nm³
Fuel consumption:
Gas operation: Total BSEC: . . . . 7410 kJ/kWh
Backup fuel operation: SFOC: . . . . 189 g/kWh
With engine driven pumps, 5% tolerance. ISO 3046 standard ambient conditions. Fuel oil LHV 42.7 MJ/kg

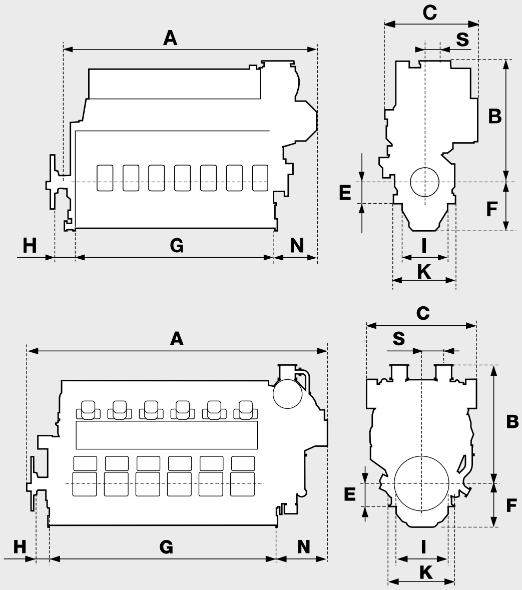
Rated power: Generating sets

Engine type	500 rpm/50 Hz, 514 rpm/60 Hz	
	Engine kW	Gen. kW
6L50DF	5 700	5 500
8L50DF	7 600	7 330
9L50DF	8 550	8 250
12V50DF	11 400	11 000
16V50DF	15 200	14 670
18V50DF	17 100	16 500

Principal engine dimensions (mm) and weights (tonnes)

Engine type	A	B	C	E	F	G
6L50DF	8 115	3 580	2 850	650	1 455	6 170
8L50DF	9 950	3 600	3 100	650	1 455	7 810
9L50DF	10 800	3 600	3 100	650	1 455	8 630
12V50DF	10 465	4 055	3 810	800	1 500	7 850
16V50DF	12 665	4 055	4 530	800	1 500	10 050
18V50DF	13 725	4 280	4 530	800	1 500	11 150
	H	I	K	N	S	Weight*
6L50DF	460	1 445	1 940	1 295	395	96
8L50DF	460	1 445	1 940	1 620	315	128
9L50DF	460	1 445	1 940	1 620	315	148
12V50DF	460	1 800	2 290	1 840	765	175
16V50DF	460	1 800	2 290	1 840	815	220
18V50DF	460	1 800	2 290	1 785	815	240

* Weights are dry weights (in Metric tons) of rigidly mounted engines without flywheel. All dimensions in mm.



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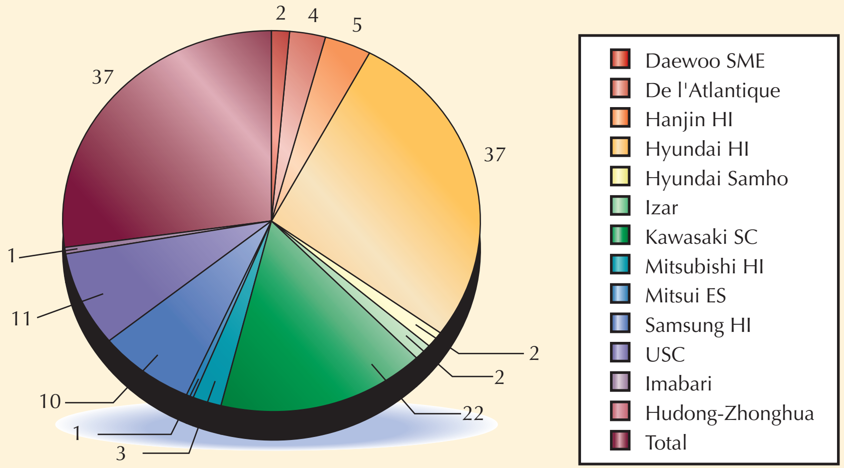
WÄRTSILÄ

Appendix A.7
Vessel Statistics from Oil & Gas Journal

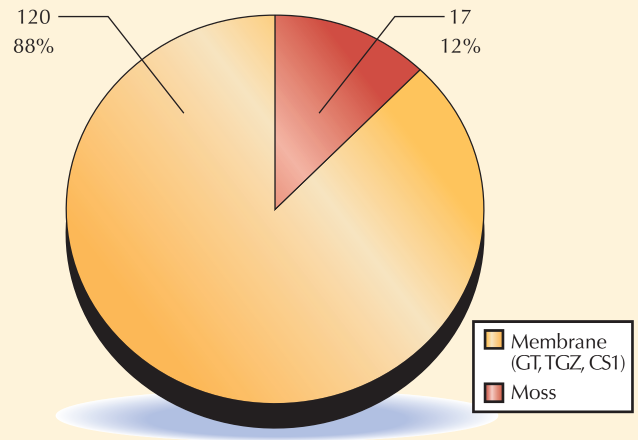
Vessels on order by shipyard

Fig. 1



Orderbook by containment system

Fig. 2



LNG tankers: present and future*

Fleet by containment system

	Total	On order	Existing
Worms/Gaz de France	1	—	1
Esso	3	—	3
IHI SPB Prismatic	2	—	2
GT	126	49	77
TGZ	106	68	38
Moss	111	16	95
CS1	3	2	1
Total	352	135	217
Summary			
Others	6	—	6
Membrane (GT,TGZ,CS1)	235	120	115
Moss	111	17	94
Total	**352**	**135**	**217**

Chartering status including orderbook

Status	Total	On order	Delivered
On charter	327	113	214
Open	25	22	3

Propulsion system

	Total	Existing	On order
ST	276	214	62
DFDE	35	1	34
SSDR	37	—	37
Total	**348**	**217**	**131**

Fleet numbers

		Count
Existing fleet	Delivered	217
Under construction	On order	135
Total		**352**

LNG tankers: present and future* (cont.)

Orders placed

Year	2002	2003	2004	2005	2006
	17	15	70	40	35

Vessels on order by region

Korea	Japan	Europe	China	Total
100	27	3	5	135
74%	20%	2%	4%	

Vessels on order by shipyard

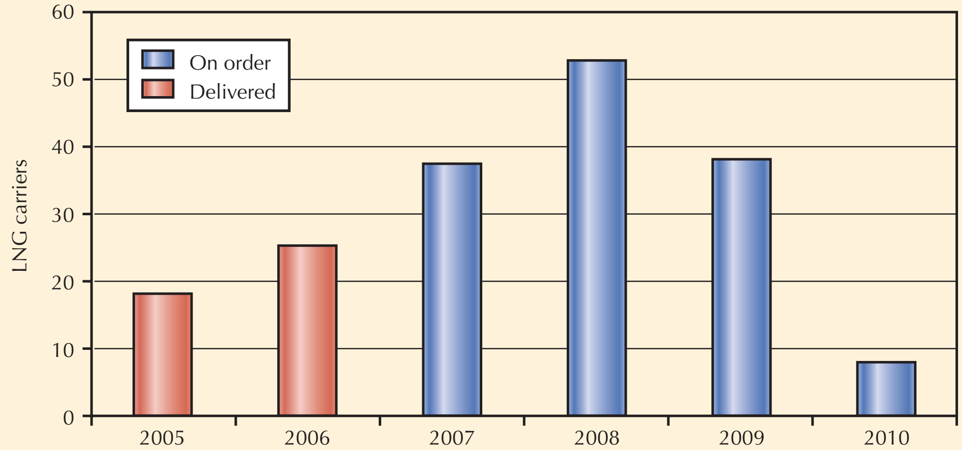
Daewoo SME	36
De l'Atlantique	2
Hanjin HI	2
Hyundai HI	22
Hyundai Samho	3
Izar	1
Kawasaki SC	9
Mitsubishi HI	11
Mitsui ES	1
Samsung HI	37
USC	2
Imabari	4
Hudong-Zhonghua	5
Total	**135**

Delivery schedule

	On order	Delivered
2003	—	15
2004	—	21
2005	—	18
2006	1	24
2007	37	—
2008	53	—
2009	38	—
2010	8	—
Total	**135**	**80**

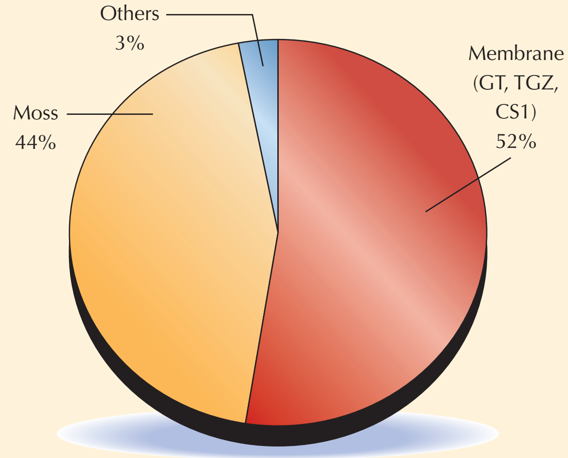
Delivery schedule

Fig. 3



Delivered fleet by containment system

Fig. 4



*As of Jan. 1, 2007. Source: LNG Shipping Solutions, London

Appendix A.8
Wartsila Emissions Data

From: <Matthew.Fisher@wartsila.com>
To: <todd.tamura@tteci.com>
cc: <rdolier@mpr.com>

Date: Tuesday, February 13, 2007 11:44AM
Subject: RE: Wartsila engine emissions

History: This message has been replied to.

Todd,

Sorry I didn't get back to you sooner, but I have been out of the office.

It sounds like you need some additional emissions information. At this point are we still just talking about general information, or will this be data to go into a air permit submittal? What units are preferred? g/kWh, ppm, lb/h, lb/mmbtu, other?

As for general information uncontrolled, what I have is in terms of ppm:

Load			100 %	90 %	75 %
NO_x	as NO_2	ppm-v, 15 % O_2, dry	120	120	110
CO		ppm-v, 15 % O_2, dry	260	260	300
VOC	as CH_4	ppm-v, 15 % O_2, dry	110	110	140

For controlled, we will be able to hold the 0.07 g/kWh NOx down to 75% load. CO emissions would also hold constant at 0.13 g/kWh. VOC's however would have an increase, to 0.19 g/kWhe at 75% load. The VOC emission rate is the one that has the most dependence on site conditions, namely fuel composition and catalyst choice (what potential poisons might be in the gas). If we can pin down the fuel more closely, then there is a chance to reduce that emission rate. PM10(total) is fairly constant, in a pound per hour rate, so at 75% load, the emission rate would be about 0.17 g/kWh. NH3 slip can be held to 10 ppm across the board, but if there is a need to reduce this, again we would need to go back and look at fuel composition and specific catalyst materials.

I hope this helps. Please let me know if you need any additional information.

Matthew

From: Fisher, Matthew
Sent: Tuesday, February 06, 2007 9:29 AM
To: 'todd.tamura@tteci.com'
Cc: 'D'Olier, Robert'
Subject: RE: Wartsila engine emissions

Todd,

For expected startup emissions for one 20W34SG gas engine:
Cold Start:
CO 3.6 kg
NOx 2.2 kg
VOC 1.2 kg

Warm
CO 2.2 kg
NOx 1.4 kg
VOC 0.8 kg

b ased on a 15 minute start window

Hope this helps.

Matthew

From: Fisher, Matthew
Sent: Monday, January 29, 2007 12:11 PM
To: 'D'Olier, Robert'
Cc: todd.tamura@tteci.com
Subject: RE: Wartsila engine emissions

Bob,
As per our conversation, for the 20V34SG running on 'pipeline' quality gas, PM (total front half and back half), VOC and CO are all right around 0.13 g/kWh each. There may be some room to reduce CO and VOC emissions further using a more aggressive catalyst, but this will depend on the other components of the fuel that may poison the catalyst. For NOx, we are at 0.07 to 0.08 g/kWh as a lower limit, depending some on engine tuning and site conditions.

I will check into the broken link and see what I can find.

Matthew

From: D'Olier, Robert [mailto:rdolier@mpr.com]
Sent: Friday, January 26, 2007 2:15 PM
To: Fisher, Matthew
Cc: todd.tamura@tteci.com
Subject: FW: Wartsila engine emissions

Matthew,

We are working to submit an air permit application for the Atlantic Sea Island Group project off New York Harbour.

Todd Tamura noticed that the link for "performance data" from the V34 website (http://www.wartsila.com/,en,productsservices,0,product,DF309996-4682-49D4-A4A5-3C9387BB06C1,34B865B8-95BD-490F-8F00-02169B38DAD8,,.htm) is broken - could you send us th is data?

Please confirm PM and VOC emission levels that Wartsila can guarantee for the 20V34SG engines for the Atlantic Sea Island Group's application at an LNG receiving terminal. Please also confirm the NOx emission options.

Thanks for your assistance.

Performance data - Wärtsilä gas engines at 60 Hz

Engine			12V34SG		W16V34SG		18V34SG		W20V34SG		18V32DF		18V50DF	
											Gas mode	LFO mode	Gas mode	LFO mode
Frequency		Hz	60	60	60	60	60	60	60	60	60	60	60	60
Engine optimisation: NOx (c		mg/nm3	250	500	250	500	250	500	250	500	500		500	
HT out		°C	91-95	91-95	91-95	91-95	91-95	91-95	91-95	91-95	91-95	91-95	91-95	91-95
HT temp diffe	min.	°C	7	7	12	11	7	7	14	13	7	10	10	15
LT out		°C	38-40	38-40	44-46	43-45	38-40	37-39	42-44	42-44	38-40	38-40	46-48	49-51
LT temp diffe	min.	°C	5	5	9	8	5	4	9	9	5	5	13	16
LO out		°C	72-74	72-74	72-74	72-74	73-75	73-75	73-75	73-75	74-76	74-76	74-76	77-79
LO temp diffe	min.	°C	10	10	9	9	11	11	10	10	12	12	12	15
CA flow	± 5%	kg/s	6,6	6,3	11,9	11,1	9,9	9,4	14,8	13,8	9,4	11,2	26,4	32,6
EG flow	± 5%	kg/s	6,8	6,5	12,2	11,4	10,2	9,7	15,2	14,2	9,6	11,5	27,2	33,5
EG temp.	± 10°C	°C	370-390	390-410	365-385	380-400	370-390	390-410	365-385	380-400	389-409	347-367	390-410	355-375
Fuel cons.		nm3/h	925	896	1602	1555	1386	1346	2005	1944	1386		3715	
		kg/h										1172		3343
		kW	9064	8800	15718	15235	13596	13200	19648	19043	13704	13912	36616	39654
Electric power		kW	3802	3802	6737	6737	5732	5732	8439	8439	5819	5819	16492	16638
Exhaust gas ε	± 10%	kW	2971	2807	5130	4855	4468	4221	6406	6051	4460	3986	12041	12638
HT-energy	± 10%	kW	1168	1090	2053	1893	1797	1674	2608	2405	1760	2321	4266	5768
LT-energy	± 10%	kW	825	803	1385	1347	1181	1155	1694	1657	1234	1355	2970	3758
Heat losses b	± 15%	kW	298	298	413	403	418	418	501	491	431	431	847	852
Efficiency		100% load	41,9%	43,2%	42,9%	44,2%	42,2%	43,4%	43,0%	44,3%	42,5%	41,8%	45,0%	42,0%
		75% load	40,6%	41,6%	41,3%	42,7%	40,8%	41,8%	41,4%	42,8%	40,4%	40,9%	43,2%	41,1%
		50% load	37,6%	38,2%	38,0%	39,4%	38,0%	38,6%	38,1%	39,5%	37,3%	39,4%	40,4%	39,4%

Note:
Heat and mass balances are dependent of ambient conditions and plant application, above given figures are for guidance
only and calculated at ISO 3046 reference conditions; 25°C ambient temperature, 100 m above sea level and 30% relative humidity.
Nm3 defined at NTP (273.15 K and 101.3kPa)

* 0% tolerance fuel consumption with Natural gas (LHV 35282 kJ/Nm3 at 0°C) or LFO (LHV 42700 kJ/kg) at 100% load and ISO 3046 reference conditions,

Abbreviations:
CA= Charge Air
EG= Exhaust gas
LO= Lubrication oil
LT= Low temperature circuit
HT= High temperature circuit

Appendix A.9
Johnston Emissions Data

From: "Bill Powell" <bill@jlpowellassoc.com>
To: <Todd.Tamura@tteci.com>
cc: <rdolier@mpr.com>

Date: Wednesday, February 14, 2007 05:54AM
Subject: RE: emissions for FIR burner
History: This message has been forwarded.

Todd,

The emissions at 100% are guaranteed, and the attached now shows guaranteed. Emissions below 100% are estimated, and I have attached the 75% condition per your request.

Please advise if I can be of any further service.

Bill

From: Todd.Tamura@tteci.com [mailto:Todd.Tamura@tteci.com]
Sent: Tuesday, February 13, 2007 3:11 PM
To: bill@jlpowellassoc.com
Cc: rdolier@mpr.com
Subject: emissions for FIR burner

Thanks, Bill. Couple of questions:

(1) I noticed that this specifically says emissions are "estimated". Are there no guarantees?

(2) Data are all for 100% load; can we get data for 75% load as well (even if not guaranteed)?

JOHNSTON BOILER COMPANY

14-Feb-07

MPR Project

Boiler Model PFTF2500-3G125WG
100% Load Condition

Fuel	**LN-Natural Gas**
Boiler Horse Power	**2500**
Boiler Efficiency	**83.02%**
BTU's / Hr	**100,804,023**
Ft^3 / Hr	**100804.0**

Guaranteed Burner Emissions

	PPMv (Corr to 3% O2)	Pounds per 1,000,000 BTU's	TOTAL Pounds / Hour @ 100% Firing Rate
PM-10 (Particulate)	**N/A**	**0.001**	**0.101**
CO (Carbon Monoxide)	**50**	**0.04**	**3.703**
SOx (<0.5% wt. Sulfur in Fuel)	**NOT APPLICABLE TO GAS**		
VOC (Methane + Non-Methane)	**10**	**0.004**	**0.403**
NOx (Nitrogen Compounds)	**9**	**0.011**	**1.080**
CO2 (Carbon Dioxide)	**2.55# / # FUEL**	**119.76**	**12072.290**
H2O (Water	**2.03# / # FUEL**	**106.16**	**10701.355**

COMBUSTION AIR / FLUE GAS

Req. Comb. Air (60 Deg. F.) SCFM	**Excess Air:**	**55%**	**25,242**
Flue Gas Volume (400 Degrees F. Gross)	**ACFM**		**41,233**
Flue Gas Velocity Ft/Min	**Stack Dia. In.**	**46.00**	**3,573**

JOHNSTON BOILER COMPANY

14-Feb-07

MPR Project

Boiler Model PFTF2500-3G125WG
75% Load Condition

Fuel	LN-Natural Gas
Boiler Horse Power	1875
Boiler Efficiency	83.75%
BTU's / Hr	74,944,030
Ft^3 / Hr	74944.0

Estimated Burner Emissions

	PPMv (Corr to 3% O2)	Pounds per 1,000,000 BTU's	TOTAL Pounds / Hour @ 100% Firing Rate
PM-10 (Particulate)	N/A	0.001	0.075
CO (Carbon Monoxide)	50	0.04	2.753
SOx (<0.5% wt. Sulfur in Fuel)	NOT APPLICABLE TO GAS		
VOC (Methane + Non-Methane)	10	0.004	0.300
NOx (Nitrogen Compounds)	9	0.011	0.803
CO2 (Carbon Dioxide)	2.55# / # FUEL	119.76	8975.297
H2O (Water	2.03# / # FUEL	106.16	7956.058

COMBUSTION AIR / FLUE GAS

Req. Comb. Air (60 Deg. F.) SCFM	Excess Air:	55%	18,766
Flue Gas Volume (400 Degrees F. Gross)	ACFM		30,655
Flue Gas Velocity Ft/Min	Stack Dia. In.	46.00	2,656

Appendix A.10
Caterpillar Emissions Data

GEN SET PACKAGE PERFORMANCE DATA [516DE5A]

JANUARY 26, 2006

Can't find what you're looking for? Click here

Performance Number: DM8263

Change Level: 01

Sales Model: 3516CDITA
Combustion: DI
Aspr: TA
Engine Power:
2000 W/F EKW 2080 W/O F EKW 2,937 HP
Speed: 1,800 RPM
After Cooler: ATAAC
Manifold Type: DRY
Governor Type: ADEM3
After Cooler Temp(F): 122
Turbo Quantity: 4
Engine App: GP
Turbo Arrangement: Parallel
Hertz: 60
Engine Rating: PGS
Strategy:
Rating Type: STANDBY
Certification: EPA TIER-2 2006 -

General Performance Data

GEN W/F EKW	PERCENT LOAD	ENGINE POWER BHP	ENGINE BMEP PSI	FUEL RATE LB/BHP-HR	FUEL RATE GPH	INTAKE MFLD TEMP DEG F	INTAKE MFLD P IN-HG	INTAKE AIR FLOW CFM	EXH MFLD TEMP DEG F	EXH STACK TEMP DEG F	EXH GAS FLOW CFM
2,000.0	100	2937	307	0.331	138.9	121.5	78.7	6,367.2	1,123.2	761.7	15,135.9
1,800.0	90	2641	276	0.333	125.5	119.7	73.4	6,130.6	1,070.1	722.5	14,097.6
1,600.0	80	2353	246	0.338	113.5	118.2	68.3	5,897.6	1,028.7	696.0	13,197.1
1,500.0	75	2212	231	0.341	107.8	117.5	65.5	5,763.4	1,009.6	685.8	12,766.3
1,400.0	70	2071	216	0.345	102.1	117.0	62.5	5,615.0	990.7	676.6	12,339.0
1,200.0	60	1795	188	0.353	90.4	115.3	55.7	5,247.8	953.2	660.4	11,357.2
1,000.0	50	1521	159	0.358	77.7	113.7	46.6	4,718.0	914.4	649.2	10,096.5
800.0	40	1253	131	0.358	64.1	111.9	35.1	4,001.2	865.2	644.2	8,521.4
600.0	30	979	102	0.365	51.0	110.7	24.3	3,330.2	804.7	635.9	7,045.3
500.0	25	839	88	0.375	44.9	110.1	19.8	3,044.1	767.5	626.7	6,384.9
400.0	20	698	73	0.389	38.7	109.8	15.7	2,782.8	724.6	614.1	5,749.2
200.0	10	409	43	0.451	26.4	109.0	8.9	2,348.4	596.1	540.5	4,516.8

Heat Rejection Data

GEN W/F EKW	PERCENT LOAD	REJ TO JW BTU/MN	REJ TO ATMOS BTU/MN	REJ TO EXHAUST BTU/MN	EXH RCOV TO 350F BTU/MN	FROM OIL CLR BTU/MN	FROM AFT CLR BTU/MN	WORK ENERGY BTU/MN	LHV ENERGY BTU/MN	HHV ENERGY BTU/MN
2,000.0	100	43,505	7,791	102,593	48,737	14,900	37,875	124,545	298,055	317,505
1,800.0	90	40,491	7,336	92,470	42,141	13,478	33,724	111,977	269,336	286,909
1,600.0	80	37,648	6,938	84,452	37,477	12,170	29,970	99,750	243,687	259,611
1,500.0	75	36,283	6,824	80,812	35,430	11,545	28,151	93,778	231,404	246,531
1,400.0	70	34,918	6,654	77,172	33,496	10,976	26,274	87,864	219,233	233,508
1,200.0	60	32,018	6,369	69,495	29,629	9,725	22,179	76,092	193,983	206,665
1,000.0	50	28,719	6,085	60,794	25,591	8,360	17,232	64,490	166,799	177,718
800.0	40	25,023	5,801	50,842	21,326	6,881	11,545	53,116	137,568	146,554
600.0	30	21,269	5,460	41,515	17,175	5,460	6,711	41,515	109,531	116,697
500.0	25	19,393	5,289	37,136	15,184	4,834	5,005	35,601	96,281	102,593
400.0	20	17,516	5,118	32,700	13,194	4,152	3,583	29,572	83,144	88,546
200.0	10	13,251	4,720	23,374	7,905	2,843	1,479	17,345	56,586	60,282

EMISSIONS DATA

EPA TIER-2 2006 - ** B5

Gaseous emissions data measurements are consistent with those described in EPA 40 CFR PART 89 SUBPART D and ISO 8178 for measuring HC, CO, PM, and NOx.

Gaseous emissions values are WEIGHTED CYCLE AVERAGES and are in compliance with the following non-road regulations:

LOCALITY	AGENCY/LEVEL	MAX LIMITS - g/kw-hr		
U.S. (incl Calif)	EPA/TIER-2	CO:3.5	NOx + HC:6.4	PM:0.20

EXHAUST STACK DIAMETER	8 IN
WET EXHAUST MASS	29,056.9 LB/HR
WET EXHAUST FLOW (761.00 F STACK TEMP)	15,146.47 CFM
WET EXHAUST FLOW RATE (32 DEG F AND 29.98 IN HG)	6,071.00 STD CFM
DRY EXHAUST FLOW RATE (32 DEG F AND 29.98 IN HG)	5,562.07 STD CFM
FUEL FLOW RATE	138 GAL/HR

RATED SPEED "Not to exceed data"

GEN PWR EKW	PERCENT LOAD	ENGINE POWER BHP	TOTAL NOX (AS NO2) LB/HR	TOTAL CO LB/HR	TOTAL HC LB/HR	PART MATTER LB/HR	OXYGEN IN EXHAUST PERCENT	DRY SMOKE OPACITY PERCENT	BOSCH SMOKE NUMBER
2,000.0	100	2937	41.87	3.43	0.91	.230	10.80	0.8	1.28
1,500.0	75	2212	22.54	1.87	1.11	.220	12.30	0.9	1.28
1,000.0	50	1521	12.85	2.00	1.13	.270	13.40	1.3	1.28
500.0	25	839	9.43	3.92	0.95	.570	14.20	3.1	1.31
200.0	10	409	6.49	4.05	1.00	.450	15.90	2.8	1.31

RATED SPEED "Nominal Data"

GEN PWR EKW	PERCENT LOAD	ENGINE POWER BHP	TOTAL NOX (AS NO2) LB/HR	TOTAL CO LB/HR	TOTAL HC LB/HR	TOTAL CO2 LB/HR	PART MATTER LB/HR	OXYGEN IN EXHAUST PERCENT	DRY SMOKE OPACITY PERCENT	BOSCH SMOKE NUMBER
2,000.0	100	2937	34.89	1.91	0.69	3,021.7	0.170	10.80	0.8	1.28
1,500.0	75	2212	18.78	1.04	0.84	2,348.7	0.160	12.30	0.9	1.28
1,000.0	50	1521	10.71	1.11	0.85	1,692.1	0.200	13.40	1.3	1.28
500.0	25	839	7.86	2.18	0.71	974.4	0.400	14.20	3.1	1.31
200.0	10	409	5.41	2.25	0.75	565.0	0.320	15.90	2.8	1.31

Appendix A.11
Clarke Fire Pump Emissions Data

From: "Wauligman,Ken" <KWauligman@clarkefire.com>
To: <Todd.tamura@tteci.com>
cc: "Strousse,Justin" <jstrousse@clarkefire.com>

Date: Friday, February 09, 2007 11:18AM
Subject: 3-mode test data for JX6H-UF40 rated 460 bhp at 1760 rpm

History: This message has been replied to.

Hell-o Todd,

Per our phone conversation, attached please find the 3-mode "raw" emissions data collected on this engine model at this speed at Southwest Research.

Note the 3-mode test is only applicable to Stationary Fire Pump Diesel Engine Drivers per 40 CFR 60 Subpart IIII (refer to Table 6 to Subpart IIII of Part 60). I am attaching a copy of this Table 6 as well for your reference.

Regards,

Ken Wauligman

Engineering Manager

Clarke Fire Protection Products

3133 E. Kemper Road

Cincinnati , Oh 45241

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Fax: 513-771-0726

E-mail: kwauligman@clarkefire.com

Website: www.clarkefire.com

Attachments:

1031-HR.pdf

40 CFR 60 - Table 6 to Subpart IIII - 3 mode test points.pdf

Southwest Research Institute - Department of Emissions Research

Custom, EPA Calcs Emission Test Results

Project No. 08-7219-001

Engine Model: John Deere
Engine Desc.: 12.5 L (762 CID) I-6
Engine Cycle: Diesel
Engine S/N: 6125H051031
Model: 6125HF001

Test No.: 1031-H
Date: 03/14/2006 Time:
Program SSDIL: 2.33-C
Cell: 26 Bag Cart: 26

DIESEL 2D, EM-5884-F
HCR: 1.800 FID Resp: 1.00

	Target			Measured			C - B	Intake Air			Factors			
Mode	Speed rpm	Load pct	Torque lb-ft	Time sec	Speed rpm	Torque lb-ft	Fuel lb/hr	Temp °F	Humid g/kg	Baro. in-Hg	NOx Hum.	Part. Hum.	Dry Wet	F (TC)
H1	1,760	100.0	1,373.0	300	1,759	1,369.4	155.9	70.0	10.5	29.39	0.995	1.003	0.978	0.989
H2	1,760	75.0	1,028.0	300	1,761	1,024.8	115.7	69.0	10.6	29.38	0.998	1.001	0.980	0.987
H3	1,760	50.0	688.0	300	1,761	684.6	78.8	70.0	10.6	29.38	0.999	1.001	0.984	0.990

	BHP						Unweighted Modal Contribution					
	from	Grams/Hour					Mode	g/hp-hr				
Mode	Work	HC	CO	NOx	Part.	CO2	wf	HC	CO	NOx	Part.	CO2
H1	457.6	35.70	167.1	2,404.4	18.05	224,714	1.000	0.08	0.37	5.25	0.04	491.04
H2	342.2	31.14	191.0	1,705.5	27.71	166,622	1.000	0.09	0.56	4.98	0.08	486.87
H3	228.8	35.51	101.4	1,177.6	20.06	113,407	1.000	0.16	0.44	5.15	0.09	495.76

Southwest Research Institute - Department of Emissions Research

Custom, EPA Calcs Emission Test Results
Project No. 08-7219-001

Engine Model: John Deere	Test No.: 1031-H	DIESEL 2D, EM-5884-F
Engine Desc.: 12.5 L (762 CID) I-6	Date: 03/14/2006 Time:	HCR: 1.800 FID Resp: 1.00
Engine Cycle: Diesel	Program SSDIL: 2.33-C	
Engine S/N: 6125H051031	Cell: 26 Bag Cart: 26	
Model: 6125HF001		

Mode Number	H1	H2	H3
Barometer, kPa (in Hg)	99.5 (29.39)	99.5 (29.38)	99.5 (29.38)
Dil. Air: Temp, °C (°F) / AH, g/kg	26.1 (79.0) / 5.5	26.1 (79.0) / 6.1	26.1 (79.0) / 5.5
Engine Air Dew Pt., °C (°F)	14.4 (57.9)	14.6 (58.3)	14.7 (58.4)
Engine Air Temp, °C (°F)	21.1 (70.0)	20.6 (69.0)	21.1 (70.0)
Engine Air: RH,% / AH, g/kg	65 / 10.5	69 / 10.6	67 / 10.6
NOx Humidity C.F.	.995	.998	.999
Dry-to-Wet C.F.	.978	.980	.984
Time, seconds	299.8	299.8	299.8
Tot. Blower Rate, scmm (scfm)*	136.52 (5,173.1)	137.73 (5,219.1)	139.23 (5,275.9)
90mm Sample Rate, scmm (scfm)*	0.0269 (1.02)	0.0270 (1.02)	0.0271 (1.03)
Total Volume, scm (scf)*	682.3 (25,853)	688.3 (26,083)	695.8 (26,367)
HC Sample Meter/Range/ppm	0.0/0/10.2	0.0/0/9.2	0.0/0/10.2
HC Bckgrd Meter/Range/ppm	0.0/0/3.5	0.0/0/3.4	0.0/0/3.5
CO Sample Meter/Range/ppm (Dry)	0.0/0/17.1	0.0/0/19.1	0.0/0/10.0
CO Bckgrd Meter/Range/ppm	0.0/0/0.1	0.0/0/0.0	0.0/0/0.1
CO2 Sample Meter/Range/% (Dry)	0.0/0/1.4720	0.0/0/1.0910	0.0/0/0.7460
CO2 Bckgrd Meter/Range/%	0.0/0/0.0480	0.0/0/0.0470	0.0/0/0.0460
NOx Sample Meter/Range/ppm (Dry)	0.0/0/147.2	0.0/0/103.0	0.0/0/70.1
NOx Bckgrd Meter/Range/ppm	0.0/0/0.4	0.0/0/0.3	0.0/0/0.3
Dilution Factor	9.29	12.50	18.20
HC Concentration, ppm	7.07	6.11	6.89
CO Concentration, ppm	16.33	18.50	9.71
CO2 Concentration, %	1.40	1.03	0.69
NOx Concentration, ppm	143.67	100.72	68.75
HC Mass, grams	2.97	2.59	2.96
CO Mass, grams	13.92	15.91	8.44
CO2 Mass, grams	18,713.71	13,875.88	9,444.28
NOx Mass, grams	200.23	142.03	98.07
Part. Mass, grams	1.498	2.305	1.669
Fuel, kg (lb)	5.889 (12.99)	4.370 (9.64)	2.974 (6.56)
KW-HR (hp-hr)	28.42 (38.11)	21.25 (28.50)	14.21 (19.05)
Filter Number	5768.0-7273	5769.0-7274	5759.0-7279
Weight Gain, mg	0.295	0.452	0.325
Sample Multiplier	5.079	5.099	5.136
Blower 1, scf	15,150.1	15,273.6	15,439.0
Blower 2, scf	10,698.3	10,804.4	10,923.1
Gas Meter 1, scf	9.745	9.711	9.723
Gas Meter 2, scf	14.836	14.826	14.857

* scf at 68°F and scm at 0°C

Analyzed: 03/14/2006 17:33

TABLE 6 TO SUBPART IIII OF PART 60.—OPTIONAL 3-MODE TEST CYCLE FOR STATIONARY FIRE PUMP ENGINES

[As stated in § 60.4210(g), manufacturers of fire pump engines may use the following test cycle for testing fire pump engines:]

Mode No.	Engine speed [1]	Torque (percent) [2]	Weighting factors
1	Rated	100	0.30
2	Rated	75	0.50
3	Rated	50	0.20

[1] Engine speed: ±2 percent of point.
[2] Torque: NFPA certified nameplate HP for 100 percent point. All points should be ±2 percent of engine percent load value.

TABLE 7 TO SUBPART IIII OF PART 60.—REQUIREMENTS FOR PERFORMANCE TESTS FOR STATIONARY CI ICE WITH A DISPLACEMENT OF ≥30 LITERS PER CYLINDER

[As stated in § 60.4213, you must comply with the following requirements for performance tests for stationary CI ICE with a displacement of ≥30 liters per cylinder:]

For each	Complying with the requirement to	You must	Using	According to the following requirements
1. Stationary CI internal combustion engine with a displacement of ≥30 liters per cylinder.	a. Reduce NO_X emissions by 90 percent or more.	i. Select the sampling port location and the number of traverse points;	(1) Method 1 or 1A of 40 CFR part 60, appendix A.	(a) Sampling sites must be located at the inlet and outlet of the control device.
		ii. Measure O_2 at the inlet and outlet of the control device;	(2) Method 3, 3A, or 3B of 40 CFR part 60, appendix A.	(b) Measurements to determine O_2 concentration must be made at the same time as the measurements for NO_X concentration.
		iii. If necessary, measure moisture content at the inlet and outlet of the control device; and,	(3) Method 4 of 40 CFR part 60, appendix A, Method 320 of 40 CFR part 63, appendix A, or ASTM D 6348–03 (incorporated by reference, see § 60.17).	(c) Measurements to determine moisture content must be made at the same time as the measurements for NO_X concentration.
		iv. Measure NO_X at the inlet and outlet of the control device.	(4) Method 7E of 40 CFR part 60, appendix A, Method 320 of 40 CFR part 63, appendix A, or ASTM D 6348–03 (incorporated by reference, see § 60.17).	(d) NO_X concentration must be at 15 percent O_2, dry basis. Results of this test consist of the average of the three 1-hour or longer runs.
	b. Limit the concentration of NO_X in the stationary CI internal combustion engine exhaust.	i. Select the sampling port location and the number of traverse points;	(1) Method 1 or 1A of 40 CFR part 60, Appendix A.	(a) If using a control device, the sampling site must be located at the outlet of the control device.
		ii. Determine the O_2 concentration of the stationary internal combustion engine exhaust at the sampling port location; and,	(2) Method 3, 3A, or 3B of 40 CFR part 60, appendix A.	(b) Measurements to determine O_2 concentration must be made at the same time as the measurement for NO_X concentration.
		iii. If necessary, measure moisture content of the stationary internal combustion engine exhaust at the sampling port location; and,	(3) Method 4 of 40 CFR part 60, appendix A, Method 320 of 40 CFR part 63, appendix A, or ASTM D 6348–03 (incorporated by reference, see § 60.17).	(c) Measurements to determine moisture content must be made at the same time as the measurement for NO_X concentration.
		iv. Measure NO_X at the exhaust of the stationary internal combustion engine.	(4) Method 7E of 40 CFR part 60, appendix A, Method 320 of 40 CFR part 63, appendix A, or ASTM D 6348–03 (incorporated by reference, see § 60.17).	(d) NO_X concentration must be at 15 percent O_2, dry basis. Results of this test consist of the average of the three 1-hour or longer runs.
	c. Reduce PM emissions by 60 percent or more.	i. Select the sampling port location and the number of traverse points;	(1) Method 1 or 1A of 40 CFR part 60, appendix A.	(a) Sampling sites must be located at the inlet and outlet of the control device.